Generate and Repair Machine Translation

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
COMPUTER SCIENCE
UNIVERSITY OF REGINA

By

Kanlaya Naruedomkul
Regina, Saskatchewan
April, 2000

© Copyright 2000: Kanlaya Naruedomkul

National Library
of Canada

Acquisitions and
Bibliographic Services

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque nationale
du Canada

Acquisitions et
services bibliographiques

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence

Our file Notre référence

The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

0-612-54676-4

Canada

*To my parents, sisters, brothers, and
my two lovely nephews*

Abstract

We propose Generate and Repair Machine Translation (GRMT), a constraint-based approach to machine translation (MT) that focuses on accurate translation output. The architecture of GRMT was designed to take advantage of, and have advantages over, the three classic strategies (Direct MT, Interlingual MT and Transfer MT), the nonlinguistic information strategies (Example-Based MT and Statistics-Based MT), and the hybrid strategies (Knowledge-Based MT and Shake-and-Bake MT) with respect to several translation aspects: simplicity, accuracy and multilingualism.

GRMT performs the translation by generating a *Translation Candidate* (TC), verifying the syntax and semantics of the TC, and repairing the TC when required. GRMT comprises three modules: Analysis Lite Machine Translation (ALMT), Translation Candidate Evaluation (TCE), and Repair and Iterate (RI).

In generating the TC, GRMT refines the scope of translation choices of each input word by taking into account the differences between languages in a unique way. In selecting an appropriate word for each input word, GRMT considers the semantic relationship between words. This semantic relationship is based on the Word Association (WordAsso) number. (WordAsso). WordAsso number is assigned to word class. Words are classified according to the meaning of words and their usage. Word classification is designed and used not only in the word selection process but also in the classifier selection process and in semantic representation.

GRMT is highly modular and extendible in the following respects: each component is separated, not only the translation process components (ALMT, TCE, RI), but also in the knowledge-bases, each component can be extended easily to a larger domain. The adding of new languages is also possible since the source language (SL) and the target language (TL) are treated separately. The SL and the TL are connected via the SL-TL dictionary which contains simple information and is manageable.

An English-Thai translation system has been implemented to illustrate the performance of GRMT. The system has been developed and run under SWI-Prolog 3.2.8. The English and Thai grammars have been developed based on the Head-Driven Phrase Structure Grammar (HPSG) and implemented on the Attribute Logic Engine (ALE).

This English-Thai MT system was evaluated and it performs in the way we intended. ALMT generated acceptable translations (grammatically correct, correct word usage and convey the original meaning) for 47 out of the 90 sentences in the test corpus without repair. TCE and RI improved 15 sentences using our current HPSG based grammars and lexicons. Twenty-one sentences which contain logical connections are first separated into linguistic units before the repair can be performed due to a current inadequacy in HPSG's semantic representation. However, each linguistic unit was then repaired successfully. Seven sentences faced with the problems of adding linking words and classifiers in Thai also require further research in order to develop ways to repair these sentences.

Acknowledgments

I would like to acknowledge the following people who, at different times, have helped me with this thesis. My deepest gratitude and appreciation goes to my advisor, Prof. Nick Cercone, who has given me a great deal of freedom to pursue ideas and research topics and who is always there when I need help and guidance. His unfailing support, his patience, his constructive criticism and his vast experience and invaluable advice have made the writing of this thesis possible and enjoyable.

I would like to thank Dr. Guy Lapalme, the external examiner, Dr. Brent Galloway, Dr. Howard Hamilton and Dr. Brien Maguire, the members of my thesis committee, for the remarkable feedback received during my viva. I also would like to thank Dr. Klaus H. Burmeister for chairing the defense.

I am thankful to Dr. Booncharoen Sirinaovakul, whose thoughtful, inventive suggestions are woven into the fabric of this work, and to whom I am deeply grateful for countless conversations and generous sharing of ideas and for explaining complex HPSG ideas with clarity and enthusiasm.

I would like to thank Dr. Douglas Arnold, Dr. Gerald Gazdar, Dr. John Luis Beaven, Dr. Carl Pollard, and Dr. Fred Popowich, for providing me advice and the materials which are very helpful to my research, and Dr. Bob Carpenter and Dr. Gerald Penn for their help with my questions about ALE.

I would like to thank the Department of Computer Science, University of Waterloo for providing me with the office and computer resources, to the academic, administrative, computing and research staff in the Department of Computer Science and Graduate Studies at University of Regina for all the support they have given me, to Dr. Paitoon Tontiwachwuthikul and Dr. Christine Chan for making my first few days in Regina a very pleasant experience.

My gratitude also goes to Assoc. Prof. Nardtida Tumrasvin and Assoc. Prof. Chinda Achariyakul, Department of Mathematics, Mahidol University, Prof. Amaret Bhumiratana, Doctor Kattaporn and Ms. Patrarawadee for supporting me to pursue my doctorate study in Computer Science in Canada. I am also thankful to Dr. Virach Somlertlamvanich, Nisanard Tannin and Kaewchai Chanchaen for providing me with the information needed for the study.

It has been a privilege indeed to have worked with these people. Also, my stay in Canada, the beautiful country, would not have been as pleasant without these fine people- Ursula Thoene, Chris Blair, Doreen Thiessen, Marnie Jeworski, Sel Murray, Dr. Brian Sveinson and Dr. Larry Saxton, I am grateful for their friendship and support.

I thank also my friends over the years, Weerapong Kritpiphat, Narate Lertpalangsunti, Amornvadee Veawab, Adisorn Aroonwilas, Teeradet Supap, Aijun An, Jessie Hou, Jianchao Han, Jian Jianna Zhang and Yingwei Wang.

I also would like to thank Margaret and Gordon, the Cooper family, for their kindness which will be forever remembered.

I also acknowledge the generous financial support I received while writing this dissertation, including The Royal Thai Government, Natural Sciences and Engineering Research Council (NSERC) and The Institute for Robotics and Intelligent Systems (IRIS).

I am thankful to the improvements in Computer Science and related fields which are very helpful to my research and thesis writing.

Lastly, I would like to express my thanks and appreciation to my parents Kiat and Somjit, my sisters Patcharee and Daranee, my brothers Taworn and Pornchai, and my nephews Sirawit and Potchara for their love and understanding.

Contents

Abstract	i
Acknowledgements	iii
Table of Contents	v
List of Tables	ix
List of Figures	xi
List of Abbreviations and Acronyms	xiv
Chapter 1 Introduction	1
1.1 Why Machine Translation	1
1.2 Objectives	3
1.3 Outline of the thesis	4
Chapter 2 Machine Translation	6
2.1 What is Machine Translation?	6
2.2 A Brief History of Machine Translation	8
2.3 Machine Translation Methodologies/Technologies	12
2.3.1 Methodologies used to develop MT systems	12
2.3.2 Techniques used to increase the performance of MT	14
2.3.2.1 Post-editing, Pre-editing and Interaction	14
2.3.2.2 Lexicon constructions and parsing techniques	17
2.3.3 Discussion of some existing MT methodologies	18

CONTENTS

2.3.3.1	Three Classic Strategies	18
2.3.3.2	Nonlinguistic Information Strategies	23
2.3.3.3	Hybrid Strategies	25
2.4	Our approach : Generate and Repair Machine Translation	28
Chapter 3 Generate and Repair Machine Translation		30
3.1	Why Generate and Repair, Not Analyze and Generate?	32
3.2	The Three Phases	35
3.3	Knowledge-bases Required	36
3.4	Translation Examples by GRMT	36
3.5	Key Features of GRMT	39
Chapter 4 Differences Between Languages: The English and Thai Languages		41
4.1	Differences between Thai and English	41
4.2	Word Classification	46
4.2.1	Word Classification Criteria	52
4.2.2	The semantic relationship development in GRMT	56
Chapter 5 Analysis Lite Machine Translation		58
5.1	Word Treatment	59
5.1.1	SL Constraints Application	59
5.1.2	Dictionary Look-up	60
5.1.3	Dictionaries	62
5.2	Word Selection	63
5.3	Word Ordering	71
5.3.1	Word Addition	71
5.3.2	Word Ordering	73
5.4	Example of ALMT	75

CONTENTS

Chapter 6 Translation Candidate Evaluation	80
6.1 The Analyzer	81
6.1.1 Parsing	81
6.1.1.1 About Head-Driven Phrase Structure Grammar	81
6.1.1.2 Words and Phrases as Feature Structures	82
6.1.1.3 Lexicon	85
6.1.1.4 Some Universal Principle and Grammar Rules	87
6.1.1.5 Attribute Logic Engine	92
6.1.1.6 English and Thai Grammars in GRMT	94
6.1.2 Semantic Extraction	104
6.1.2.1 Semantic Representation	104
6.1.2.2 Semantic Extraction Examples	106
6.2 Semantic Comparison	109
 Chapter 7 Repair and Iteration	 116
 Chapter 8 Machine Translation Evaluation	 125
8.1 What needs to be evaluated? (Types of Evaluation)	126
8.2 MT Evaluation Strategies	128
8.2.1 Error Analysis	129
8.2.2 Test Suite	129
8.2.3 The ARPA MT Evaluation	131
8.3 GRMT Evaluation	132
 Chapter 9 Discussion	 142
9.1 Contributions	142
9.2 Future Research	145
 Bibliography	 147

CONTENTS

Appendices

A	WordAsso hierarchy	161
B	SL Dictionary	185
C	SL-TL Dictionary	190
D	Types, their features and their value types	195
E	Lexical Rules	198
F	Grammars	201
G	Intelligibility and Fidelity Evaluation	205
H	Comprehensibility Evaluation	225

List of Tables

2.1	Translation examples by the commercial MT system	22
3.1	The TC and selected words generated for Example 1	34
3.2	The selected words and the TC generated for Example 2	37
3.3	Three corresponding Thai words to the word <i>spring</i>	38
3.4	The selected words and the TC generated for Example 3	38
4.1	Descriptions and the English corresponding words of คน (khon), เขว (khaw) and ที่ (thii)	42
4.2	The additional words that express Tense, Passive Voice and Plurality in Thai	43
4.3	Some information on the words นายแพทย์, สุนทร, ปลา and ปลาหมอ	49
4.4	Semantic relationships assigned for noun-noun combination in CICC MMT	49
4.5	The subgroup of <i>vehicle</i>	54
4.6	Some classified English and Thai words	55
4.7	Examples of words and their contexts	56
4.8	Classes and their sample words	57
5.1	Some SL Constraints	59
5.2	Example result of Dictionary Look-up of Example 3	61
5.3	The possible corresponding Thai words for <i>spirit, willing, flesh</i> and <i>weak</i>	69
5.4	The possible corresponding Thai words for <i>left, duckling</i> and <i>marsh</i>	70
5.5	A fraction of classifier classes	72
5.6	The selected words in Thai for the words <i>woman, cat</i> and <i>hen</i>	73

5.7	ALMT steps applied to the sentence of Example 11	76
5.8	ALMT steps applied to the sentence of Example 12	78
6.1	Some types, their features and their value types	84
6.2	Features and their value types of the types noun and verb	86
6.3	The class of <i>cover</i>	115
7.1	A part of Word Treatment output of Example 1	119
7.2	A part of Word Treatment output of Example 2	123
8.1	The intelligibility and fidelity evaluation result of evaluating ALMT on the 90 sentences test corpus	136
8.2	The comprehensible evaluation result	136
9.1	Advantages and disadvantages of the existing MT approaches	143

List of Figures

2.1	Direct MT	18
2.2	Some translations of the word <i>open</i>	19
2.3	Interlingual MT	20
2.4	Transfer MT	21
2.5	Example based MT	24
3.1	GRMT Architecture	30
3.2	The translation between languages of two language families	40
4.1	Examples of <i>kin</i> and its subjects	43
4.2	Examples of additional words to indicate different tenses and aspects	44
4.3	Examples of passive voice in Thai	44
4.4	Examples of classifiers	45
4.5	Examples of Thai attributive constructions	45
4.6	Examples of Thai constructions without auxiliary verb	46
4.7	A part of Thai Concept Classification (CICC MMT)	47
4.8	A part of Indonesian Concept Classification (CICC MMT)	48
4.9	A co-occurrence of the word <i>phrə'</i> [CICC 1995i]	49
4.10	A partition type hierarchy for <i>thing</i> [Cerccone et al. 1992]	51
4.11	A part of word classification in GRMT	53
5.1	ALMT Architecture	58
5.2	SL constraints applications examples	60
5.3	Example of SL Dictionary	62
5.4	Example of SL-TL Dictionary	62

5.5	The relationship between the proximity words -Examples 4 and 5	63
5.6	Examples of WordAsso relations	64
5.7	Example of selection steps	67
5.8	Examples of WordAsso relations	69
5.9	Examples of classifier relations	72
5.10	Word orders of จอห์น กิน ข้าว ทุก วัน	74
5.11	Word orders of ลูกเป็ด ขี้เหร่ ตัว นั้น ได้ซ่อน หัว ของเขา ใต้ ปีก ของเขา	75
5.12	A part of “The ugly duckling” and its translation	79
6.1	TCE Architecture	80
6.2	The lexical entry <i>hide</i>	83
6.3	The phrase <i>Leslie drinks milk</i>	85
6.4	The 3rd-singular verb lexical rule	86
6.5	Example output, <i>hides</i> , of the 3rd-singular verb lexical rule	87
6.6	HFP applied to <i>Leslie drinks milk</i>	88
6.7	Semantic principle applied to <i>Leslie drinks milk</i>	90
6.8	Head_complement rule applied to <i>likes John</i>	91
6.9	Specifier_head rule applied to <i>the book</i>	92
6.10	Example of result of parsing in ALE representation	94
6.11	The lexical entry for <i>hide</i>	98
6.12	The representation of <i>hide</i> in ALE with some macros	99
6.13	The parse syntax of Example 1 and that of its translation	100
6.14	The representation of <i>under</i> in ALE with some macros	101
6.15	The representation of ขี้เหร่ (khîrèe- ugly) in ALE with some macros	101
6.16	The representation of the classifier ตัว (tua) in ALE	102
6.17	The parse syntax of Example 2 and that of its translation	103
6.18	The partial description of the lexical entry <i>the</i>	104
6.19	The partial description of the lexical entry <i>Joan</i>	105
6.20	The semantic information, in ALE’s internal structure, of the SL in Example 3	107
6.21	The semantic information of the SL in Example 3	107

6.22	The semantic information, in ALE's internal structure, of the TC in Example 3	108
6.23	The semantic information of the TC in Example 3	108
6.24	The semantic information of the SL in Example 1	109
6.25	The semantic information of the TC in Example 1	110
6.26	The semantic information of the parse of the SL in Example 1	111
6.27	The semantic information of the parse of the TC in Example 1	112
6.28	The CONT value of the SL parse of Example 4	114
6.29	The CONT value of the TC parse of Example 4	114
7.1	RI Architecture	116
7.2	The QSTORE values of the SL and the TC parses of Example 1	118
7.3	The repair of Example 1	119
7.4	The semantic information of the SL and that of the repaired TC in Example 1	120
7.5	The TC parse of Example 2	122
7.6	CONT value of the SL parse	122
7.7	The repair of Example 2	123
7.8	The semantic information of the SL and that of the repaired TC in Example 2	124
8.1	A fraction of test suites [Arnold et al. 1994]	130
8.2	Examples of intelligibility and fidelity evaluation	135
8.3	Examples of comprehensibility evaluation	137
8.4	Example sentences 6, 10, 21 and 22	138
8.5	A fragment of sentence 55	139
8.6	Example sentences 26, 39 and 90	141

List of Abbreviations and Acronyms

AI	Artificial Intelligence
ALE	Attribute Logic Engine
ALMT	Analysis Lite Machine Translation
ALPAC	Automatic Language Processing Advisory Committee
ALPS	Automated Language Processing Systems
ATR-ITL	Advanced Telecommunications Research, Interpreting Telecommu- nication Research Laboratories
AVM	Attribute-Value Matrices
BYU	Brigham Young University
CAT	Computer-Aided Translation
CEC	The Commission of the European Communities
CG	Categorical Grammar
CICC	Center of the International Cooperation for Computerization
CKY	Cocke-Kasami-Younger
CLRU	The Cambridge Language Research Unit
CT	Correct Translation
DBMT	Dialogue-based MT
EBMT	Example-Based Machine Translation
GPSG	Generalized Phrase Structure Grammar
GRMT	Generate and Repair Machine Translation
HAMT	Human-Aided Machine Translation
HFP	Head Feature Principle
HPSG	Head-Driven Phrase Structure Grammar
ISI	University of Southern California's Information Sciences Institute

ITS	Interactive Translation System
KBMT	Knowledge-Based Machine Translation
LFG	Lexical Functional Grammar
MAHT	Machine-Aided Human Translation
MAT	Machine-Aided Translation
MCE	Multinational Customised English
MIT	The Massachusetts Institute of Technology
MMT	Multilingual Machine Translation
MT	Machine Translation
NLP	Natural Language Processing
PAHO	Pan American Health Organization
RI	Repair and Iterate
SAM	Script Applying Mechanism
SL	Source Language
TAUM	Traduction Automatique de l'Université de Montréal
TC	Translation Candidate
TCE	Translation Candidate Evaluation
TL	Target Language
TSNLP	Test Suites for Natural Language Processing
WordAsso	Word Association (Number)

Chapter 1

Introduction

Translation, from one language into another, presents subtle, important, ancient, and difficult problems.
— Warren Weaver (1955)

A primary objective of this research is to uncover and deploy new solutions that apply when developing an efficient machine translation (MT) system. We propose an alternative constraint-based approach to machine translation that focuses on accurate translation output. We call this approach Generate and Repair Machine Translation (GRMT) and we have implemented an advanced GRMT prototype for demonstration and evaluation purposes to translate English into Thai.

Successful results from this research should prove beneficial to machine translation studies currently underway around the world. GRMT's application should minimize the language barrier and simplify communication between peoples who speak different languages.

1.1 Why Machine Translation?

Country to country exchanges in trade, technologies, politics, telecommunications, culture, etc., continue to grow rapidly. Language plays a significant role in the communication processes between nations. To understand what is communicated, it is necessary to understand the language used in the communications process, its nuances and subtleties, hence, accurate machine translation assumes importance in order to facilitate this communications process from one language into another. When exchanges become more

globalized, the requirement for accurate machine translation increases. In multilingual countries like Canada (French-English), Switzerland (German, Italian, French, Swiss), India (32 official languages), the need for translation exists apart from increasingly globalized communications.

In countries where multiple official languages are used, translation is necessary to communicate with others who speak different languages. Translation enables people to express themselves in the way in which they wish to express themselves and to obtain the type of information they desire. Choice of language for communicative and other aspects is important in order for people to retain and enhance distinctive cultures and distinctive ways of thinking; language loss should matter to everyone.

The advance in computer technologies and the explosive growth of the World Wide Web has brought people closer together. Multilingual text has reached nearly to everyone with a computer. Information is readily accessible in growing numbers of languages. Machine translation has been integrated into man-machine communication systems which include electronic mail, information retrieval and the internet. The demand for machine translation systems has, therefore, not surprisingly, increased.

It would appear that successful machine translation efforts become a social and political necessity for modern societies (intelligent communities) that do not wish to impose a common language on their constituents. Past efforts at standardization, e.g., Esperanto, have not been successful.

For over a half century, MT research has drawn attention from people in different fields: cognitive psychology, linguistics, philosophy, cultural studies, computer science, computational linguistics. Several paradigms have developed. However, they still need improvement. No current operational MT systems can produce good quality output without either placing restrictions on input texts or involving human assistance before, during or after the translation processes. MT Research continues unabated, focused primarily on producing translations of greater accuracy.

It was for these reasons that we decided to discover a new approach to develop a machine translation system, an approach that can generate a reliable and accurate translation.

1.2 Objectives

Our goal is to find a new approach to MT which generates accurate translations, simplifies the design and the implementation of MT systems, and encourages others to adopt our approach as a usable tool.

In this thesis we describe the design of the approach we propose, GRMT. GRMT performs the translation process as follows: generate Translation Candidate (TC), verify the syntax and semantics of the TC and repair the TC when required. The tasks involved in generating the TC for the source language (SL) include:

- developing a set of constraints which are specific to resolve the syntactic differences between the source and the target languages.
- developing a SL dictionary to be used together with a set of constraints to refine the scope of the translation choices.
- developing the SL-target language (TL) dictionary to be used in relating SL and TL.
- classifying words into appropriate categories.
- developing a semantic relationship between words based on word classification to be used in selecting an appropriate translation for each input word.
- developing a set of constraints which are specific enough to resolve the syntactic differences between the target and the source languages to be used in completing the structure of the TC.
- developing the ordering rule. This rule is based on the syntactic structure differences between the SL and TL.

Tasks involved in verifying the TC requires development of the SL and TL grammars and lexicons. The grammars are used to analyze the SL and the TC to determine the accuracy of the TC. The grammars are developed based on a well-known grammar formalism, Head-Driven Phrase Structure Grammar (HPSG), since it is an integrated theory of natural language syntax and semantics. Implementation on the Attribute Logic Engine version 3.2 Beta (ALE) provides a mechanism which was designed to facilitate the use of HPSG grammar. The repair process is called upon when necessary to improve the quality of the TC.

Our English-Thai translation system is developed and implemented based on GRMT, in order to investigate the feasibility of GRMT.

GRMT is evaluated using our English-Thai translation system to examine whether the system performs in the way intended, whether the translation is acceptable and whether the system is extendable.

1.3 Outline of the thesis

In chapter 2, an introduction to MT including a brief history of MT and a discussion of the methodologies used in developing MT system is provided. Following this introduction we present the idea behind Generate and Repair Machine Translation.

Chapter 3 begins with a description of the architectural design of the GRMT system, the motivation of the design, similarities and dissimilarities between GRMT and other approaches, the knowledge-bases required in GRMT, advantages of GRMT, GRMT and multilingual MT.

We examine, in chapter 4, the difference between source language and target language, which are English and Thai respectively in this study, and in particular, on the aspects which will concern us in this work. The rest of this chapter addresses the word classification criteria. Of course, the notion of word classes is as old as the study of language itself. However, word classification has not been, in general, exploited fully in MT applications when the criteria used in classifying words includes both the meaning of the words and their usage. In addition, words in different languages are classified under the “same umbrella” even though there are differences at some levels between different languages. Finally the word association number, which plays a crucial role in GRMT, is introduced; the development of semantic relationship between words based on word classification and its usage are discussed.

Analysis Lite Machine Translation, the first phase of GRMT which generates the translation candidate for GRMT, is presented in chapter 5. Each component of ALMT is described in detail. The chapter includes some TC examples generated by ALMT.

Chapter 6 depicts the architecture of Translation Candidate Evaluation (TCE), the second phase of GRMT. After a brief description of HPSG and ALE we proceed to describe the English and Thai grammars we developed based on HPSG. The idea of how TCE extracts the semantic information from the source language input and the TC and how TCE determines the similarity between them are discussed.

Chapter 7 examines how Repair and Iteration, the last phase of GRMT, improves the quality of the translation candidate.

In Chapter 8, we describe the evaluations carried out on intelligibility, fidelity and comprehensibility of the translations for the English-Thai MT system.

Chapter 9 summarizes our contribution and concludes with some remarks about some efficiency considerations and possible improvements to GRMT.

Appendices are provided to illustrate SL Dictionary, SL-TL Dictionary, WordAsso hierarchy, Types, their features and their value types, Lexical Rules, Grammars, Intelligibility and Fidelity Evaluation and Comprehensibility Evaluation.

Chapter 2

Machine Translation

*When I look at an article in Russian, I say
"This is really written in English.
but it has been coded in some strange symbols.
I will now proceed to decode it."*
— Warren Weaver (1949)

2.1 What is Machine Translation?

Machine translation can be categorized under the more general heading of automatic natural language processing. MT is described in several ways as follows:

- MT is the application of computers to the translation of texts from one natural language into another [Hutchins 1986].
- MT is the transfer of meaning from one natural (human) language to another with the aid of a computer [Goshawke et al. 1987].
- Systems which perform a syntactic analysis of a source text and then generate a target language rendering thereof which seeks to preserve and reconstitute its semantic and stylistic elements are described as machine translation systems [Newton 1992].
- MT is the name for computerized systems responsible for the production of translations from one natural language into another, with or without human assistance [Hutchins and Somers 1992].
- MT is the translation of texts by means of computer [Rosetta 1994].

- MT is to automate all, or part of the process of translating from one human language to another [Arnold et al. 1994].

All descriptions, however, promote machine translation as an attempt to translate from one language into another (or others in the case of multilingual systems) with the aid of a computer.

The term MT usually refers to fully automatic machine translation. In the case where a computer “collaborates” with a human translator to some degree during the translation process, the system is then referred to as Machine-Aided Translation (MAT) or Computer-Aided Translation (CAT). We can further classify MAT into two categories as follows:

- Machine-Aided Human Translation (MAHT): The human performs the translation process with the assistance of a machine, e.g., consulting an on-line/automatic dictionary or terminological database, using multilingual word processors.
- Human-Aided Machine Translation (HAMT): The machine performs the translation process and consults a human user at many stages to complete the process, e.g., asking a user to make a choice in case of lexical ambiguity.

The major task of any MT system is to map the source language text onto an appropriate target language text that conveys the meaning of the original text. Therefore, the MT task includes language understanding and language generation tasks. In order to perform these tasks, MT efforts require linguistic and non-linguistic knowledge.

Required linguistic knowledge includes:

- *Morphological knowledge*- To provide the properties and meaning of an individual word.
- *Syntactic knowledge*- To recognize and form the structural relationship between words.
- *Semantic and world knowledge*- To understand and form the relations between the entities and events designated by words.
- *Pragmatic and stylistic knowledge*- To understand and form relations between the structure of texts and their communicative functions and also the idiomatic usage of the languages.

Required non-linguistic knowledge includes:

- *Real world knowledge*- Knowledge about the subject matter of a text, including general knowledge and common sense knowledge.
- *Culture/social knowledge*- The cultural and social context of a given text.

2.2 A Brief History of Machine Translation

The idea of using a machine in translation began in 1933, before the invention of the computer, and it remains a primary motivating problem for computational linguistics. Details of the MT history can be found in many books e.g., [Locke and Booth. 1955], [Hutchins 1986], [Slocum 1988], [Nirenburg et al. 1992], [Hutchins and Somers 1992], [Arnolds 1994]. Some pivotal earlier events are summarized as follows:

1933	<p>George Artsruni (a French engineer, Armenian by birth) was issued a certificate patent for a translation machine which was called a <i>Mechanical Brain</i> by its inventor. [Henisz-Dostert et al. 1979].</p> <p>P. P. Trojanskij¹, in the USSR, envisaged the three stages (see section 2.3.1) of mechanical translation [Henisz-Dostert et al. 1979]. He was issued a patent for a <i>Machine for selection and printing of words while translating from one language into another or into several others simultaneously</i> [Hutchins 1986].</p>
1946	<p>Warren Weaver (Vice-President for the Natural and Medical Sciences, Rockefeller Foundation) and Andrew D. Booth (a British Crystallographer) discussed the possibility of using computers for translation. This is the first discussion on MT [Henisz-Dostert et al. 1979].</p> <p>Weaver brought the idea of MT to general notice and suggested some techniques to be used in developing MT systems. [Henisz-Dostert et al. 1979].</p>
1948	<p>Andrew D. Booth and R. H. Ritchens implemented a word-by-word French-to-Spanish dictionary translation program.</p>

¹ The name is spelled Petr Petrovich Smirnov-Troyanskii according to Hutchins 1986 and P. P. (Smirnov-) Troyansky according to Bar-Hillel, 1964.

- 1949 The appearance of *Translation*, Warren Weaver's memorandum [Weaver 1955 reprinted].
- This memorandum drew the interest of researchers all over the United States. It is considered the starting point for research in MT.
- 1949 - 1952 The studies on MT started at a number of research institutions, universities and industries in the United States, e.g., University of Washington in Seattle, University of California at Los Angeles, The Massachusetts Institute of Technology (MIT) and The RAND Corporation in Santa Monica.
- 1952 Yehoshua Bar-Hillel organized the first MT conference at the Research Laboratory of Electronics- MIT, outlining future research in MT.
- 1954 Leon Dostert at Georgetown University collaborated with IBM on the Russian-English MT project and demonstrated their MT system to public. It is regarded as "the first generation of MT".
- The journal of *Mechanical Translation* was founded. It was edited and published by William N. Locke and Victor Yngve at MIT.
- 1955 - 1960 MT projects initiated elsewhere in the world, e.g., Cambridge Language Research Unit in the United Kingdom, University of Milan in Italy, Charles University in Czechoslovakia, Institute of Precision Mechanics and Computer Technology in the Soviet Unions and Kyoto University in Japan [Hutchins 1986].
- 1959 Yehoshua Bar-Hillel published his critique of contemporary MT research. He concluded [Bar-Hillel 1964]:
- The fully automatic, high quality translation was not really attainable in the near future so that a less ambitious aim is definitely indicated.
 - The empirical approach² seemed somewhat wasteful in practice and not sufficiently justified in theory.

² The empirical approach emphasized the need to base procedures on actual linguistic data. It was distrustful of existing grammars and dictionaries. The approach stressed statistical and distributional analyzes of texts [Hutchins 1986].

- 1964 The government sponsors of MT in the United States formed the Automatic Language Processing Advisory Committee (ALPAC) to provide directed technical assistance as well as to contribute independent observations in mechanical translation. [ALPAC 1966].
- 1966 The ALPAC report concluded that MT was slower, less accurate and twice as expensive as human translation. The report also stated that “There is no immediate or predictable prospect of useful MT”. This report brought a virtual end to MT research in the USA and damaged the public perception of MT for many years afterward [Hutchin and Somers 1992].
MT research initiated in Canada.
- 1969 In Middletown, New York, Charles Byrne and Bernard Scott found Logos to develop MT systems [Demos and Frauenfelder 2000].
- 1970 A renaissance of MT research projects in the United States after ALPAC report [Hutchins, 1986].
- 1972 The beginnings of AI-oriented research on MT [Wilks 1972].
- 1976 The Commission of the European Communities (CEC) purchased the “Systran” system for the development of translating systems for languages of the community [Hutchins 1988].
- 1978 The first multilingual MT “Eurotra project” had been developed. This system’s goal was to translate back and forth between nine languages; Danish, Dutch, English, French, German, Greek, Italian, Portuguese, and Spanish.
The first public MT system “METEO”, developed by the Université de Montreal, for translating weather reports from English to French had been used. It is one of the most successful MT systems.
- 1980 - 1982 The first commercial system, “Automated Language Processing Systems (ALPS)”, was developed.
- 1982 Speech translation had begun at British Telecom Research Laboratories in Great Britain and Advanced Telecommunications Research Laboratories in Japan.
A number of commercial MT systems had begun development, e.g., Globalink, PC-Translator.

1986	Japan launched the Advanced Telecommunications Research, Interpreting Telecommunication Research Laboratories (ATR-ITL), to study multilingual speech translation.
1988	Researchers at IBM's Thomas J. Watson Research Center revived statistical MT methods [see section 2.3.3.2]
1991	The first translator dedicated workstations appear, including STAR's Transit, IBM's TranslationManager, Canadian Translation Services' PTT, and Eurolang's Optimizer [Demos and Frauenfelder 2000], [Hutchins, 1997].
1992	ATR-ITL founds the Consortium for Speech Translation Advanced Research (C-STAR) which demonstrated the phone translation between English, German, and Japanese to the public.
1993	<p>The German-funded Verbmobil project gets under way. Researchers focus on portable systems for face-to-face English-language business negotiations in German and Japanese.</p> <p>BBN Technologies demonstrates the first off-the-shelf MT workstation for real-time, large-vocabulary (20,000 words), speaker-independent, continuous-speech-recognition software [Demos and Frauenfelder 2000].</p>
1994	Free Systran machine translation was available in selected CompuServe chat forums.
1997	AltaVista's Babel Fish offers real-time Systran translation on the Web.
1999	<p>Logos released e.Sense Enterprise Translation, the first Web-enabled multiple translator operating from a single server.</p> <p>Kevin Knight, of the University of Southern California's Information Sciences Institute (ISI), led a multi-university team that developed Egypt, a software toolkit for building statistical MT systems. Egypt examines bilingual texts for statistical relationships, analyzes those patterns, and applies what it has "learned" to its translation functions.</p>
2000	At MIT's Lincoln Laboratory, Young-Suk Lee and Clifford Weinstein demonstrate an advanced Korean-English speech-to-speech translation-system prototype.

2.3 Machine Translation Methodologies/Technologies

2.3.1 Methodologies used to develop MT systems

The translation process with the aid of a machine was proposed by P. P. Trojanskij in 1933 [Henisz-Dostert et al. 1979]. Trojanskij's translation process begins by analyzing the input words in the source language to obtain their base forms and syntactic functions. Next, the process transforms sequences of those base forms and syntactic functions into equivalent sequences in the target language. Only transformation step is performed by machine. Then the process converts the output of the transformation step into TL.

In 1946, Warren Weaver suggested that war-time cryptography techniques could be used to detect the basic elements which might be contained in all languages and A. D. Booth suggested that any digital computing machine having the necessary storage capacity could make a bilingual dictionary. Weaver also suggested some other techniques used in a translation process, e.g., statistical analysis, Shannon's communication theory, and exploration of the underlying logic and universal features of language.

A Brute-force approach was used to develop a Russian-English system [Garvin 1972]. The Brute-force approach is based on the assumption that, given a sufficiently large memory, MT can be accomplished without a complex algorithm, i.e., that MT can be accomplished with a dictionary containing not only words but also phrases, or a dictionary and a table of grammar rules. The negative opinion of ALPAC regarding the achievements of machine translation is based largely on a study of these systems, and is, of course, justified to the extent to which it concerns them [Garvin 1972].

The approach employed in nearly all MT systems until the late 1960's was the Direct translation approach. The Direct translation approach is a word-to-word replacement approach (see section 2.3.3.1). The morphology and syntax of the SL text need not be analyzed any more than is strictly necessary for the resolution of ambiguities and the specification of the TL word order. Erwin Reifler, at University of Washington in Seattle, recognized the problem of multiple meanings of word as an obstacle to successful direct translation. He began to attack the central problem of semantic ambiguity in 1950 [Bar-Hillel 1964]. Ten years later, the requirements of MT gave impetus to significant theoretical developments in linguistics and what would later become known as the disciplines of computational linguistics and artificial intelligence [Nirenburg et al. 1992]. It had been

recognized by 1960, that the achievement of acceptable MT requires a very detailed and extensive knowledge of the languages concerned, particularly with respect to the fundamental semantic problems of translation. Therefore, research on the Indirect Translation approach was begun. The treatment of linguistic structure became more sophisticated. The source language text analysis and target language text generation were treated separately and conversion was achieved via an “interlingual” representation or a “transfer” component operating on abstract representations of the SL and TL. These approaches are now known as the interlingual and transfer approaches respectively (see section 2.3.3.1).

Statistical methods were first suggested by Weaver to resolve problems of multiple meanings of words. A detailed study of statistical techniques was conducted at RAND Corporation by Abraham Kaplan in 1950. This study encouraged the belief that problems of ambiguity in MT could be overcome, however, the approach was quickly abandoned due to machine limitations and the critique of Bar-Hillel [Bar-Hillel 1964]. A decade later, the statistical approach had proven successful in speech recognition and parsing which drew the interest of the MT researchers at IBM’s T. J. Watson Research Center [Brown et al. 1988]. In 1988, a statistical approach to MT was implemented at IBM. The basic idea of the statistical approach is to carry out a translation based on complex cooccurrence and distribution probability calculations over very large aligned bilingual text corpora (see section 2.3.3.2).

An artificial intelligence approach to MT was developed by Yorick Wilks at Stanford University in 1972 [Wilks 1972]. Wilks’ system is based on an interlingual approach with a semantic grammar and inference rules (see section 2.3.3.3). A conceptually similar approach was carried on by J. Carbonell, R. E. Cullingford and A. V. Gershman in 1981 under the name of Knowledge-Based Machine Translation (KBMT) [Carbonell, Cullingford and Gershman 1981]. Other experiments were conducted at Yale University during 1978-1982, and by S. Nirenburg, V. Raskin and A. Tucker in 1985 [Nirenburg, Raskin and Tucker, 1986]. KBMT is different from the interlingual approach in terms of the expected depth of SL analysis, the building of semantic representations of the meanings of the SL, and the reliance of KBMT systems on the explicit representation of world knowledge [Hutchins 1986; Nirenburg et al. 1992; Whitelock and Kilby 1995].

A framework for MT by the analogy principle or by example-guided inference was first proposed by M. Nagao in 1984 [Nagao 1984]. His idea is that translation is achieved by imitating the translation of a similar example in a database. The task becomes one of

matching new input to the appropriate stored translation. In 1990 Sumita, Iida and Kohyama proposed a similar approach called Example-Based Machine Translation (EBMT) [Sumita, Iida and Kohyama 1990]. The basic idea of EBMT is to search for the closest match of the input text in a bilingual text archive, where text in the SL are stored and aligned with their translations into a TL. The translation of the closest match is accepted as the translation (see section 2.3.3.2).

Lexically-driven machine translation develops the translation upwards from the lexicon without translation rules or interlingual operations. Each lexical entry contains information such as orthography, syntax and semantics. Shake-and-Bake MT developed by Pete Whitelock and Mike Reape [Beaven 1992] is one sample system of a Lexically-driven MT (see section 2.3.3.3).

2.3.2 Techniques used to increase the performance of MT

Two techniques can be explored to enhance the performance of MT systems. The first technique is to accommodate the translation process by forming a collaboration between human and machine in post-editing, pre-editing and interaction. The other technique is to study the nature of the linguistic knowledge required and the approach used in acquiring it e.g., building the lexicon, parsing the SL, generation of TL text.

2.3.2.1 Post-editing, Pre-editing and Interaction

The concepts of post-editing and pre-editing were introduced by Erwin Reifler in 1950 [Locke and Booth, 1955]. Both post-editing and pre-editing are performed by a human who need not be bilingual. A post-editor reduces the translation output to a reasonable literary form while a pre-editor prepares the original text for the machine by removing ambiguities. Interaction involves human collaboration during translation processes.

Post-editing The task of the post-editor is to resolve residual problems (e.g., to select the appropriate choice from the alternative translations) appearing in the raw MT output and to tidy the style of the translation up. The post-editing technique was used at RAND Corporation in the late 1950's with a MT system that translates from French to English [Hutchins 1986]. This idea has continued to be used in a number of MT systems, e.g., AMPAR (English to Russian) developed at the USSR Centre [Marchuk 1989]), SPANAM (Spanish to English) developed by the Pan American Health Organization (PAHO) [Pan

American Health Organization 1999], and Systran (e.g., English to Chinese, French to German, English to Italian) developed by Systran [Systran 1999].

The difficulty of post-editing and the time required for it correlates well with the quality of the raw MT output: the better the output, the less the post-edit effort. The post-editing task time and cost increases as translation quality gets poorer.

Within the past few years there have been dramatic improvements in hardware (e.g., storage capabilities, processor speed, memory), software (e.g., programming languages, database management) and also developments in linguistic theory. These advances lead MT researchers to believe that good quality MT output is achievable; therefore, current research is searching for theories and methods to accomplish perfect translation and thus reduce the need for post-editing.

Pre-editing The SL text is adjusted before it is entered into the system by someone who knows the input restrictions. The text is written in a “controlled language” or “sublanguage” [Rosetta 1994]. A controlled language is a form of language usage restricted by grammar and vocabulary rules [Arnold 1994]. A sublanguage is the language used by a particular community of speakers concerned with a particular subject matter [Sager 1986]. By restriction to a controlled language or sublanguage, the problems of lexical homography and syntactic ambiguity can be reduced and, at the same time, higher levels of comprehensiveness and completeness in dictionaries are enabled. As an added benefit, the original text becomes clearer as well. The pre-edited text can sometimes be translated without the need for post-editing. The pre-editing technique is particularly cost-effective when there is a need to translate one document into many languages. The first really successful use of this technique was made by Xerox Corp. Xerox developed “Multinational Customized English³” (MCE) for writing unambiguous English. The Systran system with MCE was installed to translate from English into French, Spanish and Italian [Hutchins 1986]. In 1976, Météo was developed by the researchers at Traduction Automatique de l’Université de Montréal (TAUM) for translating weather reports from English to French, and is now in daily use. In Météo, the sublanguage grammar was written for analyzing English texts and for generating the corresponding French texts. However, the practice of “sublanguage” is now rarely adopted

³ MCE was developed based on a general and technical vocabulary of 3000 words and rules [Hutchins 1986].

since few texts are limited to single subject fields and also for economic reasons, since output inevitably requires revision as well.

Interaction Interactive MT systems involve human intervention for resolving doubts and uncertainties about the structure of the SL text or about the correct choice of the translation word in the TL texts during the translation processes. The final (raw) output does not require post-editing because ambiguities and other problems are solved. The philosophy of interactive systems was that unaided computer analysis can never be satisfactory and that difficult problems of linguistic analysis can be circumvented by calling upon human expertise at appropriate moments [Hutchins 1989a].

In the mid-1960s, the Cambridge Language Research Unit (CLRU) investigated the possibilities of an interactive English-French MT system [Hutchins 1986]. The Management of Information through Natural Discourse⁴ (MIND) was developed at The RAND Corporation in early 1970 [Bisley and Kay 1972]. MIND relies on a monolingual user to resolve ambiguities in the translation process. The Interactive Translation System⁵ (ITS) was developed at the Translation Sciences Institute of Brigham Young University (BYU) in 1970 [Hutchins 1986]. An Interactive Japanese Parser for MT, proposed in 1990, was developed at IBM Research, Tokyo Research Laboratory. This system allows a user to intervene during parsing to help the system to produce a correct parse [Maruyama and Watanabe 1990]. The Dialogue-based MT (DBMT) conducted at Grenoble allows a monolingual user (with limited ability in TL) to interact with the translation system [Boitet 1990]. InterTran, a free web translation service provided by Translation Experts Ltd⁶, allows a user to select an appropriate TL word for each SL if there are choices.

The efficiency of an interactive MT system depends on the number of questions asked during the translation process. More questions means less efficiency since a user needs to go through the entire SL text to accurately answer the questions. In addition, the time used during the interaction corresponding between a user and a system should be taken into account.

⁴ The chief designers of MIND were Martin Kay and Ronald Kaplan. Martin Kay was a member of the CLRU.

⁵ The leadership of ITS development was Eldon G. Lytle at BYU. He and other members of the ITS project left BYU and continued the development of their interactive approach to MT: the first commercial MT system Automated Language Processing System (ALPS), in 1980.

⁶ InterTran is available at "<http://www.tranexp.com:2000/InterTran>" as of December, 1999

2.3.2.2 Lexicon constructions and parsing techniques

Lexicons and parsers are vital components of any MT system. An accurate lexicon and good syntactic and semantic analyses are required to ensure a good translation. Therefore, the lexicon construction method and the parsing technique must be considered not only in the translation process, but also to improve the efficiency of a MT system. Much current research is directed at improving existing MT approaches by developing a better linguistic analysis for the analysis-based MT approach (e.g., Direct MT, Interlingual MT, Transfer MT, Knowledge-Based MT and Shake-and-Bake MT) or by developing better tools to construct and modify an accurate lexicon. Some interesting parsing techniques and lexicon construction tools are summarized below.

PARSEC, the connectionist parsing system, is one of the parsers used in JANUS [Woszczyna et al. 1995]. JANUS is a speech-to-speech translation system developed at Carnegie Mellon University. PARSEC is used as a fall-back module if the symbolic high precision parser fails to analyze the input. The important aspect of the PARSEC system is that it learns to parse sentences from a corpus of training examples.

Steven Abney proposed the idea of parsing by chunks⁷ in 1994 [Abney 1994]. In Abney's chunking parser, the syntactic analyzer comprises the *chunker* and the *attacher*. The chunker converts a stream of words into a stream of chunks, and the attacher converts the stream of chunks into a stream of sentences. Abney also compared his parser and chart parsing [Covington, 1994]. In 1996, Michael John Collins at University of Pennsylvania proposed a statistical parser which employs a simple statistical model based on dependencies between words [Collins 1996].

I. Dan Melamed, at the University of Pennsylvania, proposed a new method used in constructing a lexicon [Melamed 1998]. Melamed's method was designed to generate a word-to-word translation lexicon, and each lexical entry is tagged with its relative frequency of co-occurrence. Davide Turcato, at Simon Fraser University, proposed a method to build a bilingual lexicon [Turcato 1998]. This lexicon contains not only word equivalence but also the syntactic and semantic descriptions.

⁷ Chunks correspond to prosodic patterns. It appears, for instance, that the strongest stresses in the sentence fall one to a chunk, and pauses are most likely to fall between chunks. Chunks also represent a grammatical watershed of sorts. The typical chunk consists of a single content word surrounded by a constellation of function words, matching a fixed template [Abney 1994].

2.3.3 Discussion of some existing MT methodologies

The methodologies used for developing MT systems can be classified into three different categories: the three classic strategies (Direct MT, Interlingual MT and Transfer MT), the nonlinguistic information strategies (Example-Based MT and Statistics-Based MT), and the hybrid strategies (Knowledge-Based MT and Shake-and-Bake MT).

2.3.3.1 Three Classic Strategies

Three widely articulated strategies for developing MT systems include Direct MT, Interlingual MT and Transfer MT. **Direct MT** (Figure 2.1) is a "word-to-word" replacement approach that replaces the SL word with the TL word. Therefore, the accuracy of the translation depends primarily on the bilingual dictionary. Accuracy is rather limited because the Direct MT system takes into account only morphological information. The following examples, using the word *open* with English as the SL and Thai as the TL, illustrate this limitation (Figure 2.2).

Figure 2.1: Direct MT

The meaning of each *open* is different because of the circumstances of usage. Therefore, the translations of the word *open* into the Thai language which are shown underlined in Figure 2.2 depend on which Thai word will cover each circumstance. In phrase (1), the word *open* is translated as เปิด (pə̀əd)⁸ in Thai because it means *not shut*. However, the word *open* in phrase (2) is translated as เริ่ม (rə̀əm) since *open fire* means *to start shooting*. Nevertheless,

⁸ The parenthesizing item is the phonetic transcription of the Thai word. Thai phonetic transcription is provided from the Thai-English Student's Dictionary compiled by Mary R. Haas [Haas 1964].

	SL	TL
1.	<u>open</u> door	<u>เปิดประตู</u> (pə`əd-open) (pratuu door)
2.	<u>open</u> fire	<u>เริ่มยิง</u> (rə`əm-op en) (jīŋ-fire)
3.	<u>open</u> arms	<u>อ้าแขน</u> (?āa-open) (khe`en- arm)
4.	<u>open</u> eyes	<u>ลืมตา</u> (lyym-open) (taa-cye)
5.	<u>เปิด</u> ไฟ	<u>turn on</u> the light (pə`əd-turn on) (faj`-light)
6.	<u>ลืม</u> บอก	<u>forget</u> to tell (lyym-forget) (bə`əg`-tell)

Figure 2.2: Some translations of the word *open*

the translation of the word เปิด (pə`əd), phrase (5), into English is *turn on*, not *open*. The word ลืม (lyym), in phrase (6), cannot be translated as *open* either because it has a complete different meaning from the word ลืม (lyym) in phrase (4). The translation of the word ลืม (lyym), phrase (6), must be *forget*. The meaning of a word or phrase depends, in part, on the situation in which it is used. The relationship between the basic meaning of a word and its circumstances of usage is very complex. This complexity is one reason why the mapping from one language to another is far from direct.

The direct approach was adopted by most MT systems in the first generation of MT, e.g., the Georgetown system of Garvin 1967 [Goshawke et al. 1987]. The translation accuracy of this approach is limited because the linguistic analysis of the SL is inadequate. In addition, the design of Georgetown system was orientated towards a specific language pair, and emphasis on a bilingual dictionary as knowledge source. The addition of a new language pair means that entire new modules have to be written. The number of rules tend to be very large, and rule interaction difficult to monitor, so that the whole system is difficult to extend and maintain. However, the Direct MT is still appealing in certain circumstances. Traces of the direct approach are found in indirect approaches such as Météo and Systran [Hutchins and Somers 1992].

To generate more accurate translations, a second approach, *Interlingual MT* (IL MT) was developed. The treatment of linguistic information became more sophisticated in this approach. IL MT analyzes and represents the SL in an intermediate language-independent conceptual representation called *interlingua* (Figure 2.3). IL MT then generates the TLs (in any language) from the interlingua. The accuracy of the IL approach is based on the ability to generate an accurate interlingua. Since interlingua is a language-independent representation of the meaning of the text, the analysis and generation modules are independent from each other. The advantage is that the addition of a new language involves only the creation of two new modules: the analyzer and the generator of the new language. The all-ways translation between n languages requires n analysis and n generation modules whereas the direct approach requires $n(n-1)$ translation modules.

Figure 2.3: Interlingual MT

The IL approach is the most attractive to multilingual machine translation (MMT) systems. However, to define neutral concepts for different languages is rather a chimera. Interlingua must capture all necessary information of the analyzed SL so that the generator can generate an accurate translation in all languages. A number of interlingual systems were developed e.g., ATLAS of Fujitsu [Uchida 1989], PIVOT of NEC [Muraki 1989], Rosetta of Phillips [Landsbergen 1987a], KANT [Mitamura, Nyberg and Carbonell 1991], UNITRAN [Dorr 1991] and CICC Interlingual [CICC 1995e]. The CICC interlingual system was developed and implemented in the project “The research and development cooperation

project on a machine translation system for Japan and its neighboring countries⁹” (CICC MMT 1987-1994) [CICC 1995g]. The CICC MMT project was aimed at developing MMT, an all-ways translation between five languages: Japanese, Chinese, Malaysian, Indonesian and Thai. Some limitations and problems were encountered in developing the interlingual system for this project. For example, interlingua theory assumes that sentences in different languages which carry the same meaning must be represented by the same interlingua. However, in the CICC MMT project, the interlingual representations of these sentences are different [CICC 1995d] for several reasons [Cercone 1975; CICC 1995c; CICC 1995g; CICC 1995h; CICC 1995i]:

- The scopes and concept classification of each language are different (e.g., the concept of culture, the concept of the supernatural world, and the concept of unit).
- A single concept in one language can be mapped into many concepts in another language.
- More than one concept can be mapped into only one single concept in another language.
- Some concepts do not exist in some languages.

Different languages and different cultures result in different circumstances of language usage. Thus, it is very difficult to define a neutral concept. Interlingual then, is still an ideal despite being considered one of the best approaches.

Because of these difficulties, the compromise between the direct approach and the interlingual approach led to the idea of the third approach, *Transfer MT* (Figure 2.4). The

Figure 2.4: Transfer MT

⁹ China, Indonesia, Malaysia and Thailand.

transfer approach involves "transferring" the linguistic information of SL to TL. The transfer approach analyzes and represents the SL with a machine-readable form and maps this form into a machine-readable form of TL, then generating the TL from that representation. The accuracy of transfer approach depends primarily on the transfer module.

Unlike the intermediate representation in the interlingual approach, the intermediate representation in the transfer approach strongly depends on language pairs. Therefore, the all-ways translation of n languages requires n analysis, n generation and $n(n-1)$ transfer modules. The transfer approach is not attractive to MMT systems. However, it is still preferred to the interlingual approach among MT researchers for two reasons. There are difficulties in defining neutral concepts as mentioned earlier. Furthermore the intermediate representation of the transfer approach depends on language pairs so the analysis and generation processes are less complicated when compared to the interlingual approach (the relative complexity of the analysis and generation modules in a transfer system is much reduced because the intermediate representations involved are still language dependent). The

Table 2.1: Translation examples by the commercial MT system

English	Translation to French	Translation back to English
1. Hatchery officials are having to teach the fish to like worms.	1. <i>Les fonctionnaires de l'incubateur doivent apprendre le poisson pour aimer des vers.</i>	1. Civil servants of the incubator must learn fish for aimerdes ¹⁰ toward.
2. It does not matter if you are born in a duck yard.	2. <i>Il n'importe pas si vous naissez dans un jardin du canard.</i>	2. He/it doesn't import if you are born in a garden of the duck.
3. Only a life lived for others is a life worth while.	3. <i>Seulement une vie pour les autres vaut pendant que.</i>	3. Only a life for other is worth while.
4. I never think of the future.	4. <i>Je ne pense jamais du futur.</i>	4. I never think the future.
5. You can take a fish to school, but you can not make them think.	5. <i>Vous pouvez prendre un poisson pour scolariser, mais vous ne pouvez pas les faire penser.</i>	5. You can take a fish to school, but you don't can pasles to make think.
6. BOISE, Idaho (AP)- Trout in Idaho are not just swimming in schools- they are going to school.	6. <i>BOISE, Idaho (AP) - Truite dans Idaho ne nage pas dans les écoles juste - theyare aller scolariser.</i>	6. BOISE, Idaho (AP) - Trout in Idaho doesn't swim rightly in schools-theyare to be going to school.

¹⁰ This is how the translation actually appeared. This type of error appears through out these examples.

interlingual approach necessarily requires complete resolution of all ambiguities and anomalies of SL texts so that the translation into any other language is possible whereas in the transfer approach, only those ambiguities inherent in the language pair are tackled. Some examples of MMT systems which were developed based on the transfer approach include: Eurotra which has been developed by European Community¹¹ since 1978; Susy which was developed at the Universität des Saarlandes in Saarbrücken during 1972-1986; and METAL which has been developed at the Linguistic Research Center at the University of Texas (Austin, Texas) since 1961. Details of these MT systems can be found in Hutchins and Somers, 1992.

The transfer of structure information in the transfer approach may cause inaccuracies because of the different structures between languages and thus the transfer approach may lose some information during processing. Table 2.1 illustrates this problem. The second column in French represents the translation of the first column from English¹². Each translation fails to maintain close fidelity to the meaning of the original sentence. The translations are incorrect in both words selected and in grammar. The third column shows the translation back into English of the French translation in the second column¹³. The third and the first columns should convey the same meaning but they do not because accumulative errors occurred during the translation processes.

2.3.3.2 Nonlinguistic Information Strategies

There is a possibility that different languages require different amounts of information to be expressed. For example, the Spanish word *llegó* means either *he arrived* or *she arrived*, but in order to translate it into English, we have to choose “he” or “she” on the basis of context and background knowledge. Japanese and Thai have “polite” markers. To translate from English to these languages, the “polite” markers need to be added according to the knowledge of culture. This observation led to nonlinguistic information strategies. Nonlinguistic information strategies are currently popular, e.g., Example-based MT [Jones 1996], Statistical strategies [Brown et al. 1992].

¹¹ Eurotra project involves research groups in all member states in Europe e.g., GETA in Grenoble, IAI in Saarbrücken, and ISSCO in Geneva [Hutchins and Somers 1992].

^{12,13} These translations were provided by the commercial MT system.

Figure 2.5: Example based MT

Example-Based machine translation (Figure 2.5) attempts to achieve translations by using examples of translation in the translation process. EBMT performs a translation by mapping the input text to an example in the *bilingual corpus*: a collection of translation pairs. If the entire input phrase can be matched, then it will be translated to the translation pair of that matched example. If the entire input phrase cannot be matched then EBMT takes two approaches to translate such a sentence: *the closest mapping* and *recombining the matched segments*.

The first approach, closest mapping, looks for the closest example for the input text. If it is found, the system will use its translation pair as a template and replace the SL words with the corresponding words in TL. In case the closest example is not found, there is a possibility that its segments can be found in a number of examples. Therefore, the second approach, recombining the matched segments, is applied. All matched segments will be translated and recombined to be the translation of the input text. The measurement of similarity between an input text (segments) and a set of examples can be considered according to both surface and content. The similarity measurement can be performed by using a thesaurus. One advantage of EBMT is that translations come with scores which are measurements of similarities to known examples. These scores could be useful to a post-editor. Further details of the EBMT can be found in [Nagao 1984], [Sato and Nagao 1990], [Sumita, Iida and Kohyama 1990] and [Jones 1996].

The feasibility of EBMT depends crucially on the availability (suitability) of the translation examples. EBMT requires a large collection of translation examples (pairs) to

produce an accurate output. The coverage of EBMT system depends on the size and diversity of the collection of the translation pairs.

Statistics-Based MT tries to do away with formulating linguistic knowledge, but applies statistical techniques instead. Statistics-based MT views every sentence in one language as a possible translation of any sentence in other languages [Brown et al. 1990]. This approach attempts to search for a sentence S in the source language that maximizes $\Pr(S)\Pr(T|S)$, whereas $\Pr(T|S)$ is the translation model probability and $\Pr(S)$ is the language model probability.

The translation model probability, $\Pr(T|S)$, is assigned to every pair of sentences (S,T) . It is the probability that a translator will produce T in the target language given S in the source language. The translation model probability is calculated from the probability of word alignment. The word alignment corpus, contained the aligned translated text, is used to predict which elements of one language of the corpus are most likely to be equivalent to elements in the other. The language model probability, $\Pr(S)$, is the probability of words occurring in a particular order. Further details of the computation and searching method can be found in [Brown et al. 1988], [Brown et al. 1990], [Arnold 1994], and [Jones 1996].

One sample system of the statistics-based approach has been carried out by a research group at IBM. The researchers had access to three million sentence pairs from the Canadian (English-French) Hansard which contains the Proceedings of the Canadian Parliament.

This approach, while interesting, requires a very large and reliable aligned bilingual corpus to produce an accurate translation. As with EBMT, the statistics-based approach relies heavily on the availability of a large and diverse quality corpus; currently such corpora for most languages are underdeveloped.

2.3.3.3 Hybrid Strategies

Knowledge-Based Machine Translation is based on the interlingual approach using AI techniques. Reasoning-induction and abduction are used in interpreting the SL text by reference to world knowledge, not only a knowledge of language. The meaning representation should be sufficient for translation to a number of languages, rather than sufficient for total understanding [Nirenburg et al. 1992].

Basic Components of KBMT systems include: a parser, a reasoning system, and a generator. The *parser* (Semantic-based) recognizes semantic features of lexical items in SL text rather

than grammatical categories. Wilks' Preference Semantics (MT) system¹⁴ represents the meaning of the SL text (interlingual representation) with "binary decomposition trees" while KBMT, developed at Yale University, adopted an IL representation based on the "conceptual dependency theory" developed by Roger Schank¹⁵. The *reasoning system* (inference mechanism) applies contextual world knowledge which augments the representation, to solve ambiguities and uncertainties in the SL text. The *generator* maps the representation of the SL into the TL.

J. Carbonell, R. E. Cullingford and A. V. Gershman combined their system with a *Script Applying Mechanism* (SAM) to understand and represent the meaning of the SL. SAM is the script-based story understander developed by R. Schank and R. E. Cullingford in 1978. Carbonell, Cullingford and Gershman remarked that their system did not perform strict translation, but rather retold or summarized the SL text in the TL [quoting Carbonell, Cullingford and Gershman 1981; Carbonell and Tomita 1987]. The domain of the translation is English newspaper articles.

KBMT-89 is a larger-scale KBMT developed by researchers at the Center for Machine Translation at Carnegie Mellon University and the researchers from IBM's Tokyo Research Laboratory in 1987 [Goodman and Nirenburg 1991]. Its interlingual representation is a frame notation and can be viewed as a kind of a semantic network. The world knowledge is organized as a multiply interconnected, hierarchical network of frames. The domain of the translation is limited to personal computer manuals.

Other KBMT systems have been implemented, e.g., ATLAS-II [Uchida 1989], PIVOT [Muraki 1989], ATR [Kudo 1990] and ULTRA [Farwell and Wilks 1991].

One advantage of the KBMT approach is solving some ambiguity problems. However, the disadvantage of this approach is the expense of either abductive or inductive reasoning, even on small domains. Building the knowledge representation is also time consuming and expensive.

¹³ Details discussion on Wilk's system can be found in [Wilks 1972] and [Whitlock and Kilby 1995].

¹⁴ Schank's conceptual dependency theory, developed in 1972, is rich in semantic representation. It is designed to provide a representation of meaning of natural language in terms of which paraphrase, inference, and MT could be carried out. There are some similarities between Wilks' formulas and Schank's conceptual dependency representations (Wilks and Schank were both at Stanford in the early 1970). Wilks' formulas bear much similarity to the (binary) decomposition trees developed by Lakoff. Further discussion on Wilks' formulas and Schank's conceptual dependency theory can be found in [Cercone 1975] and [Hutchins 1986].

We doubt that a pure interlingua (semantic representation) is appropriate for MT systems since the pure IL does not contain syntactic information. The abstractness of “content” representations results in information loss about “surface” structures of text; it seems that a pure interlingua is more suitable for the paraphrase task than for the translation task.

Shake-and-Bake MT developed by Pete Whitelock and Mike Reape is Lexically-driven machine translation. In Shake-and-Bake MT, the SL is analyzed by using a SL monolingual grammar, then each SL word is replaced with its equivalent in the TL using the bilingual dictionary, and finally the translation is generated from a set of TL words by shift-reduce parsing algorithms according to the TL grammar [Whitelock 1992].

One advantage of Shake-and-Bake MT is that it relates the SL and the TL via the bilingual lexicon alone, without a transfer module or an IL representation. The semantic information of the SL is copied across by the coindexation specified in the bilingual lexicon (the variables in the semantic indices are copied from the SL word as prescribed by the bilingual lexicon.).

Shake-and-Bake MT is not efficient since it generates the translation by trying all possible permutations of the TL words. The system parses an arbitrary permutation to determine its grammatical well-formedness. If that permutation is well-formed, the system indicates success. If not, another permutation is tried. The system might have to verify all possibilities to find the appropriate translation or find none at all. A number of techniques were proposed to improve the efficiency of the generation process in Shake-and-Bake MT e.g., Brew uses a heuristic method to constrain the solution space [Brew 1992]. Beaven employs a Cocke-Kasami-Younger (CKY) baking¹⁶ to avoid recalculating the same combinations of words more than once during the generation process [Beaven 1992]. Popowich’s generation process is also based on a chart parsing algorithm with a variety of different search strategies [Popowich 1996]. Poznanski, Beaven and Whitelock proposed the idea of considering the information from the previous stages, analysis and dictionary look-up, in the generation process [Poznanski, Beaven and Whitelock 1995]. However, none of these algorithms is guaranteed to avoid protracted search times in order to achieve an accurate translation result.

¹⁶ Beaven calls his algorithm the “CKY baking” because of the great similarity between his algorithm and the CKY chart parsing algorithm.

The approaches to MT discussed thus far do not explicitly recognize the notion of incremental repair of a mistranslating and subsequent iteration through an evaluation phase to further repair and iteration.

The notion of “repair and iterate” is a well accepted methodology in computer science. It seems to us that this notion should prove useful in a MT system as we iterate to a better and better translation. we note that this concept is not unlike Verbmobil’s notion of “negotiations” [Kay, Gawron and Norvig 1994] for their speech to speech system.

We discuss Generate and Repair Machine Translation in the next section. GRMT is a novel MT paradigm that takes advantage of the best features of the more traditional MT approaches (see Table 9.1) and combines them in a Repair and Iterate architecture.

2.4 Our approach : Generate and Repair Machine Translation

There are advantages and disadvantages in each approach. The efficiency inherent in the direct MT approach is limited because linguistic elements of the languages are considered only at the morphology level. The transfer of structure information in the transfer MT approach may cause inaccuracy because of the different structures between languages and thus may lose some information during processing. In addition, the transfer approach does not appear appropriate for multilingual systems. Of the three approaches, although the interlingual MT approach appears to be the most attractive, the interlingual representation is still an ideal. Example-Based MT and Statistics-Based MT approaches requires a very large and reliable bilingual corpus to produce an accurate translation; these corpus are not available for most languages. To build the knowledge for KBMT is time consuming and expensive. The Shake-and-Bake MT approach lacks efficiency due to its generation process.

Our goal is to overcome shortcomings of earlier approaches and to increase the accuracy of the overall translation. Generate and Repair Machine Translation is a proposed solution.

The GRMT approach is designed to increase the accuracy and efficiency of MT. The architecture of GRMT was designed to take advantage of, and have advantages over, the Direct, Transfer, Interlingual, Non-linguistic and the existing hybrid approaches to MT with respect to several translation aspects: simplicity, accuracy and multilingualism. The GRMT integrates the best features of each approach. The GRMT process is relatively simple and straightforward, not unlike the Direct method. However, the GRMT is more concerned with preserving linguistic information to produce an accurate translation result, like the Transfer

approach. GRMT also treats the SL and TL separately for easy management in multilingual MT systems, like the Interlingual approach. GRMT uses simple statistical information, in part, in the word selection process like the statistic-based approach. GRMT builds the semantic relationship between words based on world knowledge, like the KBMT approach. GRMT associates the SL and TL via the bilingual lexicon, like the Shake-and-bake MT approach.

Unlike the transfer or interlingual approaches, GRMT generates a translation candidate (TC) directly from the SL input to avoid information loss during the transfer process of the transfer approach and to avoid difficulties in defining neutral concepts for different languages in the interlingual approach. GRMT does not require any bilingual corpus in the translation process, unlike EBMT or the statistical based MT approach. Unlike the Shake-and-bake MT approach, GRMT verifies the generated TC and revises it if required to achieve an accurate translation without trying all possibilities.

GRMT takes into account the differences between languages in a unique way, hence a further advantage. If languages can be grouped according to various characteristics which they share, then the translation between groups can be performed more simply by GRMT. For example: Group 1 consists of English, French and Spanish, Group 2 consists of Chinese, Japanese and Thai. To perform the translation between these two groups, the transfer approach requires six SL analyzers, six TL generations and eighteen sets of transfer rules while GRMT requires six analyzers and two sets of constraints.

The English-Thai translation system has been developed based on the GRMT approach. The initial experiments of ALMT [Naruedomkul and Cercone 1997] indicate that the translation candidates can be generated quickly with relatively high accuracy. We have greatly expanded the dictionaries used in the earlier experiment, five fold [Naruedomkul, Cercone and Sirinoavakul 1999]. All necessary knowledge bases required were updated. ALMT has been improved to increase the performance of GRMT. The English-Thai translation system we developed has been used to translate a number of phrases. These sample phrases were collected from different sources: newspapers, text books, articles, bedtime stories and fortune cookies. This dissertation presents the design and some experiments of GRMT.

As far as we are aware two commercial products were claimed to translate English to Thai, Tapestry (<http://knowledge.krdl.org.sg/MT/>) and Language Force (www.wforce.com), however,

Chapter 3

Generate and Repair Machine Translation

*'When I use a word,' Humpty Dumpty said in rather a scornful tone,
'it means just what I choose it to mean - neither more or less.'*
— Through the Looking Glass
by Lewis Carroll

Generate and Repair Machine Translation is an efficient approach to machine translation distinct from the direct, transfer, interlingual, statistical, example-based, knowledge-based approaches. The architecture of GRMT (Figure 3.1) is designed to serve two purposes: first, to generate an accurate translation and second, to be amenable to multilingual translation. An accurate translation corresponds to a translation which retains the linguistic meaning of the source language. To achieve an accurate translation, GRMT performs the translation in

Figure 3.1 GRMT Architecture

three phases: The first phase, *Analysis Lite Machine Translation* (ALMT) generates a translation candidate for the SL. The accuracy of the generated TC is evaluated by analyzing both the TC and the SL in the second phase, *Translation Candidate Evaluation* (TCE). TCE compares the semantic information of the TC with that of the SL. If there is any dissimilarity then the TC will be “repaired” in the third phase, *Repair and Iterate* (RI). The repaired TC will again be analyzed and again be compared until there is no appreciable dissimilarity between the meaning of the SL and the TC. By performing the TCE and RI processes, GRMT ensures an accurate translation.

To make GRMT attractive to a multilingual MT system, we pay attention to simplicity in accommodating new languages and the associated systems knowledge required. System maintenance also adds further complications. Therefore, GRMT treats SLs and TLs separately and relates them by using information provided in a SL-TL lexicon. The SL-TL lexicon contains simple but necessary information for the translation process, and this SL-TL lexicon is simple to construct (see section 5.1.3). GRMT organizes knowledge required for the translation process into separate modules e.g., SL constraints, TL constraints, grammar and analysis lexicon for each language so that they can be developed easily and maintained simply. SL and TL constraints represent the syntactic differences between SL and TL which GRMT considers, in part, in generating a TC. The translation between languages in different families of languages that share some characteristics should be able to take good advantage of GRMT architecture (see section 3.5).

To illustrate the performance of GRMT, translation from English to Thai has been implemented. The English-Thai MT system translates isolated sentences (sentence by sentence). This English-Thai translation system has been developed and run under SWI-Prolog 3.2.8. The English and Thai grammars (see section 6.1.1.6) have been developed based on Head-Driven Phrase Structure Grammar formalism [Pollard and Sag 1987; Pollard and Sag 1994] and implemented on the Attribute Logic Engine version 3.2 Beta [Carpenter and Penn 1999].

GRMT was tested to generate the translations for a number of sentences/phrases by using a dictionary which contains 314 English words and their translations into 731 Thai words. The sample sentences/phrases were collected from different sources: newspapers, textbooks, articles, bedtime stories and fortune cookies.

3.1 Why Generate and Repair, Not Analyze and Generate?

GRMT (Figure 3.1) *generates* a TC directly from the SL input, analyzes and *repairs* (if necessary) the TC to verify its accuracy. The generate and repair methodology draws inspiration from the following sources:

- “...and since word-for-word translations are surprisingly good, it seems reasonable to accept a word-for-word translation as a first approximation and then see what can be done to improve it.” quoting Victor H. Yngve [Yngve 1955].
- “If someone asks me how I translate,I can describe the physical process: I make a very rapid first draft, put it aside for a while, then go over it at a painfully slow pace, pencil- and eraser-in hand ...” quoting William Weaver [Weaver 1989].

Based on Victor H Yngve’s¹ investigation on the direct MT approach and William Weaver’s² (human) translation procedure, the GRMT approach begins by generating an initial translation which we called the *translation candidate* and then revises the TC, if necessary, to ensure its accuracy.

The TC, the initial translation, must be generated simply, quickly and efficiently. Therefore, we generate the TC directly from the SL. Our TC generation process is different from the old fashioned Direct MT in several important aspects. The differences between languages have been used as constraints to limit the choices of the corresponding words in the TL. We select the most appropriate choice of TL word for each SL word by considering the relationship between the close proximity words (see section 5.2). All selected words are arranged into grammatical order according to the similarities and the dissimilarities between the structure of the SL and that of the TL. Once the TC generation is completed, the revision process begins by analyzing the TC to determine whether it is grammatically correct and conveys the linguistic meaning of the SL. To verify the meaning of the TC, we compare its parse with the parse of SL in terms of semantics only since there are differences in the syntactic level between languages. Any dissimilarity appearing in the TC parse will be repaired according to the semantic information of the SL parse.

¹ Victor H. Yngve investigated a word-to-word translation and this quote is a part of his conclusion.

² William Weaver is the author of several books about opera and a translator of modern Italian literature [Weaver 1989].

Example 1, one of the most popular examples during the first generation of MT, was translated into Russian and then back from Russian into English by the direct MT approach. The three different translations are shown below. None of these translations conveys the linguistic meaning of the original sentence.

Example 1

SL: The spirit is willing but the flesh is weak³.

Translated back from Russian into English :

- The whisky is all right but the meat has gone bad.
- The vodka is good but the meat is rotten.
- The liquor is holding out all right, but the meat has spoiled.

Table 3.1 illustrates the selected words (shown in the third column) and the TC generated by our generation process for the Example 1. If we translate back from this TC into English we will achieve the following translation: “The soul is ready but the body is weak”. This result is because the corresponding Thai word, วิญญาณ (winjaan), selected for the word *spirit* means “thought of as remaining alive without appearing in physical form.” (the descriptions of each word and its corresponding translations are provided in section 5.2).

The TC is verified and repaired in the revision process. The appropriate sense of *spirit* in the Example 1 is “mental or moral strength to resist.” which corresponds to Thai จิตใจ- cidcaj. Therefore, the word วิญญาณ (winjaan) is replaced with the word จิตใจ- cidcaj in the repair process. The repaired TC is shown in Table 3.1. If we translate back from the repaired TC into English, we will achieve “The mind is ready but the body is weak”.

Our TC generation process is distinct from the direct MT approach, not only the process of translation but also its modularity and extendibility (see section 3.5). Our TC generation process is a modular system in that each component can be modified and changed independently of each other and is intended to be easily extendible to any other language.

A good translation must be generated from a precise source. To generate a good translation from the SL parse, the SL parse should contain consistent information (in terms

³ In theory of 3D semantics [Galloway 1989], both “spirit” and “flesh” have alloemes in the domain of FOOD and in the domain of ANATOMY [Galloway 1993]. The reason FOOD is wrong for “flesh” is that the alloeme “meat” is archaic and rarely used; the alloeme in ANATOMY is thus the most likely one and this makes a domain match in ANATOMY for the alloeme of “spirit” also most likely. Thus “mind” and “body” are good alloeme choices.

of both syntax and semantics) required in the generation process. Unfortunately, there is no parser which can provide such parses available in all languages. Therefore, there is a possibility that a generation process generates the translation from the input, the SL parse, and the SL parse may contain errors. The errors accumulate during the generation process, depending on how the translation is generated. For example; in the transfer MT paradigm, to generate the translation from a SL parse, the structure and lexicon of the SL is transferred to those of the TL. This transfer process results in the information-loss problem we discussed in section 2.3.3.1.

Table 3.1: The TC and selected words generated for Example 1

SL: The spirit is willing but the flesh is weak.

TC: วิญญาณ นั้น พร้อม แต่ ร่างกาย นั้น อ่อนแอ

(winjaan- spirit) (nán- the) (phrǎm-willing) (tɛ'ɛ-but) (râaŋkaaj-flesh) (nán- the) (?ə'ən?ɛɛ-weak)

Repaired TC: จิตใจ นั้น พร้อม แต่ ร่างกาย นั้น อ่อนแอ

(cidcaj- spirit) (nán- the) (phrǎm-willing) (tɛ'ɛ-but) (râaŋkaaj-flesh) (nán- the) (?ə'ən?ɛɛ-weak)

Input	Possible corresponding words in Thai	Selected Word	Description ⁴
The spirit	นั้น (nán) วิญญาณ (winjaan), จิตใจ (cidcaj), ขวัญ (khwa'n), ความมุ่งมั่น (khwaammu'ŋmân), บรรยากาศ (banjaakaad), เหล่า (lâw), นำไปอย่างลึกลับ (nampajjaŋly'gláb)	นั้น (nán) วิญญาณ (winjaan)	determiner thought of as remaining alive without appearing in physical form.
is willing	- พร้อม (phrǎm), เต็มใจ (temcaj)	- พร้อม (phrǎm)	- regarding favorably the possibility of doing something, ready
but	แต่ (tɛ'ɛ), นอกจาก (nǎ'əgcàag)	แต่ (tɛ'ɛ)	in spite of this
the flesh	นั้น (nán) เนื้อ (ny'a), ร่างกาย (râaŋkaaj)	นั้น (nán) ร่างกาย (râaŋkaaj)	determiner the physical human body as opposed to the mind or soul
is weak	- อ่อนแอ (?ə'ən?ɛɛ)	- อ่อนแอ (?ə'ən?ɛɛ)	- not strong

⁴ The descriptions are provided in Longman Dictionary of Contemporary English [Longman 1992]. WordNet [Cognitive Science Laboratory 1998] and Merriam-Webster [Franklin 1987-1998].

In shake-and-bake MT, the generation process replaces the SL words in the parse with their corresponding TL words. A number of algorithms were proposed to combine these TL words according to the TL grammar (see section 2.3.3.3). However, none of these algorithms is guaranteed to avoid protracted search times during the generation process.

In interlingual MT, the analysis produces a pure interlingua which does not contain any syntactic information. Generating the TL from this parse could result in a paraphrase, not a translation (see section 2.3.3.3).

In our approach, we generate the translation candidate directly from the SL to avoid these problems: an inaccurate input of the generation process (the SL parse), the information lost during the transfer process, protracted search times during the generation process, the doubt about paraphrase/translation. The TC is revised to ensure that the translation is grammatically correct and preserves the meaning of the SL

3.2 The Three Phases

Analysis Lite Machine Translation generates a TC by considering the differences between language pairs in terms of syntax and semantics without performing any sophisticated analysis. ALMT first simplifies the structure of SL and then considers TL words which correspond to all possible meanings of each SL word. The most appropriate TL word is selected by applying a semantic relationship between words. To make the TC grammatically correct in the TL and to retain the meaning of the SL, some words in the TL may be added and then all words are rearranged according to the grammar of the TL. ALMT comprises three modules: word treatment, word selection, and word ordering.

Translation Candidate Evaluation analyzes the generated TC, which is an output of the previous step, ALMT, to determine whether the TC retains the meaning of the SL. TCE performs the evaluation by analyzing both the TC and the SL in terms of syntax and semantics in parallel. Then only the semantic results are compared (there are syntactic level differences between languages). If the semantic results are the same, that TC will be deemed an acceptable translation. If not, any part of the TC which causes its semantics to differ from that of SL will be repaired in the next phase, RI.

Repair and Iterate will replace inappropriate words or rearrange words in the TC depending on the analysis results of the previous step, TCE. The analysis results will identify

the incorrect (inappropriate) parts and RI will use the analysis result of the SL as a pattern for repairing the TC.

3.3 Knowledge-bases Required

The essential knowledge-bases required for GRMT include: Constraints, Dictionaries, and Grammar and Lexicon. The SL and TL knowledge-bases are developed separately for easy modification, extendibility and management. The details of each knowledge-base will be discussed in later sections where appropriate.

Constraints, the different characteristics between languages, are required in ALMT. There are two sets of constraints: SL constraints and TL constraints. The *SL constraints* are the characteristics of the SL which are different from those of the TL. They are used to simplify the structure of the SL and to narrow the scope of possible TL words which correspond to each SL word (see section 5.1.1). The *TL constraints* are the characteristics of the TL which are different from those of the SL. They are required, not only to retain the meaning of SL but also to make them grammatically correct (see section 5.3.1).

The *SL dictionary* is required in ALMT. It is used in the constraint application and inflectional analysis steps. Each entry contains its syntactic categories. The SL and the TL are put into correspondence via the *SL-TL dictionary*. The SL-TL dictionary contains the SL entry and its all possible corresponding words in the TL. Each corresponding TL word is related to its Word Association (WordAsso) number (see section 4.2). All TL words are ordered according to the frequency of usage.

Grammars and lexicons of both SL and TL are required in the analysis process of TCE. Grammars and lexicons of SL and TL are developed principally based on the linguistic theories applied to GRMT, Head-Driven Phrase Structure Grammar [Pollard and Sag 1987; Pollard and Sag 1994]. Each lexical entry contains morphological, syntactic and semantic information (see section 6.1.1.3).

3.4 Translation Examples by GRMT

In this section we present the results of applying GRMT to the translation of some English example sentences into Thai. The input symbols of Example 2 are shown in the first column labeled input (Table 3.2). The second column illustrates the output after applying

the constraints. In this example, no constraint is applied. Each word in this column is used as a keyword to search for the corresponding words in Thai. All possible translations in Thai of each input word are shown in the third column. The most appropriate words are selected by ALMT (see section 5.2) and the choices are shown in the fourth column. The classifier⁵ ตัว (tua, in shaded box) is added to complete the TC (details are described in section 5.3.1).

This generated TC and the SL were analyzed in the TCE, the second phase of GRMT. The parses show that the TC requires no repair (see section 6.1.1.6). Thus, the generated TC is a complete translation of Example 2. Table 3.3 presents four different senses of the word *spring* in the classification system (see section 4.2) and their corresponding words in Thai: ฤดูใบไม้ผลิ (ry'duubajmáajphli), สปริง (sapring), กระโดด (kradòod) and น้ำพุ (námphú). Each word is classified into different classes according to its meaning as illustrated in the fourth column of Table 3.3 (see section 4.2). Consider the case that the word ฤดูใบไม้ผลิ (ry'duubajmáajphli) is chosen for the word *spring*⁶ in Example 3 by ALMT as shown in Table 3.4. The TCE indicated the inappropriate selection by comparing

Table 3.2: The selected words and the TC generated for Example 2

Example 2

SL: The ugly duckling hides his head under his wing.

TC: ลูกเป็ด ขี้เหร่ ตัว นั้น ซ่อน หัว ของเขา ได้ ปก ของเขา
(lúugpèd- duckling) (khiirèe- ugly) (tua- clas) (nán- the) (sǎʔn- hide) (hũa- head) (khǎʔnkhaw- his)
(tǎaj- under) (piig- wing) (khǎʔnkhaw- his)

Input	Constraint Application	Dic. Lookup & Inflec. Analysis	Selected Word
The	The	นั้น (nán)	นั้น (nán)
ugly	ugly	ขี้เหร่ (khiirèe), น่าเกลียด (nâakliad)	ขี้เหร่ (khiirèe)
duckling	duckling	ลูกเป็ด (lúugpèd)	ลูกเป็ด (lúugpèd)
hides	hides	ได้ซ่อน (dǎjsǎʔn), ได้ปิดบัง (dǎjpidban),	ได้ซ่อน (dǎjsǎʔn),
his	his	ของเขา (khǎʔnkhaw)	ของเขา (khǎʔnkhaw)
head	head	หัว (hũa)	หัว (hũa)
under	under	ใต้ (tǎaj), ภายใต (phaajtǎaj), ต่ำกว่า (tǎmkwǎa)	ใต้ (tǎaj).
his	his	ของเขา (khǎʔnkhaw)	ของเขา (khǎʔnkhaw)
wing	wing	ปีก (piig), บิน (bin), กองบิน (kaʔnbin)	ปีก (piig).

⁵ In Thai, *classifiers* are used to express not only a quantity but also to modify a noun (see section 4.1)

⁶ In our experiment, ALMT selected the correct corresponding Thai word for the word *spring* in this expression. This inappropriate selection is to illustrate the repair process (see section 6.1.2.2).

Table 3.3: Three corresponding Thai words to the word *spring*

English	Thai	Description	Word Class
spring	ฤดูใบไม้ผลิ (ry'duubajmáajphli)	The season between winter and summer	Season
	สปริง (sapring)	An elastic device	Elastic device
	กระโดด (kradòod)	To move suddenly upward or forward	Move forward as if by jumping
	น้ำพุ (námphú)	A place where water comes up naturally from the ground	Geology

the SL and the TC parses. The SL parse determined the appropriate meaning of the word *spring* in this expression is “An elastic device” (see section 6.1.2.2). But in the TC parse, the word ฤดูใบไม้ผลิ (ry'duubajmáajphli) means “The season between winter and summer”. According to the analysis of analyzing the SL, the RI module replaced the incorrect selection ฤดูใบไม้ผลิ (ry'duubajmáajphli) with the word สปริง (sapring) to generate the new TC for Example 3: จอห์น พูด เกี่ยวกับ สปริง⁷ ที่ หัก อัน⁷ นั้น. This new TC was analyzed and compared to

Table 3.4: The selected words and the TC generated for Example 3

Example 3

SL: John talks about the broken spring.

TC: จอห์น พูด เกี่ยวกับ ฤดูใบไม้ผลิ ที่ หัก นั้น

(cæn- John) (phûud- talk) (kiàwkàb- about) (ry'duubajmáajphli- spring, the season) (thîi-modifying) (hàg- broken) (nán- the)

Input	Constraint Application	Dic. Lookup & Inflec. Analysis	Selected Word
John	John	จอห์น (cæn)	จอห์น (cæn)
talks	talks	พูด (phûud), บรรยาย (banjaaj), คอย (khu)	พูด (phûud)
about	about	เกี่ยวกับ (kiàwkàb), ประมาณ (pramaan), ไปทั่ว (pajthûa), เกือบจะ (ky'abca)	เกี่ยวกับ (kiàwkàb)
the	the	นั้น (nán)	นั้น (nán)
broken	broken	หัก (hàg)	หัก (hàg)
spring	spring	ฤดูใบไม้ผลิ (ry'duubajmáajphli), สปริง (sapring), กระโดด (kradòod), น้ำพุ (námphú)	ฤดูใบไม้ผลิ (ry'duubajmáajphli)

⁷ The classifier อัน (?an) is added during the repair process (see chapter 7).

the SL parse again and the TCE found no semantic difference between them. Therefore, this new TC is an appropriate translation for Example 3.

3.5 Key Features of GRMT

The key features of GRMT are: simplicity, modularity, extendibility and multilinguality, by which we mean the following:

Simplicity Each step performed by GRMT is straightforward and simple to carry out.

Modularity GRMT's translation process is separated into three modules: ALMT, TCE and RI. Each module is comprised of sub-modules for easy modification and maintenance. ALMT is comprised of word treatment, word selection and word ordering. Word treatment deals with the syntax of the SL while the word ordering is concerned with the syntax of the TL. The SL and TL are treated separately and related via the SL-TL dictionary. The SL and the TC analysis modules in the TCE are separated. The repair process in the RI module does not depend on languages, it can be applied to any languages pair. The knowledge-bases: constraints, dictionaries, grammars and lexicons required in GRMT are developed separately.

Extendibility GRMT is intended to be easily extendible to any other language. Since each component is separated not only in the translation process components but also in the knowledge-bases, each component can be extended easily to a larger domain. The constraints of the SL and those of the TL are developed separately. The SL-dictionary contains only the word form and its syntactic categories information. The SL-TL dictionary contains the SL word form and its corresponding words in the TL with its WordAsso numbers. The grammars we developed are based on the HPSG formalism which provides for adequate coverage of the language with few grammar rules. HPSG theory is a lexically oriented theory and lexical entries are complex. The lexicons are very rich in information and well organized. The lexical rules reduce the number of lexical entries (see section 6.1.1.3). Therefore, the knowledge-bases of new languages can easily be integrated into GRMT which is suitable for multilingual machine translation.

Multilinguality GRMT is designed to be amenable to a multilingual MT system. The multilinguality feature depends on the modularity and extendibility features of the system. GRMT is highly modular and extendible in two major respects. The first respect is the treatment of the SL and TL are independent of each other which means the same output of the SL constraints application module can be an input to more than one TL Word selection

module, provided that those TLs share common characteristics. The second respect is the knowledge-bases of the SL and TL required are developed separately, hence it is easy to add the new languages to the system. For example, the SL-constraints (e.g., Plurality, Continuous tense, Adjective and so on; see section 5.1.1) required in translating from English into Thai can be applied to the translation from English into Chinese and Japanese since Chinese, Japanese and Thai share those characteristics. Where French and Spanish share the same syntactic features with English, features which differ from those of Thai, Chinese and Japanese, then GRMT requires six analyzers and two sets of constraints to perform the translation between the two language families (Figure 3.2) while the transfer MT approach requires six SL analyzers, six TL generations and eighteen sets of transfer rules.

Figure 3.2: The translation between languages of two language families⁸

We now go onto considerable detail of how GRMT works, first considering the English and Thai languages used to illustrate GRMT.

⁸ While Chinese is a member of the Sino-Tibetan language family and Thai and Japanese are not: Japanese is not proven to be related to any language family, but the most discussed possibility is that it could be a distant relative of the Altaic language family. Thai is a member of the unrelated Tai family [Crystal 1987]. However, Chinese, Japanese, and Thai are typologically similar in a number of ways (share certain features of phonology and syntax), which is why they have been grouped here. English, French, and Spanish, in contrast are all members of the same language family. Indo-European (This information provided by Dr. Brent D. Galloway).

Chapter 4

Differences Between Languages: The English and Thai Languages

An advantage employed by GRMT is its treatment of the differences between languages. Some significant characteristics of the source language and the target language, English and Thai in this experiment, are described in this chapter and exploited by GRMT. We conclude this chapter with the word classification and their usage in GRMT.

4.1 Differences between Thai and English

Thai is the standard spoken and literary language of Thailand. Thai is basically monosyllabic in word form. In addition to consonants and vowels¹, each syllable has one of five phonemically differentiated tones (middle, low, falling, high and rising). The Thai language is written as a string of words with no explicit boundary marker between words. Different segmentations result in different meanings or no meaning. In this dissertation, a space is used to specify the word boundary in order to make interpretation simple and clear to the reader.

In Thai, morphology is restricted to derivation² since the language makes no use of inflection³. The word form does not change according to its parts of speech. In other words, the same word form can be a noun, verb, adjective and so on (some examples are shown in

¹ Thai has 44 consonants, 21 vowel forms and 32 vowel sounds.

^{2, 3} *Inflection* provides the various forms of any single word while *Derivation* creates new words from the old ones [Covington 1994].

Table 4.1: Descriptions and the English corresponding words of คน (khon), เขว (khaw) and ที่ (thii)

Thai	Part of Speech	Semantic Description ⁴	English
คน- khon	noun	human being- a man, woman or child, not an animal	human, person
	verb	to move (esp. something mainly liquid) around and mix something into it with a spoon or similar object.	stir
	classifier ⁵	classifier of human being (see page 43)	-
เขา- khaw	pronoun	The male/female person already mentioned.	he/she
	noun	a very high hill.	mountain
ที่- thii	noun	<ul style="list-style-type: none"> a particular area or position in space in relation to others. a particular part of the Earth's surface, such as a stretch of land, a town, a building. a position that can be used by someone for a particular purpose. something measurable in length, width or depth; area or volume that can be used or filled by a physical object; room. 	place, space
	relative pronoun	corresponds to the following English pronouns: who- person, which- thing, where- place.	which, who, where
	conjunction	used for introducing various kinds of clauses.	that
	classifier	classifier of place, space.	-
	preposition	shows a point in space.	at

Table 4.1). There is no inflection due to “verb agreement”, “tense”, “passive voice” and “number”. The non-inflection feature leads to the number of constraints which are used in the first phase, ALMT, of GRMT (see section 5.1.1).

The Thai verb does not have an inflection resulting from verb agreement. In Figure 4.1, it does not matter what the subject is, the word *eat* is translated as กิน- kin. Tense, passive voice and number can be indicated by additional words as shown in Table 4.2. The words กำลัง (kamlaŋ), แล้ว (le'ɛw), ได้ (dâj), เคย (khej) and จะ (cà?) are used to indicate different time aspects.

⁴ Semantic descriptions are provided from Longman Dictionary of Contemporary English [Longman 1992] and Thai-English Student's Dictionary [Haas 1964]

⁵ Classifiers indicate the unit of a countable noun (see page 43).

⁶ Gerunds (e.g., parking, fishing,) and present participles as adjectives (e.g., boring, terrifying) are exceptions.

<u>I</u> eat rice every day.	ฉัน กิน ข้าว ทุก วัน (chân- I) (kin- eat) (khâaw- rice) (thúg- every) (wan- day)
<u>He</u> eats rice every day.	เขา กิน ข้าว ทุก วัน (khaw- he) (kin- eat) (khâaw- rice) (thúg- every) (wan- day)
<u>They</u> eat rice every day.	พวกเขา กิน ข้าว ทุก วัน (phûagkhaw- they) (kin- eat) (khâaw- rice) (thúg- every) (wan- day)
<u>John</u> eats rice every day.	จอห์น กิน ข้าว ทุก วัน (cawn- John) (kin- eat) (khâaw- rice) (thúg- every) (wan- day)

Figure 4.1: Examples of กิน (kin) and its subjects

- กำลัง (kamlaŋ) is used before the verb⁶ to mark an on-going or progressive action.
- แล้ว (le'ew) shows past tense and denotes a completed action. แล้ว (le'ew) appears immediately after the verb and its object or right after the verb if there is no object.
- ได้ (dâj) also shows past tense. It immediately precedes the verb. It is often used in conjunction with แล้ว (le'ew).
- เคย (khəj) also precedes the verb and is used to designate an action in the indefinite past.
- จะ (cǎ?) is used to mark an action to be completed in the future. It always appears directly before the verb.

Some examples are illustrated in Figure 4.2. Tenses can also be conveyed by context, or by means of adding time indicators e.g., today, tomorrow, last year, yesterday. A phrase can refer to an action at any time, without a time reference.

Table 4.2: Additional words to express Tense, Passive Voice and Plurality in Thai

Thai	English	Description
กำลัง (kamlaŋ) + V	V to be + V-ing	aspect
V + (obj)+ แล้ว (le'ew)	V2	past tense
ได้ (dâj) + V + แล้ว (le'ew)	V2	past tense
จะ (cǎ?) + V	will + V	future tense
ถูก (thùug) + V	V to be + V3	passive voice
N + หลาย (la'aj)	N-s, N-es	plurality

In Thai, passive voice is rarely used. It is used mainly when discussing an unpleasant situation; Figure 4.3 illustrates some examples. The word ถูก (thùug) denotes the passive voice in Thai. In the third example, the first of the two Thai sentences, which is passive, is not generally used in Thai even though it is grammatically correct. The second sentence carries the same meaning but it is in active voice.

I am swimming.	ฉัน กำลัง ว่ายน้ำ (chân- I) (kamlaŋ- ing) ('wâaj-náam'- swim)
He bought a book.	เขา ซื้อ หนังสือ แล้ว (khaw- he) (sy'y - buy) (naŋsy'y - book) (lɛ'ɛw - past tense marker)
The duckling hid in the farmyard.	ลูกเป็ด ตัว นั้น ได้ ซ่อน ใน ลานติดโรงนา แห่ง นั้น (lûugpèd -duckling) (tua-classifier ⁵) (nán-the) (dâj- past tense marker) (sɔ'ɔk-hid) (naj-in) (laantidroonaa-farmyard) (hɛ'ŋ- classifier) (nán-the)
The wedding will take place in December.	การแต่งงาน นั้น จะ มีขึ้น ใน เดือนธันวาคม (kaante'ŋaan- wedding) (nán-the) (cǎ?- will) (miikhy'-take place) (naj-in) (dyanthanwaakhom- December)

Figure 4.2: Examples of additional words to indicate different tenses and aspects.

He was killed.	เขา ถูก ฆ่า (khaw- he) (thùug- passive) (khâa- kill)
He was arrested.	เขา ถูก จับ (khaw- he) (thùug- passive) (càb- arrest)
The book was taken by him.	หนังสือ ถูก เขา เอา ไป (naŋsy-y- book) (thùug- passive) (khaw- him) (?aw- take) (paj - modifying) เขา เอา หนังสือ ไป (khaw- him) (?aw- take) (naŋsy'y- book) (paj- modifying)

Figure 4.3: Examples of passive voice in Thai.

In Thai, to express a quantity of countable nouns, either by quantifiers e.g., หลาย⁷ (la'aj), บาง⁸ (baaŋ) or numbers, *classifiers* are required. A classifier indicates the unit of a noun, each countable noun is compatible with a specific classifier (see Figure 4.4).

⁷ หลาย- la'aj corresponds to the word *many* in English.

⁸ บาง- baaŋ corresponds to *some* in English.

The structure of a Thai phrase is similar to that of English in that the typical sentence contains subject, verb and object, in that order. However, some structures are different e.g., in Thai the head (noun) must precede its attributes, possessive pronouns and determiners. The negative of “can”, and “could” is formed in the reverse order of the order in English. Some examples are shown in Figure 4.5. These differences must be considered in the ordering process (see section 5.3).

two fish.	ปลา 2 ตัว (plaa-fish) (sǎʔ-two) (tua-classifier)
two books.	หนังสือ 2 เล่ม (naʔsyʔ-y-book) (sǎʔ-two) (lêṃ-classifier)
some animals.	สัตว์ บาง ชนิด (sǎd- animal) (baaʔ - some) (chaníḍ- classifier)
many people.	คน หลาย คน (khon- people) (many- laʔaj) (khon- classifier)

Figure 4.4: Examples of classifiers

In addition, auxiliary verbs in English are needed in many cases, e.g., in front of an adjective or negative “not”, but they are not used in Thai for the same expression as shown in Figure 4.6. The English pronoun “there” followed by auxiliary “to be” shows that something or someone exists or happens (see Figure 4.6). “There” plus auxiliary “to be” corresponds to the word มี (mii) in Thai. These differences are considered in the constraint application process.

gray ugly duckling	ลูกเป็ด ขี้เหร่ สีเทา (lúṃpèḍ- duckling) (khīrèe- ugly)
her brown hen	ไก่ สีน้ำตาล ของเธอ (kāj- hen) (sǐʔínámtaan- brown) (khǎʔṇthǎə- her)
the old lady	ผู้หญิง แก่ คน นั้น (phūṃjǐʔ- woman) (kɛʔ- old) (khon -classifier)(nán -the)
should not	ไม่ ควร (māj -not) (khuan -should)

Figure 4.5: Examples of Thai attributive constructions

Of course there are additional significant differences between Thai and English. The differences illustrated in this section are to provide the reader with some insight of differences GRMT takes advantage of in generating accurate translations.

4.2 Word Classification

In chapter 3, we sketched the overall architecture of GRMT in which the relationship between words was employed in several modules e.g., TL word selection and classifier selection in ALMT (the classifier selection is applied to some languages which require classifiers e.g., Thai, Chinese, Japanese), analysis in TCE, comparison and repair in RI. The semantic relationship between words was built based on the words' classes. In this section, we discuss our word classification technique and criteria by which we created the semantic relationship between words and word classes.

I am <u>glad</u>	ฉัน ดีใจ (chân- I) (diicaj- glad)
He does <u>not</u> eat	เขา ไม่ กิน (khaw- he) (mâj- not) (kin- eat)
His neck was <u>long</u> .	คอ ของเขา ยาว (khaw- neck) (khaw~khaw- his) (jaaw- long)
There <u>is</u> a book.	มี หนังสือ หนึ่ง เล่ม (mii- 'There-is') (nan'sy-y- book) (ny'- a) (lêm- unit)

Figure 4.6: Examples of Thai constructions without auxiliary verb

In designing our word classification, we have considered the *A Kind Of* (AKO) relation which was designed to be used in the CICC MMT project (see section 2.3.3.1), the topic hierarchy for physical objects [Cercone et al. 1992] and Hypernym in WordNet 1.6 for English [Cognitive Science Laboratory 1998] with significant introspection⁹.

⁹ Different point of view will result in different epistemologies (word classification). What important is that independent of epistemologies, the same classification be use across languages to whatever extent possible. Our word classification is the first attempt based on the CICC AKO, topic hierarchy for physical objects, and Hypernym in WordNet 1.6. as GRMT evolves so will the word classification.

In the CICC MMT project; AKO, co-occurrence information and concept identifier (concept-id) were developed. *AKO* is basically a relationship between a word and its concept class (or semantic domain). Each participating country developed the concept classification for its language based on its own criteria; therefore, the resulting AKO systems are different. For example, the Thai concept classification was developed by grouping words with a specific definitions into the same class [CICC 1995f]. A part of Thai concept classification is shown in Figure 4.7. Each class was assigned a number. The digit which comes after a hyphen “-” is the subclass number, the digit which comes before a hyphen is the superclass number. For example, *Animal* with AKO number 1-1-2 is a second subclass of the superclass 1-1 which is an AKO number of a class *Living Thing*. The Indonesian concept classification (Figure 4.8) was developed based on syntactic categories, e.g., nouns are classified into two main classes: *concrete thing* and *abstract thing*; verbs are classified into class *event* with three subclasses state, process and action. Adjective and adverb are classified into classes *properties* and *manner* respectively [CICC 1995b]. The numbering system of the Indonesian AKO is the same as that of Thai AKO. However, AKO specifications for Thai, Indonesian and Chinese have the same problems regarding consistency and coverage [CICC 1995a; CICC 1995g; CICC 1995h].

Figure 4.7: A part of Thai Concept Classification (CICC MMT)

Co-occurrence information indicates the syntactic relationship between words e.g., subject and verb relation, verb and second complement relation [CICC 1995j]. Thai co-

occurrence information was designed from the co-occurrence of two to five adjacent words. The Indonesian version only considered co-occurrence from two adjacent words [CICC 1995c].

Figure 4.8: A part of Indonesian Concept Classification (CICC MMT)

Concepts (variant meanings or alloemes) of words in each language were assigned a concept-id. For example, the concept-id *3be7d8* is assigned to the Thai word เครื่องกรอง (khry^ˆan^ˆkrð^ˆη) which corresponds to the English word *filter* in the sense of “a porous material through which a fluid is passed to separate out matter in suspension.” [CICC 1995g]. Each country designed its own concept-id system. Therefore, a concept-id linking table was needed to link the concepts of each language to IL.

In the Thai analysis process, AKO and syntactic information were used to determine the semantic relationship between two nouns [CICC 1995f]. For example, the syntactic categories of นายแพทย์ (naajphe^ˆed) and สุนทร (su^ˆnthð^ˆan), Example 1, are *title noun* and *proper noun* (Table 4.3); therefore, the semantic relationship between นายแพทย์ (naajphe^ˆed) and สุนทร (su^ˆnthð^ˆan) is “name” according to the information available in Table 4.4. The semantic relationship between ปลา (plə^ˆg) and ปลาหมึก (pàagkaa), Example 2, is “part-of” since their syntactic categories are *common nouns* with the AKO numbers 1-2-6 and 1-2-5-1-2 respectively.

Co-occurrence information was used to solve lexical ambiguity problems [CICC 1995j]. In the Thai generation process, co-occurrence was used in selecting the surface form of verbs and adjectives. For example: the word *beautiful* in “beautiful lady” corresponds to the

wordสวย (su^{aj}) which means “having beauty”. However, the word *beautiful* in “beautiful song” corresponds to the word เพราะ (phrə^ʔ) in the sense of “very good” according to the co-occurrence information available in Figure 4.9 [CICC 1995i].

Example 1: นายแพทย์ สุนทร
(naajphe^{ed}- Dr.) (su^{nthaa}- Sunthorn)

Example 2: ปากก ปากกา
(plə^{ag}- cap) (paa^{gkaa}- pen)

Table 4.3: Some information of the words นายแพทย์, สุนทร, ปากก and ปากกา

Thai	Corresponding Word in English	Syntactic Categories	AKO	Description
นายแพทย์- naajphe ^{ed}	Dr.	title noun	-	Abbreviation of doctor.
สุนทร- su ^{nthaa}	Sunthorn	proper noun	-	person’s given name.
ปากก- plə ^{ag}	cap	common noun	1-2-6	a movable cover
ปากกา- paa ^{gkaa}	pen	common noun	1-2-5-1-2	an instrument for writing or drawing with ink.

Table 4.4: Semantic relationships assigned for noun-noun combination in CICC MMT

Semantic relationship	Syntactic category and AKO number	Syntactic category and AKO number
modifier	collective noun AKO = 2-3-4	common noun
part of	common noun AKO= 1-3-1-1-2, 1-3-1-1-4, 1-3-2-3, 1-2-6	common noun AKO =1-1-1,1-3-1-1,1-3-1-1-3, 1-2-5-1-2
name	title noun	proper noun

เพราะ
 /phr@/
 c#beautiful
 BEAUTIFUL
 ECAT. {V}
 ESUBCAT.{VATT}
 EMAPS.{SUB=ATT}
 ATT.{c#song}

Figure 4.9: A co-occurrence of the word เพราะ (phrə^ʔ) [CICC 1995i]

AKO was used in the analysis process of Indonesian and Chinese also but no public document was produced to show how AKO was used. In the Indonesian generation process, co-occurrence was used to determine whether the occurrence of two adjacent words in a sentence was correct [CICC 1995d].

Developing an AKO system required great effort; however, AKO application was not fully utilized in the CICC MMT system. Our explorations revealed that suitably constructed AKO information is useful in selecting the surface form of TL words in a translation process and it helps to determine the occurrence of adjacent words in the expression. In addition, if AKO information for each language was designed using the same criteria, the AKO information might also be used in linking concept-id.

The topic hierarchy for physical objects was designed to be used in the English Conversation System (ECO) family formalism of semantic network [Cercone et al. 1992]. ECO was developed at University of Alberta during 1974-1978 by Len Schubert, Nick Cercone, Randy Goebel and Al Covington. ECO represents an extended semantic network formalism which is used for representing troublesome natural language constructions, e.g., logical connectives, quantifiers, descriptions, modalities. ECO classifies propositions according to their topic e.g., color proposition, location proposition, size proposition and so on. ECO structures propositions associated with each concept according to a topic hierarchy. A topic is defined as a predicate over proposition-concept pairs. For example, for the proposition *A zebra has black and white stripes*, a topic predicate *coloring* is instantiated in relation to the concept *zebra*. Topic predicates which are linked by subtopic and supertopic form a topic hierarchy. Topic hierarchies provide a basis for organizing the propositions attached to a node of a particular kind. Topic hierarchies are useful in organizing the retrieval of information relevant to the implications of concepts. To accelerate a deductive inference for *Types* in the ECO family, the partitioning hierarchies of type predicates are used as a logical representation of the relationships among the predicates that appear in the . . . hierarchy. Figure 4.10 illustrates a partitioning type hierarchy for *thing*. The numbers following the predicates are assigned when the hierarchy is created or changed. This number is used to determine the

Figure 4.10: A partition type hierarchy for *thing* [Cerccone et al. 1992]

subsumption or disjointness relationships. For example: *wolf* and *human* are disjoint because there is no overlap between the numbering range associated with wolf [38,38] and human [17,26]. *Wolf* is subsumed by *creature* because wolf [38, 38] is ranged within creature [16,40]. The same predicate can appear in several hierarchies, all connected at that predicate. Overlap hierarchies are also possible.

WordNet 1.6 is a program that allows users to explore an on-line dictionary on the basis of semantic, rather than alphabetic, similarities [Cognitive Science Laboratory 1998]. WordNet does not contain syntagmatic relations linking words from different syntactic categories because the syntactic categories noun, verb, adverb and adjective are treated separately due to the semantic differences between the relations that link words and concepts from those syntactic categories [Fellbaum 1998]. For example, the relation that links nouns differs from the relation that links verbs. The semantic relation that is most important in organizing nouns is a relation between lexicalized concepts. This relation is called *Hypernym*. Hypernym is the generic term used to designate a whole class of specific instances. Y is a hypernym of X if X is a (kind of) Y. For example: *bird* is a hypernym of *robin*. This semantic relation organizes nouns into a lexical hierarchy. A lexical hierarchy can be reconstructed by following the trail of hypernymically related synonym sets. The semantic relation between sets is *is-a* or *is-a-kind-of*. This hierarchy goes from many specific terms at the lower levels to a few generic terms at the top. The nouns in WordNet form a lexical

inheritance system where by all of the properties of the superordinate are assumed to be properties of the subordinate as well. For example: according to the WordNet; *robin* is-a *thrush*, a *thrush* is-an *oscine*, an *oscine* is-a *passerine*, a *passerine* is-a *bird*. Therefore, robin inherited perching from passerine, singing from oscine, and flying and migration from thrush (This example is taken from [Miller, 1998]). In WordNet, verbs are grouped together as sets of synonyms, like nouns. However, the semantic relation between set of verbs is expressed by *is one way to*. For example: *see* is-one-way-to *perceive*, *drink* is-one-way-to *consume* or *ingest*.

We further developed our notion of word classification by classifying words into categories based on shared characteristics. From ECO we borrow the notion that subclasses are subsumed by their superclasses, cf., the topic hierarchy for physical objects. Words in our classification form a lexical inheritance system like nouns in WordNet. Since we were concerned with consistency as well and we wanted to apply this classification in MT, we needed to classify words in any language under the “same umbrella” even though there were differences at some levels between different languages. Our solution is to classify words into categories according to the same criteria, regardless of language as discussed in the next section.

4.2.1 Word Classification Criteria

In GRMT, word classification information is applied to be used in word selection, classifier selection, TCE analysis, comparison and repair processes.

To select the most appropriate word for each input word in ALMT, we consider the relationship between the close proximity words. We must know which word can occur with which word in the same expression. To obtain that information, semantic information of each word should be considered and also the semantic relationship between proximity words. Thus, the criteria used in classifying words considers the definition or meaning of words and their usage. Words which share significant features are classified into the same group. With these criteria, words in GRMT dictionaries are classified into thirteen categories: Thing, Abstraction, Phenomenon, Event, State, Be, Reference term for thing, Group/Grouping, Be able to, Get/Acquire, Have, Accumulate/Collect, and Attribute value. New categories can be added in future if it is necessary to do so. A classification fragment is shown in Figure 4.11 (see also appendix A).

Since we classified words not only according to their meaning but also their usage, words in the same class will automatically be in the same syntactic category, e.g., words in the class *thing* are nouns, words in the class *act* (a subclass of *abstraction*) are verbs, words in the class *attribute value* are adjectives and adverbs. The semantic relation between classes and their superclass is *is-a*. For example: *turkey is-a fowl*, *fowl is-a bird*, *bird is-a vertebrate*, *vertebrate is-an animal*, *animal is-a living thing*, *living thing is-a concrete thing*, *concrete thing is-a thing*; *say is-a way to utter*, *utter is-a way to communicate*, *communicate is-a way to interact*, *way to interact is-a way to act*, *act is-an abstraction*. The semantic relation forms a lexical inheritance hierarchy which generally means all properties of the superclass are assumed to be

Figure 4.11: A part of word classification in GRMT.

properties of the subclasses as well. This property is useful in the comparison step of TCE, the second phase of GRMT.

A word can be classified into more than one class depending on context and usage. For example: *turkey* is also classified into the class of *poultry*, *poultry* is-a *meat*, *meat* is-a *foodstuff*, *foodstuff* is-a *food*, *food* is-a *substance*, *substance* is-an *object*, *object* is-a *non-living thing*, *non-living thing* is-a *concrete thing*, *concrete thing* is-a *thing*.

Words which are used to link phrases with clauses or connect clauses together or provide the basis for a descriptive phrase e.g., prepositions, conjunctions, definite determiner are classified as well. A separate classification is built for those words, see appendix D for examples.

The scope of any class can be narrowed, if necessary, by subdividing a class into subclasses. For example, consider the class “vehicle”. If we classify “vehicle” into two subgroups by mode of transportation as shown in Table 4.5: by land, and by sea or by air. Then the classifiers คั้น-khan and ขบวน (khabuan) are compatible with the first subgroup, by land, while the classifier ลำ- lam is compatible with the second subgroup, by sea or by air. The group “by land” can be classified further into “Train” and “Road/Rails vehicle (but not train)”. The classifiers ขบวน (khabuan) and คั้น (khan) are compatible with the group “train” and “Road/Rails vehicle” respectively. This classification is used to select an appropriate classifier for a noun if it is required, in the word addition step of ALMT and the analysis process of TCE.

Table 4.5. The subgroup of *vehicle*.

Class	Subclass	Examples	Classifier
Land	Train	รถไฟ (ródfaj-train)	ขบวน (khabuan) คั้น (khan)
	Road/ Rail vehicle	รถยนต์ (ródjon-automobile) รถพ่วง (ródpũan-trailer) รถลาก (ródlâag-rickshaw) รถม้า (ródmâa-horse carriage) รถจักรยาน (ródcâgkajaan- bicycle) รถราง (ródraan-streetcar, tram)	
	Air or Sea	เรือใบ (ryabaj-sailboat)	ลำ (lam)
		เรือหางยาว (ryaha'anjaaw-“long-tailed boat”)	
		เครื่องบิน (khry'anbin-“airplane”)	

For efficient MMT, words in different languages must be classified into the same classification system, some examples are shown in Table 4.6. For example, we can use the classification information of each word as a part of the semantic information of any phrase which contains that word. The last issue that we must be concerned with in classifying words is “consistency”.

Each class is assigned a number which is called *Word Association* (WordAsso) *number*. WordAsso number represents a relation between a word and its class. Words which belong to the same class are assigned the same WordAsso number. We number classes using the convention that was used in CICC AKO for Thai. The digit which comes after a hyphen “-” is the subclass number, the digit which comes before a hyphen is the superclass number. For example, in Table 4.6, *Imaginary creature* with WordAsso number 1-2-1-2-2 is a second subclass of the superclass 1-2-1-2 which is a WordAsso number of a class *Imaginary being*. The class *Imaginary being* is the second subclass of a class *Supernatural thing* with WordAsso number 1-2-1. This numbering system is used for easy modification.

Table 4.6: Some classified English and Thai words

Class	Sample Word
1 Thing	
1-2 Abstract thing	
1-2-1 Supernatural thing	
1-2-1-1 Supernatural being	Jesus, God, เทวดา (theewadaa- male angel), angel, นางฟ้า (naanfǎa- female angel), พระพุทธเจ้า (phráphúthacǎaw-The Lord Buddha)
1-2-1-1-1 Spirit	ghost, ผี (phī-i- ghost) วิญญาณ (winjaan- spirit, soul)
1-2-1-1-1-1 Good spirit	
1-2-1-1-1-2 Evil spirit	satan, devil, demon, ผีปอบ (phī-īpǎʼəb- ghou!) ปีศาจ (piisǎad- devil, demon)
1-2-1-2 Imaginary being	
1-2-1-2-1 Imaginary person	Santa Claus, tooth-fairy, mermaid, นางเงือก (naanngyǎag- mermaid)
1-2-1-2-2 Imaginary creature	Pegasus, unicorn, ครุฑ (khrúd - Garuda ¹⁰), นาคร (nāag-Naga ¹¹)

¹⁰ Garuda is a supernatural half-man and half-bird vehicle or bearer of Vishnu. It is a state symbol of Thailand.

¹¹ Naga is a legendary serpent (Longman Dictionary).

4.2.2 The semantic relationship development in GRMT

Since the word classification is based on semantic information of words and their usage, a link between WordAsso numbers indicates a relationship between words. This relationship indicates which word can occur with which word in the same expression. Based on this observation, we have built a relationship between words in the form of WordAsso numbers according to the contexts in which the words occur.

The possible contexts in which a given word can occur are part of a word's meaning. Therefore, we make use of the contextual knowledge to disambiguate polysemous words. For example, we interpret the meaning of *quack* in the first and the second sentences in Table 4.7 (the first column) differently. In the first sentence, the relationship between *duck* (in the sense of “a common swimming bird with short legs and a wide beak, either wild or kept

Table 4.7: Examples of words and their contexts

Sample sentences in English/Thai	Description of a given word	WordAsso relation
“ <i>quack, quack</i> ”, said the mother duck.	to make the sound that ducks make.	1-1-1-2-1-2-1, 4-1-1-2
A <i>quack</i> is an untrained physician.	a person dishonestly claiming to have medical knowledge or skills.	13-5-1, 13-5-1
How <i>high</i> is the mountain?	having a top that is some distance, especially a large distance, above the ground.	-
She likes that <i>tall</i> man.	having a greater than average height,	13-8-9-2, 1-1-1-1-1-1

for meat, eggs and soft feathers.”) and *quack* indicates the meaning of *quack* as “to make the sound that ducks make” shown in the second column. However, the relationship between *quack* and *physician* in the second sentence determine the meaning of *quack* as “a person dishonestly claiming to have medical knowledge or skills”. Based on this observation, the WordAsso relation between the classes *animal* and *animal made sound*, *human's occupation* and *human's occupation* are established as shown in the third column of Table 4.7. The class *animal* and *animal made sound* are related since *duck* belongs to the class *aquatic bird* with the WordAsso number 1-1-1-2-1-2-1 and *quack* belongs to the class *Animal made sound*

Table 4.8: Classes and their sample words

WordAsso Number	Class	Sample words
1-1-1-2-1-2-1	Aquatic Bird	duck, เป็ด (pèd- duck), duckling, ลูกเป็ด (lûugpèd- duckling), swan, หงส์ (hõ̀- swan), stork, นกกระสา (nógkrasā- stork)
4-1-1-2	Animal made sound	quack, แควก (khwæ̃'g- quack), peep, เป็ด (pîp- peep)
13-5-1	Human's occupation	nurse, พยาบาล (phajaabaan- nurse), quack, หมอเถื่อน (mǎ̌'athy'an- quack), physician, หมอ (mǎ̌- doctor, physician)
13-8-9-2	Attribute value of height used for people	tall, สูง (sũ̀n- tall), short, เตี้ย (tîa- short)
1-1-1-1-1-1	Male ¹²	boy, เด็กผู้ชาย (dègphûuchaaj- boy), man, ผู้ชาย (phûuchaaj- man)

with the WordAsso number 4-1-1-2 (Table 4.8). Both *quack* and *physician* belong to the same class *Human's occupation* with the WordAsso number 13-5-1.

In Table 4.7, the attribute values (of height) *high* and *tall* in the third and the fourth sentences are selective about the nouns they modify. *High* is used for measurements of distance above ground while *tall* is used for height measurements, e.g., for people [Longman 1992]. According to their usage and implied reference set, the relationship between the classes *Attribute value of height used for people* and *Male* (the third column of Table 4.7) is developed. *tall* belongs to the class *Attribute value of height used generally for people* with the WordAsso number 13-8-9-2 and *man* belongs to the class *Male* with the WordAsso number 1-1-1-1-1-1.

In addition to consider the possible contexts in which a given word can occur, the associations between words that are interchangeable in a context and the associations between words that frequently occur together are considered in developing the WordAsso relations for GRMT (see section 5.2).

The construction of WordAsso relation and its use will be presented in chapter 5, some examples will be provided.

¹² The classes *Male* (1-1-1-1-1-1) and *Female* (1-1-1-1-1-2) are subclasses of *Individual* (1-1-1-1-1). This classification is for associating words in *Male* and *Female* with the particles ครั้น- khráb and ค่ะ- khâ in Thai. Particles are sentence-ending words. ครั้น- khráb and ค่ะ- khâ are used to show politeness, courtesy and respect to another person. ครั้น- khráb is used by men and ค่ะ- khâ is used by women.

Chapter 5

Analysis Lite Machine Translation

*...and since word-for-word translations are surprisingly good,
it seems reasonable to accept a word-for-word translation
as a first approximation
and then see what can be done to improve it.*

— Victor H. Yngve (1955)

Analysis Lite Machine Translation, the first phase of GRMT, generates an appropriate translation candidate for an input text. ALMT was designed around two simple notions: the more accurately ALMT generates a TC, the less work is required in the latter phases; and generating the TC must be done quickly. Therefore, ALMT generates a TC by considering the differences between language pairs in terms of syntax and semantics without performing any sophisticated analysis. ALMT performs its task by judiciously selecting a few efficient heuristics, constraints, and semantic principles to apply when appropriate. ALMT first applies

Figure 5.1: ALMT Architecture

the SL constraints to simplify the structure of the SL, maps each SL word into all possible meanings in the TL. The most appropriate TL word is selected by applying a semantic relationship between words and then rearranging the selected words according to the grammar of the TL. ALMT comprises three modules as shown in Figure 5.1, word treatment, word selection, and word ordering.

5.1 Word Treatment

There are two steps performed by *word treatment* module: SL-Constraints Application and Dictionary look-up (Figure 5.1). The SL constraints are used to simplify the structure of the SL. After simplification, the word treatment maps each SL word to all possible corresponding words in TL by consulting the SL-TL dictionary. An inflectional analysis might be needed in the dictionary look-up stage. This analysis is quite simple but useful as it saves dictionary space and reduces search time. The knowledge-bases required in the word treatment module are: the SL constraints, the inflectional rules, the SL dictionary and the SL-TL Dictionary.

5.1.1 SL Constraints Application

The SL constraints, the morphological and syntactic characteristics of the SL which differ from those of the TL, are incorporated in this step to narrow the scope of possible TL words which correspond to each SL word. Table 5.1 illustrates some SL constraints we considered according to the differences between English and Thai as discussed in section 4.1 .

Table 5.1: Some SL Constraints

SL-Constraints	Descriptions	Examples
Plurality ¹	noun_(e)s → noun + plural	The books ... → The book + plural
Continuous tense	V to be + V-ing → V + ing	I am swimming. → I + ing + swim
Passive voice	be + V3 → passive + V	He was arrested. → He passive + arrest
Adjective	V to be + adj → adj	I am glad. → I glad
Negative	do + not → not	He does not eat → He not eat

¹ This constraint does not apply in the case of the irregular plural forms, e.g., children, feet, men, women, and so on. The irregular plural forms are entries in the dictionaries.

Since Thai word form does not have an inflection resulting from plurality or tense, the inflections of plural noun and present participle forms in English are removed in this step. Once the inflections are removed, the features *plural* and *ing* are added to preserve the meaning of the original sentence. The structure of a passive voice is examined as well; the verb inflection and auxiliary *to be* are removed. The feature *passive* is added to indicate the passive voice. The features *plural*, *ing* and *passive* will be replaced with the appropriate corresponding TL words in the ordering step of ALMT.

The auxiliaries *to be* which precedes an adjective and *to do* which precedes a negative “not” are discarded since they are not required in the same expression in Thai. Figure 5.2 illustrates the outputs of SL constraints applications of Example 1 and Example 2. The auxiliary *is* is removed from Example 1 according to the *adjective constraint*. The inflection *-s* of the word *symbol* in Example 2 is removed and the feature *plural* is added, the passive voice form *are used* is replaced with *passive use*, the auxiliary *do* is discarded and the continuous tense form is replaced with *ing talk*.

Example 1:

SL: The spirit is willing but the flesh is weak.

SL Constraints- output: The spirit _ willing but the flesh _ weak.

Example 2:

SL: Algebraic symbols are used when you do not know what you are talking about.

SL Cons- output: Algebraic plural symbol passive use when you not know what you ing talk about.

Figure 5.2: SL constraints applications examples

5.1.2 Dictionary Look-up

After the SL constraints are applied, each SL word will be used as a keyword to search for its corresponding words in the TL. If the keyword used is found in the SL-TL dictionary, all possible corresponding TL words will be attached to that SL word. If the keyword is not found, inflectional analysis is performed and the search is restarted. The inflections of each entry are not entries in the dictionaries, therefore the size of the SL dictionary and the search times are reduced.

In our case in which English is regarded as SL, the following inflectional forms are considered: past simple tense (-d, -ed), gerund (-ing), subject-verb agreement (-s, -es) and

comparatives (-er, -est); plurality and present participle are treated in the SL Constraints Application. An output of this step is a list of all possible corresponding words of SL words in the TL with their WordAsso numbers. The second column (Table 5.2) shows the dictionary look-up result for Example 3 based on the information available in SL-TL dictionary. The descriptions of the words are provided in the third column.

Table 5.2: Example result of Dictionary Look-up of Example 3

Example 3:

SL: The spirit is willing but the flesh is weak.

SL Constraints- output: The spirit willing but the flesh weak.

Dictionary Look-up-output:

SL Constraints output	Dictionary Look-up output	Descriptions
The spirit	<p>นั้น [a20]</p> <p>วิญญาณ [1-2-1-1-1. 1-2-4]</p> <p>จิตใจ [2-5-6-1]</p> <p>ขวัญ [2-5-6-2]</p> <p>ความมุ่งมั่น [2-5-1-1]</p> <p>บรรยากาศ [5-6]</p> <p>เหล้า [1-1-2-1-2-1-3-1]</p> <p>นำไปอย่างลึกลับ [2-24-2]</p>	<p>determiner</p> <ul style="list-style-type: none"> thought of as remaining alive without appearing in physical form. a life-giving force <p>mental or moral strength to resist</p> <p>a quality of lively determination</p> <p>the general atmosphere of a place or situation</p> <p>distilled alcoholic liquor (often plural)</p> <p>to carry off secretly or mysteriously</p>
willing	<p>พร้อม [13-16-3]</p> <p>เต็มใจ [13-30]</p>	<p>ready</p> <p>accepted voluntarily or without reluctance</p>
but	<p>แต่ [r10]</p> <p>นอกจาก [r11]</p>	<p>against what might be expected; on the other hand</p> <p>other than, except</p>
the flesh	<p>นั้น [a20]</p> <p>เนื้อ [1-4-1-3-1]</p> <p>ร่างกาย [1-1-2-1-4-2]</p>	<p>determiner</p> <p>the soft parts of an animal's body; especially muscular tissue</p> <p>the physical being of man as distinguished from the soul</p>
weak	<p>อ่อนแอ [13-21-1. 13-10-3]</p>	<ul style="list-style-type: none"> not strong; especially not strong enough to work or last properly not strong or firm in character; lacking power

5.1.3 Dictionaries

The *SL dictionary* provides the information required in the constraint application and the inflectional analysis steps. Each lexical entry contains its syntactic categories. The inflections of each entry are not included. Figure 5.3 illustrates a fragment of SL dictionary which is in a Prolog representation: the categories of the word *all* are adjective, adverb, pronoun, noun and determiner. *Hid* is an adjective and a past simple tense form of *hide*, therefore one of its categories is *vpast*. *Vpast* is a category of the verbs which are in a past simple tense form (see also appendix B).

```
entry_e('Egyptian',[n]).
entry_e(all,[adj,adv,pron,n,det]).
entry_e(dream,[v,n]).
entry_e(duckling,[n]).
entry_e(hid,[adj,vpast]).
entry_e(should,[aux]).
entry_e(that,[pron,conj,adj]).
```

Figure 5.3: Example of SL Dictionary

The SL-TL dictionary is required in the dictionary look-up step. It is used to map the SL word to all possible corresponding words in the TL. The SL-TL dictionary contains the SL entry and all of its possible corresponding words in the TL. The TL words are ordered according to the frequency of their usage. Each TL word is related to its WordAsso numbers. Figure 5.4 illustrates a part of SL-TL dictionary which is in a Prolog representation: the word

```
entry('Egyptian',[wordasso('คนไทย',['13-6-1']),wordasso('ภาษาอียิปต์',['2-15-1-3-1'])]).
entry(dream,[wordasso('ฝัน',['2-1-8-2-1','2-6']),wordasso('ความฝัน',['2-5-1-2'])]).
entry(duck,[wordasso('เป็ด',['1-1-1-2-1-2-1','1-1-2-1-2-1-2-4-1']),wordasso('กั๊ก',['2-1-5-2']),
wordasso('จิ้งกคลง',['2-1-5-4-1']),wordasso('นาลินินขาว',['1-1-2-1-1-1'])]).
entry(hidden,[wordasso('ซ่อน',['2-10-1']),wordasso('ปิดบัง',['2-10-2'])]).
entry(old,[wordasso('แก่',['13-7-1']),wordasso('เฒ่า',['13-7-2'])]).
entry(should,[wordasso('ควร',['a12'])]).
entry(that,[wordasso('ว่า',['r12']),wordasso('นั้น',['r13']),wordasso('ที่',['r14'])]).
```

Figure 5.4: Example of SL-TL Dictionary

duck corresponds to four Thai words; เป็ด (pèd) with WordAsso 1-1-1-2-1-2-1 (Aquatic Bird) and 1-1-2-1-2-1-2-4-1 (Poultry), ก้ม (kôm) with WordAsso 2-1-5-2 (A way to move so as of a body part), จับตกลง (càbkòdlon) with the WordAsso 2-1-5-4-1 (a way to move thing with force) and ผ้าลินินขาว (phâalininkha[~]aw) with the WordAsso 1-1-2-1-1-1 (Fabric). see also appendix C.

5.2 Word Selection

One difficult task in the MT process is to select the most appropriate word in the TL which preserves the meaning of the corresponding word in the SL if there are more than one possibility. To select the most appropriate word in TL for each SL input word, we need to know the meaning of the input word. The meaning of the input word can be determined by the context in which the input word occurs as we discussed in section 4.2.2. In Example 4 (Figure 5.5), the semantic relationship between the word เป็ด (pə`əd) and ตู้ (tûu) indicates that the word เป็ด (pə`əd) means “not shut”. Therefore, its corresponding word in English is *open*; this expression means “He opens the closet.” The word เป็ด (pə`əd) in Example 5, Figure 5.5, cannot be translated as “open” since the semantic relationship between เป็ด (pə`əd) and (ไฟ-faj') is stronger than the relationship between (เป็ด-pə`əd) and (ตู้-tûu). Thus, the meaning of the sentence in Example 5 corresponds to “He turns on the light in the closet”. This example and others like it lead to the notion that physical proximity implies a stronger connection. Therefore, the word selection process in ALMT is carried out by considering the relationship between the close proximity words.

Example 4:	เขา	เปิด	ตู้
	(khaw- he)	(pə`əd-open)	(tûu- closet)
Example 5:	เขา	เปิด	ไฟ ใน ตู้
	(khaw- he)	(pə`əd-turn on)	(faj'-light) (naj-in) (tûu- closet)

Figure 5.5. The relationship between the proximity words -Examples 4 and 5.

Figure 5.6 illustrates some Wordasso relations we developed for ALMT (see section 4.2.2), the word with WordAsso number in the first argument can occur with the word which has a WordAsso number shown in the second argument. For example: words with the

WordAsso number 1-1-1-2-1-1 can occur with any word which has WordAsso number 13-8-2 or 13-8-5-2.

```
wordasso_rel('1-1-1', ['2-1-5-1']).
wordasso_rel('1-1-1-2', ['2-6']).
wordasso_rel('1-1-1-2-1-1', ['13-8-2', '13-8-5-2']).
wordasso_rel('1-1-1-1-1-2', ['13-7-1']).
wordasso_rel('2-5-5', ['r12']).
```

Figure 5.6. Examples of WordAsso relations

As well as applying the semantic relationship between words in the form of the WordAsso relation, the selection step continues. According to a linguistic theory, a collocation² consists of basically two or three lexical words [Newmark 1981] and our investigation of a number of sample sentences; we consider the relationship between words in the range of four consecutive words in our selection step. Words in close proximity are considered to have stronger connections. Our selection steps are designed as follows:

```
Program word_selection;
X and newX are arrays of xi;
xi is a list of the TL words which corresponds to the ith word of the SL input sentence;
n is the number of words in the SL input sentence;
i, j, m and n are integers;
xi is null if i < 1;
xi is null if i > n;

% Use xi to determine the most appropriate word for xi-j and xi-j.
Procedure select (j, newX);
begin
  for i = 1 to n do
```

² collocation is a group of words in a sentence in which a word with particular meaning is supplanted by another word because of other words in the environment. For example: the word *pay* in *to pay attention* means *to use*; the word *commit* in *commit a crime* means *to do*.

```

begin
  if  $x_i$  contains only one word
  then begin
    use the word in  $x_i$  to select the appropriate TL word(s) in  $x_{i-j}$ ;
    if wordasso_rel ( $x_i$ ,  $x_{i-j}$ ) = true
    then begin
       $x_{i-j}$  = new  $x_{i-j}$ ;
      end;
    else begin
      newX=X;
      use the word in  $x_i$  to select the appropriate TL word(s) in  $x_{i+j}$ ;
      if wordasso_re ( $x_i$ ,  $x_{i+j}$ ) = true
      then begin
         $x_{i+j}$  = new  $x_{i+j}$ ;
        end;
      else newX=X;
      end;
    end;
     $i=i+1$ ;
  end;

%
Procedure word_check (j, X);
begin
  do while ( $j \leq 3$ )
  begin
    select (j,newX);
    if  $X \neq \text{newX}$ 
    then begin
       $X = \text{newX}$ ;
       $j = 1$ ;
      word_check (j, X);
    end;
    else begin
      if  $j < 3$ 
      then begin
         $j = j+1$ ;
        word_check (j, X);
      end;
      else begin
        select_final (j, X);
         $j = 1$ ;
        word_check(j, X);
      end;
    end;
  end;
end;
end;

```

```

% Select the first meaning appearing on the list of meanings of each word
Procedure select_final (j, newX);
begin
  for i = 1 to n do
    begin
      if  $x_i$  contains only one word
      then  $i = i+1$ 
      else select the first word in  $x_{i+j}$  as the most appropriate word;
      end;
    end;
  end;

% main
begin
  X = input sentence;
  newX = X;
  if each  $x_i$  contains only one word
  then return X as an output
  stop.
  else begin
    j = 1;
    word_check (j, X);
    end;
end.

```

Figure 5.7: Example of selection steps

Figure 5.7 illustrates an example of the selection step process. In this illustration an eight (input) words sentence is examined with words A, B, C, ...H. Some words correspond to more than one TL word e.g., A corresponds to three TL words, A₁, A₂ and A₃. Some words correspond to one TL word e.g., B, C and F correspond to B1, C1 and F1 respectively. Based on our selection step and the WordAsso relation template, the appropriate meaning of each word is selected in ten steps as follows:

1. B1 is used to determine the meanings of A and C which are adjacent to B on the left and right. A has three different meanings, A1, A2 and A3 while C has one meaning. Therefore, we select only the meaning of the first word by considering the WordAsso relation between B1 and A1, B1 and A2, and B1 and A3 respectively. Suppose A2 and A3 have meaningful relations with B1, then keep both of them. Next, we use C1 to determine the meanings of B and D in a similar manner. In the case that there is no relationship between C1 and the corresponding words of D (D1, D2 and D3), the three meanings (D1, D2 and D3) remains the same. F1 is used to determine the meaning of E and G, in the case that F1 has a relationship with E4; E4 is selected.
2. E4 is used to determine its adjacent words (D and F). There is no relationship between E4 and D, therefore the string remains the same.
3. B1 is used to determine the meaning of D (one word apart); D1 and D2 are selected. C1 is used to determine the meanings of A and E (which corresponds to E4 alone at this step), there is no relationship between C and A. G2 is selected according to its relationship with E4.
4. G2 is used to determine its adjacent words (F and H). G2 has a relationship with H3 and H4. then H3 and H4 are selected.
5. B1, C1, E4, F1 and G2 are used to determine the words which are one word apart from each of them. There is no relationship between any of them, the string remains unchanged.
6. E4 is used to determine B and H (two words apart from E4), B already has one meaning and there is no relationship between E4 and H, the string remains the same.
7. A2 is selected for A since A2 is the first meaning appearing at this step according to the SL-TL dictionary.
8. A2 is used to determine the meanings of D, D2 is selected.
9. H3 is selected for H since H3 is the first meaning (most common of those remaining) appearing at this step according to the SL-TL dictionary.
10. A2, B1, C1, D2, E4, F1, G2 and H3 are selected.

The first column of Table 5.3 illustrates the constraint application result of Example 6. The dictionary look-up result is shown in the second column. Each word *spirit*, *willing*, *but* and *flesh* has more than one meaning (the descriptions of each meaning are shown in Table 5.2). To select the appropriate words for *spirit*, *willing*, *but* and *flesh*, ALMT first considers the relationship between *the* and its adjacent words since *the* has a unique meaning. However, there is no relationship between any of them. ALMT then considers the relationship between *weak* and its adjacent word, *flesh*. The word *רָאֵה* (râaḥkaaj) is selected for *flesh* (the fourth column) according to the WordAsso relation, 13-21-1 and 1-1-2-1-4-2, see Figure 5.8. The first meaning left on the list of the words *spirit*, *willing* and *but*; *רוּחַ*

(winjaan), พร้อม (phrǎʔəm) and แต่ (tɛ̀ɛ) are selected since there is no relationship between *spirit*, *willing*, *but* and their proximity words according to our WordAsso relation template. The selected words for example 6 are shown in the fourth column of Table 5.3.

To associate the input words *so*, *ugly* and *left* in Example 7 (Table 5.4) with the most appropriate words in Thai, ALMT considers the relationship between those words with words

Table 5.3 The possible corresponding Thai words for *spirit*, *willing*, *flesh* and *weak*

Example 6: The spirit is willing but the flesh is weak.

SL Constraints output	Dictionary look-up output	WordAsso number	Word Selection Output
The spirit	นั้น- nán	a20	นั้น- nán
	วิญญาณ- winjaan	1-2-1-1-1	วิญญาณ- winjaan
		1-2-4	
	จิตใจ- cidcaj	2-5-6-1	
	ขวัญ- khwaʔn	2-5-6-2	
	ความมั่งมัน- khwaammunʔmân	2-5-1-1	
	บรรยายาศ- banjaakâad	5-6	
	เหล่า- lâw	1-1-2-1-2-1-3-1	
	นำไปอย่างลึกลับ- nampajjanʔly'gláb	2-24-2	
	พร้อม- phrǎʔəm	13-16-3	พร้อม- phrǎʔəm
willing	เต็มใจ- temcaj	13-30	
but	แต่- tɛ̀ɛ	r10	แต่- tɛ̀ɛ
	นอกจาก- nǎʔgcâag	r11	
the flesh	นั้น- nán	a20	นั้น- nán
	เนื้อ- ny'a	1-4-1-3-1	
	ร่างกาย- rǎaŋkaaj	1-1-2-1-4-2	ร่างกาย- rǎaŋkaaj
weak	อ่อนแอ- ʔǎʔnʔɛɛ	13-21-1,	อ่อนแอ- ʔǎʔnʔɛɛ
		13-10-3	

```
wordasso_rel('1-1-1-2-1-2-1',['2-1-1-6','2-13','2-1-25']).
wordasso_rel('1-1-2-1-5-1',['2-13']).
wordasso_rel('13-21-1',['1-1-2-1-4-2']).
wordasso_rel('1-1-2-1-1-2',['2-2-8']).
wordasso_rel('1-2-1-2-1',['2-8-3','2-9-1']).
```

Figure 5.8: Examples of WordAsso relations

in their proximity. There is a relationship between the words *duckling* (ลูกเป็ด (lûugpèd), 1-1-1-2-1-2-1) and *left* as indicated in the WordAsso relation template (Figure 5.8). The WordAsso number 1-1-1-2-1-2-1 can occur with any word with WordAsso number 2-1-1-6 or

Table 5.4. The possible corresponding Thai words for *left*, *duckling* and *marsh*.

Example 7: So the ugly duckling left the marsh.

SL Constraints output	Word Treatment Output	Description	WordAsso number	Selected word
So	ดังนั้น- daṇnán	with the result that	r30	ดังนั้น- daṇnán
the ugly	อย่างนั้น- jàṇṇán	to such a (great) degree	2-4-8	
	นั้น- nán	determiner	a20	นั้น- nán
	ซีเหร์- khîilèe	unpleasant to look at (use with living thing)	13-8-4-1	ซีเหร์- khîilèe
	น่าเกลียด- nàakliad	unpleasant to look at (use with non-living thing, abstract thing)	13-8-4-2	
duckling	ลูกเป็ด- lûugpèd	A young duck.	1-1-1-2-1-2-1	ลูกเป็ด- lûugpèd
left	ซ้าย- sáaj	The left side or direction	2-35-18	
	จาก ³ - càag	To stop being in or with.	2-1-1-6	
	ทิ้ง ⁴ - thîṇ	To go without taking.	2-19	
	ออกจาก ⁵ - à'əgcàag	To go away (from)	2-13	ออกจาก- à'əgcàag
the marsh	นั้น- nán	determiner	a20	นั้น- nán
	หนอง- ṇə'əṇ	low land that is soft and wet.	1-1-2-1-5-1	หนอง- ṇə'əṇ

2-13. Therefore, the words จาก (càag, 2-1-1-6) and ออกจาก (à'əgcàag, 2-13) are selected.

Next, to select the most appropriate word from these two possibilities; จาก (càag) and ออกจาก (à'əgcàag), the relationship between the words *marsh* and *left* is considered. There is no relationship between *ugly* and *left*, or *the* and *left* according to the WordAsso relationship template. Therefore, *marsh* which is one word apart from *left* and has only one meaning, หนอง (ṇə'əṇ), with the WordAsso 1-1-2-1-5-1 is considered. According to the WordAsso

^{3, 4, 5} The meanings of *left* which is a past tense and a participle of leave [Longman 1992].

WordAsso number 2-13. Then, the word สกจกน (ə'əgcàag) is selected for *left*.

The word ชี้เหร์ (khîilèe) is selected for *ugly* according to the relationship between *ugly* and *duckling* as indicated in the WordAsso relationship template (Figure 5.8). There is no relationship between the word *so* and other words, therefore the first meaning on the list, ดังนั้น (daṇnán), is selected. The selected words for example 7 are shown in the fifth column of Table 5.4.

5.3 Word Ordering

The syntactic level differences between SL and TL are reconsidered at this point to complete the TC. Some words which are necessary in the TL, not only to retain the meaning of the SL but also to make the TL grammatically correct, are added to the string before the ordering can be performed. For example, the words แล้ว (lɛ'ɛw) and le^6 are required to indicate the *past tense* in Thai and Chinese respectively (see section 4.1). After all necessary words are added, ALMT rearranges the selected words without performing any analysis in a TL grammatical order according to the ordering rule. Therefore, two steps are performed by *word ordering* module: word addition and word ordering (Figure 5.1).

5.3.1 Word Addition

The morphological and syntactic characteristics of the SL which are removed in the SL constraints application step will be replaced with the appropriate corresponding words in the TL in the *word addition step*. In the case that English is the SL and Thai is the TL, the features plural, ing, and passive which are used to indicate the plurality, continuous tense and passive voice features of the SL are replaced with the words หลาย (la'aj), กำลัง (kamlan) and ถูก (thùug) respectively (see section 5.1.1).

In case of pluralities, *classifiers* are required (see section 4.1) to express the quantity. Each noun relates to a specific classifier; therefore, the classifier relation was designed in the form of WordAsso numbers to be used to select the appropriate classifier for each noun.

⁶ Phonetic transcription of Chinese.

In Thai, a noun and its classifier were stipulated by the Thai Royal Institute. To date, there are approximately 3000 different classifiers [The Thai Royal Institute 1995]. From our studies, we classified the classifiers into classes as shown in Table 5.5. With this classification together with the specification of the Thai Royal Institute, we then developed the relation between nouns and their classifiers, some examples are illustrated in Figure 5.9. The noun with the WordAsso number in the first argument is compatible with a classifier with a WordAsso number shown in the second argument.

Table 5.5 A small fraction of classifier classes

Class	Sample Word
2-4-2 Classifier	
2-4-2-1 Classifier of object	
2-4-2-1-1 Classifier of living thing	
2-4-2-1-1-1 Classifier of human	คน
2-4-2-1-1-2 Classifier of animal	ตัว
2-4-2-1-1-3 Classifier of plant	ต้น
2-4-2-1-2 Classifier of non-living thing	
2-4-2-1-2-1 Classifier of tool	อัน
2-4-2-1-2-2 Classifier of room	ห้อง
2-4-2-1-2-3 Classifier of external body part	ขา หัว มือ
2-4-2-1-2-5 Classifier of root vegie	หัว
2-4-2-2 Classifier of collection	ชนิด ประเภท
2-4-2-2-1 Classifier of human	กลุ่ม
2-4-2-2-2 Classifier of animal	ฝูง
2-4-2-3 Classifier of time period	day วัน hour ชั่วโมง
2-4-2-5 Classifier of frequency	ที ครั้ง

```

clf_rel('1-1-1-1',[[wasso('คน',['2-4-2-1-1-1'])]]).
clf_rel('1-1-1-2',[[wasso('ตัว',['2-4-2-1-1-2'])]]).
clf_rel('1-1-2-1-6-1',[[wasso('แห่ง',['2-4-2-1-2-2'])]]).
clf_rel('2-4-3-1-2',[[wasso('วัน',['2-4-2-3'])]]).
clf_rel('1-1-2-1-1-2-2',[[wasso('หลัง',['2-4-2-1-2-10'])]]).

```

Figure 5.9. Examples of classifier relations.

Example 8 illustrates how to select the appropriate classifiers for the words *woman*, *cat* and *hen*. The selected words in Thai corresponding to the words *woman*, *cat* and *hen* in Example 8 are shown in the second column of Table 5.6. The indefinite determiners *a* and

an in this expression, corresponding to the word หญิง (ny`η) in Thai, indicate the need for classifiers for the words ผู้หญิง (phûujĩ`η), แมว (mɛɛw) and ไก่ (kâj) respectively. The word ผู้หญิง (phûujĩ`η) belongs to the class Female (1-1-1-1-2), a subclass of Human (1-1-1-1). A noun which belongs to the class 1-1-1-1 is compatible with a classifier with the WordAsso number 2-4-2-1-1-1 based on the classifier relation illustrated in Figure 5.9. Therefore, the classifier คน (khon) with 2-4-2-1-1-1 in Table 5.5 is selected for the word ผู้หญิง (phûujĩ`η-woman).

Table 5.6. The selected words in Thai for the words *woman*, *cat* and *hen*

Example 8: An old woman lived in the cottage, with a fat black cat and a plump brown hen.

English	Selected Word in Thai	WordAsso	Class	Classifier
woman	ผู้หญิง (phûujĩ`η)	1-1-1-1-2	Female	คน (khon)
cottage	กระท่อม (krathə̂m)	1-1-2-1-2-2	Housing	หลัง (la`η)
cat	แมว (mɛɛw)	1-1-1-2-1-1	Mammal	ตัว (tua)
hen	ไก่ (kâj)	1-1-1-2-1-2-2	Fowl	ตัว (tua)

The words แมว (mɛɛw-cat) and ไก่ (kâj-hen) belong to the classes mammal (1-1-1-2-1-1) and fowl (1-1-1-2-1-2-2) respectively. Both classes are subclasses of animal (1-1-1-2). Since a noun with the WordAsso number 1-1-1-2 relates to a classifier with 2-4-2-1-1-2 according to the classifier relation shown in Figure 5.9, the classifier ตัว (tua) with 2-4-2-1-1-2 is selected for the words แมว (mɛɛw-cat) and ไก่ (kâj-hen).

The definite determiner *the* corresponding to the word นั้น (nán) in Thai indicates the need for a classifier for the word กระท่อม (krathə̂m). The word กระท่อม (krathə̂m) belongs to the class Housing (1-1-2-1-2-2) which is compatible with a classifier with the WordAsso number 2-4-2-1-2-10 based on the classifier relation illustrated in Figure 5.9. Therefore, the classifier หลัง (la`η) with the WordAsso 2-4-2-1-2-10 is selected for the word กระท่อม (krathə̂m).

5.3.2 Word Ordering

In some MT systems, e.g., Shake-and-Bake MT, the ordering process has been performed by generating valid combinations of words and analyzing (parsing) to see whether the combination is grammatically correct. If the combination is correct then it will be selected as an output; if not, another combination is tried until the grammatically correct sentence is

found. The disadvantage is that the generator has to consider a number of possibilities which is factorial in the number of signs in the TL sentence. In GRMT, the selected words are ordered according to rules without performing any analysis. These ordering rules account for syntactic level differences between languages. The structure of the SL which is similar to that of the TL remains the same, only the sentence fragments that are different will be rearranged into the grammatical order of the TL.

The structure of the English sentence which contains subject, verb and object in that order is similar to that of the Thai sentence. Therefore, when English is translated into Thai, its structure remains the same as illustrated in Example 9 (Figure 5.10). However, in the case that the English phrase contains attributes, possessive pronouns or determiners, the word order must be rearranged to make translation of the phrase grammatically correct since the structure of such a phrase is different between English and Thai (see section 4.1). The first row of Figure 5.11 illustrates the corresponding words in Thai of Example 10 selected by ALMT. The classifier *ตัว* (tua) is added in the word addition step. The translations of the noun phrase *The ugly duckling, his head* and *his wing* are formed in reverse order of the order in English according to the ordering rules (the third row of Figure 5.11).

Some other structures which are different between English and Thai are examined as well. For example, the negative of *can* and *could* (cannot, could not); the adverb *very* which modifies an adjective (very good, very warm) and their translations are formed in the reverse order of the order in English.

Example 9: John eats rice every day.

จอห์น กิน ข้าว ทุก วัน
(cæŋ- John) (kin- eat) (khâaw- rice) (thúg- every) (wan- day)

Selected words				
John	eats	rice	every	day
จอห์น (cæŋ)	กิน (kin)	ข้าว (khâaw)	ทุก (thúg)	วัน (wan)
Word ordering output				
จอห์น (cæŋ)	กิน (kin)	ข้าว (khâaw)	ทุก (thúg)	วัน (wan)
John	eats	rice	every	day

Figure 5.10: Word orders of จอห์น กิน ข้าว ทุก วัน

Example 10: The ugly duckling hid his head under his wing.

ลูกเป็ด ขี้เหร่ ตัว นั้น ได้ซ่อน หัว ของเขา ใต้ ปีก ของเขา
(lûugpèd- duckling) (khiirèe- ugly) (tua- clas) (nán- the) (sǎn- hide) (hũa- head)
(khǎwkhaw- his) (tǎaj- under) (piig- wing) (khǎwkhaw- his)

Selected words									
The	ugly	duckling	hid	his	head	under	his	wing	
นั้น	ขี้เหร่	ลูกเป็ด	ได้ซ่อน	ของเขา	หัว	ใต้	ของเขา	ปีก	
(nán)	(khiirèe)	(lûugpèd)	(dǎjsǎn)	(khǎwkhaw)	(hũa)	(tǎaj)	(khǎwkhaw)	(piig)	
Word addition output									
นั้น	ตัว	ขี้เหร่	ลูกเป็ด	ได้ซ่อน	ของเขา	หัว	ใต้	ของเขา	ปีก
(nán)	(tua)	(khiirèe)	(lûugpèd)	(dǎjsǎn)	(khǎwkhaw)	(hũa)	(tǎaj)	(khǎwkhaw)	(piig)
Word ordering output									
ลูกเป็ด	ขี้เหร่	ตัว	นั้น	ได้ซ่อน	หัว	ของเขา	ใต้	ปีก	ของเขา
(lûugpèd)	(khiirèe)	(tua)	(nán)	(dǎjsǎn)	(hũa)	(khǎwkhaw)	(tǎaj)	(piig)	(khǎwkhaw)
duckling	ugly	clas	The	hid	head	his	under	wing	his

Figure 5.11: Word orders of ลูกเป็ด ขี้เหร่ ตัว นั้น ได้ซ่อน หัว ของเขา ใต้ ปีก ของเขา

5.4 Example of ALMT

In this section we present the results of applying ALMT to some example sentences. The SL of Example 11 is shown in the first column of Table 5.7. The second column illustrates the output after applying the constraints e.g., the inflection *-s* triggers the “plurality constraint”, *are used* triggers the “passive voice” constraint, *do not* triggers the “negative” constraint and *are talking* triggers “present continuous” constraint as discussed in section 5.1.1. Each word in the second column is used as a keyword to search for the corresponding words in Thai. All possible meanings of each SL word are shown in the third column. Some of the words have more than one meaning e.g., *symbol*, *when*, *know*, etc. The appropriate meaning of *use*, *know* and *about* can be selected by considering the semantic relationship between words and the choice for each of these is shown in the fourth column. However, the appropriate words for *symbol* and *when* cannot be selected in the same manner because all possible meanings of each word have the same WordAsso number. Therefore, the first meaning appearing on the list of meaning of each word is selected. All selected words are shown in the fourth column. Before performing the ordering step, the features *plural*, *passive* and *ing* are replaced with the appropriate words; หลาย (laʼaj), ถูก (thùug) and กำลัง (kamlan) respectively (the fifth column). The classifier ตัว (tua) is added to express the

Table 5.7: ALMT steps applied to the sentence of Example 11

Example 11: Algebraic symbols are used when you do not know what you are talking about.

TC: สัญลักษณ์ ทางพีชคณิต ถูก ใช้ เมื่อ คุณ ไม่ รู้ ว่า คุณ กำลัง พูด เกี่ยวกับ อะไร

CT: สัญลักษณ์ ทางพีชคณิต ถูก ใช้ เมื่อ คุณ ไม่ รู้ ว่า คุณ กำลัง พูด เกี่ยวกับ อะไร

(sanjalág- symbol) (thaanphichakhanid- algebraic) (thùug- passive) (cháj- use) (my^ˆa- when) (khun- you) (mâj- not) (rúu- know) (wâa- connective) (khun- you) (kamlan- ing) (phûud- talk) (kiàwkàb- about) (araj- what)

English	SL Constraints output	Dictionary look-up output	Selected words in Thai	Word Addition	Word ordering
Algebraic	Algebraic plural	ทางพีชคณิต (thaanphichakhanid)	ทางพีชคณิต (thaanphichakhanid)	หลาย (la ^ˆ aj)	สัญลักษณ์ (sanjalág) (thaanphichakhanid)
symbols	symbol	สัญลักษณ์ (sanjalág), เครื่องหมาย (khry ^ˆ anma ^ˆ aj)	สัญลักษณ์ (sanjalág)	ตัว (tua)	หลาย (la ^ˆ aj) ตัว (tua)
are	passive			ถูก (thùug)	ถูก (thùug)
used	use	ใช้ (cháj), ประโยชน์ (prajòod)	ใช้ (cháj)		ใช้ (cháj)
when	when	เมื่อ (my ^ˆ a), เมื่อไหร่ (my ^ˆ araj), ขณะที่ (khanathii)	เมื่อ (my ^ˆ a)		เมื่อ (my ^ˆ a)
you do not know	you - not know	คุณ (khun) - ไม่ (mâj) รู้ (rúu), รู้จัก (rúucàj)	คุณ (khun) - ไม่ (mâj) รู้ (rúu)	-	คุณ (khun) - ไม่ (mâj) รู้ (rúu)
what you are talking about	what you are talk	อะไร (araj) คุณ (khun) ประมาณ (pramaan), เกี่ยวกับ (kiàwkàb), รอบๆ (rò ^ˆ ab)	อะไร (araj) คุณ (khun) เกี่ยวกับ (kiàwkàb)	ว่า (wâa) กำลัง (kamlan)	ว่า (wâa) คุณ (khun) กำลัง (kamlan) พูด (phûud) เกี่ยวกับ (kiàwkàb) อะไร (araj)

quantity of *symbol*. The word ว่า (wâa) is added to combine clauses. The word ว่า (wâa) is a translation of the word *that* which is omitted in this sentence, however, it cannot be omitted in Thai otherwise the translation in Thai will be grammatically incorrect. The selected words are put into the correct order according to the Thai grammar as shown in the last column (The shaded area). In Example 10, the generated TC formed the *Correct translation* (CT) for the input sentence without the necessity of performing any correction.

In generating the TC for Example 12, once all words are selected (the fourth column, Table 5.8), the word ได้ (dâj) is added to clarify the past tense (lived). The classifiers คน (khon), หลัง (la~η) and ตัว (tua) are also added as we discussed in section 5.3.1. The selected words in each noun phrase; *an old woman, the cottage, a fat black cat and a plump brown hen* are rearranged into the Thai grammatical order. The generated TC is exactly the same as the CT.

Figure 5.12 illustrates the translation of a fraction of *The ugly duckling* (version written by Ronne Randall, 1987) by ALMT. In the fourth sentence, ALMT selected the first translation word in the list, ที่ไหน (thîina~j), for the word *where* since there is no significant relationship between *where* and its proximity words. This selection is inappropriate for this expression and it will be repaired in the later phases, TCE and RI. The word ได้ (dâj) was added to clarify the past tense (lived). It retains the meaning of the original sentence and is grammatically correct, however, ได้ (dâj) is usually omitted in such expression in Thai. In the eighth and fifteenth sentences, the translations of the phrases *You are certainly not one* and *One evening* (the shaded areas) are misordered and will be rearranged in the TCE and RI phrases. The word กับ (kâb) is an inappropriate translation for the word *to* in the fifteenth sentence since it means “for the attention or possession of/ intended to be given to”. This selection will be replaced with the more appropriate word ถึง (thy~η) which is a translation of the word *to* in the sense of “reaching as far as” in the TCE and RI phrases.

Example 12: An old woman lived in the cottage, with a fat black cat and a plump brown hen.

TC: ผู้หญิง แก่ คน หนึ่ง ได้ อยู่ ใน กระท่อม หลัง นั้น กับ แมว สีดำ อ้วน ตัว หนึ่ง และ ไก่ สีนํ้าตาล อวบ ตัว หนึ่ง
CT: ผู้หญิง แก่ คน หนึ่ง ได้ อยู่ ใน กระท่อม หลัง นั้น กับ แมว สีดำ อ้วน ตัว หนึ่ง และ ไก่ สีนํ้าตาล อวบ ตัว หนึ่ง

(phûuji~η- woman) (ke`ε- old) (khon- classifier) (ny`η- an) (dâj- past) (ju`u- live) (naj- in) (krathâ`m- cottage) (la~η- classifier) (nán- the) (kâb- with) (mæew- cat) (si`idam- black) (?ûan- fat) (tua- classifier) (ny`η- a) (le`- and) (kâj- hen) (si`inámtaan- brown) (?ûab- plump) (tua- classifier) (ny`η- a)

Table 5.8: ALMT steps applied to the sentence of Example 12

English	Constraint Application output	Dictionary look-up output	Selected Word in Thai	Word Addition	Word ordering
An	An	หนึ่ง (ny`η)	หนึ่ง (ny`η)		ผู้หญิง (phûujĩ`η)
old woman	old woman	แก่ (kε`ε), เก่า (kâw) ผู้หญิง (phûujĩ`η)	แก่ (kε`ε) ผู้หญิง (phûujĩ`η)	คน (khon)	แก่ (kε`ε) คน (khon)
lived	lived	อยู่ (ju`u), มีชีวิต (miichiiwĩd), ดำรงชีวิต (damronchiiwĩd)	อยู่ (ju`u)	ได้ (dâj)	ได้ (dâj) อยู่ (ju`u)
in	in	ใน (naj), เข้ามา (khâwmaa), เข้าไป (khâwpaj), อย่าง (jâan)	ใน (naj)		ใน (naj)
the	the	นั้น- nán	นั้น- nán		กระท่อม (krathə`m)
cottage	cottage	กระท่อม (krathə`m)	กระท่อม (krathə`m)	หลัง (la`η)	หลัง (la`η) นั้น- nán
with	with	กับ (káb), ด้วย (dúaj), ซึ่งมี (sy`η)	กับ (káb)		กับ (káb)
a	a	หนึ่ง (ny`η)	หนึ่ง (ny`η)		
fat	fat	อ้วน (?úan) , ไขมัน (kha`jman)	อ้วน (?úan)	ตัว (tua)	แมว (mεεw) สีดำ (sĩ`idam) อ้วน (?úan)
black cat	black cat	ดำ (dam), สีดำ (sĩ`idam) แมว (mεεw), ผู้หญิงไม่ดี (phûujĩ`ηmâjdii)	สีดำ (sĩ`idam) แมว (mεεw)		ตัว (tua) หนึ่ง (ny`η)
and a	and a	และ (lε`) หนึ่ง (ny`η)	และ (lε`) หนึ่ง (ny`η)	ตัว (tua)	และ (lε`) โก (kâj) สีน้ำตาล (sĩ`inámtaan)
plump brown	plump brown	อวบ (?úab) สีน้ำตาล (sĩ`inámtaan), เกรียม (kriam), คล้ำ (khlám)	อวบ (?úab) สีน้ำตาล (sĩ`inámtaan)		อวบ (?úab) ตัว (tua)
hen	hen	ไก่ (kâj)	ไก่ (kâj)		หนึ่ง (ny`η)

The ugly duckling. Written by Ronne Randall.

...1. The ugly duckling hid in a corner of the farmyard and cried. 2. The next morning, the ugly duckling decided to run away. 3. "I will find a place where no one will make fun of me," he said to himself. 4. He left the farmyard and ran to the great marsh, where the wild ducks lived. 5. "Perhaps they will be kind to me," he said sadly. 6. But the wild ducks were not kind. 7. "You are very ugly," they said. 8. "You are certainly not one of us." 9. And the wild ducks laughed at the duckling. 10. So the ugly duckling left the marsh. 11. The wind was blowing, and it was cold. 12. Winter was coming. 13. The ugly duckling was very tired. 14. He had to find a place to stay where he could be warm and safe. 15. One evening, he came to a little cottage. 16. The door was open and he went inside. 17. An old woman lived in the cottage, with a fat black cat and a plump brown hen....

ลูกเป็ดขี้เหร่ตัวนั้น เขียนโดย รอนนี แรนเดล

...1. ลูกเป็ดขี้เหร่ตัวนั้นได้ซ่อนในมุมมุมหนึ่งของลานคตโรงนาแห่งนั้นและได้ร้องไห้ 2. เช้าวันถัดไปนั้น, ลูกเป็ดขี้เหร่ตัวนั้นได้ตัดสินใจที่จะหนีจากไป 3. "ฉันจะหาที่พบบที่ที่หนึ่งซึ่งไม่มีใครจะเยาะเย้ยฉัน," เขาได้พูดกับตัวเขาเอง 4. เขาได้จากลานคตโรงนาแห่งนั้นและได้วิ่งไปที่หนองน้ำใหญ่มากหนองนั้นที่ไหน เป็ดป่าหลายตัวนั้นได้ อาศัยอยู่ 5. "บางทีพวกเขาจะใจดีกับฉัน," เขาได้พูดอย่างเศร้าสร้อย 6. แต่เป็ดป่าหลายตัวนั้นไม่ใจดี 7. "คุณขี้เหร่มากๆ," พวกเขาได้พูด 8. "คุณเป็นอย่างแน่นอนไม่หนึ่ง ของพวกเรา." 9. และเป็ดป่าหลายตัวนั้นได้หัวเราะเยาะลูก เป็ดตัวนั้น 10. ดังนั้นลูกเป็ดขี้เหร่ตัวนั้นได้จากหนองน้ำหนองนั้น 11. ลมนั้นกำลังพัดและมันหนาว 12. ฤดูหนาว กำลังมา 13. ลูกเป็ดขี้เหร่ตัวนั้นเหนื่อยมากๆ 14. เขาต้องการให้พบบที่ที่หนึ่งที่จะอยู่ที่ซึ่งเขาจะได้อุ่นและปลอดภัย 15. หนึ่งเย็น เขาได้มา กับ กระท่อมเล็กหลังหนึ่ง 16. ประตูประตุนั้นถูกเปิดและเขาได้ไปข้างใน 17. ผู้หญิงแก่คนหนึ่งได้อาศัยอยู่ในกระท่อมหลังนั้น ด้วย แมวสีดำอ้วนตัวหนึ่งและไก่สีน้ำตาลอ้วนตัวหนึ่ง...

Figure 5.12: A part of "The ugly duckling" and its translation

Chapter 6

Translation Candidate Evaluation

The second phase of GRMT, Translation Candidate Evaluation, determines whether the generated translation candidate retains the meaning conveyed by the source language. TCE analyzes both the SL and the TC in parallel, then compares the results of the parses in terms of semantics alone since there are syntactic level differences between languages (Figure 6.1). If the semantic information in each of the SL and the TC parses are acceptably similar, the TC will be deemed an appropriate translation. If their semantic information is different, the TC and their semantic differences will be reconciled in the third phase, Repair and Iterate. TCE comprises two modules as illustrated in Figure 6.1, the analyzer and semantic comparison.

Figure 6.1: TCE Architecture

6.1 The Analyzer

The analysis module analyzes the TC to examine its syntax and semantics: whether the TC is grammatically correct according to the TL grammar and whether the TC retains the meaning of the source language. Therefore, two steps are performed by the analyzer: Parsing and Semantic Extraction.

6.1.1 Parsing

Parsing is applied to both the SL and the TC. We have developed English and Thai grammars within the Head-Driven Phrase Structure Grammar formalism [Pollard and Sag; 1987; Pollard and Sag, 1994]. Our grammar is a modification to the grammars which were provided by Gerald Penn [Penn 1993] and Colin Matheson [Matheson 1996]. The grammars we developed have been implemented using the Attribute Logic Engine version 3.2 Beta. ALE is an integrated phrase structure parsing and definite clause logic programming system in which the terms are typed feature structures [Carpenter and Penn 1999].

In the next section, a very brief overview of HPSG and some notation are introduced. Further details on HPSG can be found in [Pollard and Sag 1987], [Pollard and Sag 1994], [Sag and Wasow 1999], HPSG homepage at <http://hpsg.stanford.edu/> [Center for the Study of Language and Information 1999] and the typed feature formalism is described in [Carpenter 1992].

6.1.1.1 About Head-Driven Phrase Structure Grammar

Head-Driven Phrase Structure Grammar, the grammatical theory developed by Carl Pollard and Ivan Sag during the mid 1980s [Pollard and Sag 1987; Pollard and Sag 1994], was developed by synthesizing several contemporary linguistic theories, including Categorical Grammar (CG), Generalized Phrase Structure Grammar (GPSG) [Gazdar et al. 1985], and Lexical Functional Grammar (LFG) [Bresnan and Kaplan 1982], from which it borrows some interesting ideas. The HPSG architecture has been largely pursued by an increasing number of linguists, since the formally well-defined framework allows for an explicit formalization of a linguistic theory.

HPSG, an integrated theory of natural language syntax and semantics, is a feature-based grammatical framework which is characterized by a modular specification of linguistic

generalizations through extensive use of principles and lexicalization of grammatical information.

HPSG is formulated in terms of order-independent constraints. In other words, the grammar is formulated as a declarative system of constraints. These constraints provide partial grammatical information that can be flexible, consulted in a variety of language processing models based on the notion of incremental, on-line integration of heterogeneous types of information. Key advantages of HPSG which are appropriate for use in MT are as follows:

- **Small number of rules and rich-information lexicon**
Based on the assumption of a universal syntax, a small number of highly schematic syntactic rules are assumed to apply universally; the task of explaining the variations between languages must be carried out in the lexicon [Carpenter 1991]. The detailed lexical entries of HPSG are concisely expressed within a multiple inheritance hierarchy and lexical rules. Such hierarchical lexicons allow cross-cutting generalizations about words to be expressed in a highly efficient and compact organization.
- **Unification-based constraints**
Recent work in the unification framework [Shieber 1986] has shown that a formalism based on unification is particularly well-suited for declarative modes of problem solving. In addition, a declarative mode allows the construction of grammars which can be neutral as to the processes applying to them, whether parser or generator [Estival 1994].
- **Language-independent principles**
The modular design of HPSG offers a large degree of flexibility for applying the framework to new languages and changing individual components of a grammar.

6.1.1.2 Words and Phrases as Feature Structures

Utterances in HPSG are modeled in terms of feature structures of type *sign*, with its two immediate subtypes *word* and *phrase* [Ginzburg and Sag 1998]. The lexical entries are descriptions of feature structures of type *word* while phrase structure rules are partial descriptions of feature structures of type *phrase*.

A feature structure is a description of an object; it specifies some or all of the information that is asserted to be true of the object. The features CATEGORY (CAT) and CONTENT (CONT) (Figure 6.2) specify the syntactic and semantic information of an object

respectively. Figure 6.2 represents a partial description of the lexical entry *hide* in an attribute-value matrix (AVM) diagram¹ (the detailed explanation of this representation can be found in section 6.3.1). Each feature takes a value of a particular and appropriate type. The grammar must include a specification of what types are included, which features are appropriate for which type, and what type of value is appropriate for each feature. Some types, their features and their value types are shown in Table 6.1 (see also appendix D).

Figure 6.2: The lexical entry *hide*

Figure 6.3 presents a (simplified) partial description of the phrase *Leslie drinks milk* (this example is taken from Ginzburg and Sag, 1998) in terms of typed feature structures. This representation indicates that *Leslie drinks milk* is the type of head-subject phrase² (hd-subj-ph). The hd-subj-ph is a subtype of the type headed-phrase (hd-ph). The hd-ph is the type of

¹ The AVM diagram is the standard method of representing grammatical information in modern computation grammar theories.

² There are two types of phrases in English: headed phrase (e.g., head-subject phrase, head-complement-phrase, head-modifier-phrase) and nonheaded phrase (e.g., imperative-phrase, coordinate-phrase). Further details can be found in [Ginzburg and Sag 1998] and [Sag and Wasow 1999].

the phrase in which one daughter is assigned special status as the HEAD DAUGHTER (HD-DTR). Other subtypes of hd-ph are *head-specifier-phrase* (hd-spr-ph), *head-complement-phrase* (hd-comp-ph), *head-adjunct-phrase* (hd-adjunct-ph). Instances of the hd-ph are governed by the feature declarations shown in the last row of Table 6.1. The indices [1], [2], [3] specified in the feature PHONOLOGY (PHON) called tags indicate the *structure sharing* between feature values: two or more different features within the feature structure may have their values specified by one and the same feature structure. The effect of structure sharing is to force two (or more) distinct nodes in a tree admitted by a rule to have identical values for a given feature. In Figure 6.3, the first phonology (phonology here means phonological shape) of the hd-subj-ph is the same as the phonology of its NON-HD-DTRS which, in this case, is *Leslie*, the second and the third phonologies are the same as those of its HD-DTR which are *drinks* and *milk* respectively. The syntactic category of *Leslie drinks milk* is a sentence (synsem: s). The syntactic category of the NON-HD-DTRS (*Leslie*) of the given phrase is a noun phrase (NON-HD-DTRS:SYNSEM: np). The syntactic category of its HD-DTR (*drinks milk*) is a verb phrase (HD-DTR:SYNSEM: vp). The type of this verb phrase *drinks milk* is a hd-comp-ph with the HD-DTR, *drinks*, and the NON-HD-DTRS, *milk*.

Table 6.1: Some types, their features and their value types

Type	Features/Type of value	Immediate Supertype
sign	$\left[\begin{array}{ll} \text{PHON} & \text{list(speech-sound)} \\ \text{SYNSEM} & \text{synsem} \end{array} \right]$	entity
phrase	...	sign
word	...	sign
synsem	$\left[\begin{array}{ll} \text{LOC} & \text{loc} \\ \text{NONLOCAL} & \text{nonlocal} \end{array} \right]$	mod_synsem
loc	$\left[\begin{array}{ll} \text{CAT} & \text{cat} \\ \text{CONT} & \text{cont} \\ \text{CONX} & \text{conx} \end{array} \right]$	entity
cat	$\left[\begin{array}{ll} \text{HEAD} & \text{head} \\ \text{SPR} & \text{list_synsem} \\ \text{SUBJ} & \text{list_synsem} \\ \dots & \dots \end{array} \right]$	entity
hd-ph	$\left[\begin{array}{ll} \text{HD-DTR} & \text{sign} \\ \text{NON-HD-DTRS} & \text{list(sign)} \end{array} \right]$	phrase

Figure 6.3: The phrase *Leslie drinks milk*

6.1.1.3 Lexicon

The lexical types (e.g., noun, verb, adj), a type inheritance and the lexical rules allow complex lexical information (as shown in Figure 6.2) to be derived via the logic of the lexicon, rather than simply stipulated.

The *lexical types* were introduced to define feature appropriateness, to avoid having to specify values for features that are irrelevant to particular classes. Table 6.2 illustrates the type constraints that state general properties (in terms of particular feature-value specifications) of particular lexemic types, noun and verb. Noun and verb are subtypes of substantive³ (subst). The feature CASE is appropriate only for nouns (in English) and its value is either *nominative* (nom) or *accusative* (acc). The features VERB-FORM (VFORM), INVERTED (INV) and AUXILIARY (AUX) are specifiable only for verbs. The forms of verbs can be classified as base, finite, gerund, infinitive, passive participle, present participle and past participle form [Pollard and Sag 1987]. The feature INV and AUX are used to distinguish auxiliary (helping) verbs from all others. The values of INV and AUX are the type of *boolean*. In interrogatives, a finite auxiliary verb precedes the subject, therefore, the INV and AUX values of a finite auxiliary verb are *plus* while the INV and AUX values of other kinds of verb

³ According to Pollard and Sag, noun, verb, adjective, preposition, relativizer are subtypes of *substantive*, whereas marker (e.g., complementizers) and determiner are subtypes of *functional* [Pollard and Sag 1994].

are *minus*.

Each type in the lexical hierarchy has constraints associated with it - some inviolable, and others that are default in nature. The inheritance of constraints in this type hierarchy is *default*. The *default inheritance* allows contradictory information associated with a subtype to take precedence over (or override) constraints that would otherwise be inherited from a supertype. In other words, lexical items have many properties in common but may differ from one another in terms of particular constraints that override the general constraints governing their supertypes. By organizing the lexicon in terms of a type hierarchy and the use of *default inheritance* of constraints, the stipulations associated with particular lexical entries can be minimized and the shared properties of different word classes can be expressed.

Table 6.2: Features and their value types of the types noun and verb

Type	Features/Type of value	Immediate Supertype
noun	[CASE case]	subst
verb	[VFORM vform INV boolean AUX boolean]	subst

The *lexical rule* is a mechanism for further reducing redundancy and stipulation in the lexicon by using information in one lexical entry as the basis for generating another lexical entry. The lexical rules are used for deriving predictably related lexical entries, e.g., inflected forms of verbs and nouns. A lexical rule applies to a lexical entry (of type *word*) and produces as output a new lexical entry whose (morphological) form, syntactic category and semantics are systematically related to the input [Sag and Wasow, 1999]. Figure 6.4 illustrates the (simplified) rule that applies to verb bases in English, giving their 3rd-singular

Figure 6.4: The 3rd-singular verb lexical rule

verb form. This 3rd-singular verb lexical rule is taken from hpsg.pl written by Gerald Penn [Penn 1993]. The rule suffixes an -s or -ies (in case the verb ended with y), thus it generates *hides* for *hide* and *flies* for *fly*. The rule says that for every verb whose form is uninflected (VFORM: bse), not an auxiliary verb (AUX: minus) and it takes a nominative as its subject (SUBJ: NP (nom)), there is a corresponding lexical entry for a 3rd-singular verb whose form is dictated by the 3rd-singular verb lexical rule: finite (VFORM: fin) and it takes a subject which is nominative and singular (SUBJ: NP (nom, sg)). Figure 6.5 illustrates *hides*, the output of the 3rd-singular verb lexical rule applied to the lexical entry *hide* shown in Figure 6.2. See appendix E for additional lexical rules.

Figure 6.5: Example output, *hides*, of the 3rd-singular verb lexical rule

6.1.1.4 Some Universal Principles and Grammar rules

In this section, we explain some of the universal principles proposed in HPSG and consider some phrasal constructions with HPSG grammar rules.

The **Head Feature Principle** (HFP) can be formulated as a constraint on phrases of the type hd-ph. This principle restricts the sharing of the HEAD feature between a mother sign and its head daughter as shown in (1). HEAD always takes as its value a feature structure appropriated to each category as discussed in the last section (see the values of the HEAD

principally with linguistic information that bears directly on semantic interpretation. The CONT value of nominals (e.g., lexical nouns and their phrasal projections) is the feature structure of INDEX and restriction (RESTR).

$$(2) \quad \text{hd-ph} \Rightarrow \left[\begin{array}{ll} \text{SYNSEM|LOC|CONT} & \boxed{1} \\ \text{HD-DTR} & [\text{SYNSEM|LOC|CONT} \quad \boxed{1}] \end{array} \right]$$

with the exception of the hd-adjunct-ph

$$\text{hd-ph} \Rightarrow \left[\begin{array}{ll} \text{SYNSEM|LOC|CONT} & \boxed{1} \\ \text{ADJUNCT-DTR} & [\text{SYNSEM|LOC|CONT} \quad \boxed{1}] \end{array} \right]$$

The type INDEX is classified into three subtypes: *referential* (ref), *there* and *it* [Pollard and Sag 1994]. The types *there* and *it* are used only for the expletive pronouns *there* and *it* while the type *ref* are used for nouns. INDEX introduces the three agreement features: PERSON (PER), NUMBER (NUM) and GENDER (GEN). The INDEX values of *Leslie* and *milk* are shown in Figure 6.7. According to the AVM diagram representation illustrated in Figure 6.7, the linguistic meaning of *Leslie* is that the object is referred to as Leslie, its quantity is one and its gender is masculine. The PERSON feature is unspecified for *Leslie*. *Milk* is a 3rd person, singular and neutral. The INDEX feature⁴ plays an important role in HPSG account of binding theory. For example: the indices for John and himself, in the sentence *John shaved himself*, should be shared [Matheson 1996].

The value of the feature RESTR is a set of parametrized states-of-affairs (psoas). States-of-affairs (soa, the term used in situation semantics, it is what philosophers call propositions) are possible ways the world might be construed [Pollard and Sag 1987]. Psoa is like a soa except that certain of its argument roles (its parameter) have not yet been anchored to determinate objects. The idea behind the feature RESTR is that it contains the basic semantic information on a referent [Matheson 1996], e.g., the RESTR value of the lexical entry *milk* contains the basic semantic information that the object concerned is *milk*. In addition, the values of the INSTANCE and INDEX features are unified (the restriction imposed by the common noun is associated with the marker in the discourse as discussed in Footnote 3) [Matheson 1996].

⁴ The INDEX feature is used in the HPSG analysis of discourse structure. For example, in the sentences: "the man likes books. he often reads them", the two markers representing *the man* and *books* in the first sentence should be identified with the markers for *he* and *them* , in the second sentence, respectively [Matheson 1996].

Figure 6.7: Semantic principle applied to *Leslie drinks milk*

The CONT value of verb is the feature structure of predication specified: what kind of relation is involved and who (or what) is participating in the relation. The CONT value of the lexical entry *drinks* is illustrated in Figure 6.7, it corresponds to the condition that [5] drinks [4].

The effect of the semantic principle is illustrated in Figure 6.7 (marked by the shaded ellipse). The CONT value of the *hd-comp-ph* *drinks milk* is passed from its HD-DTR *drinks* (indicated by the tag [6]) and the CONT value of *drinks milk* is passed to that of *hd-subj-ph* (indicated by the tag [6]) since *drinks milk* is the HD-DTR of *Leslie drinks milk*. The semantic representation in Figure 6.7 means *Leslie drinks milk* depicts a proposition which satisfies the conditions that [5] is a masculine referred to as Leslie, [4] is milk, and Leslie drinks milk. This

principle is applied to all grammar rules. For more principles e.g., Spec Principle, Marking Principle, Nonlocal Feature Principle and Relative Uniqueness Principle, consult [Pollard and Sag 1987], [Pollard and Sag 1994], and [Matheson 1996].

The **Head_complement rule** allows a lexical head to combine with the zero or more complements that it selects to form a phrase of type `hd-comp-ph`. This kind of phrase is subject to the constraint as in (3). The `COMPLEMENTS (COMPS)` value of the head must match a sequence of `SYNSEM` values of `NON-HD-DTRS`. The `COMPS` value is a list of feature structures. The list specifies a sequence of categories corresponding to the complements that the word combines with. For example: a verb *likes* (Figure 6.8), a `HD-DTR`, combines with its (only one) complement *John* in a `hd-comp-ph`. This means that the `SYNSEM` value of the `NON-HD-DTRS` of the phrase *likes John* is identified with [2].

$$(3) \quad \text{hd-comp-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \left[\begin{array}{l} \text{word} \\ \text{SYNSEM|LOC|CAT|COMPS} \end{array} \left(\begin{array}{l} \text{[1], [2], ..., [n]} \end{array} \right) \right] \\ \text{NON-HD-DTRS} \left(\begin{array}{l} [\text{SYNSEM [1]}], [\text{SYNSEM [2]}], \dots, [\text{SYNSEM [n]}] \end{array} \right) \end{array} \right]$$

$$\left[\begin{array}{l} \text{hd-comp-ph} \\ \text{PHON} \quad \langle \text{likes, John} \rangle \\ \text{SYNSEM|LOC|CAT} \left[\begin{array}{l} \text{SUBJ} \quad \langle \text{[1]} \rangle \\ \text{COMPS} \quad \langle \rangle \end{array} \right] \\ \text{HD-DTR} \left[\begin{array}{l} \text{word} \\ \text{PHON} \quad \langle \text{like} \rangle \\ \text{SUBJ} \quad \langle \text{[1] NP} \rangle \\ \text{COMPS} \quad \langle \text{[2] NP} \rangle \end{array} \right] \\ \text{NON-HD-DTRS} \left[\begin{array}{l} \text{PHON} \\ \text{COMPS} \quad \langle \text{John} \rangle \end{array} \right] \end{array} \right]$$

Figure 6.8: Head_complement rule applied to *likes John*

The **Specifier_head rule** (`spr_hd`) allows a lexical head to combine with its specifier that it selects to form a phrase of type `spr-hd-ph` as in (4). The `spr_hd` rule requires a two-way restriction: specifiers restrict their heads and heads restrict their specifiers [Matheson 1996]. For example, a specifier *this* selects singular nouns while common nouns select determiners as their specifiers. Therefore, the features `SPECIFIER`, `SPR` and `SPEC`, are introduced. `SPR` restricts the co-occurrence for heads and the specifiers they select. `SPEC` restricts the heads,

the kinds of things they specify. A noun *book* (Figure 6.9), a HD-DTR of a spr-hd-ph *the book*, combines with its determiner *a*, SPEC-DTR, which instead selects singular nouns to be specified.

$$(4) \quad \text{spr_hd_ph} \Rightarrow \left[\begin{array}{l} \text{SPEC-DTR} \quad [1] \quad [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} | \text{SPEC} \quad [2]] \\ \text{HD-DTR} \quad [2] \quad \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} | \text{SPR} \quad [1] \end{array} \right] \end{array} \right]$$

$$\left[\begin{array}{l} \text{hd-spr-ph} \\ \text{PHON} \quad \langle \text{a book} \rangle \\ \text{SYNSEM} | \text{LOC} | \text{CAT} \quad \left[\begin{array}{l} \text{SUBJ} \quad \langle \rangle \\ \text{SPR} \quad \langle \rangle \end{array} \right] \\ \text{HD-DTR} \quad [1] \quad \left[\begin{array}{l} \text{word} \\ \text{PHON} \quad \langle \text{book} \rangle \\ \text{SUBJ} \quad \langle \rangle \\ \text{SPR} \quad \langle [2] \text{ det} \rangle \\ \text{CONT} | \text{INDEX} | \text{NUM} \quad \text{sg} \end{array} \right] \\ \text{SPEC-DTR} \quad [2] \quad \left[\begin{array}{l} \text{PHON} \quad \langle \text{a} \rangle \\ \text{det} \\ \text{SPEC} \quad [1] \quad \text{NP} [\text{sg}] \end{array} \right] \end{array} \right]$$

Figure 6.9: Specifier_head rule applied to *the book*

6.1.1.5 Attribute Logic Engine

The Attribute Logic Engine 3.2 Beta⁵, was written in SICStus Prolog and developed by Bob Carpenter and Gerald Penn. ALE is a grammar parsing system which was developed to facilitate the use of HPSG and any typed feature structure grammar. Every structure used in ALE comes with a type. These types are arranged in an inheritance hierarchy whereby type constraints on more general types are inherited by their more specific subtypes [Carpenter and Penn 1999]. ALE differs from other approaches to feature structures in at least three notions. First, there is a strong type discipline enforced on feature structures. This means each type must specify which features it can be defined for and which types of values such features can take. The second notion is the type inference whereby types for structures which are underspecified can be automatically inferred. The third notion is that types in ALE are semantic which means that types are used at run-time. Even though ALE employs

⁵ ALE 3.2 Beta also contains a generator.

semantic typing, a type system is employed to detect type errors in grammars.

ALE also offers macros, to be used in description. Macros allow the user to define a description once and then use a shorthand for it in other descriptions. Macros can also contain other macros. The advantages of macros is not only to make the grammars more readable (especially to organize lexical information) but also to reduce the number of simple typing errors that lead to inconsistencies. Some sample macros and their usage are illustrated in section 6.1.1.6.

The format ALE provides for stating lexical rules is similar to that found in HPSG. However, the lexical rule system of ALE is productive in that it allows lexical rules to apply sequentially to their own output or the output of other lexical rules. Thus, it is possible to derive the nominal *runner* from the lexical entry *run* by the *nominal lexical rule*, and then derive the plural nominal *runners* from *runner* by the *plural_noun lexical rule*.

The ALE system employs a bottom-up active chart parser [Carpenter and Penn 1999]. The rules are evaluated from left to right, with the mother description coming last. The chart is filled in using a combination of depth-first and breadth-first control. The parser proceeds breadth-first in the sense that it incrementally moves through the string from right to left, one word at a time, recording all of the inactive edges that can be created beginning from the current left-hand position in the string.

ALE provides a number of routines for displaying and debugging grammar specifications as well. In executing ALE, the input string must be entered as a Prolog list of atoms. In particular, it must have an opening and closing bracket, with words separated by commas. No variable should occur in the query, nor anything other than an atom. The first part of the parsing output repeats the input string, separated by numbers (nodes in the chart) which indicates positions in the string for using in inspecting the chart directly (Figure 6.10). The second part of the output is a category which is derived for the input string. If there are multiple parses, these can be iterated through by providing positive answers (yes) to the query "Another?". The parsing stops when no more parses are found. Further details on ALE can be found at ALE homepage "<http://www.sfs.nphil.uni-tuebingen.de/~gpenn/ale.html> #Obtain", available as of May, 1999.

```

STRING:
0 the 1 ugly 2 duckling 3 hides 4 his 5 head 6 under 7 his 8 wing 9
CATEGORY:

phrase
QSTORE ne_set_quant
...
SYNSEM synsem
LOC loc
CAT cat
COMPS e_list
HEAD verb
AGR agr
  GENN gend
  NUM num
  PER per
  AUX minus
  INV minus
  LANG eng
  MOD none
...
Another?

```

Figure 6.10: Example of result of parsing in ALE representation

6.1.1.6 English and Thai Grammars in GRMT

In HPSG, the grammatical categories are broken down into features and the feature values are broken down into features as well. In this process, more and more syntactic information is moved out of the grammar rules and into the lexicon. This philosophy results in rules with very general patterns that cut across grammatical categories. The following seven grammar rules we developed cover a wide range of cases in both English and Thai (see also appendix F).

The *subject_head rule* (subj_hd), the *head_complement rule* (hd_comp), and the *coordination rule* cover the phrasal structures not only in English but also in Thai (the similarity between the typical phrasal structures of English and those of Thai was discussed in section 4.1). The *head_subject_complement rule* (hd_subj_comp) is used to license an English inverted sentence. The hd_subj_comp can also be used to analyze the phrasal structures which have verb-subj-object order in any language. The *specifier_head rule* (spr_hd) combines a lexical head with its selected specifier in English. The *adjunct_head* and *head_adjunct* rules allow a phrase to consist of a phrasal head and its modifier. The *head_specifier* (hd_spr) rule combines a lexical head with its specifier in Thai .

$$(5) \quad \text{subj-hd-ph} \Rightarrow \left[\begin{array}{ll} \text{SUBJ-DTR} & [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} \boxed{1}] \\ \text{HD-DTR} & [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{SUBJ} \boxed{1}] \end{array} \right]$$

The `subj_hd` rule allows a lexical head to combine with its selected head according to the constraint as in (5). The `HEAD` value of the `SUBJ-DTR` must match the `SUBJECT` value of the `HD-DTR`.

$$(6) \quad \text{hd-comp-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \left[\begin{array}{l} \text{word} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} | \text{COMPS} \quad \langle [1], [2], \dots, [n] \rangle \end{array} \right] \\ \text{NON-HD-DTRS} \quad \langle [\text{SYNSEM } [1]], [\text{SYNSEM } [2]], \dots, [\text{SYNSEM } [n]] \rangle \end{array} \right]$$

The `hd_comp` rule, combines a head with its complements, according to the constraint as in (6), was discussed in section 6.1.1.4.

$$(7) \quad \text{coordination-ph} \Rightarrow \left[\begin{array}{l} \text{CONJUNCT-DTR1} \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} \quad [1] \end{array} \right] \\ \text{COORDINATE-DTR} \quad [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} \quad \text{conj}] \\ \text{CONJUNCT-DTR2} \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} \quad [1] \end{array} \right] \end{array} \right]$$

This coordination⁶ rule says that the two occurrences⁷ of elements of the same syntactic category can be conjoined to make a coordinate element of that category (7). This rule requires that all conjuncts of a coordinate structure have identical values for `HEAD`, `SPR` and `COMPS`.

The `hd_subj_comp` rule allows a lexical head to combine with its subject and complements that it selects to form a phrase of verb-subj-object, in that order, as in (8). The `HD-DTR` must be an inverted verb and its `HEAD` value must match the `SUBJ` value of the `SUBJ-DTR`. The `COMPS` values of the `HD-DTR` must match a sequence of `SYNSEM` values of `NON-HD-DTRS`.

⁶ The coordinate conjunctions are words connecting elements that are, intuitively, of equal status. In English, the paradigmatic coordinate conjunctions are *and* or *or* [Sag and Wasow 1999].

⁷ The number of the conjuncts of a coordinate structure in the coordination rule proposed by Sag and Wasow [Sag and Wasow 1999] is not limited at two: it could be any number of occurrences of conjuncts. However, the semantics transfer from the conjuncts to the mother is not yet finalized at this time: therefore, our coordination rule considers only two conjuncts for simplicity.

$$(8) \quad \text{hd-subj-comp-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \left[\begin{array}{l} \text{word} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} \left[\begin{array}{l} \text{HEAD} \quad [\text{INV} \quad \text{yes}] \\ \text{SUBJ} \quad [4] \\ \text{COMPS} \quad \langle [1], [2], \dots, [3] \rangle \end{array} \right] \end{array} \right] \\ \text{SUBJ-DTR} \quad [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{SUBJ} \quad [4]] \\ \text{NON-HD-DTRS} \quad \langle [\text{SYNSEM} \quad [1]], [\text{SYNSEM} \quad [2]], \dots, [\text{SYNSEM} \quad [3]] \rangle \end{array} \right]$$

$$(9) \quad \text{spr-hd-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \quad [2] \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} | \text{SPR} \quad [1] \end{array} \right] \\ \text{SPEC-DTR} \quad [1] [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} | \text{SPEC} \quad [2]] \end{array} \right]$$

The `spr_hd` rule (9) says that the a phrase can consist of a phrasal head preceded by its specifier, as we discussed extensively in section 6.1.1.4.

$$(10) \quad \begin{array}{l} \text{adjunct-hd-ph} \Rightarrow \left[\begin{array}{l} \text{ADJUNCT-DTR} \quad [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} | \text{MOD} \quad [2] , \\ \text{HD-DTR} \quad [2] [\text{phrase}] \end{array} \right] \\ \text{hd- adjunct-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \quad [2] [\text{phrase}] \\ \text{ADJUNCT-DTR} \quad [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} | \text{MOD} \quad [2] , \\ \text{post_mod_synsem}] \end{array} \right] \end{array}$$

In English, adjuncts (modifiers) appear both before and after the objects they modify (HD-DTR), e.g., the *ugly* duckling, the duckling *in the farmyard*. Therefore, two rules: `adjunct_hd` rule and `hd_adjunct` rule are required to combine the HD-DTR with its modifier as in (10). In Thai, the modifiers must follow the HD-DTR (see section 4.1): thus only the `hd_adjunct` rule is required. The MODIFIER (MOD) values of the ADJUNCT-DTRs indicate the types of the object that the adjunct modifies. The subtypes `pre_mod_synsem` and `post_mod_synsem` specified in the ADJUNCT-DTR restrict which rule will be applied.

$$(11) \quad \text{hd-spr-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \quad [2] \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} | \text{SPR} \quad [1] \end{array} \right] \\ \text{SPEC-DTR} \quad [1] [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} | \text{SPEC} \quad [2]] \end{array} \right]$$

Figure 6.11: The lexical entry for *hide*

The grammars we developed have been implemented using the Attribute Logic Engine. Figure 6.12 illustrates the representation of the lexical entry *hide* (its AVM diagram is shown in Figure 6.11) in ALE with some macros. The use of the macro is specified by the @ sign followed with the macro name e.g., @np, @case.

Figure 6.12: The representation of *hide* in ALE with some macros

Figure 6.13 illustrates the parse (in ALE representation) of the SL in Example 1 and the parse of its TC. The TC is generated by ALMT. The parses are in ALE representations. Both the SL and TC are licensed by our grammars. Their syntax is shown in the dotted boxes. The SL analysis begins by analyzing the word *wing* and combines it with *his* by the *spr_hd* rule. The phrase *his head under his wing* are licensed by *hd_comp* and the *subj_hd* rules since the lexical entry *under* requires subject and complement as specified lexically in Figure 6.14. *Ugly* and *duckling* are combined by the *adjunct_hd* rule, then the *spr_hd* rule combines *ugly duckling* with *the*. The phrase *The ugly duckling hides his head under his wing* results from combining *The ugly duckling* and *his head under his wing* via the *hd_comp* and the *subj_hd* rules. Again, everything is specified lexically; *hides* requires a subject and two complements. The lexical entry *hides* is generated by the 3rd-singular verb lexical rule (Figure 6.5). The

Example 1:

SL: The ugly duckling hides his head under his wing.

TC: ลูกเป็ด ชีเหร์ ตัว นั้น ซ่อน หัว ของเขา ได้ ปีก ของเขา
(lûugpèd- duckling) (khiirèe- ugly) (tua- clas) (nán- the) (sǎʼan- hide) (huʼa- head) (khǎʼəŋkhaw- his)
(tâaj- under) (piig- wing) (khǎʼəŋkhaw- his)

<p>STRING: 0 the 1 ugly 2 duckling 3 hides 4 his 5 head 6 under 7 his 8 wing 9</p> <p>CATEGORY:</p> <p>phrase QSTORE ne_set_quant</p> <p>...</p> <p>NUCLEUS bodypart WORDASSO 1-4-1-1-1 INSTANCE [1] SURFACE head</p> <p>...</p> <p>NUCLEUS animal WORDASSO 1-1-1-2-1-2-1 INSTANCE [4] SURFACE duckling</p> <div> <p>SYNSEM synsem</p> <p>LOC loc</p> <p>CAT cat</p> <p>COMPS e_list</p> <p>HEAD verb</p> <p>AGR agr</p> <p>GENN gend</p> <p>NUM num</p> <p>PER per</p> <p>AUX minus</p> <p>INV minus</p> <p>LANG eng</p> <p>MOD none</p> <p>NEG boolean</p> <p>PRD boolean</p> <p>VFORM fin</p> <p>MARKING unmarked</p> <p>SPR list_synsem</p> <p>SUBJ e_list</p> </div> <p>CONT psua</p> <p>NUCLEUS hide2 WORDASSO 2-10-1 HID1 [1] HID_PLACE [3] HIDER1 [4] SURFACE hide</p> <p>QUANTS e_list</p> <p>CONX conx</p> <p>BACKGR e_set</p> <p>...</p>	<p>STRING: 0 ลูกเปิด 1 ซี่เหว 2 ตัว 3 นั้น 4 ซ่อน 5 หัว 6 ของเขา 7 ใต้ 8 ปีก 9 ของเขา 10</p> <p>CATEGORY:</p> <p>phrase QSTORE ne_set_quant</p> <p>...</p> <p>NUCLEUS bodypart WORDASSO 1-4-1-1-1 INSTANCE [1] SURFACE หัว</p> <p>...</p> <p>NUCLEUS animal WORDASSO 1-1-1-2-1-2-1 INSTANCE [4] SURFACE ลูกเปิด</p> <div> <p>SYNSEM synsem</p> <p>LOC loc</p> <p>CAT cat</p> <p>COMPS e_list</p> <p>HEAD verb</p> <p>AGR agr</p> <p>GENN gend</p> <p>NUM num</p> <p>PER per</p> <p>AUX minus</p> <p>INV minus</p> <p>LANG thai</p> <p>MOD none</p> <p>NEG boolean</p> <p>PRD boolean</p> <p>VFORM bse</p> <p>MARKING unmarked</p> <p>SPR ne_list_synsem</p> <p>HD synsem</p> <p>LOC loc</p> <p>CAT cat</p> <p>COMPS list_synsem</p> <p>...</p> <p>MARKING comp</p> <p>SPR list_synsem</p> <p>SUBJ list_synsem</p> </div> <p>...</p> <p>SUBJ e_list</p> <p>CONT psua</p> <p>NUCLEUS hide2 WORDASSO 2-10-1 HID1 [1] HID_PLACE [3] HIDER1 [4] SURFACE 'ĒÖπ</p> <p>QUANTS e_list</p> <p>CONX conx</p> <p>BACKGR e_set</p> <p>...</p>
--	---

Figure 6.13: The parse syntax of Example 1 and that of its translation

Figure 6.14: The representation of *under* in ALE with some macros

Figure 6.15: The representation of ขี้เหร่ (khîrèe- ugly) in ALE with some macros

phrase *The ugly duckling* and *his head under his wing* also obeys the Head Feature Principle in which the HEAD value of the mother (HEAD: verb, Figure 6.13) is identified with that of the HD-DTR. The effect of the semantic principle (CONT) will be discussed in section 6.2. The TC is analyzed in an analogous fashion, however, different rules are applied due to the syntax differences between languages. For example, ของเขา (khǎw-khaw- his) and ปีก (piig-wing) are combined with hd_spr rule to be ปีก ของเขา (corresponding to *his wing*). The phrase ลูกเป็ด ขี้เหร่ (corresponding to *ugly duckling*) results from combining ลูกเป็ด (lûugpèd-duckling) and ขี้เหร่ (khîrèe- ugly) via the hd_adjunct rule since ขี้เหร่ (khîrèe- ugly) is the type of post_mod_synsem as indicated in the lexcial entry shown in Figure 6.15. The phrase ลูกเป็ด ขี้เหร่ ตัว นั้น (corresponding to *The ugly duckling*) are formed by the hd_spr rule. The WORDASSO1 value of the classifier ตัว (tua), Figure 6.16, indicates the WordAsso number of the object that compatible with the classifier ตัว (tua).

```
'ตัว'→
word,
synsem:(loc:(cat:(head:(clas,
                        prd:minus,
                        mod:(post_mod_synsem,
                            @ nbar(Ind),
                            @ restr(Restrs),
                            @ wordassol('1-1-1-2-1-1')),
                        lang:thai),
spr:[],
subj:[],
comps:[],
marking:unmarked),
cont:(mode:reft,
      index:Ind,
      restr:Restrs),
...
```

Figure 6.16: The representation of the classifier ตัว (tua) in ALE

Figure 6.17 illustrates the parse of the SL in Example 2 and the parse of its TC. The SL is licensed by our English grammar, however, there is no parse for the TC since จอห์น (john-John) and ค่าเช่า (khâachâw- rent, rental fee) cannot be combined according to our Thai grammar; it is syntactically incorrect. Use of the semantic information of the parse is discussed in the next section.

```

STRING:
0 john 1 rents 2 a 3 room 4 from 5 joan 6
CATEGORY:

phrase
QSTORE ne_set_quant
...
      NUCLEUS room1
      WORDASSO 1-1-2-1-1-2-3
      INSTANCE [0]
      SURFACE room
...
SYNSEM synsem
  LOC loc
  CAT cat
  COMPS e_list
  HEAD verb
  AGR agr
  GENN gend
  NUM num
  PER per
  AUX minus
  INV minus
  LANG eng
  MOD none
  NEG boolean
  PRD boolean
  VFORM fin
  MARKING unmarked
  SPR ne_list_synsem
  HD synsem
  LOC loc
  CAT cat
  COMPS list_synsem
  HEAD head
  AGR agr
  GENN gend
  NUM num
  PER per
  LANG lang
  MARKING comp
  SPR list_synsem
  SUBJ list_synsem
...
  SUBJ e_list
  CONT psoa
  NUCLEUS rent1
  WORDASSO 2-1-3-3-2-2
  LANDLORD [2] ref
  IGENN fem
  INUM sg
...
  OBJECT [0]
  SURFACE rent
  TENANT [1] ref
  IGENN masc
...
  CONX conx
  BACKGR ne_set_psoa
...
  BEARER [1]
  NAME john
...
  BEARER [2]
  NAME joan
...

```

Example 2:

SL: John rents a room from Joan.

TC: จอห์น ค่าเช่า ห้อง ห้อง หนึ่ง จาก โจแอน
(จอน- John) (khâachâw- rent, rental fee) (หะ- room) (หะ- clas) (nyη- a) (câag- from) (joo?en- Joan)

```

STRING:
0 จอห์น 1 ค่าเช่า 2 ห้อง 3 ห้อง 4 หนึ่ง 5
จาก 6 โจแอน 7
No

```

Figure 6.17: The parse syntax of Example 2 and that of its translation

6.1.2 Semantic Extraction

Once the SL and the TC are parsed successfully, their semantic information will be extracted so that we can cross-examine the meaning of the TC with that of the SL. We first discuss how the semantic information is represented in our grammar. The semantic representation of an expression in GRMT is generally based on the representation in HPSG provided by Pollard and Sag, 1994 and Sag and Wasow, 1999 which will be presented in the next section.

6.1.2.1 Semantic Representation

The features `CONT`, `CONTEXT (CONX)` and `QUANTIFIER-STORE (QSTORE)` hold the semantics of the words. The semantic representation described in `CONT` (Figure 6.11) corresponds to the situation in which [1] (*the hider*) hides [2] (*the hid*) in (or under, from, etc.) [3] (*the hid_place*). The features `SURFACE` and `WORDASSO` indicate the word form and WordAsso number of the lexical entry. These features, `SURFACE` and `WORDASSO`, are used in the Repair and Iterate phrase. The feature `QSTORE` is storage for the quantifiers. The `QSTORE` value of *the* in Figure 6.18 is token-identical to the `CONT` value. The `QSTORE` value of the mother is passed from its constituents according to the *Quantifier Inheritance Principle* (QIP) [Pollard and Sag 1994]. QIP says that the `RETRIEVED-QUANTIFIERS` (`RETRIEVED`, its

Figure 6.18: The partial description of the lexical entry *the*

value is a list of quantifiers) value of the mother is a list whose set of elements forms a subset of the union of the QSTOREs of the daughters, and is nonempty only if the CONTENT of the semantic head is of type *psoa*, and the QSTORE value is the relative complement of the RETRIEVED value.

The CONX feature contains linguistic information that bears on certain context-dependent aspects of semantic interpretation [Pollard and Sag 1994]. The CONX value is a feature BACKGROUND (BACKGR) whose value is a set of *psoas*. Each background *psoa* restricts the possible anchors of indices that correspond to presuppositions or conventional implicature. The BACKGR value of *Joan* is illustrated in Figure 6.19. The atomic value *Joan* refers to the name *Joan*, not to an individual named *Joan*. Therefore, its *psoa* corresponds to the presupposition that the referent be identifiable in the utterance context by means of the name *Joan*. The BACKGR value of the mother obeys the *Contextual Consistency Principle* in which the BACKGR value of the mother is the union of the BACKGR values of the daughters as in (12).

Figure 6.19: The partial description of the lexical entry *Joan*

$$(12) \quad \text{hd-ph} \Rightarrow \begin{bmatrix} \text{HD-DTR} & [\text{SYNSEM} | \text{LOC} | \text{CONX} | \text{BACKGR} | \boxed{1} \cup \boxed{2} \cup \dots \cup \boxed{n}] \\ \text{DTRS} & \langle [\text{BACKGR } \boxed{1}], [\text{BACKGR } \boxed{2}], \dots, [\text{BACKGR } \boxed{n}] \rangle \end{bmatrix}$$

6.1.2.2 Semantic Extraction Examples

To extract the semantic information, CONT, QSTORE and CONX from the parse, we use a predicate *rec/5* provided in ALE as shown in Figure 6.20. However, this predicate *rec/5* binds the result (the feature values) to variables in the internal representation of feature structures of ALE. This result will be converted into a Prolog list for use in further procedure, *Semantic Comparison*.

Figure 6.20 illustrates the extracted internal representation of the semantic information of the SL parse of Example 3. This representation corresponds to the display in Figure 6.21 which illustrates QSTORE, CONT and CONX, the three semantics indicates used in HPSG and explained as follows. This semantic representation corresponds to the situation in which the *talker* is masculine and his name is John (CONT: TALKER1 [1] : IGENN: masc, CONX: BACKGR: (BEARER [1], NAME: john); the TALKER1 and BEARER are unified as indicated by [1]). The *talked* is about the device (spring) which is broken (CONT: TALKED [0], QSTORE: RESTIND: RESTR: (INSTANCE:[0], {broken1, device})); the TALKED and INSTANCES are unified via [0]).

Figure 6.22 and Figure 6.23 illustrate the extracted (as above for 6.20 and 6.21) semantic information, in ALE's internal structure and its corresponding display respectively, of the TC parse of Example 3. This semantic representation corresponds to the situation in which the *talker* is masculine and his name is จอห์น (จอห์น- John) (CONT: TALKER1 [1] : IGENN: masc, CONX: BACKGR: (BEARER [1], NAME: จอห์น); the TALKER1 and BEARER are unified as indicated by [1]). The *talked* is about the season (ฤดูใบไม้ผลิ- spring, in the sense of the season between winter and summer) which is broken (CONT: TALKED [0], QSTORE: RESTIND: RESTR: (INSTANCE: [0], {broken, season})); the TALKED and INSTANCES are unified via [0]). According to this analysis, the TC carries no meaning since *season* cannot be "broken" either physically and forcibly separated into pieces or cracked or split.

Note that Example 3 is intended to demonstrate the situation in which the SL and the TC convey different meanings. In this example, we forced ALMT to disregard the relationship between the words *broken* and *spring* during the *word selection* process. Therefore, the word ฤดูใบไม้ผลิ (ry'duubajmáajphli- the season) is selected as a translation for *spring*. As a result, the TC obtained is incorrect. Other possible translations of *spring* are สปริง (sapring- an elastic device), กระโดด (kradòod- to move suddenly upward or forward) and น้ำพุ (námphú- place where water comes up naturally from the ground).

In the next section, the semantic representations of the SL and the TC are compared to

determine whether they convey acceptably similar meaning.

Example 3:

SL: John talks about the broken spring.

TC: จอห์น พูด เกี่ยวกับ ฤดูใบไม้ผลิ ที่ หัก นั้น
(caən- John) (phũud- talk) (kiàw kàb- about)
(ry'duubajmáajphli- spring, the season)
(thii- modifying) (hàg- broken) (nán- the)

```
rec([john,talks,about,the,broken,spring]_._._[qs,
(qstore:Q,synsem:loc:(cont:Cont,
conx:Conx))).

QSTORE = _G8274-ne_set_quant(_G8280-
quant(_G8286-the._G8289-
nom_obj(_G8296-ref(_G8303-neut.
_G8306-sg._G8309-per). _G8312-ref.
_G8315-ne_set_psoa(_G8321-
_psoa(_G8327-broken1(_G8334-13-8-5.
_G8296-ref(_G8303-neut. _G8306-sg.
_G8309-per). _G8353-broken). _G8356-
e_list). _G8359-ne_set_psoa(_G8365-
_psoa(_G8371-device(_G8378-1-1-2-1-1-
3-1-4. _G8296-ref(_G8303-neut.
_G8306-sg. _G8309-per). _G8397-
spring). _G8400-e_list). _G8403-
e_set))). _G8406-e_set)

CONT = _G8598-psoa(_G8604-talk2(_G8612-2-
1-3-1-1. _G8615-talk. _G8296-
ref(_G8303-neut. _G8306-sg. _G8309-
per). _G8634-ref(_G8641-masc.
_G8644-sg. _G8647-per)). _G8650-
e_list)

CONX = _G8653-conx(_G8658-
ne_set_psoa(_G8664-psoa(_G8670-
naming(_G8678-wordasso. _G8634-
ref(_G8641-masc. _G8644-sg. _G8647-
per). _G8697-john. _G8700-surface).
_G8703-e_list). _G8706-e_set))
```

Figure 6.20: The semantic information, in ALE's internal structure, of the SL in Example 3

```
STRING:
0 john 1 talks 2 about 3 the 4 broken 5 spring 6
CATEGORY:

phrase
QSTORE ne_set_quant
  ELT quant
    DET the
    RESTIND nom_obj
      INDEX [0] ref
        IGENN neut
        INUM sg
        IPER per
        MODE refl
        RESTR ne_set_psoa
          ELT psoa
            NUCLEUS broken1
              WORDASSO 13-8-5
              INSTANCE [0]
              SURFACE broken
            QUANTS e_list
            ELTS ne_set_psoa
              ELT psoa
                NUCLEUS device
                  WORDASSO 1-1-2-1-1-3-1-4
                  INSTANCE [0]
                  SURFACE spring
                QUANTS e_list
                ELTS e_set
            ELTS e_set
          ...
        CONT psoa
          NUCLEUS talk2
            WORDASSO 2-1-3-1-1
            SURFACE talk
            TALKED [0]
            TALKER1 [1] ref
              IGENN masc
              INUM sg
              IPER per
            QUANTS e_list
          CONX conx
            BACKGR ne_set_psoa
              ELT psoa
                NUCLEUS naming
                  WORDASSO wordasso
                  BEARER [1]
                  NAME john
                  SURFACE surface
                QUANTS e_list
                ELTS e_set
              ...
```

Figure 6.21: The semantic information of the SL in Example 3


```

rec(['จอห์น', 'พูด', 'เกี่ยวกับ',
    'ฤดูใบไม้ผลิ', 'ที่', 'ห้ก', 'นั้น'],
lqs,(qstore:Q.synsem:loc:(cont:Cont.
conx:Conx))).

QSTORE = _G9202-ne_set_quant(_G9208-
quant(_G9214-the. _G9217-
nom_obj(_G9224-ref(_G9231-neut.
_G9234-sg. _G9237-per), _G9240-ref.
_G9243-ne_set_psoa(_G9249-
_psoa(_G9255-broken1(_G9262-13-8-5.
_G9224-ref(_G9231-neut. _G9234-sg.
_G9237-per), _G9281-À—°). _G9284-
e_list), _G9287-ne_set_psoa(_G9293-
_psoa(_G9299-season(_G9306-2-4-3-2.
_G9224-ref(_G9231-neut. _G9234-sg.
_G9237-per), _G9325-ฤดูใบไม้ผลิ).
_G9328-e_list), _G9331-e_set))).
_G9334-e_set)

CONT = _G9526-psoa(_G9532-talk2(_G9540-2-
1-3-1-1, _G9543-พูด, _G9224-
ref(_G9231-neut. _G9234-sg. _G9237-
per), _G9562-ref(_G9569-masc. _G9572-
sg. _G9575-per)), _G9578-e_list)

CONX = _G9581-conx(_G9586-
ne_set_psoa(_G9592-psoa(_G9598-
naming(_G9606-wordasso, _G9562-
ref(_G9569-masc. _G9572-sg. _G9575-
per), _G9625-จอห์น, _G9628-surface),
_G9631-e_list). _G9634-e_set))

```

Figure 6.22: The semantic information, in ALE's internal structure, of the TC in Example 3

```

STRING:
0 จอห์น 1 พูด 2 เกี่ยวกับ 3 ฤดูใบไม้ผลิ 4 ที่ 5 ห้ก 6
นั้น 7
CATEGORY:

phrase
QSTORE ne_set_quant
  ELT quant
    DET the
    RESTIND nom_obj
      INDEX [0] ref
      IGENN neut
      INUM sg
      IPER per
      MODE reff
      RESTR ne_set_psoa
        ELT psoa
          NUCLEUS broken1
            WORDASSO 13-8-5
            INSTANCE [0]
            SURFACE ห้ก
            QUANTS e_list
            ELTS ne_set_psoa
              ELT psoa
                NUCLEUS season
                  WORDASSO 2-4-3-2
                  INSTANCE [0]
                  SURFACE ฤดูใบไม้ผลิ
                  QUANTS e_list
                  ELTS e_set
            ELTS e_set
          ...
        CONT psoa
          NUCLEUS talk2
            WORDASSO 2-1-3-1-1
            SURFACE พูด
            TALKED [0]
            TALKER1 [1] ref
              IGENN masc
              INUM sg
              IPER per
            QUANTS e_list
          CONX conx
            BACKGR ne_set_psoa
              ELT psoa
                NUCLEUS naming
                  WORDASSO wordasso
                  BEARER [1]
                  NAME จอห์น
                  SURFACE surface
                  QUANTS e_list
                  ELTS e_set
              ...

```

Figure 6.23: The semantic information of the TC in Example 3

6.2 Semantic Comparison

In comparing the meaning between the SL and its TC, the values of the features CONT, QSTORE and CONX are considered. If the values of these features of the SL parse are the same as those of the TC parse, TCE concludes that the TC does not require repair. If any of these features are different, TCE will provide information of the SL parse which differs from that of the TC parse. This information will be used in the repair process phrase, *Repair and Iterate*.

The comparison process begins by investigating the CONT value of both SL and TC parses. Figure 6.24 and Figure 6.25 illustrate the semantic information of the SL and that of the TC in Example 1 (section 6.1.1.6). Their simplified displays are illustrated in Figure 6.26 and 6.27. The CONT values of both parses represent the same kind of relation involved, *hide2*,

```
rec([the,ugly,duckling,hides,his,head,under,his.wing],_._,Iqs.(qstore:Q.synsem:loc:(cont:Cont.conx
:Conx))).

QSTORE = _G18818-ne_set_quant(_G18824-quant(_G18830-the._G18833-nom_obj(_G18840
-ref(_G18847-gend._G18850-num._G18853-per)._G18856-mode._G18859-
ne_set_psoa(_G18865-psoa(_G18871-possess(_G18879-wordasso._G18882-ref
(_G18889-gend._G18892-sg._G18895-per)._G18840-ref(_G18847-gend._G18850-
num._G18853-per)._G18914-surface)._G18917-e_list)._G18920-ne_set_psoa
(_G18926-psoa(_G18932-bodypart(_G18939-'1-4-1-1'._G18882-ref(_G18889-gend.
_G18892-sg._G18895-per)._G18958-head(_G18964-agr(_G18971-gend._G18974-
num._G18977-per)._G18980-lang))._G18983-e_list)._G18986-e_set)))._G18989-
ne_set_quant(_G18995-quant(_G19001-the._G19004-nom_obj(_G19011-ref(_G19018-
gend._G19021-num._G19024-per)._G19027-mode._G19030-ne_set_psoa(_G19036-
psoa(_G19042-possess(_G19050-wordasso._G19053-ref(_G19060-gend._G19063-sg.
_G19066-per)._G19011-ref(_G19018-gend._G19021-num._G19024-per)._G19085-
surface)._G19088-e_list)._G19091-ne_set_psoa(_G19097-psoa(_G19103-bodypart
(_G19110-'1-4-1-1-3-1'._G19053-ref(_G19060-gend._G19063-sg._G19066-per).
_G19129-wing)._G19132-e_list)._G19135-e_set)))._G19138-ne_set_quant(_G19144
quant(_G19150-the._G19153-nom_obj(_G19160-ref(_G19167-gend._G19170-sg.
_G19173-per)._G19176-ref._G19179-ne_set_psoa(_G19185-psoa(_G19191-beauty
(_G19198-'13-8-4'._G19160-ref(_G19167-gend._G19170-sg._G19173-per)._G19217
-ugly)._G19220-e_list)._G19223-ne_set_psoa(_G19229-psoa(_G19235-animal
(_G19242-'1-1-1-2-1-2-1'._G19160-ref(_G19167-gend._G19170-sg._G19173-per).
_G19261-duckling)._G19264-e_list)._G19267-e_set)))._G19270-e_set)))
CONT = _G19356-psoa(_G19362-hide2(_G19371-'2-10-1'._G18882-ref(_G18889-gend._G18892-
sg._G18895-per)._G19053-ref(_G19060-gend._G19063-sg._G19066-per)._G19160-
ref(_G19167-gend._G19170-sg._G19173-per)._G19422-hide)._G19425-e_list)
CONX = _G19428-conx(_G19433-e_set)
```

Figure 6.24: The semantic information of the SL in Example 1

```

rec(['ลูกเบ๊ค', 'ชี้เหาะ', 'คัว', 'นับ', 'ซ่อน', 'หัว', 'ของเข่า', 'ไค', 'ปึก', 'ของเข่า'], __lqs.(qstore:Q.synsem:loc:
(cont:Cont.conx:Conx))).

QSTORE = _G21257-ne_set_quant(_G21263-quant(_G21269-the. _G21272-nom_obj(_G21279
-ref(_G21286-gend. _G21289-num. _G21292-per). _G21295-mode. _G21298-
ne_set_psoa(_G21304-psoa(_G21310-possess(_G21318-wordasso. _G21321-ref
(_G21328-gend. _G21331-sg. _G21334-per). _G21279-ref(_G21286-gend. _G21289-
num. _G21292-per). _G21353-surface). _G21356-e_list). _G21359-ne_set_psoa
(_G21365-psoa(_G21371-bodypart(_G21378-'1-4-1-1-1'. _G21321-ref(_G21328-
gend. _G21331-sg. _G21334-per). _G21397-หัว). _G21400-e_list). _G21403-e_set
))). _G21406-ne_set_quant(_G21412-quant(_G21418-the. _G21421-nom_obj
(_G21428-ref(_G21435-gend. _G21438-num. _G21441-per). _G21444-mode.
_G21447-ne_set_psoa(_G21453-psoa(_G21459-possess(_G21467-wordasso.
_G21470-ref(_G21477-gend. _G21480-sg. _G21483-per). _G21428-ref(_G21435-
gend. _G21438-num. _G21441-per). _G21502-surface). _G21505-e_list). _G21508-
ne_set_psoa(_G21514-psoa(_G21520-bodypart(_G21527-'1-4-1-1-3-1'. _G21470-
ref(_G21477-gend. _G21480-sg. _G21483-per). _G21546-ปึก). _G21549-e_list).
_G21552e_set))). _G21555-ne_set_quant(_G21561-quant(_G21567-the. _G21570-
nom_obj(_G21577-ref(_G21584-gend. _G21587-sg. _G21590-per). _G21593-ref.
_G21596-ne_set_psoa(_G21602-psoa(_G21608-beauty(_G21615-'13-8-4'.
_G21577-ref(_G21584-gend. _G21587-sg. _G21590-per). _G21634-ชี้เหาะ).
_G21637-e_list). _G21640-ne_set_psoa(_G21646-psoa(_G21652-animal
(_G21659-'1-1-1-2-1-2-1'. _G21577-ref(_G21584-gend. _G21587-sg. _G21590-per).
_G21678-ลูกเบ๊ค). _G21681-e_list). _G21684-e_set))). _G21687-e_set)))
CONT = _G21879-psoa(_G21885-hide2(_G21894-'2-10-1'. _G21321-ref(_G21328-gend.
_G21331-sg. _G21334-per). _G21470-ref(_G21477-gend. _G21480-sg. _G21483-
per). _G21577-ref(_G21584-gend. _G21587-sg. _G21590-per). _G21945-ฮาว).
_G21948-e_list)
CONX = _G21951-conx(_G21956-e_set)

```

Figure 6.25: The semantic information of the TC in Example 1

and the same type of persons (or things), *ref*, who/that are participating in this relation (*_G18882-ref*, *_G19053-ref* and *_G19160-ref* in the *CONT* value of the *SL* parse; *_G21321-ref*, *_G21470-ref* and *_G21577-ref* in the *CONT* value of the *TC* parse), each *ref* is *singular*. The right of a hyphen is a feature value which is bound to the variable on the left of the hyphen.

Once the *CONT* values of the *SL* parse and that of the *TL* parse are recognized as the same. *TCE*, then cross-examines the *QSTORE* and the *CONX* values of the *SL* parse with those of the *TC* parse to determine whether each variable (index) in the *CONT* value is associated to the appropriate object. In Figure 6.24 and 6.25, the first variable in the *CONT* value of the *SL* parse is *_G18882-ref* and that of the *TC* parse is *_G21321-ref*. Both variables are associated to a *bodypart* in the class of 1-4-1-1-1 (in the *QSTORE* value), it is *singular* and referred to as *head* in the *SL* and as หัว (*hǔa*) in the *TL*. หัว (*hǔa*) is the translation of the

Figure 6.26: The semantic information of the parse of the SL in Example 1

STRING:
0 ลูกเปิด 1 ซี่เหว่ 2 ตัว 3 นั้น 4 ซ่อน 5 หัว 6 ของเขา 7 ได้ 8 ปก 9 ของเขา 10

CATEGORY:

phrase

QSTORE ne_set_quant

ELT quant

DET the

RESTIND nom_obj

INDEX [0] ref

IGENN gend

INUM num

IPER per

MODE mode

RESTR ne_set_psoa

ELT psoa

NUCLEUS possess

WORDASSO wordasso

POSSESSED [1] ref

IGENN gend

INUM sg

IPER per

POSSESSOR [0]

SURFACE surface

QUANTS e_list

ELTS ne_set_psoa

ELT psoa

NUCLEUS bodypart

WORDASSO 1-4-1-1-1

INSTANCE [1]

SURFACE หัว

QUANTS e_list

ELTS e_set

ELTS ne_set_quant

ELT quant

DET the

RESTIND nom_obj

INDEX [2] ref

IGENN gend

INUM num

IPER per

MODE mode

RESTR ne_set_psoa

ELT psoa

NUCLEUS possess

WORDASSO wordasso

POSSESSED [3] ref

IGENN gend

INUM sg

IPER per

POSSESSOR [2]

SURFACE surface

QUANTS e_list

ELTS ne_set_psoa

ELT psoa

NUCLEUS bodypart

WORDASSO 1-4-1-1-3-1

INSTANCE [3]

SURFACE ปก

QUANTS e_list

ELTS e_set

ELTS ne_set_quant

ELT quant

DET the

RESTIND nom_obj

INDEX [4] ref

IGENN gend

INUM sg

IPER per

MODE reff

RESTR ne_set_psoa

ELT psoa

NUCLEUS beauty

WORDASSO 13-8-4

INSTANCE [4]

SURFACE ซี่เหว่

QUANTS e_list

ELTS ne_set_psoa

ELT psoa

NUCLEUS animal

WORDASSO 1-1-1-2-1-2-1

INSTANCE [4]

SURFACE ลูกเปิด

QUANTS e_list

ELTS e_set

ELTS e_set

CONT psoa

NUCLEUS hide2

WORDASSO 2-10-1

HID1 [1]

HID_PLACE [3]

HIDER1 [4]

SURFACE ซ่อน

QUANTS e_list

CONX conx

BACKGR e_set

...

Figure 6.27: The semantic information of the parse of the TC in Example 1

word *head* in Thai. The second variables are _G19053-ref (of the SL CONT value) and _G21470-ref (of the TC CONT value). These variables correspond to a *bodypart* in the class of 1-4-1-1-3-1, it is singular and referred to as *wing* in the SL and ปีก (piig) in the TL. Again, ปีก (piig) is a translation of *wing* in Thai. The last variables are _G19160-ref and _G21577-ref. They are associated with an animal in the class of 1-1-1-2-1-2-1 which is *singular* and referred to as *duckling* in the SL and ลูกเป็ด (lûugpèd) in the TL. ลูกเป็ด (lûugpèd) is the translation of the word *duckling* in Thai. The CONX feature in this example contains no value. According to the comparison process, TCE found no difference between the CONT, QSTORE and CONX of the SL parse and those of the TC parse. Therefore, the TC is deemed as an appropriate translation for the SL in the Example 1.

The CONT values of the SL and the TC parses in Example 3 (section 6.1.2.2) are not the same. The first variable of the SL CONT (_G8296-ref, Figure 6.20) relates to a *device* in the class of 1-1-2-1-1-3-1-4 which is referred to as *spring* (indicated in the QSTORE value) whereas its corresponding variable in the TC CONT (_G9224-ref, Figure 6.22) relates to a *season* in the class of 2-4-3-2 which is referred to as ฤดูใบไม้ผลิ (ry'duubajmáajphli). ฤดูใบไม้ผลิ (ry'duubajmáaj-phli) is one of the possible translations of the word *spring*. However, it is not an appropriate translation of *spring* in the expression of Example 3. The differences between the SL QSTORE and TC QSTORE indicate that the TC requires a repair.

The CONT values of the SL parse and the TC parse in Example 4 (Figure 6.28 and Figure 6.29) represent the same relation involved, *cover2*, and the same types of persons or things who/which are participating in this relation, COVERED, COVERED_PLACE and COVERER1. The SURFACE value in the CONT of the SL parse is *cover* and that of the TC is คลุม (khlum). The value of the feature SURFACE is a word form. คลุม (khlum) is a translation of *cover*. However, their WORDASSO values are different, *cover* belongs to the class of 2-1-19 whereas คลุม (khlum) belongs to the class of 2-1-19-2 as illustrated in Figure 6.30. Although *cover* and its translation คลุม (khlum) carry the same meaning, they are different in language usage. Differences in languages and cultures result in different circumstances of language usage. The word *cover* in *John covers his ears with his hands* corresponds to ปิด (pid) in Thai. When verifying the meaning of *cover*, the word and its translation are considered acceptably similar in principal features since they belong to the same superclass.

Example 4:

SL: John covers his head with his coat.

TC: จอห์น คลุม หัว ของเขา ด้วย เสื้อคลุม ของเขา
(caən- John) (khlum- cover) (hu'a- head) (khə'əŋkhaw- his) (dūaj- with) (sy'akhlum- coat)(khə'əŋkhaw- his)

STRING:
0 john 1 covers 2 his 3 head 4 with 5 his 6 coat 7
CATEGORY:

phrase
QSTORE ne_set_quant

```
...
  CONT psoa
    NUCLEUS cover2
      WORDASSO 2-1-19
      COVERED [1]
      COVERED_PLACE [3]
      COVERER1 [4] ref
        IGENN masc
        INUM sg
        IPER per
      SURFACE cover
      QUANTS e_list
      CONX conx
  ...
```

rec([john.covers.his.head.with.his.coat],_._I
qs,(synsem:loc:(cont:Cont))).

CONT = _G15498-psoa(_G15504-
cover2(_G15513-2-1-19, _G15156-
ref(_G15163-gend, _G15166-sg,
_G15169-per), _G15327-ref(_G15334-
neut, _G15337-sg, _G15340-per).
_G15548-ref(_G15555-masc,
_G15558-sg, _G15561-per).
_G15564-cover), _G15567-e_list)

Figure 6.28: The CONT value of the SL parse of Example 4

STRING:
0 จอห์น 1 คลุม 2 หัว 3 ของเขา 4 ด้วย 5 เสื้อคลุม 6 ของเขา
7
CATEGORY:

phrase
QSTORE ne_set_quant

```
...
  CONT psoa
    NUCLEUS cover2
      WORDASSO 2-1-19-2
      COVERED [1]
      COVERED_PLACE [3]
      COVERER1 [4] ref
        IGENN masc
        INUM sg
        IPER per
      SURFACE คลุม
      QUANTS e_list
      CONX conx
  ...
```

rec(['จอห์น', 'คลุม', 'หัว', 'ของเขา', 'ด้วย', 'เสื้อคลุม',
'ของเขา'],_._Iqs,
(synsem:loc:(cont:Cont))).

CONT = _G13854-psoa(_G13860-
cover2(_G13869-2-1-19-2, _G13428-
ref(_G13435-gend, _G13438-sg,
_G13441-per), _G13577-ref(_G13584-
neut, _G13587-sg, _G13590-per).
_G13904-ref(_G13911-masc,
_G13914-sg, _G13917-per),
_G13920-§=y;), _G13923-e_list)

Figure 6.29: The CONT value of the TC parse of Example 4

Table 6.3: The class of *cover*

WordAsso and Class description	Word
2-1-19 Cover as to place something on or over to protect or hide.	cover
2-1-19-1 Cover as to cover eyes, ears.	ปิด (pid)
2-1-19-2 Envelop	คลุม (khlum)

Chapter 7

Repair and Iterate

The last phase of GRMT, Repair and Iterate, performs the repair process if the translation candidate carries a different meaning from the SL. The repaired TC is then returned to the Translation Candidate Evaluation module. TCE re-analyzes the repaired TC to determine if additional repair is further required (a different meaning from the source language remains). The repair process repeats until the semantic information (CONT, QSTORE and CONX) of the SL and the TC are acceptably similar¹.

Figure 7.1: RI Architecture

RI examines the result of TCE. The TCE output is the TC with the semantic information of the SL which differs from that of the TC (Figure 7.1). With this information, RI is able to

¹ By acceptably similar we mean that a native TL speaker would find the TL translation represents the meaning of the SL statement to some acceptable degree (this degree may vary from language to language).

detect the part of the TC which causes the mis-translation. The mis-translated part will be replaced with a more appropriate translation. RI searches the *Word Treatment output* (generated by ALMT, see section 5.1) for a more appropriate translation based on the information provided by TCE. The TC with the new selection is then put through the *Word Ordering* module (see section 5.3) to revise its syntax. Once the revision is completed, the repaired TC is returned to TCE.

The semantic information described is represented in terms of CONT, QSTORE and CONX features (see section 6.1.2.1). In the case that the CONT or the QSTORE value of the SL is different from that of the TC, the SL CONT value: SURFACE and WORDASSO features are passed to RI. The SURFACE value indicates the surface form of the word which causes the mis-translation. The WORDASSO value specifies the proper meaning of the word in question in terms of WordAsso number. Therefore, to repair the CONT or QSTORE value of the TC, RI re-selects the corresponding word in the TL for the word specified in the SURFACE value. The re-selection is done by searching the *Word Treatment output* for the corresponding word which has the same WordAsso number as specified in the WORDASSO value.

In the case that the CONX value of the SL differs from that of the TC, the SL CONX value: the BEARER and NAME features are passed to RI. The BEARER value specifies the index which associates with the certain name specified in the NAME value. RI repairs the TC by associating the right names to the right indices based on the information provided by TCE.

The results of analyzing the SL and the TC in Example 1, below, indicate that the TC requires a repair since it carries a different meaning from the SL (see Example 3 in section 6.1.2.2). The CONT values of the SL and the TC are the same; however, parts of their QSTORE values are different. The QSTORE values of the SL and the TL illustrated in Figure 7.2 indicates that the word *spring* is mis-translated (SURFACE: spring). According to the QSTORE of the SL, the proper meaning of *spring* in Example 1 is *a device* which is classified into the class of 1-1-2-1-1-3-1-4 (WORDASSO: 1-1-2-1-1-3-1-4). Therefore, RI begins the repair process by re-selecting the translation of the word *spring*. RI searches the *Word Treatment output* (Table 7.1) for the translation of *spring* which has WordAsso number 1-1-2-1-1-3-1-4 and thus, the translation สปริง (sapring) is selected. The word ฤๅไนไม้ผลิ (ry'duubajmáajphli) in the TC is then replaced with สปริง (sapring). The TC with the new

selection (Figure 7.3) is put through the *Word Ordering* module to revise its syntax. At this step, the classifier อัน (?an- classifier) is added to complete the repaired TC.

Once the repair processes successfully, the repaired TC is analyzed by TCE. Figure 7.4 illustrates the semantic information of the SL parse and that of the repaired TC. Their CONT

Example 1:

SL: John talks about the broken spring.

TC: จอห์น พูด เกี่ยวกับ ฤดูใบไม้ผลิ ที่ หัก นั้น

(cǎn- John) (phūud- talk) (kiǎw kǎb- about) (ry'duubajmáajphli- spring, the season) (thii-modifying) (hǎg- broken) (nán- the)

<p>STRING: 0 john 1 talks 2 about 3 the 4 broken 5 spring 6</p> <p>CATEGORY:</p> <p>phrase</p> <p>QSTORE ne_set_quant</p> <p>ELT quant</p> <p>DET the</p> <p>RESTIND nom_obj</p> <p>INDEX [0] ref</p> <p>IGENN neut</p> <p>INUM sg</p> <p>IPER per</p> <p>MODE reff</p> <p>RESTR ne_set_psoa</p> <p>ELT psoa</p> <p>NUCLEUS broken1</p> <p>WORDASSO 13-8-5</p> <p>INSTANCE [0]</p> <p>SURFACE broken</p> <p>QUANTS e_list</p> <p>ELTS ne_set_psoa</p> <p>--- ELT psoa ---</p> <p>NUCLEUS device</p> <p>WORDASSO 1-1-2-1-1-3-1-4</p> <p>INSTANCE [0]</p> <p>SURFACE spring</p> <p>QUANTS e_list</p> <p>ELTS e_set</p> <p>ELTS e_set</p> <p>...</p>	<p>STRING: 0 จอห์น 1 พูด 2 เกี่ยวกับ 3 ฤดูใบไม้ผลิ 4 ที่ 5 หัก 6</p> <p>นั้น 7</p> <p>CATEGORY:</p> <p>phrase</p> <p>QSTORE ne_set_quant</p> <p>ELT quant</p> <p>DET the</p> <p>RESTIND nom_obj</p> <p>INDEX [0] ref</p> <p>IGENN neut</p> <p>INUM sg</p> <p>IPER per</p> <p>MODE reff</p> <p>RESTR ne_set_psoa</p> <p>ELT psoa</p> <p>NUCLEUS broken1</p> <p>WORDASSO 13-8-5</p> <p>INSTANCE [0]</p> <p>SURFACE หัก</p> <p>QUANTS e_list</p> <p>ELTS ne_set_psoa</p> <p>--- ELT psoa ---</p> <p>NUCLEUS season</p> <p>WORDASSO 2-4-3-2</p> <p>INSTANCE [0]</p> <p>SURFACE ฤดูใบไม้ผลิ</p> <p>QUANTS e_list</p> <p>ELTS e_set</p> <p>ELTS e_set</p> <p>...</p>
--	---

Figure 7.2 The QSTORE values of the SL and the TC parses of Example 1

Table 7.1 A part of Word Treatment output of Example 1

English	Word Treatment Output	Description
spring	ฤดูใบไม้ผลิ (ry'duubajmáajphli), 2-4-3-2	the season between winter and summer
	สปริง (sapring), 1-1-2-1-1-3-1-4	an elastic device
	กระโดด (kradòod), 2-1-5-5-1	to move suddenly upward or forward
	น้ำพุ (námphú), 1-1-2-1-4-1	place where water comes up naturally from the ground

TC: จอห์น (cəŋ- John) พูด (phûud- talk) เกี่ยวกับ (kiàw kàb- about) ฤดูใบไม้ผลิ (ry'duubajmáajphli- spring, the season) ที่ (thii- modifying) หัก (hàg- broken) นั้น (nán- the)

TC with the new selection: จอห์น (cəŋ- John) พูด (phûud- talk) เกี่ยวกับ (kiàw kàb- about) สปริง (sapring- the device) ที่ (thii- modifying) หัก (hàg- broken) นั้น (nán- the)

Repaired TC: จอห์น (cəŋ- John) พูด (phûud- talk) เกี่ยวกับ (kiàw kàb- about) สปริง (sapring- the device) อัน (?an- classifier) ที่ (thii- modifying) หัก (hàg- broken) นั้น (nán- the)

Figure 7.3: The repair of Example 1

<p>STRING: 0 john 1 talks 2 about 3 the 4 broken 5 spring 6</p> <p>CATEGORY:</p> <p>phrase</p> <p>QSTORE ne_set_quant</p> <p>ELT quant</p> <p>DET the</p> <p>RESTIND nom_obj</p> <p>INDEX [0] ref</p> <p>IGENN neut</p> <p>INUM sg</p> <p>IPER per</p> <p>MODE reff</p> <p>RESTR ne_set_psoa</p> <p>ELT psoa</p> <p>NUCLEUS broken1</p> <p>WORDASSO 13-8-5</p> <p>INSTANCE [0]</p> <p>SURFACE broken</p> <p>QUANTS e_list</p> <p>ELTS ne_set_psoa</p> <p>ELT psoa</p> <p>NUCLEUS device</p> <p>WORDASSO 1-1-2-1-1-3-1-4</p> <p>INSTANCE [0]</p> <p>SURFACE spring</p> <p>QUANTS e_list</p> <p>ELTS e_set</p> <p>ELTS e_set</p> <p>...</p> <p>CONT psoa</p> <p>NUCLEUS talk2</p> <p>WORDASSO 2-1-3-1-1</p> <p>SURFACE talk</p> <p>TALKED [0]</p> <p>TALKER1 [1] ref</p> <p>IGENN masc</p> <p>INUM sg</p> <p>IPER per</p> <p>QUANTS e_list</p> <p>CONX conx</p> <p>BACKGR ne_set_psoa</p> <p>ELT psoa</p> <p>NUCLEUS naming</p> <p>WORDASSO wordasso</p> <p>BEARER [1]</p> <p>NAME john</p> <p>SURFACE surface</p> <p>QUANTS e_list</p> <p>ELTS e_set</p> <p>...</p>	<p>STRING: 0 จอห์น 1 พูด 2 เกี่ยวกับ 3 สปริง 4 ที่ 5 หัก 6 อัน 7 นั้น 8</p> <p>CATEGORY:</p> <p>phrase</p> <p>QSTORE ne_set_quant</p> <p>ELT quant</p> <p>DET the</p> <p>RESTIND nom_obj</p> <p>INDEX [0] ref</p> <p>IGENN neut</p> <p>INUM sg</p> <p>IPER per</p> <p>MODE reff</p> <p>RESTR ne_set_psoa</p> <p>ELT psoa</p> <p>NUCLEUS broken1</p> <p>WORDASSO 13-8-5</p> <p>INSTANCE [0]</p> <p>SURFACE หัก</p> <p>QUANTS e_list</p> <p>ELTS ne_set_psoa</p> <p>ELT psoa</p> <p>NUCLEUS device</p> <p>WORDASSO 1-1-2-1-1-3-1-4</p> <p>INSTANCE [0]</p> <p>SURFACE สปริง</p> <p>QUANTS e_list</p> <p>ELTS e_set</p> <p>ELTS e_set</p> <p>...</p> <p>CONT psoa</p> <p>NUCLEUS talk2</p> <p>WORDASSO 2-1-3-1-1</p> <p>SURFACE พูด</p> <p>TALKED [0]</p> <p>TALKER1 [1] ref</p> <p>IGENN masc</p> <p>INUM sg</p> <p>IPER per</p> <p>QUANTS e_list</p> <p>CONX conx</p> <p>BACKGR ne_set_psoa</p> <p>ELT psoa</p> <p>NUCLEUS naming</p> <p>WORDASSO wordasso</p> <p>BEARER [1]</p> <p>NAME จอห์น</p> <p>SURFACE surface</p> <p>QUANTS e_list</p> <p>ELTS e_set</p> <p>...</p>
---	---

Figure 7.4: The semantic information of the SL and that of the repaired TC in Example 1

QSTORE and CONX values are the same. The repaired TC is, then, deemed as an appropriate translation for the SL in Example 1.

In the case that TCE finds no parse for a TC since it is grammatically incorrect according to TL grammar, TCE outputs the TC with the CONT and QSTORE values of the SL. RI begins the repair process by verifying the translation of the word specified in the CONT: SURFACE value of the SL. If the WordAsso number of that translation is the same as the WordAsso number specified in the CONT: WORDASSO value of the SL, then RI proceeds to verify the translation of the word specified in the QSTORE: SURFACE. However, if the WordAsso number of that translation is different from the WordAsso number specified in the CONT: WORDASSO value of the SL, then RI replaces that translation with another translation which has the same WordAsso number specified in the CONT: WORDASSO value of the SL. The TC with the new selection is then put through the *Word Ordering* module to revise its syntax. If the repaired TC remains syntactically incorrect, then RI verifies the words specified in the QSTORE: SURFACE value.

TCE found no parse for the TC in Example 2 (Figure 7.5) since the TC is grammatically incorrect (see Example 2 in section 6.1.1.6). RI verifies the translation of the word *rent*, since it is specified in the CONT: SURFACE value of the SL as illustrated in Figure 7.6. The selected translation of *rent* in the TC is ḵāchâw (khâachâw) with 2-1-3-3-2. However, the WordAsso number specified in the CONT: WORDASSO value of the SL is 2-1-3-3-2-2. Therefore, RI searches the *Word Treatment Output* (Table 7.2) for another translation of *rent* which has the WordAsso number 2-1-3-3-2-2. RI, then replaces ḵāchâw (khâachâw) with châw (châw, Figure 7.7) and revises the syntax of the TC with the new selection. The repaired TC is analyzed and compared to the SL parse. TCE now finds no difference between the SL and the repaired TC parses (Figure 7.8).

Example 2:

SL: John rents a room from Joan.

TC: จอห์น ค่าเช่า ห้อง ห้อง หนึ่ง จาก โจแอน

(cæn- John) (khâachâw- rent, rental fee) (hăŋ- room) (hăŋ- clas) (nyŋ- a) (càag- from) (joo?en- Joan)

STRING:

0 จอห์น 1 ค่าเช่า 2 ห้อง 3 ห้อง 4 หนึ่ง 5 จาก 6 โจแอน 7

No parse

Figure 7.5: The TC parse of Example 2

STRING:

0 john 1 rents 2 a 3 room 4 from 5 joan 6

CATEGORY:

...

CONT psoa

NUCLEUS rentI

WORDASSO 2-1-3-3-2-2

LANDLORD [2] ref

IGENN fem

INUM sg

IPER per

OBJECT [0]

SURFACE rent

TENANT [1] ref

IGENN masc

INUM sg

IPER per

QUANTS e_list

...

Figure 7.6: CONT value of the SL parse

Table 7.2: A part of Word Treatment output of Example 2

English	Word Treatment Output	Description
rent	ค่าเช่า (khâachâw), 2-1-3-3-2	money paid for the use of another's property
	ให้เช่า (hâjchâw), 2-1-3-3-2-1	to give possession and use of in return for rent
	เช่า (châw), 2-1-3-3-2-2	to take and hold under an agreement to pay rent
	รอยขาด (rôjkhâad), 2-3-11-1	a large tear
	ฉีก (chiig) ¹ , 2-1-6-1-3	to divide by force
	ดึง (thiŋ) ² , 2-1-6-1-2	to pull violently

TC: จอห์น (cæn- John) ค่าเช่า (khâachâw- rent, rental fee) ห้อง (hâŋ- room) ห้อง (hâŋ- clas) หนึ่ง (nyŋ- a) จาก (càag- from) โจแอน (joo?en- Joan)

TC with the new selection: จอห์น (cæn- John) เช่า (khâachâw- rent, rental fee) ห้อง (hâŋ- room) ห้อง (hâŋ- clas) หนึ่ง (nyŋ- a) จาก (càag- from) โจแอน (joo?en- Joan)

Repaired TC: จอห์น (cæn- John) เช่า (khâachâw- rent, rental fee) ห้อง (hâŋ- room) ห้อง (hâŋ- clas) หนึ่ง (nyŋ- a) จาก (càag- from) โจแอน (joo?en- Joan)

Figure 7.7: The repair of Example 2

^{1,2} The meanings of *rent* here are a past tense and a participle of *rend* [Longman 1992].

<p>STRING: 0 john 1 rents 2 a 3 room 4 from 5 joan 6 CATEGORY:</p> <p>phrase QSTORE ne_set_quant ELT quant DET exists RESTIND nom_obj INDEX [0] ref IGENN neut INUM sg IPER per MODE mode RESTR ne_set_psoa ELT psoa NUCLEUS room1 AKO 1-1-2-1-1-2-3 INSTANCE [0] SURFACE room QUANTS e_list ELTS e_set ELTS e_set ... CONT psoa NUCLEUS rent1 AKO 2-1-3-3-2-2 LANDLORD [2] ref IGENN fem INUM sg IPER per OBJECT [0] SURFACE rent TENANT [1] ref IGENN masc INUM sg IPER per QUANTS e_list CONX conx BACKGR ne_set_psoa ELT psoa NUCLEUS naming AKO ako BEARER [1] NAME john SURFACE surface QUANTS e_list ELTS ne_set_psoa ELT psoa NUCLEUS naming AKO ako BEARER [2] NAME joan SURFACE surface QUANTS e_list ELTS e_set </p>	<p>STRING: 0 จอห์น 1 เช่า 2 ห้อง 3 ห้อง 4 ห้อง 5 จาก 6 โฉนด 7 CATEGORY:</p> <p>phrase QSTORE ne_set_quant ELT quant DET exists RESTIND nom_obj INDEX [0] ref IGENN neut INUM sg IPER per MODE ref RESTR ne_set_psoa ELT psoa NUCLEUS room1 WORDASSO 1-1-2-1-1-2-3 INSTANCE [0] SURFACE ห้อง QUANTS e_list ELTS e_set ELTS e_set ... CONT psoa NUCLEUS rent1 WORDASSO 2-1-3-3-2-2 LANDLORD [2] ref IGENN fem INUM sg IPER per OBJECT [0] SURFACE เช่า TENANT [1] ref IGENN masc INUM sg IPER per QUANTS e_list CONX conx BACKGR ne_set_psoa ELT psoa NUCLEUS naming WORDASSO wordasso BEARER [1] NAME จอห์น SURFACE surface QUANTS e_list ELTS ne_set_psoa ELT psoa NUCLEUS naming WORDASSO wordasso BEARER [2] NAME โฉนด SURFACE surface QUANTS e_list ELTS e_set </p>
--	---

Figure 7.8: The semantic information of the SL and that of the repaired TC in Example 2

Chapter 8

Machine Translation Evaluation

'There is never a single right translation, and therefore never a solid ground truth against which MT output may be compared'

— John White, 1999

Evaluation plays a crucial role in machine translation for system developers, funding agencies and technology users. The system developers (at least) want to determine whether the system performs in the ways intended. The funding agencies aim at determining whether a particular research project should be funded whereas the technology users want to determine which system best suits their needs and is cost-effective. More importantly, all system developers, funding agencies and technology users want to determine whether the output is acceptable as a translation. Information necessary to make informed judgments is required. Unfortunately, a universally accepted methodology for evaluating MT systems is not yet available, partly because there are different purposes for MT, different interests of the participants in the process, radically different theoretical approaches to MT and different languages. In addition, it is difficult to evaluate the end product of an MT system since “there is never a single *right* translation, and therefore never a solid ground truth against which MT output may be compared” [quoting White 1999]. Moreover, most evaluations have been done under contracts and often under confidentiality agreements. Consequently relatively little constructive criticism of the techniques employed is in the public domain [King 1990].

GRMT represents an approach to MT that is not unlike what HPSG represents with respect to grammar theory. GRMT has borrowed many ideas from the major translation

paradigms (Direct MT, Interlingual MT, Transfer MT, Example-Based MT, Knowledge-Based MT and Shake-and-Bake MT) and included the notion of adding constraints where applicable, as found in HPSG theory. In this sense GRMT represents a new paradigm for MT systems. Just as it is difficult to evaluate past MT efforts (no generally accepted evaluation methodology), it is difficult to evaluate GRMT precisely. Nonetheless, we outline in this chapter some initial requirements for evaluation and some strategies which we hope to apply to GRMT.

8.1 What needs to be evaluated? (Types of Evaluation)

As in other areas of natural language processing (NLP), three types of evaluation appropriate to three different goals are recognized [Hirschman and Thompson 1996], [Hutchin 1996]:

- *Adequacy Evaluation* is to determine the fitness of MT systems (e.g., will the system do what is required, how well and at what cost) within a specified operational context. Adequacy evaluation is typically performed by funding agencies and by technology users.
- *Diagnostic Evaluation* is to identify limitations, errors and deficiencies, which may be corrected or improved by the researcher or by the developers. Diagnostic evaluation is the concern mainly of researchers and developers.
- *Performance Evaluation* to assess stages of system development or different technical implementations. Performance evaluation may be undertaken by either researchers or developers.

MT evaluations typically include features not present in evaluations of other NLP systems including:

- Quality of the *raw* translations.
- Usability of facilities for creating and updating dictionaries.
- Extendibility to new language pairs and/or new subject domains.
- Cost-benefit comparisons with human translation performance.

Quality of the raw translations: It is extremely difficult to determine what counts as a *good* translation whether produced by human or machine. “The relative adequacy of

different translations of the same text can only be determined in terms of the extent to which each translation successfully fulfills the purpose for which it was intended” [quoting Nida 1976]. Therefore, intelligibility (or clarity) and fidelity (or accuracy) are the most common criteria in determining a quality of the raw translation [Hutchins and Somers 1992], [Arnold et al. 1994]. However, they remain subjective judgments.

- *Intelligibility* determines whether the translation consists of the correct words in the target language and whether the evaluators can understand the translation with ease. Intelligibility, therefore, can be measured by considering whether the translation is affected by grammatical errors, mistranslations and untranslated words. A common measurement is to assign scores to the translation. ALPAC’s intelligibility scale is a nine-point scale [ALPAC, 1966]. The ALPAC scoring scale ranges from 1, *hopelessly unintelligible*, to 9, *perfectly intelligible*. Another intelligibility scale is proposed by Nagao, Tsujii and Nakamura; this scoring scale ranges from 1, *the meaning of the translation is clear and needs no rewriting*, to 5, *the translation cannot be understood at all* [Nagao et al. 1988]. Generally, only individual sentences are evaluated. However, by isolating sentences from their contexts, such measurements are made even more subjective and uncertain than they might be [Hutchins and Somers 1992].
- *Fidelity* determines whether the translation preserves the meaning of the source language or whether the translation contains the same information as the original. Various tests have been proposed and implemented to provide measurements of fidelity. For example, the evaluators read the translation and judge how much more *informative* was the original. However, this procedure can be criticized as being excessively subjective. Another practical measurement which is feasible for measuring accuracy of translated instruction manuals is to determine whether the person who uses the translated manuals can carry out the instructions as well as the person using the original manual. An alternative measurement is to translate the translation output (generated by MT) back into the original language and then compare the result with the original text. Note that shortcomings are generally magnified by this double translation process. Also note that a translation which is faithful to the original may be difficult to understand while a translation which is easy to read may have distorted the original message [Hutchins and Somers 1992].

Usability of facilities for creating and updating dictionaries: The practical MT system should provide facilities for users to expand and update the dictionaries. Changes in dictionary information may result in improvements. The basic questions to determine the degree of usability are whether the system allows the users to make changes to dictionaries, whether the users can update the dictionaries with ease, and whether there is a limitation on the size of the dictionaries.

Extendibility to new language pairs and/or new subject domains: MT systems designed for one particular subject area are inherently more difficult to extend to other areas, not only because of differences in vocabulary but also because of differences of grammar. The basic question to determine the degree of expansion is whether components developed for one language pair can be applied or easily adapted for another language pair. The extendibility of the system depends highly on the modularity of its components [Hutchins and Somers 1992].

Cost-benefit comparisons with human translation performance: Cost estimates and benefits of the system must be taken into account. Costing of MT systems include the basic cost of software, the cost of installation, upgrading and maintenance, and the cost of pre-editing and post-editing (if any). A comparison will be made with the costs of producing the same quality of output by human translators. Benefits trade-off against costs. Possible benefits include faster production of translations, faster translation of large volumes of text, and simultaneous translation in many languages. Furthermore, the costs of maintaining dictionaries may well diminish with time since the dictionary contains large numbers of lexical entries [Hutchins and Somers 1992].

8.2 MT Evaluation Strategies

Some specialized evaluation strategies have been proposed and implemented. For example, scoring scales for measuring quality of the *raw* translations (see section 8.1), and error analysis, and the test suite. The error analysis and test suite are briefly discussed in this section. Further discussion on MT evaluation can be found in [Lehrberger and Bourbeau 1988], [King 1990], [King and Falkedal 1990], [Hutchins and Somers 1992] and [Arnold et al. 1994].

8.2.1 Error Analysis

Error analysis strategies focus on the errors the MT system makes. Error counting indicates the amount of work required to correct *raw* MT output to a standard considered acceptable as a translation [Hutchins and Somers 1992]. During the evaluation, all the errors that occurred in the translation are counted, for example, counting each addition or deletion of a word, or each substitution of one word by another. Different kinds of errors require different correction efforts. Therefore, the errors are classified by relatively difficulty of correction and assigned a *weighting factor*. For example, the weight factor for incorrect *preposition* selection in one system is 0.6 while the weight factor for incorrect number agreement (e.g., a computers) is 0.2 (this example is taken from [Arnold 1994]). Then the quality of a translation is determined by calculating the total error score. The total error score for each individual sentence or for the whole text is the sum of all the weighted errors.

Although the error analysis strategy provides more direct information on the quality of the translation, there are problems: differences in what is considered to be an error, different levels of acceptability, and difficulties in classifying errors. The more serious problem is that error types are not independent of each other and it is then difficult to count errors accurately e.g., failure to supply any number inflection for a main verb will often mean that the subject and verb do not agree in number as required [Arnold et al. 1994]. Should this failure be counted as one error or two errors?

8.2.2 Test Suite

A test suite is a useful evaluation tool for NLP participants especially for developers. A test suite is a systematic collection of specially constructed linguistic expressions (e.g., sentences), perhaps with associated annotations and descriptions [Fouvry and Balkan 1996]. Figure 8.1 illustrates a fragment of English test suites (this example is taken from [Arnold, et al. 1994]). This fragment lists combinations of modal verbs (e.g., can, may) with negative *not*.

The test suite may include ill-formed sentences (grammatically unacceptable sentences e.g., John not run) which the parser component of the MT system should recognize as incorrect.

The test suite can be constructed as follows [Estival et al. 1994], [Balkan, Arnold and Fouvry 1995]:

- by collecting the data (test items) from specific text types, actual texts or knowledge bases. This kind of test suite may be limited to specific problems and a specific vocabulary .
- by collecting from a list of linguistic phenomena which is abstracted from any particular application. This type of test suite is referred to as an artificial test suite. In this test suite, the range of test items and the vocabulary used is unbiased by any particular text type, corpus or knowledge base.

John runs.	
John will run.	modal auxiliaries
John can run.	
John may run.	
John should run.	
John does not run.	negation (with do-support)
John not run.*	
John will not run.	negation and modal auxiliaries
John may not run.	

Figure 8.1: A fraction of test suites [Arnold et al. 1994]

Test suites present language phenomena in an exhaustive and systematic way starting with the simplest and increasing in complexity. Furthermore, combinations of phenomena can be generated in a controlled fashion as shown in Figure 8.1.

Test suites can be used for *diagnostic evaluation* or *adequacy evaluation* depending on their design [Estival et al. 1994]. With test suites, system developers can determine how their system will perform on a range of controlled examples. A number of test suites have been developed for evaluating MT systems [Estival et al. 1994]. For example:

- The English Eurotra “ET-UK” test suite was developed at Eurotra Essex in 1991. It consists of 955 English test sentences for evaluating the Eurotra translation system. This test suite was designed to test only a restricted number of common syntactic phenomena.
- The English-French and French-English Aerospatiale “AS-NL” test suites were constructed in 1991 to evaluate the commercial MT systems. These test suites contain 1440 English test items, and 346 French test items.

- The French-German SYSTRAN test suite was developed at Stuttgart in 1991 for evaluating the SYSTRAN French-German translation system. This test suite contains 853 French test items.
- The IAI test suite was developed at IAI Saarbrücken in 1993. This test suite was developed for evaluating the LOGOS, German to English and French translation system. The IAI test suite contains 2481 German test items.

The AS-NL, SYSTRAN and IAI test suites were designed for both diagnostic and adequacy evaluations whereas the ET-UK test suite was designed for diagnostic and progress evaluations¹. According to the Report to LRE 62-089 (D-WP1)² [Estival et al. 1994], none of these test suites is claimed to be complete. None of these test suites actually tests the full inflectional morphology of a language systematically and none of them includes testing at a semantic level. The data of the AS-NL and ET-UK test suites are partly derived from sentences occurring in a specific corpus while the data of SYSTRAN and IAI test suites are artificially constructed. Information about the actual use of these test suites is not fully provided.

Methodology and tools are provided by Test Suites for Natural Language Processing (TSNLP) for constructing test suites [Fouvry and Balkan 1996]. The test data constructed by this method are general purpose. They are not specific to a particular domain or text type and they focus on syntactic phenomena. These test data have been validated in a testing phase where a parser, a grammar checker and a controlled language checker have been tested. However, apparently there have not yet been tested on MT systems. Therefore, the problem lies in defining an appropriate test suite for evaluating MT systems.

8.2.3 The ARPA MT Evaluation

The *Advanced Research Projects Agency* (ARPA) conducted the evaluation of three research MT systems (Candide: IBM Thomas Watson Research Laboratory, Pangloss: Carnegie Mellon University and Lingstat: Dragon Systems), six commercial MT systems

¹ The progress evaluation compares successive stages of development of a system over a period of time [Fouvry and Balkan 1996].

² The Report to LRE 62-089 (D-WP1) presents the characteristics of the existing nine test suites. Four test suites were designed for evaluating MT systems (as listed above) whereas another five test suites were designed for other applications of NLP. This report was written by TSNLP [Estival et al. 1994].

(Metal: Sietec, Pivot: NEC, Power Translator: Globalink, SPANAM: Pan American Health Organization, SYSTRAN: SYSTRAN, XLT: SOCATRA) and three human translations [White 1994]. To produce the human translation for this evaluation, the expert translators were prohibited from adding extra value to the text. For example, there are no parenthetical explanations of geographical locations or social customs. The ARPA MT Evaluation methodology consisted of a collection of human judgments on the quality of MT and statistical analyses of those judgments. Each translation was evaluated for adequacy, fluency and informativeness. However, the purposes of each evaluation in ARPA are different from those defined in section 8.1. In the ARPA MT evaluation:

- Adequacy determines to what extent the meaning conveyed in an expert human translation is presented in the translation under evaluation. The measurement is that the evaluators compare the translation under evaluation with human translation of the same passage and assign a score to the translation. The scoring scale ranges from 1, *None of the meaning expressed in human translation is expressed in the MT translation*, to 5, *All meaning expressed in human translation is expressed in the MT translation*.
- Fluency determines the intuitive reactions of evaluators to the well-formedness and fluency in context of the translation under evaluation. The measurement is that the evaluators assign a score of 1 to 5, where 1 represents *very poor* and 5 represents *excellent*, to the translations.
- Informativeness determines whether a translation under evaluation provides specific information which the evaluators need. Evaluators must answer a test of six questions that determine an informativeness measurement. These questions are based on the information available in the original text.

8.3 GRMT Evaluation

GRMT is in the research and development stage which includes design and development of an advanced prototype system, including compiling dictionaries and grammars. Evaluation is then restricted to the testing of processes without consideration of potential environments. We are unable to make detailed statistical comparison between GRMT and other MT systems. A proper and reliable statistical comparison requires very large dictionaries and corpora, the development of which is part of our future research. In addition, comparison to

other systems permit only a *black box*³ approach to evaluation; we do not generally have access to their internal structures or algorithms. In contrast we want to discuss the various characteristics which we found in GRMT. The evaluation presented here, therefore, was conducted to answer the following questions⁴:

- whether the programs written for the system perform in the ways intended.
- whether the output is acceptable as a translation.
- whether the expansions of dictionaries affect translation performance.
- whether the extendibility to new language pairs is difficult.

To determine whether the programs written for the system perform in the ways intended, we used a *diagnostic trace*. The diagnostic trace is a record of the stages through which a program goes to produce output. A sentence is submitted to the system for processing and the results of each stage are displayed (on screen or in print) to enable us to examine the actual operations taking place. On this basis we can discover whether the program is doing what is intended and if it is not, identify where the mistakes are occurring. We tested each component of the system (ALMT, TCE and RI) separately and together as a complete system (GRMT).

To determine whether the output is acceptable as a translation, the test is performed by running a number of sentences against the system and testing the adequacy of the dictionary information and the grammar. The outputs are then compared to two human translations. One translator is a Thai linguist (HM1) and the other translator is a Thai student (HM2) in graduate school. This evaluation concerns both *intelligibility* and *fidelity*. The evaluator render judgments by answering to the following questions:

- Is the translation is grammatically correct according to Thai grammar?
- Does the translation consist of the correct words in Thai?
- Does the translation convey the meaning presented in the human translation?

³ In the black box evaluation, the evaluators have only input/output(s) pairs to work with while it is assumed that the evaluator has access to all the inner working of the system and can inspect intermediate results in the glass box evaluation [King 1990].

⁴ These questions need to be asked and answered for all MT systems; we answer here for GRMT alone.

The outputs are also evaluated in terms of *comprehensibility*. In this evaluation, the evaluators are a linguist, a grade 7 student and a grade 4 student⁵. All evaluators are native Thai speakers. The measurement is conducted by reading the translation to the evaluators without providing the source text. The evaluator then determines:

- whether the translation can be understood: if the translation cannot be understood what is the cause of the misunderstanding, e.g., inappropriate word usage, inappropriate word order, or missing word.
- whether it is colloquial Thai.

ALMT was tested to generate translation candidates for 76 sentences from the bedtime story, *The ugly duckling*, version written by Ronne Randall (1987) based on the original story by H. C. Anderson), and 14 sentences from other sources including, newspapers and articles. The outputs of ALMT (translation candidates) are compared to the two human translations to determine their *intelligibility* and *fidelity*. The words used in the TCs of the 23th and 27th sentences (Figure 8.2) are correct. The 23th and 27th TCs are licensed by the Thai grammar and convey the same meaning as presented in the human translations. The 26th sentence carries no meaning since the word *where* is incorrectly translated, ที่ไหน (thīina-j- where), and it results in a grammatically incorrect TC. In the 37th sentence, หนึ่ง (ny`n- one) is wrongly placed and the translation of the word *to*, ้ (kàb- to), is incorrect. The misplaced word and incorrect translation render the TC grammatically incorrect. A complete evaluation of all 90 sentences is illustrated in Appendix G. According to the evaluation results shown in Table 8.1: 23 sentences require word re-selection, 15 sentences require word re-arrangement and 47 sentences require no repair. The number of incorrectly translated words in each sentence ranges between 1-3 words. The number of misplaced words which results in a grammatically incorrect translation ranges between 1-3 words.

Figure 8.3 illustrates a fragment of the *comprehensible* evaluation. A complete evaluation is provided in Appendix H. 57 sentences, Table 8.2, are comprehensible (e.g., sentence 14, Figure 8.3), however, two of them do not convey the intended meaning (e.g., sentence 51, Figure 8.3). The reason the translation does not convey the intended meaning

⁵ The grade 7 and grade 4 students were selected as evaluators because the main part of the source text is a children's bedtime story.

23. SL: The ugly duckling hid in a corner of the farmyard and cried.
 TC: ลูกเป็ด (duckling) ที่ (which) ชีเหฺร (ugly) ตัว (classifier) นั้น (the) ได้ซ่อน (hid) ใน (in) มุม (corner) มุม (classifier) หนึ่ง (a) ของ (of) ลานคืดโรงนา (farmyard) แห่ง (classifier) นั้น (the) และ (and) ไดร้องไห้ (cried)
 HM1: ลูกเป็ด (duckling) ชีเหฺร (ugly) แอม (hide) อยู่ (combine clauses) มุม (corner) หนึ่ง (a) ใน (of) ฟาร์ม (farmyard) และ (and) ร้องไห้ (cry)
 HM2: ลูกเป็ด (duckling) ที่ (which) นาเกลียด (ugly) เลยซ่อนตัว (hid) ที่ (combine clauses) มุม (corner) หนึ่ง (a) ของ (of) ฟาร์ม (farmyard) แลว (then) ร้องไห้ (cry)
 No repair required
26. SL: He left the farmyard and ran to the great marsh, where the wild ducks lived.
 TC: เขา (he) ได้จาก (left) ลานคืดโรงนา (farmyard) แห่ง (classifier) นั้น (the) และ (and) ได้วิ่ง (ran) ไปที่ (to) หนองน้ำ (marsh) ใหญ่มาก (great) หนอง (classifier) นั้น (the) ที่ไหน (where) เป็ด (duck) ป่า (wild) หลาย (plurality) ตัว (classifier) นั้น (the) ได้อาศัยอยู่ (lived)
 HM1: มัน (it) ออกไปจาก (leave) ฟาร์ม (farmyard) และ (and) ตรงไปยัง (ran to) บึง (marsh) ใหญ่ (great) แห่ง (a) ที่ (where) มี (there are) เป็ด (duck) ป่า (wild) อาศัยอยู่ (lived)
 HM2: มัน (it) ออกจาก (leave) ฟาร์ม (farmyard) แลว (then) วิ่ง (run) ไปที่ (to) หนอง (marsh) ใหญ่ (great) ที่ (where) เป็ด (duck) ป่า (wild) อาศัยอยู่ (live)
 I incorrectly translated word.
27. SL: "Perhaps they will be kind to me," he said sadly.
 TC: "บางที (perhaps) พวกเขา (they) จะ (will) ใจดี (kind) กับ (to) ฉัน (me)," เขา (he) ได้พูด (said) อย่างเศร้าสร้อย (sadly)
 HM1: "บางที (perhaps) พวกมัน (that group) อาจจะ (may) ดี (kind) กับ (to) ฉัน (me) ก็ได้อ (??)," มัน (it) พูด (said) กับ (to) ตัวเอง (itself) อย่างเศร้าสร้อย (sadly)
 HM2: "บางที (perhaps) พวกเขา (they) อาจจะ (may) ดี (kind) กับ (to) เรา (me) ก็ได้อ (??)," มัน (it) พูด (said) ด้วยความเศร้าสร้อย (sadly)
 No repair required.
37. SL: One evening, he came to a little cottage.
 TC: หนึ่ง (one) เย็น (evening), เขา (he) ได้มา (came) กับ (to) กระหม่อม (cottage) เล็ก (little) หลัง (classifier) หนึ่ง (a)
 HM1: เย็น (evening) วั่น (classifier) หนึ่ง (one) ลูกเป็ด (duckling) ชีเหฺร (ugly) เดิน (walk) มา (come) ถึง (to) กระหม่อม (cottage) เล็กๆ (little) หลัง (little) หนึ่ง (little)
 HM2: เย็น (evening) วั่น (classifier) หนึ่ง (one) มัน (it) มา (come) ถึง (to) กระหม่อม (cottage) เล็ก (little) หลัง (classifier) หนึ่ง (a)
 I misplaced words, I incorrectly translated word.

Figure 8.2: Examples of intelligibility and fidelity evaluation

Table 8.1: The intelligibility and fidelity evaluation result of evaluating ALMT on the 90 sentences test corpus

Measurement	Number of Sentences
grammatically correct, correct word usage and convey the original meaning- require no repair	47
required repair	43
grammatically correct, correct word usage but convey different meaning from the original sentence	2
1 inappropriate word usage	4
1 incorrectly translated word	15
2 incorrectly translated words	7
3 incorrectly translated words	1
1 misplaced word	8
2 misplaced words	4
3 misplaced words	1
grammatically incorrect	9

is that some words are incorrectly translated. 33 sentences are incomprehensible. According to the evaluation results (Table 8.2), the reasons the translations are not comprehensible are:

- Some words are missing. These words need to be added to make the sentence complete and correct in terms of meaning and grammar e.g., sentence 6 (Figure 8.3).
- Some words are incorrectly translated. These words may cause grammatical incorrectness which results in a meaningless sentence e.g., sentence 57 (Figure 8.3).
- Some words are misplaced. The word is wrongly placed and it causes the sentence to be meaningless e.g., sentence 30 (Appendix H).

Table 8.2: The comprehensible evaluation result

Measurement	Number of Sentences
comprehensible	56
incomprehensible	34
not colloquial Thai	9
does not convey the intend meaning	2

6. SL: The biggest egg hatched last of all
 TC: ไข่ (egg) ^๑ ที่ (which) ใหญ่ที่สุด (biggest) ได้ฟัก (hatched) ^๑ สุดท้าย (last) ของ (of) ทั้งหมด (all)
 HM3: incomprehensible, 1 additional word required.
 HM4: incomprehensible, 2 additional words required.
 HM5: incomprehensible, 2 additional words required.
 incomprehensible.
14. SL: But when they saw the big gray duckling, they began to laugh.
 TC: แต่ (but) เมื่อ (when) พวกเขา (they) ได้เห็น (saw) ลูกเป็ด (the) สีเทา (gray) โต (big) ตัว (classifier) นั้น (the). พวกเขา (they) ได้เริ่ม (began) ที่จะ (to) หัวเราะ (laugh)
 HM3: comprehensible.
 HM4: comprehensible, 1 additional word required.
 HM5: comprehensible.
 comprehensible.
51. SL: He grew more and more sad and more and more tired
 TC: เขา (he) ได้ ^๑ สูงขึ้น (grew) ^๑ อึก (more) และ (and) เศร้า (sad) มากขึ้น (more) และ (and) เหนื่อย (tired) มากขึ้น (more)
 HM3: comprehensible, does not convey the intended meaning, not colloquial Thai.
 HM4: comprehensible, does not convey the intended meaning, not colloquial Thai.
 HM5: comprehensible, does not convey the intended meaning.
 comprehensible, does not convey the intended meaning, not colloquial Thai.
57. SL: The ugly duckling watched them from his hiding place in the reeds.
 TC: ลูกเป็ด (duckling) ที่ (which) ชั่วเหว (ugly) ตัว (classifier) นั้น (the) ได้เฝ้าดู (watched) พวกเขา (them) จาก (from) สถานที่ (place) การซ่อน (hiding) ของเขา (his) ใน (in) ตกก (reed) หลาย (plurality) ต้น (classifier) นั้น (the)
 HM3: incomprehensible, 1 meaningless word.
 HM4: incomprehensible, 1 meaningless word.
 HM5: comprehensible
 incomprehensible.

Figure 8.3: Examples of comprehensibility evaluation

6. SL: The biggest egg hatched last of all
 TC: ไข่ (egg) ที่ (which) ใหญ่ที่สุด (biggest) ได้ฟัก (hatched) สุดท้าย (last) ของ (of) ทั้งหมด (all)
 Expected TC: ไข่ (egg) ที่ (which) ใหญ่ที่สุด (biggest) ได้ฟัก (hatched) เป็น (to be) ไข่ (classifier) สุดท้าย (last) ของ (of) ทั้งหมด (all)
10. SL: You are the ugliest duckling I have ever seen
 TC: คุณ (you) เป็น (are) ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ที่สุด (ugliest) ฉัน (I) เคย (have_ever) เห็น (seen)
 Expected TC: คุณ (you) เป็น (are) ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ที่สุด (ugliest) ี่ (that) ฉัน (I) เคย (have_ever) เห็น (seen)
21. SL: The geese and the turkeys ran after the duckling and tried to chase him away.
 TC: พวกมัน (geese) นั้น (the) และ (and) ไก่จวน (turkey) หลาย (plurality) ตัว (classifier) นั้น (the) ได้ไล่ตาม (tried) ลูกเป็ด (duckling) ตัว (classifier) นั้น (the) และ (and) ได้พยายาม (tried) ที่จะ (to) ไล่ (chase) เขา (him) หนี (away)
 Expected TC: พวกมัน (geese) นั้น (the) และ (and) ไก่จวน (turkey) หลาย (plurality) ตัว (classifier) นั้น (the) ได้ไล่ตาม (tried) ลูกเป็ด (duckling) ตัว (classifier) นั้น (the) และ (and) ได้พยายาม (tried) ที่จะ (to) ไล่ (chase) เขา (him) หนี (to cause to do something) หนี (away)
22. SL: Even his own brothers and sisters joined in and called him names.
 TC: แม้แต่ (even) พี่น้องชาย (brother) หลาย (plurality) คน (classifier) ของเขา (his) เอง (own) และ (and) พี่สาวน้องสาว (sister) หลาย (plurality) คน (classifier) เขาร่วม (joined_in) และ (and) ตั้งฉายาเขาต่างๆ (called_him_names)
 Expected TC: แม้แต่ (even) พี่น้องชาย (brother) หลาย (plurality) คน (classifier) ของเขา (his) เอง (own) และ (and) พี่สาวน้องสาว (sister) หลาย (plurality) คน (classifier) ี่ (also, too) เขาร่วม (joined_in) และ (and) ตั้งฉายาเขาต่างๆ (called_him_names)

Figure 8.4: Example sentences 6, 10, 21 and 22

Of the 43 sentences which required repair (Table 8.1), 14 sentences are comprehensible and convey the meaning of the original sentences.

We are interested in evaluating the outputs of GRMT (translations) in an analogous way to the ALMT evaluation just discussed. Of the 43 sentences which required repair, 15 sentences are repairable using the current our HPSG based grammars and lexicons. 7 sentences cannot be repaired by the current RI. They are grammatically incorrect although they contain correctly translated words. To complete the TC, according to the Thai grammar, some words (e.g., classifier or linking word) need to be added while some words (e.g., plurality or classifier) need to be removed. In sentences 10, 21, 22, 58 and 81 (Appendix H), the linking word ที่ (thīi- that, which, who), ก็ (kǎ-also, too) and ให้ (hàj- to cause to do something)⁶ are required as shown in Figure 8.4. Sentence 6 requires เป็น (pen- to be) while the words หลาย (laʼaj- plurality) and ตัว (tua-classifier) in sentence 55 need to be removed. The linking word in Thai can be classified into at least 17 categories [Punmetha 1984] e.g., ที่ (thīi- that, which, who) is a linking word used to add an instrumental relationship as in “He lives in the house which is big”. ก็ (kǎ-also, too) and ทั้ง (thán- and also, together with) are linking words using to combine two sentences which are in agreement as in “If you go then I will also go”. ให้ (hàj- to cause to do something) is a linking word to indicate the purpose of the preceding action, as in “He give the book to me to make me happy”. There is no explicit rule saying when and which linking word is required.

As we discussed in section 4.1, there is no plural form for nouns in Thai. A quantity of nouns can be expressed either by quantifiers or numbers and *classifiers* are required. However, adding the plurality หลาย (laʼaj) and ตัว classifier (tua) to the translation of the word *bird* in sentence 55 (Figure 8.5) is redundant and grammatically incorrect since *flock* indicates that there is more than one bird. It is unlike English in which *flock* requires a plural noun form.

<p>a flock of beautiful birds</p> <p>นก (bird) ที่ (which) สวย (beautiful) ของ (of) ฝูง (flock) ตัว (classifier) นิ่ง (a) หลาย (plurality)</p>
--

Figure 8.5: A fragment of sentence 55.

⁶ The conjunction ที่ (thīi- that, which, who), ก็ (kǎ-also, too) and ให้ (hàj- to cause to do something) often are not translated in English.

We will be expanding the *word addition* (section 5.3.1) rule to cover additional linking words and to add a plurality indicator and classifier (only when necessary) as part of future research.

The remaining 21 sentences of the 90 sentence test corpus require further nontrivial development of the HPSG formalism to account for their semantic representation, for example, sentences containing the logical connections *and*, *or*, *but*, *nor* or the negation *not*. Due to this limitation, the sentences which contain logical connections are separated into linguistic units as illustrated in Figure 8.6 (each unit is underlined). In sentence 26, the word *he* (circled) was added to complete the structure of the second unit. Each linguistic unit is then repaired separately so that we can determine whether the TCE and RI phases improve the quality of the TC. Some example sentences are illustrated in Figure 8.6; the repaired TCs are grammatically correct and convey the meaning of the original sentences.

We will be expanding the lexicon and the language coverage of our HPSG parsers as part of future research and expect that outcomes of that effort to contribute to both the novel MMT paradigm GRMT espouses and to HPSG theory, e.g., the semantics of coordination.

In the first version of ALMT, we developed dictionaries containing 80 English words and 150 Thai words. The dictionaries were expanded to 348 English words and 731 Thai words in the second version of ALMT. There has been no appreciable increase in processing time when running ALMT using the larger dictionaries. This experiment lends positive evidence that a more advanced prototype will scale up reasonably.

Modification to the lexicons and grammars of the SL and TL analyzers will result in improvements. Expanding the lexicons or the coverage of language structure via HPSG formalism is relatively simple. The use of the HPSG formalism provide advantages in terms of comprehensive lexical entries. The lexicons are easy to manage. The use of ALE facilitates lexicon development and grammar writing.

Expansion in terms of adding new languages to the system is manageable since SLs and TLs are treated separately and they are related by using information provided in a SL-TL lexicon. The lexicon and grammar used in the analyzer of each language is developed separately.

26. SL: He left the farmyard and he ran to the great marsh where the wild ducks lived.
 Repaired TC: เขา (he) ได้จาก (left) ลานคตโรงนา (farmyard) แห่ง (classifier) นั้น (the) และ (and) ได้วิ่ง (ran) ไปที่ (to) หนองน้ำ (marsh) ใหญ่มาก (great) หนอง (classifier) นั้น (the) ที่ซึ่ง (where) เบ็ด (duck) ป่า (wild) หลาย (plurality) ตัว (classifier) นั้น (the) ได้อาศัยอยู่ (lived)
 HM1: มัน ออกจาก ฟาร์ม และ ตรงไปยัง บึง ใหญ่ แห่ง หนึ่ง ที่ มี เบ็ด ป่า อาศัยอยู่
 HM2: มัน ออกจาก ฟาร์ม แล้ว วิ่งไป ที่ ทุ่งเบี่ยงๆ ที่ เบ็ด ป่า อาศัยอยู่
 No repair required.
39. SL: An old woman lived in the cottage with a fat black cat and a plump brown hen.
 TC: ผู้หญิง (woman) แก่ (old) คน (classifier) หนึ่ง (an) ได้อาศัยอยู่ (lived) ใน (in) กระท่อม (cottage) หลัง (classifier) นั้น (the) ด้วย (with) แมว (cat) สีดำ (black) อ้วน (fat) ตัว (classifier) หนึ่ง (a) และ (and) ไก่ (hen) สีนํ้าตาล (brown) อวบ (plump) ตัว (classifier) หนึ่ง (a)
 HM1: มี หญิงชรา อาศัยอยู่ ใน กระท่อม นาง อยู่ กับ แมว ตัว อ้วน สีดำ และ แม่ ไก่ ตัว ใหญ่ สีนํ้าตาล
 HM2: หญิงชรา อาศัยอยู่ ใน กระท่อม กับ แมว สีดำ ตัว อ้วน และ ไก่ สีนํ้าตาล ตัว อวบ
 No repair required.
90. SL: The spirit is willing but the flesh is weak.
 Repaired TC: จิตวิญญาณ (spirit) นั้น (the) พร้อม (willing) แต่ (but) ร่างกาย (flesh) นั้น (the) อ่อนแอ (weak)
 HM1: จิตวิญญาณ นั้น กล้าแกร่ง หาก กาย กลับ อ่อนล้า
 HM2: จิตวิญญาณ นั้น พร้อม หาก ร่างกาย กลับ อ่อนล้า
 No repair required.

Figure 8.6: Example sentences 26, 39 and 90

Chapter 9

Discussion

9.1 Contributions

The central theme of this thesis is to find new solutions that apply when developing an efficient MT and our solution is *Generate and Repair Machine Translation*. GRMT is a novel multi-phase architecture for an accurate machine translation system. The main concept of GRMT was introduced in chapter 3. The architecture of GRMT was designed to take advantage of, and have advantages over, the Direct, Transfer, Interlingual, Non-linguistic and the existing hybrid approaches to MT as illustrated in Table 9.1. GRMT consists of three major components Analysis Lite MT, Translation Candidate Evaluation and Repair and Iteration. ALMT generates the translation candidate, TCE verifies an accuracy of the TC and RI repairs the TC when required.

The main features of ALMT are the use of constraints and the use of the semantic relationship between words. ALMT applies the different sets of constraints to deal with the syntax of the SL and that of the TL in separate modules. ALMT refines the scope of translation choices of each input word by applying the SL constraints. SL constraints apply to the syntax of the SL which is different from that of the TL. The selected translation words are put into grammatical order by applying the TL constraints. TL constraints apply the syntax of the TL which is different from that of the SL. The set of constraints can be applied to languages which share common significant features.

The semantic relationship between words has been developed in the form of the WordAssociation relation. The WordAsso relation is a link between WordAsso numbers. The WordAsso number represents a relation between a word and its class. We classified words according to their meanings and their usages regardless of language which makes it possible to

Table 9.1: Advantages and disadvantages of the existing MT approaches

Category	Approach	Advantages	Disadvantages
Three Classic Strategies	Direct MT	Simple approach.	Limited accuracy
	Interlingual MT	Treat SL and TL separately.	Difficulties in developing interlingual system.
	Transfer MT	Less complexity in analysis and generation.	<ul style="list-style-type: none"> Information lost during the transfer process. Language dependent.
Nonlinguistic Information Strategies	Example-Based MT	Translations come with scores which might be useful to a post editor.	Relies heavily on the availability of a large and diverse quality corpus which are not available for most languages.
Hybrid Strategies	Statistics-Based MT	Apply statistical techniques in translation process.	
	Knowledge-Based MT	Interpreting the SL by reference to world knowledge.	<ul style="list-style-type: none"> Reasoning is complex. More suitable for paraphrase than for translation
	Shake-and-Bake MT	SL and TL are associated via bilingual lexicon without a transfer module or interlingual.	Lack efficiency due to the generation process which tries all possibilities.

to apply these to a multilingual MT system. This word classification plays a crucial role throughout the GRMT translation process.

The use of the WordAsso relation together with the designed (word selection) algorithm allows ALMT to select an appropriate translation for each input word efficiently. The WordAsso relation indicates a relationship between words (e.g., which word can occur with which word in the same expression) including the relationship between nouns and their classifiers. The use of classifiers in Asian languages e.g., Chinese, Japanese and Thai is similar, therefore, with some modifications it is possible to apply our classifier selection to those Asian languages.

GRMT ensures an accuracy of the translation by the TCE and RI phases. TCE analyzes the TC to verify its syntax and semantics. The semantics of the TC is extracted and compared to that of the SL to determine whether the TC conveys the meaning of the SL.

The SL and TL grammars should be developed based on grammar theory which is an integrated theory of natural language syntax and semantics, e.g., the Head-Driven Phrase Structure Grammar. We include the WordAsso number in the semantic representation since the WordAsso number represents the word meaning and the word's usage. Differences in languages and cultures result in different circumstances of language usage; therefore, the word and its translation are considered acceptably similar in principal features if they belong to the same superclass as illustrated in chapter 6. If TCE detects any dissimilarity between the meaning of the TC and that of the SL, TCE will then provide that (dissimilarity) information to RI.

RI improves the quality of the TC by replacing the mis-translated part with a more appropriate translation according to the information TCE provides.

Each step performed by GRMT is straightforward and simple to implement. GRMT is highly modular and extendible in the following respects. Each component, ALMT, TCE and RI are developed separately. Each module comprises of sub-modules for easy modification and maintainance. The SL and TL are treated separately and related via the SL-TL dictionary. The SL-TL dictionary contains simple information, a SL word form and its possible translations, with the WordAsso number, and nothing else. Other knowledge-bases e.g., the dictionary, constraints, lexicons, and grammars are developed separately, independent of languages. This would seem to be the optimal distribution of information, both from the point of building a larger, possibly multilingual MT system, and for maintaining and extending it. A further note is that GRMT translation process is not limited to a single direction translation. With a few modifications of the SL-TL dictionary, GRMT is reversible.

I hope to have demonstrated the idea of GRMT by constructing the English-Thai MT system. The English-Thai MT system translates isolated sentences (sentence by sentence). This English-Thai translation system has been developed and run under SWI-Prolog 3.2.8. The English and Thai grammars have been developed based on the Head-Driven Phrase Structure Grammar formalism [Pollard and Sag 1987; Pollard and Sag 1994] and implemented on the Attribute Logic Engine (ALE) [Carpenter and Penn 1994].

This English-Thai MT system was evaluated and it performs in the way we intended. ALMT generated acceptable translations (grammatically correct, correct word usage and convey the original meaning) for 47 out of the 90 sentence test corpus without repair. TCE and RI improved 15 sentences using the current our HPSG based grammars and lexicons.

Twenty-one sentences which contain logical connections are first separated into linguistic units before the repair can be performed due to a current inadequacy in HPSG's semantic representation. However, each linguistic unit was then repaired successfully. Seven sentences faced with the problems of adding linking words and classifiers in Thai also require further refinements in order to repair such sentences.

9.2 Further Research

Several issues presented in this thesis require further research. The *word addition* module can be improved since it currently fails to account properly for some connecting words and some plurality indicators in Thai (see chapter 8). Further research is needed to determine when and which connecting word or plurality indicator is required. With the word classification provided, it is possible to select a proper linking word for each situation and to be able to identify when the plurality indicator is needed.

To develop the WordAsso relations in the future, the semantic concordance which was created at the Princeton Cognitive Science Laboratory can be used as sample set. A semantic concordance is a database combining a text and a lexicon so that words in the text are linked to the appropriate senses in the lexicon [Fellbaum 1998]. We also hope consider how statistical methods or machine learning techniques can be used to help assign the WordAsso numbers to words in an appropriate way.

The lexicon and grammar coverage is limited. When large dictionaries (SL-TL dictionary and SL dictionary) and lexicons are used, more efficient ways of indexing the entries are required. At the moment the dictionaries and the lexicons are held in Prolog's working memory, an approach that is unlikely to satisfy requirements for larger systems.

Additional research is also required to explore the semantic representation of some language structures, e.g., structures containing logical connections and negation. This additional research should be useful not only for GRMT but also for another natural language processing applications e.g., search engines and information retrieval.

I believe the results of this research will contribute to current attempts to develop accurate and reliable machine translation systems and to produce quality translations from one language to another. This accurate and reliable translation methodology should enhance the effectiveness of communication among people.

Nevertheless, I hope to have shown that pursuing further research in this direction is a worthwhile aim, and one likely to result in commercial machine translation systems in the not too distant future.

Bibliography

Abney, S. (1994) Parsing by Chunks, available at “<http://www.sfs.nphil.uni-tuebingen.de/~abney/>”, as of January, 2000.

ALPAC (1966) Language and Machines: Computers in Translation and Linguistics. A report by the Automatic Language Processing Advisory Committee, Division of Behavioral Sciences, National Academy of Sciences, National Research Council, Washington, D.C.

Arnolds, D. J., et al., (1994) *Machine Translation: An Introduction Guide*, NCC Blackwell, London.

Balkan, L., D. Arnold and F. Fouvry (1995) Test Suites for NLP, available at “<http://clwww.essex.ac.uk/group/projects/tsnlp/papers/tsnlp-csnlp95.ps.gz>” as of January, 2000.

Balkan, L., D. Arnold and S. Meijer (1994) Test Suites for Natural Language Processing, available at “<http://clwww.essex.ac.uk/group/projects/tsnlp/papers/tsnlp-groningen95.ps.gz>” as of January, 2000.

Bar-Hillel, J., (1964) Language and Information: Selected Essays on Their Theory and Application, Addison-Wesley Publishing Company.

Bell, R., (1996) Equivalence and Fidelity: Of What, to What and to Whom? Some Pseudo-Problems of Translation Theory *In* The Knowledges of the Translator: From Literary Interpretation to Machine Classification Edited by Malcolm Coulthard and Patricia Anne Odber de Baubeta. The Edwin Mellen Press, Ltd., United Kingdom.

Beven, J. L. (1992) Lexicalist Unification-Based Machine Translation, Ph.D. Thesis, University of Edinburgh.

- Bisbey, R. and M. Kay (1972) The MIND Translation System: A Study in Man-Machine Collaboration, The RAND Corporation, Santa Monica, California, March.
- Boitet, C. (1990) Towards Personal MT: General Design, Dialogue Structure, Potential Role of Speech *In* The Proceedings of The 13th International Conference on Computational Linguistics, COLING-90, Edited by Hans Karlgren, Helsinki, Vol. 3, p. 30-35.
- Brensnan, J., and Ronald M. Kaplan (1982) Introduction *In* Brensnan, ed.
- Brew, C. (1992) Letting The Cat Out of The Bag Generation for Shake-and-Bake MT *In* The proceedings of the fifteenth International Conference on Computational Linguistics, COLING-92, Nantes, France, August 23-28, p. 610-616.
- Brown, P., J. Cocke, S. A. Della Pietra, V. J. Della Pietra, F. Jelinek, J. D. Lafferty, R. L. Mercer and P. S. Roossin (1990) A Statistical Approach to Machine Translation *In* Computational Linguistics, 16(2), June, p. 79-85.
- Brown, P., J. Cocke, S. Della Pietra, V. Della Pietra, F. Jelinek, R. Mercer and P. Roossin (1988) A Statistical Approach to Language Translation *In* Proceedings of the 12th International Conference on Computational Linguistics, COLING BUDAPEST, Vol. I, John von Neumann Society for Computing Sciences, Busapest.
- Brown, P.F., A.D.P. Stephen, J.D.P Vincent, J.D. Lafferty and R.L. Mercer (1992) Analysis, Statistical Transfer, and Synthesis in Machine Translation. *In* Proceedings of the Fourth International Conference on Theoretical and Methodological Issues in Machine Translation of Natural Languages, Montreal, p. 83-100.
- Carroll, L. (1992) Through the Looking Glass, *In* Alice's Adventures in Wonderland and Through the Looking Glass published by Alfred A. Knopf, Inc., New York.
- Carbonell, J. G., R. E. Cullingford and A. V. Gershman (1981) Steps Toward Knowledge-Based Machine Translation. *In* IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol. PAMI-3, NO. 4, July, p. 376- 392.
- Carbonell, J. G. and M. Tomita (1987) Knowledge-based Machine Translation, The CMU Approach *In* Machine Translation: Theoretical and Methodological Issues Edited by S. Nirenburg, Cambridge University Press, Cambridge.

- Carpenter, B. (1991) The Generative Power of Categorical Grammars and head-Driven Phrase Structure Grammars with Lexical Rules, *In Computational Linguistics*, Association for Computational Linguistics, 17(3), p. 301-313.
- Carpenter, B. (1992) The Logic of Typed Feature Structures, Cambridge University Press, USA.
- Carpenter, B. and G. Penn (1999). ALE: The Attribute Logic Engine User's Guide Version 3.2 Beta, available on line at "<http://www.sfs.nphil.unituebingen.de/~gpenn/ale.html#AleGrammars>", as of May.
- Carpenter, B. and G. Penn (1999) Compiling Typed Attribute-Value Logic Grammars.
- Center for the Study of Language and Information, (1999) Head-Driven Phrase Structure Grammar (homepage), <http://hpsg.stanford.edu/>, Stanford University, November.
- Cercone, N. (1975) Representing Natural Language in Extended Semantic Networks, Ph.D. Thesis, Department of Computer Science, The University of Alberta, Edmonton.
- Cercone, N., R. Goebel, J. D. Haan and S. Schaeffer (1992) The ECO Family *In Semantic Networks in Artificial Intelligence* Edited by F. Lehmann, Pergamon Press, Oxford, p. 95-131.
- CICC, (1995a) Chinese Concept Dictionary. Technical Report 6-CICC-MT58, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- CICC, (1995b) Indonesian Basic Dictionary. Technical Report 6-CICC-MT53, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- CICC, (1995c) Indonesian Concept Dictionary. Technical Report 6-CICC-MT65, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.

- CICC, (1995d) Indonesian Generation Rules. Technical Report 6-CICC-MT39, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- CICC, (1995e) Interlingual Final Edition. Technical Report 6-CICC-MT36, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- CICC, (1995f). Thai Analysis Rules. Technical Report 6-CICC-MT46, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- CICC, (1995g) Thai Basic Dictionary. Technical Report 6-CICC-MT55, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- CICC, (1995h) Thai Concept Classification. Technical Report 6-CICC-MT60, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- CICC, (1995i) Thai Generation Rules. Technical Report 6-CICC-MT50, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- CICC. (1995j) Thai Co-occurrence Dictionary. Technical Report 6-CICC-MT57, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- CICC, (1997). Technical Report on Interlingual and Concept Classification. Technical Report 6-CICC-MT31, Machine Translation System Laboratory, Center of the International Cooperation for Computerization, Tokyo.
- Cognitive Science Laboratory, Princeton University. (1998). WordNet-A Lexical Database for English. "<http://www.cogsci.princeton.edu/~wn/>", February.
- Collins, M. J. , (1996) A New Statistical Parser Based on Bigram Lexical Dependencies, *In* The Proceedings of The 34th Annual Meeting of The Association for Computational Linguistics, Santa Cruz, California, June, p. 184-191.

- Covington, M. A. (1994), *Natural Language Processing for Prolog Programmers*, Prentice Hall.
- Cranias, L., H. Papageorgiou and S. Piperidis, (1995), A Matching Technique in Example-Based Machine Translation *The Computation and Language E-Print Archive*.
- Crystal, D. (1987) *The Cambridge Encyclopedia of Language*, Cambridge University Press, Cambridge.
- Dagan, I. (1996) Bilingual Word alignment and Lexicon Construction, Tutorial *In* The 34th Annual Meeting of The Association for Computational Linguistics, Santa Cruz, California, June.
- Daudé, J., L. Padró and G. Rigau (1999) Mapping Multilingual Hierarchies Using Relaxation Labeling. CS.CL/9906025, "<http://xxx.lanl.gov/abs/cs/9906025>" as of December.
- Demos, K. and M. Frauenfelder (2000) Machine Translation's Past and Future *In* Wired Magazine, Archive 8.05 - May 2000, "<http://www.wired.com/wired/archive/8.05/>" as of May.
- Dorr, B. J. (1991), Parameterization of the Interlingua in Machine Translation, Computer Science Technical Report UMIACS-TR-91-119, CS-TR-2743, Institute for Advanced Computer Studies, University of Maryland, August.
- Estival, D. (1994) Reversible Grammars and Their Application in Machine Translation *In* Reversible Grammar in Natural Language Processing, Kluwer Academic Publishers, The Netherlands, p. 293- 320.
- Estival, D., A. Ballim, G. Russell and S. Warwick (1990) A Syntax and Semantics for Feature-Structure Transfer *In* The Proceedings of The Third International Conference on Theoretical and Methodological Issues in Machine Translation of Natural Language, Linguistics Research Center, University of Texas at Austin.
- Estival, D. et al., (1994) Analysis of Existing Test Suites, Report to LRE 62-089 (D-WP1), Test Suites for Natural Language Processing (TSNLP), University of Essex, January.

- Farwell, D. and Y. Wilks (1991) ULTRA: A Multilingual Translator *In* Proceedings of Machine Translation Summit III, Washington and Pittsburgh: Center for Machine Translation, Carnegie Mellon University, 19-24.
- Fellbaum, C. (1998) (Ed) WordNet: An Electronic Lexical Database, The MIT press, Cambridge.
- Fouvry, F., and L. Balkan (1996) Test Suites for Quality Evaluation of NLP Products, available at "<http://clwww.essex.ac.uk/group/projects/tsnlp/papers/index.html>" as of January, 2000.
- Franklin[®], (1998) Language Master LM-6000b, Franklin[®] Electronic Publishers, INC. Burlington, USA (Words from Merriam-Webster).
- Galloway, B. D., (1989) 3-D Semantics and the First Halkomelem Dictionary *In* The Proceedings of The 28th Conference on American Indian Languages, AAA Annual Meetings, 14-19, November, Washington, D. C., p. 45-58.
- Galloway, B. D., (1993) A Grammar of Upriver Halkomelem, University of California Press, Berkeley.
- Garvin, P. L. (1972) On Machine Translation Selected Papers, Mouton & Co. N. V. , Publishers, The Hague.
- Gazdar, G., E. Klein, G. K. Pullum and I. V. Sag (1985) Generalized Phrase Structure Grammar, Oxford: Basil Blackwell, Cambridge, Massachusetts, Harvard University Press.
- Gazdar, G., and C. Mellish (1989) Natural Language Processing in Prolog, Addison-Wesley Publishing Company.
- Ginzburg, J. and I. V. Sag, (1998) English Interrogative Constructures (Draft of July) *In* Construction : an HPSG Perspektive by I. A. Sag and A. Kathol, Language Advanced Course, 10th European Summer School in Logic, Language and Information, Saarbrücken, 17- 28 August.
- Goodman, K. and S. Nirenburg (eds.) (1991) The KBMT Project: A Case Study in Knowledge-Based Machine Translation. San Mateo, California, Morgan Kaufmann Publishers .

- Goshawke, W., I. D. K. Kelly and J. D. Wigg (1987) *Computer Translation of Natural Language*, SIGMA Press.
- Haas, M. R. (1964) Thai-English Student's Dictionary. Stanford University Press, Stanford, California.
- Haruno, M. and T. Yamazaki (1996) High-Performance Bilingual Text Alignment Using Statistical and Dictionary Information *In* The Proceedings of The 34th Annual Meeting of The Association for Computational Linguistics, Santa Cruz, California, June, p. 131-138.
- Henisz-Dostert, B., R. R. Macdonald and M. Zarechnak (1979) *Machine Translation*, Mouton Publishers.
- Hirschman, L. and H. S. Thompson (1996) Overview of Evaluation in Speech and Natural Language Processing *In* Survey of the State of the Art in Human Language Technology Edited by R. A. Cole et al., This document is available at <http://cslu.cse.ogi.edu/HLTsurvey/>, April, 2000.
- Hutchins, J (1997) Computer-based translation systems and tools, "<http://www.bcs.org.uk/sig-group/sg37.htm>" as of June.
- Hutchins, J (1996) Evaluation of Machine Translation and Translation Tools *In* Survey of the State of the Art in Human Language Technology Edited by R. A. Cole et al., This document is available at <http://cslu.cse.ogi.edu/HLTsurvey/>, April, 2000.
- Hutchins, W. J., (1986) *Machine Translation: Past, Present, Future*, Ellis Horwood Limited, Chichester, UK.
- Hutchins, W. J., (1988) *Recent Developments in Machine Translation : A Review of the Last Five Years* *In* New Directions in Machine Translation edited by Maxwell D., K. Schuber and T. Witkam, , Conference Proceedings, Budapest 18-19 August 1988, Foris Publications.
- Hutchins, W. J. (1989a) Methods of Linguistic Analysis in Machine Translation *In* Progress in Machine Translation: Natural Language and Personal Computer Edited by Ian D. K. Kelly, SIGMA Press, UK, p. 3-35.

- Hutchins, W. J. (1989b) Prospects In Machine Translation *In Machine Translation Summit* Edited by M. Nagao, et al., Ohmsha, Ltd., Tokyo.
- Hutchins, W. J. and H. L. Somers, (1992) *An Introduction to Machine Translation*, Academic Press Limited.
- Jones, D. (1996) Analogical Natural Language Processing. UCL Press Limited, London.
- Kay, M. (1989) Machines and People in Translation *In Machine Translation Summit* Edited by M. Nagao, et al., Ohmsha, Ltd., Tokyo.
- Kay, M., J. M. Gawron and P. Norvig (1994) Verbmobil: A Translation System for Face-to-Face Dialog, Lecture Notes No. 33, CSLI Publication, Stanford.
- King, M. (1990) A Workshop on Evaluation: Background Paper *In The Proceedings of The Third International Conference on Theoretical and Methodological Issues in Machine Translation of Natural Language*, Linguistics Research Center, University of Texas at Austin, 11-13 June.
- King, M. and K. Falkedal (1990) Using Test Suits in Evaluation of Machine Translation Systems *In The Proceedings of The 13th International Conference on Computational Linguistics, COLING-90*, Edited by Hans Karlgren, Helsinki, Vol. 2, p 211-216.
- Kittredge, R. and J. Lehrberger (1982) Sublanguage: Studies of Language in Restricted Semantic Domains. Walter de Gruyter & CO.
- Landsbergen, J. (1987a) Isomorphic grammars and their use in the ROSETTA Translation System *In Machine Translation Today: The state of the Art*. Edinburgh University Press, Edinburgh.
- Landsbergen, J. (1987b) Montague Grammar and Machine Translation *In Linguistic Theory and Computer Applications* Edited by P. Whitelock, M. M. Wood, H. L. Somers, R. Johnson and P. Bennett, Academic Press, London, p. 113- 147.
- Lehrberger, J. and L. Bourbeau (1988) Machine Translation: Linguistic Characteristics of MT Systems and General Methodology of Evaluation, John Benjamins Publishing Company, Amsterdam.

Levin, L (1990) Syntactic Theory and Grammar Design for Machine Translation *In* The Proceedings of The Third International Conference on Theoretical and Methodological Issues in Machine Translation of Natural Language, Linguistics Research Center, University of Texas at Austin, 11-13 June.

Locke, W. N. and A. D. Booth (1955) Machine Translation of Languages: Fourteen Essays, The Technology press of The Massachusetts Institute of Technology and John Wiley & Sons, Inc., New York.

Longman, (1992) Longman Dictionary of Contemporary English, Clays Ltd., St. Ives plc, English.

Marchuk, Y. N. (1989) Machine Translation in the USSR *In* Progress in Machine Translation: Natural Language and Personal Computer Edited by Ian D. K. Kelly, SIGMA Press, UK, p37-49.

Maruyama, H. and H. Watanabe (1990) An Interactive Japanese Parser for Machine Translation *In* The Proceedings of The 13th International Conference on Computational Linguistics, COLING-90, Edited by Hans Karlgren, Helsinki, Vol. 3 p 257-262.

Matheson, C. (1996) HPSG Grammars in ALE, available at <http://www.ltg.hcrc.ed.ac.uk/projects/ledtools/ale-hpsg/>, as of May.

Melamed, I. D. (1998) Empirical Methods for MT Lexicon Development *In* Machine Translation and the Information Soup, Edited by D. Farwell, L. Gerber and E. Hovy, The Proceedings of The Third Conference of the Association for Machine Translation in the Americas, AMTA'98, Langhorne, PA, USA, October 28-31, p. 18- 30.

Miller, G. A. (1998) Nouns in WordNet *In* WordNet: An Electronic Lexical Database Edited by C. Fellbaum, The MIT press, Cambridge, p. 23-46.

Mitamura, T. Nyberg, E.H.3rd and Carbonell J.G. (1991) An Efficient Interlingua Translation System for Multi-lingual Document Production. *In* Proceedings of Machine Translation Summit III, Washington D.C., July.

Muraki, K. (1989) PIVOT: Two-phase Machine Translation System. *In* Proceedings of the Second Machine Translation Summit, Tokyo, Omsha Ltd.

- Nagao, M. (1984) A Framework of a Mechanical Translation Between Japanese and English by Analogy Principle. *In* Artificial and Human Intelligence Edited by Alick Elithorn and Ranan Banerji, Elsevier Science Publishers, B.V.
- Nagao, M., J. Tsujii and J. Nakamura (1988) The Japanese Government Project for Machine Translation *In* Machine Translation System Edited by J. Slocum, Cambridge University Press, Cambridge, p. 141- 186.
- Naruedomkul, K. and N. Cercone (1997) Steps Toward Accurate Machine Translation. *In* Proceedings of the 7th International Conference on Theoretical and Methodological Issues in Machine Translation, Santa Fe, New Mexico, USA, p. 63-75.
- Naruedomkul, K., N. Cercone and B. Sirinaovakul (1999) English-Thai Translation: Initial Experiments with a Multiphase Translation system. *Computational Intelligence*, **15**(2):128-151.
- Newmark, P. (1981) Approaches to Translation, Pergamon Press, Oxford.
- Newmark, P. (1988) A Text Book of Translation, Prentice Hall, New York.
- Newton, J. (Edited) (1992) *Computers in Translation*, Routledge.
- Nida, E. (1976) A Framework for the Analysis and Evaluation of Theories of Translation *In* Translation: Application and Research, Edited by R. W. Brislin, Gardner Press, Inc., New York.
- Nirenburg, S., J. Carbonell, M. Tomita and K. Goodman (1992) Machine Translation: A Knowledge-Based Approach, Morgan Kaufmann Publishers.
- Nirenburg, S., V. Raskin and A. Tucker (1986) On Knowledge-Based Machine Translation *In* The Proceedings of 11th International Conference on Computational linguistics (COLING'86), Bonn, August, 627-638.
- Pan American Health Organization (1999) Machine Translation at the Pan American Health Organization SPANAM® and ENGSPAN®, <http://www.paho.org/english/ags/mt-home.htm>, December.

- Pendergraft, E. D. (1968) *Translating Languages In Automated Language Processing*, Edited by H. Borko, John Wiley and Sons, Inc. New York.
- Penn, G. (1993) *hpsg.pl* available at “<http://www.sfs.nphil.uni-tuebingen.de/~gpenn/ale.html#AleGrammars>” as of January 1996.
- Pollard, C. and Sag, I. A. (1987) *Information-Based Syntax and Semantics*, Lecture Notes No. 13, Stanford, Calif: CSLI Publication.
- Pollard, C. and I.A. Sag (1994) *Head-Driven Phrase Structure Grammar*, Center for the Study of language and Information, Stanford, The university of Chicago Press, Chicago & London.
- Popowich, F. (1996) *A Chart Generator for Shake and Bake Machine Translation In The Proceedings of the 11th Canadian Conference on artificial intelligence, AI'96, May 22-24.*
- Poznanski, V., J. L. Beaven and P. Whitelock (1995) *An Efficient Generation Algorithm for lexicalist MT In Proceedings of the 33rd Annual Meeting of the Association for Computational Linguistics, Boston, MA.*
- Punmetha, N. (1984) *Thai Grammar, 2nd Edition*, Rungrangsang Publishers, Bangkok, Thailand. (นววรรณ พันธุเมธา (2527) ไวยากรณ์ไทย. รุ่งเรืองสาส์นการพิมพ์. กรุงเทพฯ. ประเทศไทย)
- Randall, R. (1987) *The ugly duckling*, Ladybird, Loughborough, England.
- Rosetta, M. T.(1994) *Compositional Translation*, Kluwer Academic Publishers.
- Russell, S.J. and P. Norvig (1995) *Artificial Intelligence: A Modern Approach*, Prentice Hall, New Jersey.
- Sag, I. A. and T. Wasow. 1999 *Syntactic Theory: A Formal Introduction*, CSLI Lecture Notes Number 92, Center for the Study of language and Information, Stanford, California.
- Sager, N. (1986) *Sublanguage: Linguistic Phenomenon, Computational Tool In Analyzing Language in Restricted Domains: Sublanguage Description and Processing* Edited by R. Grishman and R. Kittredge. Lawrence Erlbaum Associates Publishers, London.

Sato, S. and M. Nagao (1990) Toward Memory-based Translation *In* The Proceedings of The 13th International Conference on Computational Linguistics, COLING-90, Edited by Hans Karlgren, Helsinki, Vol. 3, p. 247- 252.

Schubert, L. K., R. G. Goebel and N. Cercone (1979) The Structure and Organization of a Semantic Net for Comprehension and inference. *In* Associative Networks: Representation and Use of Knowledge by Computers. Edited by N. V. Findler. Academic Press, New York, p. 121-175.

Shieber, S. M. (1986) An Introduction to Unification-Based Approaches to Grammar, CSLI Lecture Notes Number 4, Center for the Study of Language and Information CSLI, Leland Stanford Junior University.

Slocum, J. (1988) Machine Translation System, Cambridge University Press, Cambridge.

Somers, H. L. (1990) Current Research in Machine Translation *In* The Proceedings of The Third International Conference on Theoretical and Methodological Issues in Machine Translation of Natural Language, Linguistics Research Center, University of Texas at Austin.

Sumita, Iida and Kohyama (1990) Translating with Examples: A New Approach to Machine Translation *In* The Proceedings of The third International Conference on Theoretical and Methodological Issues in machine Translation of Natural language, University of Texas at Austin, 11-13 June.

Systran (1999) Translation software, available at <http://www.systransoft.com/>, as of December.

The Thai Royal Institute (1995) Classifiers, Kurusapa Ladpao Publishers, Bangkok, Thailand.
(ราชบัณฑิตยสถาน (1995) ลักษณะนาม ฉบับราชบัณฑิตยสถาน, โรงพิมพ์คุรุสภา ลาดพร้าว, กรุงเทพฯ, ประเทศไทย)

Tomita, M. (1985) Feasibility Study of Personal/Interactive Machine Translation Systems. CMU-CS-85-140. Department of Computer Science, Carnegie-Mellon University.

Trujillo, A. and S. Berry (1996) Connectivity in bag Generation *In* Proceedings of The 16th International Conference in Computational Linguistics, COLING'96, Copenhagen, Denmark, p. 101-106.

- Turcato, D. (1998) Automatically Creating Bilingual Lexicons for Machine Translation from Bilingual Text, *In* The Proceedings of The 36th Annual Meeting of the Association for Computational Linguistics and 17th International Conference on Computational Linguistics COLING-ACL'98, Volume II, Montreal, Quebec, Canada, August 10-14, p. 1299- 1305.
- Uchida, H. (1989) ATLAS-II: A Machine Translation System Using Conceptual Structure As An Interlingua. *In* Proceedings of the Second Machine Translation Summit, Tokyo, Omsa Ltd.
- Weaver, W., (1955) Translation *In* Machine Translation of Languages: Fourteen Essays Edited by W. N. Locke and A. D. Booth, The Technology press of The Massachusetts Institute of Technology and John Wiley & Sons, Inc., New York.
- Weaver, W., (1989) The Process of Translation *In* The Craft of Translation Edited by J. Biguenet and R. Schulte, The University of Chicago Press, Chicago, p. 117-124.
- White, J. S. (1999) MT Evaluation, A Tutorial Description *In* Machine Translation and the Information Soup
- White, J. S., T. A. O'Connell, F. E. O'Mara (1994) Advanced Research Projects Agency Machine Translation Program: 3Q94 Evaluation, The Final Report for the 3Q94 ARPA MT Evaluation, PRC Inc.
- Whitelock, P. (1992) Shake-and-Bake Translation *In* The proceedings of the fifteenth International Conference on Computational Linguistics, COLING-92, Nantes, France, August 23-28, p. 784-791.
- Whitelock, P. and K. Kilby (1995) Linguistic and Computational Techniques in Machine Translation System Design, 2nd Edition, UCL Press Limited, London.
- Wielemaker, J. (1999) SWI-Prolog available at <http://www.swi.psy.uva.nl/projects/SWI-Prolog/>, August.
- Wilks, Y. (1972) An Artificial Intelligence Approach to Machine Translation, Report CS-264, Computer Science Department, Stanford University.

Woszczyna, M. et al., (1995) Recent Advances in JANUS: A Speech Translation System, available at <http://www.is.cs.cmu.edu/~monika/papers/html/euro93.janus/>, available as of August.

Yngve, V. H. (1955) Syntax and the Problem of Multiple Meaning *In* Machine Translation of Languages: Fourteen Essays Edited by W. N. Locke and A. D. Booth, The Technology press of The Massachusetts Institute of Technology and John Wiley & Sons, Inc., New York.

Zajac, R. (1988) Interactive Translation: A New Approach *In* The Proceedings of The 12th International Conference on Computational Linguistics COLING BUDAPEST, Vol. II, 22-27 August, Budapest, p. 785-790.

Appendix A

WordAssociation Hierarchy

This appendix illustrates the WordAssociation hierarchy, discussed in section 4.2.1. Class and its WordAsso number are shown in the first column. Examples of each are shown in the second column.

A.1 The IS-A Classes

The semantic relation between classes and their superclasses is represented by *is-a*.

WordAsso Number and Class	Examples
1. Thing (Entity)	
1-1 Concrete thing	
1-1-1 Living thing	
1-1-1-1 Human	คน
1-1-1-1-1 Individual (Person)	adult child friend เด็ก เพื่อน
1-1-1-1-1-1 Male ¹	boy man ผู้ชาย
1-1-1-1-1-2 Female ¹	girl woman ผู้หญิง
1-1-1-1-1-3 Relative	cousin aunt
1-1-1-1-1-3-1 Ancestor	parent mother father grandma แม่
1-1-1-1-1-3-2 Male sibling	brother พี่ชายน้องชาย
1-1-1-1-1-3-3 Female sibling	sister พี่สาวน้องสาว
1-1-1-1-1-3-4 Spouse	husband wifeสามี ภรรยา
1-1-1-1-1-3-5 Offspring	ลูก child ลูกๆ children
1-1-1-1-1-3-5-1 Male offspring	ลูกชาย
1-1-1-1-1-3-5-2 Female offspring	ลูกสาว
1-1-1-1-1-4 Juvenile	หนุ่มสาว young children เด็กๆ

¹ This classification is for associating with the ending in Thai ค่ะ ครับ

WordAsso Number and Class	Examples
1-1-1-1-5 Associate	member พี่น้องร่วมอาชีพ brother
1-1-1-1-6 Helper	Supporter ผู้สนับสนุน friend
1-1-1-1-7 Socialist	
1-1-1-1-7-1 Communist	red คอมมิวนิสต์
1-1-1-1-8 Unpleasant person	worm ไส้เดือน
1-1-1-2 Animal	สัตว์
1-1-1-2-1 Vertebrate	
1-1-1-2-1-1 Mammal	cat แมว แกะ sheep
1-1-1-2-1-2 Bird	bird สัตว์ปีก นก
1-1-1-2-1-2-1 Aquatic Bird	หงส์ นกกระสา swan stork goose เป็ด duck duckling ลูกเป็ด geese ห่าน
1-1-1-2-1-2-2 Fowl	ไก่งวง ไก่ hen turkey
1-1-1-2-1-3 Aquatic Vertebrate	
1-1-1-2-1-3-1 Fish	ปลาเทราท์
1-1-1-2-1-4 Amphibian	frog
1-1-1-2-1-5 Reptile	งู snake
1-1-1-2-2 Invertebrate	worm ไส้เดือน
1-1-1-2-2-1 Arthropod	spider
1-1-1-2-2-1-1 Insect	butterfly
1-1-1-2-2-1-2 Crustacean	shrimp, crab เคย
1-1-1-2-2-2 Shellfish	mussel
1-1-1-3 Plant	
1-1-1-3-1 Vascular Plant	
1-1-1-3-1-1 Woody Plant	
1-1-1-3-1-1-1 Tree	maple
1-1-1-3-1-1-1-1 Palm	coconut, nipa plam, จาก
1-1-1-3-1-1-2 Bush	rose, hydrangea, jasmine กุหลาบ
1-1-1-3-1-2 Herb	lettuce ผักกาดแก้ว carrot taro cauliflower brocolli vegetable ผีข
1-1-1-3-1-2-1 Gramineous plant	reed ต้นกก
1-1-1-3-1-2-1-1 Cereal	wheat ข้าวสาลี
1-1-1-3-1-3 Vine	potato มัน grape
1-1-1-3-1-3-1 Gourd	cucumber แตงกวา white_gourd ฟัก
1-1-1-3-2 Fungus	mushroom เห็ด
1-1-1-4 Microorganism	seaweed
1-1-2 Non-living thing	
1-1-2-1 Object	ของ
1-1-2-1-1 Artifact (Man-made object)	
1-1-2-1-1-1 Fabric	duck ผ้าลินินขาว
1-1-2-1-1-2 Construction	
1-1-2-1-1-2-1 Barrier	
1-1-2-1-1-2-1-1 Movable barrier	hatch ฝาปิดห้องห้องเรือ door ประตู
1-1-2-1-1-2-2 Housing	cottage กระท่อม home บ้าน
1-1-2-1-1-2-3 Room	toilet can ห้องน้ำ

WordAsso Number and Class	Examples
1-1-2-1-1-2-4 Establishment ²	
1-1-2-1-1-2-4-1 Institution ³	
1-1-2-1-1-2-4-1-1 Penal Institution ⁴	prison, can คคุก
1-1-2-1-1-2-4-1-2 Educational Insti.	school, university โรงเรียน มหาวิทยาลัย
1-1-2-1-1-2-4-1-3 Medical Insti.	hospital โรงพยาบาล
1-1-2-1-1-3 Instrumentation	
1-1-2-1-1-3-1 Device	พัด fan
1-1-2-1-1-3-1-1 Holding device	last แบบรองเท้า
1-1-2-1-1-3-1-2 Musical instrument	reed ขลุ่ย
1-1-2-1-1-3-1-3 Airfoil	wing ปีก
1-1-2-1-1-3-1-4 Elastic device	spring สปริง
1-1-2-1-1-3-1-5 Measuring instrument	
1-1-2-1-1-3-1-5-1 Timekeeper	watch นาฬิกาข้อมือ
1-1-2-1-1-3-2 Container	กระป๋อง can
1-1-2-1-1-3-2-1 Box	safe ตู้เหล็ก
1-1-2-1-1-3-3 Implement	
1-1-2-1-1-3-3-1 Tool	saw เลื่อย
1-1-2-1-1-3-4 Means	
1-1-2-1-1-3-4-1 Telecommunication	call โทรศัพท์
1-1-2-1-1-4 Enclosure	farmyard ลานติดโรงนา
1-1-2-1-1-5 Covering	
1-1-2-1-1-5-1 Protective covering	
1-1-2-1-1-5-1-1 Blind	curtain ม่าน
1-1-2-1-1-5-1-2 Binding	cover หน้าปก
1-1-2-1-1-5-2 Clothing	coat
1-1-2-1-1-6 Strip	ที่รัด stay
1-1-2-1-1-7 Creation	
1-1-2-1-1-7-1 Representation	
1-1-2-1-1-7-1-1 Picture/Image	reflection ภาพสะท้อน
1-1-2-1-2 Substance ⁵	
1-1-2-1-2-1 Food	
1-1-2-1-2-1-1 Nutriment	ก้น dish
1-1-2-1-2-1-1-1 Dish	salad สลัด
1-1-2-1-2-1-2 Foodstuff ⁶	egg ไข่
1-1-2-1-2-1-2-1 Vegetable	cucumber แตงกวา vegetable ผัก
	white_gourd ฟัก
1-1-2-1-2-1-2-1-1 Root vegetable	carrot, taro root, potato

² Establishment is a public or private structure (business or government or educational) including buildings and equipment for business or residence.

³ Institution is a building or complex of buildings where an organization for the promotion of some cause is situated.

⁴ Penal Institution is an institution where persons are confined for punishment and to protect the public.

⁵ Substance is that which has mass and occupies space.

⁶ A substance that can be used or prepared for use as food.

WordAsso Number and Class	Examples
1-1-2-1-2-1-2-1-2 Leafy vegetable	lettuce ผักกาดแก้ว
1-1-2-1-2-1-2-1-3 Crucifer	cauliflower, broccoli
1-1-2-1-2-1-2-2 Fruit	
1-1-2-1-2-1-2-3 Seafood	shrimp เคย trout ปลาเทราท์ ปลา
1-1-2-1-2-1-2-4 Meat	
1-1-2-1-2-1-2-4-1 Poultry	duck hen เป็ด ไก่ turkey ไก่จิ้ง
1-1-2-1-2-1-2-5 Grain	wheat ข้าวสาลี
1-1-2-1-2-1-3 Beverage	
1-1-2-1-2-1-3-1 Alcoholic Beverage	spirit เหล้า whisky
1-1-2-1-2-2 Chemical Element ⁷	hydrogen, oxygen
1-1-2-1-2-2-1 Metal	copper, silver
1-1-2-1-2-3 Material	
1-1-2-1-2-3-1 Earth	soil
1-1-2-1-2-3-3 Animal material	hide หนังสัตว์
1-1-2-1-2-3-4 Natural fiber	flock เส้นใย
1-1-2-1-2-4 Fluid	
1-1-2-1-2-4-1 Liquid	water น้ำ
1-1-2-1-2-4-2 Gas	hydrogen, oxygen, air
1-1-2-1-2-5 Lipid	fat ไขมัน
1-1-2-1-2-6 Solid	
1-1-2-1-2-6-1 Crystal	ice น้ำแข็ง
1-1-2-1-2-7 Body substance	pusหนอง
1-1-2-1-3 Location	where ที่ไหน
1-1-2-1-3-1 Point ⁸	place ⁹ ที่ corner มุม there ที่นั่น here ที่นี่
1-1-2-1-3-1-1 Residence	home ที่อยู่อาศัย
1-1-2-1-3-2 Region ¹⁰	wild ป่า
1-1-2-1-3-2-1 Area ¹¹	ข้างนอก outside place สถานที่ ข้างใน inside ภายใน out place ¹³ ที่
1-1-2-1-3-2-1-1 Space ¹²	
1-1-2-1-3-2-2 Geographical area	
1-1-2-1-3-2-2-1 Rural area	countryside ชนบท
1-1-2-1-3-2-2-2 piece of land	yard ลาน
1-1-2-1-3-2-2-2-1 Field	yard สนามหญ้า
1-1-2-1-3-2-3 Heavenly	sky ท้องฟ้า
1-1-2-1-3-2-4 Boundary	edge ขอบ
1-1-2-1-4 Natural object	nest รัง
1-1-2-1-4-1 Geology	mountain เขา spring fountain น้ำพุ
1-1-2-1-4-2 Organic Structure	flesh ร่างกาย body
1-1-2-1-5 Land	

⁷ Element is any of more than a hundred simple substances that consist of atoms of only one kind and that, alone or in combination, make up all substances.

⁸ Point is the precise location of something.

⁹ Place is a point located with respect to surface features of some region; this place is nice.

¹⁰ Region is a large indefinite location on the surface of the earth.

¹¹ Area is a particular geographical region of indefinite boundary.

¹² Space is an area reserved for some particular purpose.

¹³ Place is a space reserved for sitting (as in a theater or on a train or airplane).

WordAsso Number and Class	Examples
1-1-2-1-5-1 Wetland	marsh หนอง
1-1-2-1-6 Body of water	
1-1-2-1-6-1	lake ทะเลสาบ
1-1-2-1-6-2	pond แอ่งน้ำ
1-1-2-1-7 Part/Portion	
1-1-2-1-7-1 Component	
1-1-2-1-7-1-1 Addition/Improver	wing ปีก
1-2 Abstract thing	
1-2-1 Supernatural thing	
1-2-1-1 Supernatural being	Jesus, God, angel, นางฟ้า เทวดา
1-2-1-1-1 Spirit	ผี ghost, วิญญาณ
1-2-1-1-1-1 Good spirit	
1-2-1-1-1-2 Evil spirit	satan, devil, demon, ปีศาจ ผีปอบ
1-2-1-2 Imaginary being	
1-2-1-2-1 Imaginary person	santa claus tooth-fairy mermaid นางเงือก
1-2-1-2-2 Imaginary creature	pegasus, unicorn, ครุฑ นาค
1-2-2 Vital principle	spirit, จิตวิญญาณ
1-2-3 Physics forces ¹⁴	แสง เสียง พลังงาน light sound energy ลม wind
1-2-4 Life Form	soul, วิญญาณ
1-3 Cell ¹⁵	
1-3-1 Reproductive cell/Germ cell	egg ไข่
1-4 Part	
1-4-1 Body part	
1-4-1-1 External body part	
1-4-1-1-1	head หัว
1-4-1-1-2	neck คอ leg ขา
1-4-1-1-3 External body part of animal	horn เขา
1-4-1-1-3-1 External body part of bird/ insects	ปีก wing
1-4-1-1-4 External body part of plant	
1-4-1-1-4-1 Plant organ	stem
1-4-1-1-4-2 Reproductive structure	flower anther fruit ผลไม้
1-4-1-2 Body covering	
1-4-1-2-1 Growth from the skin of person or animal	hair ขน
1-4-1-2-2 On the head of human being	hair ผม
1-4-1-2-3 body covering of bird	feather ขนนก
1-4-1-3 Tissue	
1-4-1-3-1 Animal Tissue	flesh เนื้อ
2. Abstraction	
2-1 Act	

¹⁴ Physics is the science concerned with the study of matter and natural forces, such as light, heat, movement, etc.

¹⁵ Cell is the basic structural and functional unit of all organisms; A tiny mass of protoplasm that contains a nucleus, is enclosed by a membrane, and forms the fundamental unit of living matter.

WordAsso Number and Class	Examples
2-1-1 Change	warm อุ่น
2-1-1-1 Change state	ตื่น wake (up) เปิด open เปลี่ยนเป็น go went become became come turn
2-1-1-2 Change in size or magnitude	
2-1-1-2-1 Increase	
2-1-1-2-1-1 Become larger, greater or bigger	grow, grown ¹⁶ , เติบโตขึ้น rise rose ขึ้น grew
2-1-1-2-1-1-1 Natural development	grow, grown ¹⁷ , เติบโตขึ้น grew
2-1-1-2-1-1-1-1 Height	สูงขึ้น ¹⁸
2-1-1-2-1-1-1-2 Length	ยาวขึ้น ¹⁹
2-1-1-2-1-2 Increase in degree	grow, grown, มากขึ้น ²⁰ more grew
2-1-1-2-1-3 Come by degree/Pass into a condition gradually	grow, grown, เพราะ ²¹ grew
2-1-1-3 Change to the contrary	spread ²² กาง
2-1-1-4 Change so as to cover or include a greater area	spread ²³ แผ่ขยาย
2-1-1-5 Change posture	rise rose arise ลุกขึ้น
2-1-1-6 Depart (To stop being in or with)	left จาก leave
2-1-1-7 Form	blow เป่า
2-1-1-8 Cook	brown ทำให้เป็นสีน้ำตาล
2-1-1-9 Correct	ปรับ adjust
2-1-1-10 Purify	fine ทำให้บริสุทธิ์
2-1-1-11 To improve by making or becoming thinner	fine ทำให้ละเอียดขึ้น
2-1-1-12 Break	
2-1-1-12-1 Break open	crack แตก
2-1-1-12-2 Break without dividing	crack
2-1-1-12-2-1	ร้าว
2-1-1-12-2-2	ปริ crack_open ปริแตกออก
2-1-1-13 To break open	
2-1-1-13-1 To Crack open	crack
2-1-1-13-1-1	แกะ ²⁴
2-1-1-13-1-2	ดอก ²⁵
2-1-1-14 Terminate	

¹⁶ Grow is to increase in amount, size e.g., The company has grown rapidly in the last five years.

¹⁷ Grow is to increase in size by natural development e.g., Grass grows after rain.

¹⁸ Grow is to increase in size by natural development e.g., He's grown six inches.

¹⁹ Grow is to increase in size by natural development e.g., She doesn't like her hair short, so she's letting it grow.

²⁰ Grow is to increase in degree e.g., A growing number of people are taking part-time jobs.

²¹ Grow is to come by degree or to pass into a condition gradually, e.g., He grew more and more sad.

²² Spread is to cause to open, stretch out, e.g., Spread the map out.

²³ Spread is to stretch out so as to cover or include a greater area, e.g., The city has spread out rapidly in all directions.

²⁴ แกะ, to break open (break off with the fingers and thumb), e.g., To crack nuts.

²⁵ ดอก, to break open, e.g., I cracked two eggs.

WordAsso Number and Class	Examples
2-1-1-14-1 Interrupt	
2-1-1-15 Improve	
2-1-1-15-1 Educate	school สอน
2-1-1-15-2 Refine	school อบรม
2-1-1-16 Be born ²⁶	
2-1-1-16-1	be born เกิด
2-1-1-16-2	hatch ²⁷ ฟัก
2-1-1-17 Cause to be/cause to do something	make ²⁸ ทำให้
2-1-1-18 change integrity	
2-1-1-18-1 Break up	melt หลอม
2-1-1-18-2 Liquify	melt ละลาย
2-1-2 Come to pass	happen, occur, be ²⁹ เกิดขึ้น on
2-1-3 Interact	
2-1-3-1 Communicate	ask ถาม talkคุย
2-1-3-1-1 Utter	say พูด said cried ร้อง talk call
	ตะโกน บอก told shout
2-1-3-1-2 Express emotion/feeling	cry ร้องไห้ cried laugh หัวเราะ
2-1-3-1-3 Ask/Order	call เรียก
2-1-3-1-3-1 Request	ask ขอร้อง
2-1-3-1-3-2 Order	
2-1-3-1-4 Demand	ask ต้องการ want ³⁰
2-1-3-1-5 Inform	
2-1-3-1-5-1 Teach	lecture talk บรรยาย
2-1-3-1-5-2 Let something be known	told บอก
2-1-3-1-5-3 Narrate/Give a detailed account of	told เล่า
2-1-3-1-6 Telecommunicate	call โทรศัพท์
2-1-3-1-7 Declare	call ประกาศ
2-1-3-2 Treat/Interact in the certain way	
2-1-3-2-1 Mock	make fun of เยาะเย้ย laughed at
	หัวเราะเยาะ
2-1-3-3 Transfer	
2-1-3-3-1 Give	give ให้
2-1-3-3-2 Exchange	
2-1-3-3-2-1	let ให้เช่า rent
2-1-3-3-2-2	give ³¹ pay จ่าย rent เช่า
2-1-3-3-3 Payment	
2-1-3-3-3-1 Penalty	fine ค่าปรับ
2-1-3-3-3-2 Regular payment	ค่าเช่า rent
2-1-3-4 Charge	
2-1-3-4-1 Impose	fine ปรับ

²⁶ Be born is to come into existence through birth.

²⁷ Hatch is (of an egg) to break, letting the young bird out.

²⁸ Make is to put into a certain state, position., e.g., Eating the unripe apples made him ill.

²⁹ Be e.g., Ex: I lost my wallet, this was during the visit to my parents' house.

³⁰ Want is to wish or demand the presence of e.g., I want you here at noon.

³¹ Give, e.g., I can't believe you gave \$3000 for that broken-down old car.

WordAsso Number and Class	Examples
2-1-3-5 Collect in one place	gather จับกลุ่ม
2-1-4 Support	
2-1-4-1 Take care	mother เลี้ยงดู รดน้ำ water
2-1-5 Move	
2-1-5-1 Move so as to change position	walk เดิน went ไป go wander เดินไปเดินมา wing บิน fly เดินแถว march turn เลี้ยว flew duck ก้ม หัน turn turn หมุน ³² turn พลิก
2-1-5-2 Move so as of a body part	
2-1-5-2-1 Move round a central or fixed point	turn หมุน ³²
2-1-5-2-2 Move so that a different side faces upwards or outwards	turn พลิก
2-1-5-3 Move to change a residence, affiliation	move ย้าย
2-1-5-4 Move thing	ขน carry
2-1-5-4-1 Move thing with force	poke ทิ่ม duck จับกดลง
2-1-5-4-2 Move thing from one place to another /Transport/carry	
2-1-5-4-2-1 Move a moving thing	พา ³³ take bring took
2-1-5-4-2-2 Move a non-moving thing	take ³⁴ เอา took
2-1-5-5 Move forward slowly, as if by inches	edge เชื้อขยับ
2-1-5-5-1 Move forward as if by jumping	spring กระโดด
2-1-5-6 Move toward something	come มา come_over_to ตรงมาที่
2-1-5-7 Move upward	ขึ้น rise ขึ้นสู่ rose_into
2-1-5-8 Move downward	
2-1-5-8-1 Submerge	dive ดำ
2-1-5-9 Move very fast	วิ่ง ran
2-1-5-10 Follow	ran afterไล่ตาม ตาม
2-1-5-11 Put in the certain place	place วาง
2-1-5-12 Drift	blow ปลิว
2-1-5-13 Go across or through	through ผ่าน
2-1-5-14 Cause to move in a circular movement	wind หมุน
2-1-5-15 Move to (cause to) have influence or effect over a wider area	spread กระจาย
2-1-5-15-1 Diseases	แพร่
2-1-5-15-2 Fire	ลาม
2-1-5-16 Stir	คน
2-1-6 Displace	chaseไล่ คำ transplant
2-1-6-1 Separate	
2-1-6-1-1 Cut	saw เลื่อย
2-1-6-1-2 Pull violently	rent หัก rend
2-1-6-1-3 Tear	rent ฉีก rend
2-1-7 Prod	egg กระตุ้น
2-1-8 Make/Create	make ³⁵ ทำ

³² Turn is to move around an axis or a center, e.g., The wheels are turning.

³³ Take, e.g., We usually take the children to school in the car.

³⁴ Take, e.g., Don't forget to take your bag when you go.

³⁵ Make is to produce something, e.g., She made a cake.

WordAsso Number and Class	Examples
2-1-8-1 Reproduce	hatch ³⁶ ฟัก
2-1-8-2 Create mentally	hatch คิด
2-1-8-2-1 Imagine	dream ฝัน ³⁷
2-1-8-3 Produce	คลอด bear lay วาง give ³⁸ ก่อให้เกิด born
2-1-8-4 Create verbally	written เขียน
2-1-8-5 Create from raw material	แกะ carve
2-1-8-6 Create by combining materials and parts	nest ทำรัง
2-1-9 Think/Cerebrate	think ³⁹ คิด cogitate
2-1-9-1 Think logically	คิด compute, calculate คำนวณ
2-1-9-2 Plan	will ตั้งใจจะ would
2-1-10 Appear/Come into sight or view	poke โผล่ peep
2-1-11 Conduct	led นำ take took
2-1-12 Cause	led ชักจูง
2-1-13 Control	
2-1-13-1 Manage	
2-1-13-1-1 Direct (be in charge of)	ran ดำเนิน operate
2-1-14 Breathe	
2-1-14-1 Breathe out	blow เป่า
2-1-15 Cause to be perceived	
2-1-15-1 Make a certain sound or noise	blow เป่า
2-1-16 Cause to open	open เปิด
2-1-17 Cause to start operating	open เริ่ม
2-1-18 Touch	
2-1-18-1 Make physical contact with	
2-1-18-1-1 Caress	neck กอดจูบ
2-1-18-1-2 Cause to be in brief contact with	ต๋อง touch
2-1-18-1-3 Strike	
2-1-18-1-3-1 Beat	คอก hammer
2-1-18-1-4 Handle ⁴⁰	
2-1-18-1-4-1 Operate/Control	fly, flew บิน
2-1-18-2 Be in contact with	cover ⁴¹ ปกคลุม
2-1-19 To place something on or over to protect or hide	cover ⁴²

³⁶ Hatch is to (sit) on eggs.

³⁷ Dream is to imagine something, e.g., I never said that! You must have been dreaming; have a daydream.

³⁸ Give, e.g., I hope my son didn't give you any trouble.

³⁹ Think is to use the power of reason; make judgments or careful considerations; use the mind to form ideas and opinion, e.g., She thought long and hard before coming to the decision.

⁴⁰ Handle is to touch, lift or hold with hands.

⁴¹ Cover is to be or lie on or over the surface of something; spread over something e.g., The furniture was covered with dust.

⁴² Cover is to place something upon or over something in order to protect or hide it, e.g., The noise was so loud that she covered her ears with her hands.

WordAsso Number and Class	Examples
2-1-19-1 Cover as to cover eyes, ears	ปิด ⁴³
2-1-19-2 Envelop	คลุม ⁴⁴
2-1-20 To provide with a covering or caused to be covered	spread ทา
2-1-21 Close	close ปิด
2-1-22 Inactive	rest พัก
2-1-23 Attempt	tried try พยายาม
2-1-24 Consume	have has had
2-1-24-1 Take in liquids	drink ดื่ม
2-1-24-2 Take in solid food	eat กิน
2-1-24-3 Inhale/exhale smoke from cigarettes	smoke สูบ
2-1-25 Watch	watch เฝ้าดู
2-2 Activity	use การใช้
2-2-1 Human activity	
2-2-1-1 Movement	chase การตามล่า
2-2-1-1-1 Stoke/A single complete movement	poke การกระทุ้ง
2-2-1-1-2 Walking	march การสวนสนาม
2-2-1-1-3 Group action	
2-2-1-1-3-1 Group procession	march การเดินขบวน
2-2-1-1-3-2 Business	fishing การประมง
2-2-1-1-4 Play	let การเสิร์ฟลูกกระเ็นด
2-2-1-2 Stay	stay การพักอยู่
2-2-1-3 Recreation	
2-2-1-3-1 Sport	fishing ตกปลา
2-2-1-4 Work	
2-2-1-4-1 Investigation	research งานวิจัย
2-2-1-5 Keeping something secret	hiding การซ่อน
2-2-2 Sensory activity	
2-2-2-1 Looking	look การมอง การแอบมอง peep
2-2-3 Action	
2-2-3-1 Arrival/Reaching	coming การมาถึง
2-2-3-2 Departure	leave การลาจาก
2-2-3-3 Rescue	release การปล่อย
2-3 Attribute	name ชื่อ age, appearance ability, trait, kind, sort ชนิด ประเภท sex, kindness, weight, healthy, aliveness occupation, position, title function
2-3-1 Property of living thing	shape
2-3-1-1 Property of Human	greasy
2-3-1-2 Property of Animal	degree
2-3-2 Property of non-living thing	happiness
2-3-2-1 of food/thing	
2-3-3 Property of temperature	
2-3-4 Property of emotion	

⁴³ ปิด e.g., covered her ears.. covered her eyes.

⁴⁴ คลุม e.g., covered the body.

WordAsso Number and Class	Examples
2-3-5 Property of vision (Visual property)	dark มืด light, lightness, brightness, ความสว่าง สี color
2-3-6 Property of movement	
2-3-6-1 Come forth	out ⁴⁵ ออกมา
2-3-6-2 Go forth	out ⁴⁶ ออกไป off
2-3-6-3 Away from the open air/outside	in ⁴⁷ เข้าไป
2-3-6-4 To or toward the inside	in ⁴⁸ เข้ามา
2-3-7 Property of quality	importance ความสำคัญ
2-3-8 Away from a surface or edge	
2-3-8-1 away from a surface or edge	out ออกจาก
2-3-9 Property of space	distance position
2-3-10 The inner part of a solid object or the faces away from the open air	ด้านใน ⁴⁹ inside outside ด้านนอก
2-3-11 Form/Shape	
2-3-11-1 Amorphous shape	รอยร้าว crack rent รอยขาด
2-3-12 Time	timing
2-3-13 Property of physically or mentally strong	strength
2-4 Measure/Quantity	
2-4-1 Number	one, 1, หนึ่ง five ห้า
2-4-2 Classifier	
2-4-2-1 Classifier of object	
2-4-2-1-1 Classifier of living thing	
2-4-2-1-1-1 Classifier of person	คน
2-4-2-1-1-2 Classifier of animal	ตัว
2-4-2-1-1-3 Classifier of plant	ต้น
2-4-2-1-2 Classifier of non-living thing	
2-4-2-1-2-1 Classifier of tool	อัน
2-4-2-1-2-2 Classifier of room	ห้อง
2-4-2-1-2-3 Classifier of external body part	ขา หัว มือ
2-4-2-1-2-4 Classifier of wing	ปีก
2-4-2-1-2-5 Classifier of root veggie, crucifer	หัว
2-4-2-1-2-6 Classifier of place	ที่
2-4-2-1-2-7 Classifier of marsh	แอ่ง
2-4-2-1-2-8 Classifier of place, lake	แห่ง
2-4-2-1-2-9 Classifier of marsh	หนอง
2-4-2-1-2-10 Classifier of housing	หลัง
2-4-2-1-2-11 Classifier of door	ประตู
2-4-2-2 Classifier for pairs of anything	คู่
2-4-2-2 Classifier of collection	ชนิด ประเภท

⁴⁵ Out is away from the inside e.g., “Open the bag and take the money out”, “Blood poured out from the wound”.

⁴⁶ Out is away from the inside e.g., “She opened the cage and let the bird out”.

⁴⁷ In is away from the outside e.g., “Open the box and put the money in”.

⁴⁸ In is to or toward the inside e.g., “There was a loud explosion and the walls fell in”.

⁴⁹ Inside. e.g., He reached into his inside jacket pocket.

WordAsso Number and Class	Examples
2-4-2-2-1 Classifier of human	กลุ่ม
2-4-2-2-2 Classifier of animal	ฝูง
2-4-2-3 Classifier of time	day วัน hour ชั่วโมง
2-4-2-4 Classifier of measurement	yard หลา
2-4-2-5 Classifier of frequency	ที ครั้ง
2-4-2-6 Classifier of action	
2-4-3 Time	
2-4-3-1 Time period	
2-4-3-1-1	สุดสัปดาห์ weekend ตอนเช้า แต่เช้า เช้า morning กลางวัน เวลาเย็น กลางคืน evening ในตอนนั้น then decade ทศวรรษ hour month day วัน winter ฤดูหนาว ฤดูใบไม้ผลิ spring march เดือนมีนาคม leave การลาหยุด midnight, noon, 2:00 am. เทียงคิน very มากๆ น้อย little great มาก many มากที่สุด most handsome มากมาย more หลาย ส่วนใหญ่ most several
2-4-3-1-2	
2-4-3-2 Season	
2-4-3-3 Calendar month	
2-4-3-4 Time off	
2-4-4 Clock time	
2-4-5 Indefinite quantity	
2-4-5-1 Indefinite number more than 2 or 3 but not many (normally followed by clf.)	
2-4-6 Definite quantity	all ทั้งหมด
2-4-6-1 The complete amount of something including all its component elements or parts.	ตลอด ⁵⁰ all, whole
2-4-7 Degree of truth	จริงๆ
2-4-8 To such a (great) degree	so อย่างนั้น
2-4-9 Linear unit	yard หลา
2-5 Psychological feature (a feature of the mental life of a living organism)	ความรู้สึก feeling
2-5-1 Cognition	
2-5-1-1 Intention	will ความตั้งใจ spirit
2-5-1-2 Imaginary	dream ความฝัน
2-5-1-3 Representational process	symbol สัญลักษณ์
2-5-1-4 Problem solving	research การวิจัย
2-5-1-5 Ability	mind ⁵¹ สติปัญญา
2-5-1-6 Content	matter เรื่อง
2-5-1-6-1 Concept	
2-5-1-6-1-1 Category	make ยี่ห้อ
2-5-1-7 Learning	
2-5-1-7-1 Education	school การศึกษา
2-5-2 Motivation	
2-5-3 Feeling	
2-5-3-1 Desire	want ความต้องการ
2-5-3-2 Emotion	anger ความโกรธ

⁵⁰ All, e.g., We walked all the way.

⁵¹ Mind is the ability to think and reason: intellect. e.g., He has a very sharp mind.

WordAsso Number and Class	Examples
2-5-4 Remember	think ⁵² นึก recall
2-5-5 Confidence	sure แน่ใจ
2-5-6 Mind	ใจ mind ⁵³
2-5-6-1	spirit
2-5-6-2	spirit
2-6 Perceive (to become aware of through the senses)	รู้สึก feel seen เห็น saw heard ได้ยิน dream ⁵⁴ ฝัน
2-6-1 Look	look มอง แอบมอง peep looked_around มองไปรอบๆ watch เผาตุ
2-6-1-1 Look attentively	
2-6-2 Feel	
2-6-2-1 Unsatisfy	anger โกรธ
2-6-2-2 Satisfy	pleased พอใจ happy ⁵⁵
2-6-2-3 Pleased	pleased ยินดี
2-6-2-4 Like	like ชอบ love รัก
2-6-2-5 Separated	lonely อ้างว้าง เหงา
2-6-2-6 Dislike	hate
2-6-2-7 Reject/Disapprove	mind รังเกียจ
2-6-2-8 Desire ⁵⁶	want ต้องการ กระหาย hungry
2-7 Continue to exist	last persist ยาวนาน
2-8 Remain in good condition	last คงทน
2-9 Judge ⁵⁷	
2-9-1 Think	think ⁵⁸ คิด believe, consider
2-9-2 Expect ⁵⁹	think นึกว่า must คงจะ เชื่อว่า believe
2-9-3 Test/Prove ⁶⁰	test prove tried ทดลอง try
2-9-4 Accept ⁶¹	เชื่อ believe
2-10 Keep	
2-10-1 To put or keep out of sight	hid ซ่อน hidden hide hiding
2-10-2 To keep from being known	hide hid hidden ปิดบัง hiding
2-11 Confine/Deprive of freedom	corner จมนม
2-12 Decide/Come to decision about something	decide ตัดสินใจ ตกลงใจ
2-13 Leave	left จากไป leave
2-13-1 Escape	run away, หนีจากไป
2-14 Leave behind	left ทิ้ง leave
2-15 Social relation	

⁵² Think is to recall knowledge from memory, e.g., I can't think what her last name was.

⁵³ Mind is a person's (way of) thinking or feeling; thoughts, e.g., She looks very worried. I wonder what is on her mind.

⁵⁴ Dream, experience while sleeping, e.g., What did you dream about?

⁵⁵ Happy, feeling that something is right or good, satisfied, e.g., The government won't be very happy about the latest unemployment statistics.

⁵⁶ Desire is to feel or have a desire for; want strongly e.g., I want to go home now.

⁵⁷ Judge is to form an opinion of or pass judgement on.

⁵⁸ Think is to believe, consider; have an opinion e.g., I think he is very smart.

⁵⁹ Expect is to regard something as probable or likely. e.g., I didn't think to find her in the kitchen.

⁶⁰ Test/Prove is to put to the test or give experiment.

⁶¹ Accept is to consider or hold as true. accept as true, e.g., I believed his report.

WordAsso Number and Class	Examples
2-15-1 Communication	
2-15-1-1 Written material	will ผนังกรรม
2-15-1-2 Content	
2-15-1-2-1 Significant	point, there, ตรงนั้น
2-15-1-3 Language	
2-15-1-3-1 Natural language	Egyptian ภาษาอียิปต์
2-15-1-4 Signal	symbol เครื่องหมาย
2-15-1-4-1 Visual signal	traffic lights, สัญญาณไฟจราจร
2-15-1-4-2 Written symbol	font
2-15-1-5 Visual communication	
2-15-1-5-1 Facial gesture	laugh การหัวเราะ การยิ้ม smile
2-15-1-6 Auditory communication	
2-15-1-6-1 Utterance	shout การตะโกน
2-16 To discover by chance or experience	find หาให้พบ
2-17 Encounter	meet พบ
2-18 Search ⁶²	มองหา look for
2-19 Examine ⁶³	ดู look
2-20 Blow	blow พัด ⁶⁴
2-21 Relation	
2-21-1 Part	rest ส่วนที่เหลือ
2-21-2 Isolated	alone, all by yourself โดยลำพัง
2-21-3 Spatial relation	room ที่ว่าง
2-22 Stop	stop หยุด stopped
2-23 Not stopping/Continuously	on ⁶⁵ ต่อเนื่อง ไม่หยุด all ⁶⁶ ตลอด
2-24 Remove	
2-24-1	throw off, shake off สลัด
2-24-2	spirit
2-25 Treat/Provide treatment for	
2-25-1 Operate	
2-25-1-1 Sterilize	ตอน castrate
2-26 Cause to grow or develop	grow grown grew
2-26-1 Plant/Crops	ปลูก
2-26-2 Hair/Beard	ไว้
2-27 Let go/Set free	release ปล่อย
2-27-1 To press so as to allow something to move	release ปลด ⁶⁷
2-28 Utilize	use ใช้
2-29 Be familiar or acquainted with a person or an object, place	know รู้จัก
2-30 Know how to do or perform something	know รู้

⁶² Search is to try to find, try to locate or discover, e.g., looking for a lost book/ a new job.

⁶³ Examine is to observe carefully or inspect; to use the eyes in order to find something, e.g., You could see it if you'd only look.

⁶⁴ Blow is to be blowing or storming e.g., "The wind blew from the west".

⁶⁵ On, e.g., We worked on (and on) all night.

⁶⁶ All, e.g., He worked hard all last year.

⁶⁷ Release a button, a handle, etc. that can be pressed to allow part of machine to move.

WordAsso Number and Class	Examples
2-31 To have knowledge of something; have information in the mind	know รู้
2-32 Study	
2-32-1 Investigate	research วิจัย
2-33 Designate	
2-33-1 Label	call เรียกว่า ตั้งชื่อ name
2-34 Do/Perform ⁶⁸	do ทำ make ⁶⁹
2-35 Wait	wait_for รอ
2-36 Begin	begin, start, เริ่ม began
2-37 Arrive/reach a destination	come มาถึง
2-38 Pay attention to	mind สนใจ
2-39 Let/allow	
2-39-1 Give permission	let อนุญาต
2-39-2 Make it possible through lack of action for something to happen	let ปล่อยให้
2-40 Join/Get together	joined_in เข้าร่วม
2-41 have ownership/possession of	own เป็นเจ้าของ
3 Phenomenon ⁷⁰	luck โชค fortune
3-1 Natural Phenomenon	
3-1-1 Physical phenomenon	lightning, reflection การสะท้อน
3-1-2 Geological phenomenon	flood
3-2 Chemical phenomenon	fire
4 Event ⁷¹	fire, ไฟไหม้, accident
4-1 Nature event	
4-1-1 Sound	
4-1-1-1 Human made sound	call เสียงตะโกน
4-1-1-2 Animal made sound	quack แควก ทำเสียงพ้ออย่างแมว purr peep บ๊ีบ
4-1-2 Movement	spread การแพร่กระจาย
5 State ⁷²	
5-1 Relationship	motherhood พี่ชายน้องชาย พี่สาวน้องสาว
5-2 Alive/living	เป็น live มีชีวิต
5-3 Survive	live ดำรงชีวิต
5-4 Physiological state	
5-4-1 Illness	cold ไข้หวัด
5-4-2 State of body and mind	tired เหนื่อย กระหาย hungry thirsty หิว
5-5 Reputation	name ชื่อเสียง
5-6 Atmosphere	spirit ⁷³ บรรยากาศ

⁶⁸ Perform is to act or perform an action.

⁶⁹ Make is to perform an action, e.g., to make a decision.

⁷⁰ Phenomenon is any state or process known through the senses rather than by intuition or reasoning.

⁷¹ Event is something that happens at a given place and time.

⁷² State is the way something is with respect to its main attributes: "the current state of knowledge". "in a weak financial state".

⁷³ Spirit is the general atmosphere of a place or situation, e.g., He came to the party. but didn't really enter into the spirit of it.

WordAsso Number and Class	Examples
6 Be ⁷⁴	be อยู่ live, stay ⁷⁵
6-1 Be upright	stand ยืน
6-2 Be seated	sit นั่ง sat
6-3 Be in a horizontal position	lie, lay นอน
6-4 Cover	cover ⁷⁶ ครอบคลุม
6-5 Not move	
6-6 Stay ⁷⁷	stay พักอยู่
6-7 Seem ⁷⁸	look ดูเหมือน
6-8 count/carry weight	matter สำคัญ
6-9 belong	belong เป็นส่วนหนึ่งของ
7 Reference term for thing	
7-1 Reference term for a living thing	ฉัน คุณ you me
7-1-1 Reference term for male living thing	he him himself ตัวเขาเอง เขา
7-1-2 Reference term for female living thing	she ตัวเธอเอง herself her เธอ
7-1-3 Reference term for a group of living thing	they พวกเขา them พวกเรา us we
7-1-4 Reference term for human	คน one
7-1-5 Reference term for animal	ตัว one
7-2 Reference term for a non living thing	it มัน what อะไร
7-3 Reference term for a time	when เมื่อไหร่
8 Group/Grouping	
8-1 Social group	
8-1-1 Organization	
8-1-1-1 Political party	wing ฝ่ายซ้าย faction bloc
8-1-1-2 Military Unit	
8-1-1-2-1 Air unit	wing กองบิน
8-2 A group of human	flock กลุ่ม
8-3 A group of animal	ฝูง
8-3-1 A group of fish	school shoal
8-3-2 A group of birds/sheep/goats	flock
8-3-3 A group of goats/cattle/elephants	herd
8-3-4 A group of dogs/wolves	pack
9 Be able to/have the ability to	สามารถ can could
10 Get/acquire	ได้ obtain have ⁷⁹ ได้รับ has had
10-1 Accept	take ⁸⁰ รับ took
11 Have	have got, have has มี possess had
12 Accumulate/Collect ⁸¹	gather ⁸² รวบรวม

⁷⁴ Be is to occupy a certain position or area, be somewhere, e.g., The boy is in the house.

⁷⁵ Stay is to stop and remain rather than go on or leave, e.g., Can you stay for dinner?

⁷⁶ Cover is to fill; extend over, e.g., The city covers 25 square miles.

⁷⁷ Stay is to live in a place for a while as a visitor or guest e.g., My mother is staying with us this week.

⁷⁸ To seem by expression or appearance, e.g., You look tired.

⁷⁹ Have is to receive or obtain, e.g., We must have your answer by Friday.

⁸⁰ Take is to accept, e.g., Do you take traveller's check?

⁸¹ Collect, e.g., collect evidence.

⁸² Gather, e.g., He travels about the world gathering facts about little-known diseases.

WordAsso Number and Class	Examples
13 Attribute value	
13-1 Name	Johns, Mary, คำแดง จอห์น รอนนี่
13-2 Sex	John, Ronne Randall โจนส์
13-3 Title	male, female ชาย หญิง
13-4 Job position	prof, mr, mrs, miss, dr. นาง คุณ
13-5 Occupation/function	dean, chairman, president
13-5-1 Human's occupation	faculty, student, nurse, doctor, nun, quack ยาม นางชี sister หมอเดือน
13-5-2 Animal's function	priest watch นักเรียน working dog, watching dog, hunting dog, toy dog, guard dog, quide dog, carriage dog
13-6 Kind/Sort	
13-6-1 Person (of color)	Asian, European, Negro, black คนดำ white คนขาว Egyptian คนอียิปต์ ไทย Thai
13-6-2 Animal (kind /pedigree)	dalmatian, toy poodle, doberman, alsatian, siamese cat, persian cat, butterfly
13-6-3 Plant (genus)	mountain rose, tea rose, china rose,
13-6-4 Equipment	Mac, PC, Unix
13-6-5 Number	even คู่
13-7 Age	10, 20, 30
13-7-1 Age of living thing	young, old แก่
13-7-1-1 Age of plant	young อ่อน
13-7-1-1-1 Age of plant part	green อ่อน
13-7-1-1-1-1 Age of fruit	green คับ
13-7-1-2 Age of human	
13-7-1-2-1 Age of male	หนุ่ม
13-7-1-2-2 Age of female	สาว
13-7-2 Age of non-living thing	เก่า old new ใหม่
13-8 Appearance	young, old
13-8-1 Size	little เล็ก
13-8-1-1 Size of a living thing	biggest โตที่สุด big โต
13-8-1-2 Size of a non-living thing	biggest ใหญ่ที่สุด big ใหญ่ ใหญ่มาก great
13-8-2 Weight	fat อ้วน อวบ plump
13-8-3 Length	short สั้น long ยาว
13-8-4 Beauty	ugly ugliest beautiful สวย สวยงาม
13-8-4-1 Beauty of a living thing	handsome รูปงาม
13-8-4-2 Beauty of a non-living thing	ซีเห่ร์ ซีเห่ร์ที่สุด
13-8-5 Texture	น่าเกลียด น่าเกลียดที่สุด
13-8-5-1 Covered in fresh grass and leaves	fine บาง
	green ⁸³ เขียวชุ่ม

⁸³ Green, e.g., The countryside is very green.

WordAsso Number and Class	Examples
13-8-5-2 Color	yellow สีเหลือง สีเทา gray black สีดำ ดำ brown สีน้ำตาล สีขาว white rose สีชมพูหลาย red สีแดง สีเขียว green bright สด even เรียบ
13-8-5-2-1	
13-8-5-3 Evenness	
13-8-9 Height	
13-8-9-1	high
13-8-9-2	tall
13-9 Trait	animal ⁸⁴ อย่างสัตว์
13-9-1 Wildness (A state of nature)	wild ป่า
13-9-2 Behavior	violent, wild อย่างบ้าคลั่ง
13-9-3 Inexperience	green ⁸⁵ อ่อนหัด
13-10 Quality	ดีมาก great ยิ่งใหญ่ beautiful น่ารัก lovely ความคิดที่ดีมาก ความสำเร็จที่ยิ่งใหญ่ fine ดีเลิศ use ประโยชน์ สดใส bright ⁸⁶
13-10-1 Kindness ⁸⁷	kind ใจดี
13-10-2 Humaneness ⁸⁸	kind กรุณา
13-10-3 Ability	เป็น able weak ⁸⁹ อ่อนแอ
13-10-4 movement and form	graceful อ่อนช้อย
13-10-5 Importance	important สำคัญ
13-10-6	bright ⁹⁰ ฉลาด clever
13-10-7	fine งดงาม
13-11 Healthy	fine สมายดี
13-12 Degree	
13-12-1 of temperature/weather	warm อุ่น cold หนาว fine ปลอดโปร่ง
13-12-2 of brightness	แจ่มใส sunny gleaming เป็นประกาย สว่าง bright
13-12-3 of emotionality	warm อบอุ่น มั่น ⁹¹ sadly อย่างเศร้าสร้อย cold เขียวเข็น เบื่อ tired อย่างภาคภูมิใจ proudly happy เป็นสุข เศร้า sad certainly อย่างแน่นอนแน่นอน sure true จริง
13-12-3-1 Happiness	
13-12-4 of certainty	
13-12-5 of truth	
13-13 Duration	long นาน สั้น little (while)
13-14 Timing	
13-14-1 before the usual/ arranged or expected time	early เร็วกว่าที่กำหนด

⁸⁴ Animal c.g., animal desires.

⁸⁵ Green is a young and inexperienced and therefore easily deceived and ready to believe anything.

⁸⁶ Bright is showing hope or signs of future success, e.g., You have a bright future ahead of you.

⁸⁷ Kindness is tendency to be kind and forgiving.

⁸⁸ Humaneness is the quality of compassion or consideration for others (people or animals).

⁸⁹ Weak is lacking power.

⁹⁰ Bright is clever, e.g., She's very bright.

⁹¹ มั่น is to feel a strong urge, to be having great pleasure.

WordAsso Number and Class	Examples
13-14-2 near the beginning of a period	early ตอนต้น
13-15 Frequency	
13-15-1 at any time	ever เคย, have ever
13-15-2 not ever	never ไม่เคย
13-15-3 more	อีก more ⁹² again
13-15-4 once again	again อีกครั้ง
13-15-5 one at a time	one_by_one ทีละหนึ่ง
13-16 State	
13-16-1 State of living thing	
13-16-1-1 out of danger	safe ปลอดภัย
13-16-1-2 danger	dangerous
13-16-2 State of non-living thing	
13-16-2-1 Not working/not operating	off ⁹³ ปิด
13-16-3 Readiness	willing
13-17 Order	
13-17-1 Immediately pass order	ที่แล้ว last
13-17-2 Coming after all others in time or space or degree or being the only one remaining	last สุดท้าย
13-17-3 Following in time	after หลังจาก
13-17-4 Immediately following in time	next ครั้งหน้า
13-17-5 (of time) before	to ก่อน by before
13-17-6 at an earlier point in an order than; ahead of	ก่อน before
13-17-7 Closest in space, order or degree; without anything coming before or between	next ถัดไป
13-17-8 Just afterward ⁹⁴	next ต่อไป then หลังจากนั้น
13-17-9 Further in space or time/forward	on ⁹⁵ ต่อไป
13-17-10 Finally	at last, ในที่สุด
13-17-11 A place or appointed time in a fixed order	turn ⁹⁶ รอบ
13-18 Likeness	
13-18-1 in the same way as; with the same quality as	like เหมือน
13-18-2 similar to; almost but not exactly the same	similar คล้าย
13-19 Distance in space or time	away ห่างไป
13-20 Position	left ซ้าย
13-21 Strength	
13-21-1 physically or mentally strong	weak อ่อนแอ
13-21-2 having a lot of the material which gives taste	strong แก่ (coffee)
13-22 Possibility	perhaps บางที
13-23 Cleanness	dirty ค่ำ

⁹² more; again, e.g., I'll repeat the question once more.

⁹³ off; not working; not operating; (of a machine or electrical apparatus). e.g., The TV is off.

⁹⁴ Just afterward, e.g., First, you heat that fat; next, you add the onions.

⁹⁵ On, e.g., If you walk on you'll come to the church; It's time to move on.

⁹⁶ Turn, e.g., You've missed your turn so you'll have to wait; It's my turn to drive next.

WordAsso Number and Class	Examples
13-24 Property of location	lonely ⁹⁷ โดดเดี่ยว
13-25 Shape	bend turn ทางโค้ง
13-26 Of or relating to	algebraic ทางพีชคณิต
13-27 in or into a state of being disconnected or removed	off ⁹⁸ ออก
13-28 Equality	even เสมอกัน
13-29 Correctness	right ถูก correct
13-30	willing
13-31 Aliveness	dead

⁹⁷ Lonely is a (of a building or other object) with no others of the same type near, e.g., a lonely house in the wood.

⁹⁸ off, e.g., How do you get this lid off?

A. 2 Other Classes

Words which are used to link phrases with clauses or connect clauses together or provide the basis for a descriptive phrase e.g., prepositions, conjunctions, definite determiner are classified as well in a separate classification.

WordAsso number and Class	Examples
R1 be someone or something, being, to be	be คือ เป็น (e.g., He is a teacher. The chairman of the department is Dr.Cercone.)
R2 too/ together/ in addition	with ด้วย
R3 in each other's company	with กับ
R4 by means of using, by means of	with ด้วย in ¹ through ผ่าน ² by on ³
R4-1 Using as a means of traveling	โดย on ⁴
R5 supported by	ด้วย on ⁵
R6 a having/possessing	with ซึ่งมี
R7 belonging to	of ของ animal ⁶ ของสัตว์
R7-1 belonging to a living thing	's ของ ของฉัน my
R7-1-1 belonging to him	his ของเขา
R7-1-2 belonging to her	her ของเธอ
R7-1-3 belonging to animal/plant	its ของมัน
R8 made from	of ทำด้วย
R9 from the group that includes	of ใน ภายใน
R10 against what might be expected; on the other hand	but แต่ only ⁷
R11 other than, except	but นอกจาก
R12 introductory various kind of clause	that ว่า
R13 being the one of two or more people or things that is far or further in time, place thought	that นั้น
R14 being the person, thing, idea, etc., which is understood or has just been mentioned	that ที่ ที่ซึ่ง where
R15 used to join two things; then, afterwards	and และ
R16 used before the last of a set of possibilities	or หรือ
R17 the remaining one of the set; what is left as well as that mentioned; an additional person or thing	other อื่น
R18 the remaining persons or things of the set; what are left as well as those mentioned; additional persons or things	others อื่นๆ
R19 so as to be in	into เข้าไป to ที่จะ

¹ In. e.g., Write it in pencil.

² Through, e.g., I got this job through an employment agency.

³ On, e.g., A car runs on petrol.

⁴ On, e.g., on foot, on a ship.

⁵ On, e.g., He went round the world on the money his aunt gave him.

⁶ Animal e.g., cooking with animal fats.

⁷ Only: except that, but; e.g., She wants to go, only she hasn't got enough money.

WordAsso number and Class	Examples
R20 so as to be	into เป็น
R21 in the direction toward	to ไปที่
R22 reaching as far as	to ถึง
R23 until and including	to จนกระทั่ง
R24 for the attention or possession of/ intended to be given to	to กับ for สำหรับ
R25 show a position	
R25-1 show a position/a contained by thing with depth, length and height; within an enclosed space, surrounded by an area	in ใน
R25-2 showing position in relation to a surface or supported by a surface	on บน
R25-3 in or to a lower place than; directly below	under ใต้
R26 being included as part of	in ⁸ ใน
R27 wearing	in ⁹ ใน
R28 at the time of/during	in ¹⁰ ใน on ¹¹
R29 showing the way something is done or happens	in ¹² อย่าง
R30 with the result that; therefore	so ดังนั้น then แล้ว
R31 in that case	then ถ้าเช่นนั้น
R32 as a result of; because of	เนื่องจาก through ¹³ for ¹⁴ as ด้วยเหตุที่ ¹⁵
R33 shows purpose	for สำหรับ เพื่อที่จะ to
R34 instead of	for แทน
R35 shows length of time	เป็นเวลา for ¹⁶
R36 shows distance	เป็นระยะ for ¹⁷
R37 as regards or in regard to ???	ในเรื่อง for ¹⁸
R38 on the subject of ???/with regard to	about เกี่ยวกับ on ¹⁹
R39 around; here and there; in all parts of	about ห้าง
R40 show name of the person who wrote	โดย by
R41 show the person or thing that performs an action or causes a result	โดย by
R42 passing through or along	by ทาง ²⁰
R43 near; beside	by ข้างๆ
R44 not later than	by ภายใน

⁸ In, e.g., Can you see the mistake in this sentence?

⁹ In, e.g., A man in uniform.

¹⁰ In, e.g., In spring, in January.

¹¹ On, e.g., on the morning of July.

¹² In, e.g., Speaking in anger.

¹³ Through, e.g., The war was lost through bad organization.

¹⁴ For, e.g., He was rewarded for his bravery.

¹⁵ ด้วยเหตุที่ e.g., As she has no car, she cannot get there easily.

¹⁶ For, e.g., She didn't answer for several minutes.

¹⁷ For, e.g., They ran fast for a mile or two.

¹⁸ For, e.g., France is famous for its wines.

¹⁹ On, e.g., a book on India.

²⁰ ทาง e.g., They came in by the back door., It's quicker if you go by the main road.

WordAsso number and Class	Examples
R45 in accordance with/according to	by ตาม ²¹ under ภายใต้ ²²
R46 used to show the size of units or groups that follow each other	by ทีละ
R47 show a point in space	at ²³ ที่
R48 at the time that	when ²⁴ เมื่อ as ขณะที่ ²⁵
R48-I show an exact point in time	at ²⁶ ตอน
R49 show an intended aim or object towards which a thing or action is directed	at ²⁷ ไปที่
R50 show the subject or activity in which a judgment about someone's ability is made	at ²⁸ ใน
R51 earlier than the time when	ก่อนที่ before ²⁹
R52 in or into a state of	under ภายใต้ ³⁰
R53 considering that	ในเมื่อ when ³¹
R54 on condition that; supposing that	if ถ้า
R55 although	if แม้ว่า
R56 exclusive of anyone or anything else	only ³² เท่านั้น
R57 nothing more than	only ³³ เพียงแต่
R58 every single one of two or more things or people considered separately.	each แต่ละ
R59 used in comparison	as เท่า ³⁴
R60 in the way or manner that	as ดังที่ ³⁵
R61 from one place to another	around ไปทั่ว ³⁶
R62 on all sides; surrounding a centre	around รอบๆ ³⁷
R63 somewhere near; in the area	around แถวนี้ ³⁸
R64 away from inside	ออกจาก out_of ³⁹
R65 starting at	
R65-I starting at (the stated place, position, or condition)	from จาก

²¹ ตาม e.g., to play by the rules.

²² Under: according to. e.g., Under the terms of the agreement, you have to pay weakly rent.

²³ At. e.g., at my house.

²⁴ When; at the time that: e.g., Things were different when I was a child.

²⁵ ขณะที่, while, when, e.g., He saw her as he was getting off the bus.

²⁶ At, e.g., at 10:00 pm; I often work at night.

²⁷ At, e.g., Aim at the target.

²⁸ At, e.g., He's clever at arranging things.

²⁹ Before, e.g., It will be some time we know the full results.

³⁰ Under, e.g., At last we brought the fire under control.

³¹ When; considering that, e.g., why do you want a new job when you've got such a good one already?

³² Only, e.g., I will have this car and this car only.

³³ Only, e.g., I was only asking.

³⁴ As, e.g., He's not as old as me.

³⁵ As, e.g., Do as I say; He does as his father said. (Another person gives an order).

³⁶ ไปทั่ว e.g., I travelled around for a few years.

³⁷ รอบๆ e.g., The children gathers around to hear the story.

³⁸ แถวนี้ e.g., Is there anyone around?

³⁹ out_of, e.g., We are moving out of our flat.

WordAsso number and Class	Examples
R65-2 starting at (the stated time)	from ตั้งแต่
R66 which is more than might be expected	even แม้แต่
R67 belonging to oneself and to no one else	own เอง
R68	to ให้

Appendix B

SL Dictionary

This appendix illustrates a fragment of the English dictionary, discussed in sections 3.3 and 5.1.3, in Prolog representation style as illustrated in (1). Each entry contains the English entry and all its possible syntactic categories.

(1) entry_e (English, [cat1, cat2, ...]).

```
entry_e('Egyptian',[n]).
entry_e('John',[n]).
entry_e('Mrs',[n]).
entry_e('Ronne Randall',[prop]).
entry_e(a,[det]).
entry_e(about,[prep,adv,adj]).
entry_e(again,[adv]).
entry_e(algebraic,[adj]).
entry_e(all,[adj,adv,pron,n,det]).
entry_e(all_by_yourself,[adj]).
entry_e(an,[det]).
entry_e(and,[conj]).
entry_e(anger,[n,v]).
entry_e(animal,[n,adj]).
entry_e(around,[adv,prep,adj]).
entry_e(as,[adv,conj,prep]).
entry_e(ask,[v]).
entry_e(at,[prep]).
entry_e(at_last,[adv]).
entry_e(away,[adv,adj]).
entry_e(be,[v,aux]).
entry_e(beautiful,[adj]).
entry_e(before,[adv,conj,adj,prep]).
entry_e(began,[vpast]).
```

entry_e(believe,[v]).
 entry_e(belong,[v]).
 entry_e(big,[adj]).
 entry_e(biggest,[adj]).
 entry_e(bird,[n]).
 entry_e(black,[adj,n]).
 entry_e(blow,[v]).
 entry_e(born,[vpast,adj]).
 entry_e(bright,[adj]).
 entry_e(brother,[n]).
 entry_e(brown,[adj,v]).
 entry_e(but,[conj,prep]).
 entry_e(by,[prep,adv]).
 entry_e(call,[v,n]).
 entry_e(came,[vpast]).
 entry_e(came_over,[vpast]).
 entry_e(can,[v,n]).
 entry_e(cat,[n]).
 entry_e(certainly,[adv]).
 entry_e(chase,[n,v]).
 entry_e(children,[n]).
 entry_e(cold,[adj,n,adv]).
 entry_e(come,[v]).
 entry_e(coming,[v,n]).
 entry_e(corner,[n,v]).
 entry_e(cottage,[n]).
 entry_e(could,[vpast]).
 entry_e(countryside,[n]).
 entry_e(cover,[v,n]).
 entry_e(crack,[v,n]).
 entry_e(crack_open,[v]).
 entry_e(cried,[vpast]).
 entry_e(cucumber,[n]).
 entry_e(curtain,[n]).
 entry_e(day,[n]).
 entry_e(decide,[v]).
 entry_e(do,[v]).
 entry_e(door,[n]).
 entry_e(dream,[v,n]).
 entry_e(duck,[n,v]).
 entry_e(duckling,[n]).
 entry_e(each,[adj,pron,adv]).
 entry_e(early,[adv,adj]).
 entry_e(eat,[v]).
 entry_e(edge,[n,v]).
 entry_e(egg,[v,n]).
 entry_e(even,[adj,adv]).
 entry_e(evening,[n]).
 entry_e(ever,[adv]).
 entry_e(farmyard,[n]).
 entry_e(fat,[adj,n]).

entry_e(feather,[n]).
 entry_e(feeling,[n,v]).
 entry_e(find,[v]).
 entry_e(fine,[n,v,adj,adv]).
 entry_e(fish,[n]).
 entry_e(fishing,[n,v]).
 entry_e(five,[n]).
 entry_e(flesh,[n]).
 entry_e(flew,[vpast]).
 entry_e(flock,[n,v]).
 entry_e(for,[prep,conj]).
 entry_e(friend,[n]).
 entry_e(from,[prep]).
 entry_e(gather,[v]).
 entry_e(geese,[n,plur]).
 entry_e(give,[v]).
 entry_e(happy,[adj]).
 entry_e(has,[v]).
 entry_e(hatch,[n,v]).
 entry_e(have,[v]).
 entry_e(have_ever,[v]).
 entry_e(he,[pron]).
 entry_e(head,[n]).
 entry_e(heard,[vpast]).
 entry_e(hen,[n]).
 entry_e(her,[pron]).
 entry_e(here,[adv]).
 entry_e(herself,[pron]).
 entry_e(hid,[vpast]).
 entry_e(hide,[v]).
 entry_e(hidden,[adj,vpast]).
 entry_e(hiding,[v]).
 entry_e(him,[pron]).
 entry_e(himself,[pron]).
 entry_e(his,[pron]).
 entry_e(home,[n]).
 entry_e(into,[prep]).
 entry_e(it,[pron]).
 entry_e(its,[pron]).
 entry_e(kind,[n,adj]).
 entry_e(knew,[vpast]).
 entry_e(know,[v]).
 entry_e(lake,[n]).
 entry_e(last,[v,adj,adv]).
 entry_e(led,[vpast]).
 entry_e(left,[adj,vpast]).
 entry_e(leg,[n]).
 entry_e(let,[n,v]).
 entry_e(lettuce,[n]).
 entry_e(like,[v,adj,prep]).
 entry_e(little,[adj,adv]).
 entry_e(live,[v,adj]).

entry_e(lonely,[adj]).
 entry_e(long,[adj,adv]).
 entry_e(look,[v,n]).
 entry_e(look_around,[v]).
 entry_e(love,[adj]).
 entry_e(make,[v,n]).
 entry_e(make_fun_of,[v]).
 entry_e(many,[adj]).
 entry_e(march,[v,n]).
 entry_e(marsh,[n]).
 entry_e(matter,[n,v]).
 entry_e(me,[pron]).
 entry_e(melt,[v]).
 entry_e(mind,[n,v]).
 entry_e(peep,[v,n]).
 entry_e(ran,[vpast]).
 entry_e(ran_after,[vpast]).
 entry_e(reed,[n]).
 entry_e(reflection,[n]).
 entry_e(release,[v,n]).
 entry_e(rend,[v]).
 entry_e(rent,[v,vpast]).
 entry_e(research,[n,v]).
 entry_e(rest,[n,v]).
 entry_e(room,[n]).
 entry_e(rose,[n,vpast,adj]).
 entry_e(run_away,[v]).
 entry_e(sad,[adj]).
 entry_e(sadly,[adv]).
 entry_e(safe,[adj,n]).
 entry_e(said,[vpast]).
 entry_e(salad,[n]).
 entry_e(sat,[vpast]).
 entry_e(saw,[n,v,vpast]).
 entry_e(school,[n,v]).
 entry_e(seen,[vpast]).
 entry_e(several,[adj]).
 entry_e(she,[pron]).
 entry_e(should,[aux]).
 entry_e(shout,[v,n]).
 entry_e(so,[adv,conj]).
 entry_e(spirit,[n,v]).
 entry_e(spread,[v,n]).
 entry_e(spring,[v,n]).
 entry_e(stay,[n,v]).
 entry_e(stopped,[vpast]).
 entry_e(stork,[n]).
 entry_e(student,[n]).
 entry_e(sunny,[adj]).
 entry_e(sure,[adj,adv]).
 entry_e(swan,[n]).
 entry_e(symbol,[n]).

entry_e(take,[v]).
 entry_e(talk,[v]).
 entry_e(that,[pron,conj,adj]).
 entry_e(them,[pron]).
 entry_e(then,[adv,adj]).
 entry_e(there,[adv,pron,n]).
 entry_e(they,[pron]).
 entry_e(think,[v]).
 entry_e(thought,[vpast]).
 entry_e(through,[prep,adv]).
 entry_e(tired,[adj,vpast]).
 entry_e(to,[prep,adv]).
 entry_e(told,[vpast]).
 entry_e(took,[vpast]).
 entry_e(traffic_light,[n]).
 entry_e(tried,[vpast]).
 entry_e(trout,[n]).
 entry_e(true,[adj]).
 entry_e(try,[v]).
 entry_e(turkey,[n]).
 entry_e(turn,[n,v]).
 entry_e(ugliest,[adj]).
 entry_e(ugly,[adj]).
 entry_e(under,[prep,adv]).
 entry_e(us,[pron]).
 entry_e(use,[n,v]).
 entry_e(vegetable,[n]).
 entry_e(very,[adj,adv]).
 entry_e(wait,[v]).
 entry_e(wander,[v]).
 entry_e(want,[v,n]).
 entry_e(warm,[adj,v]).
 entry_e(what,[pron,adj]).
 entry_e(wheat,[n]).
 entry_e(when,[pron,adv,conj]).
 entry_e(where,[adv,conj,n]).
 entry_e(white,[adj,n]).
 entry_e(wild,[adj,adv,n]).
 entry_e(will,[v,n,aux]).
 entry_e(willing,[n,adj]).
 entry_e(wind,[n,v]).
 entry_e(wing,[n,v]).
 entry_e(winter,[n]).
 entry_e(with,[prep]).
 entry_e(woman,[n]).
 entry_e(worm,[n]).
 entry_e(would,[vpast,aux]).
 entry_e(written,[vpast]).
 entry_e(yard,[v]).
 entry_e(yellow,[adj]).
 entry_e(you,[pron]).
 entry_e(young,[adj,n]).

SL-TL Dictionary

(1) entry (English, [wordasso ('Thail',[wordassol,wordasso2,...]),
wordasso ('Thai2',[wordassoa,wordassob,...]),...]).

190

```

entry(away, [wordasso('ห่างไป', ['13-19'])]).
entry(be, [wordasso('เป็น', ['r1']), wordasso('อยู่', ['6']), wordasso('คือ', ['r1']),
wordasso('เกิดขึ้น', ['2-1-2'])]).
entry(beautiful, [wordasso('สวย', ['13-8-4']), wordasso('สวยงาม', ['13-8-4']),
wordasso('ดีมาก', ['13-10'])]).
entry(before, [wordasso('ก่อน', ['13-17-5', '13-17-6']), wordasso('ก่อนที่', ['r51'])]).
entry(began, [wordasso('เริ่ม', ['2-36'])]).
entry(believe, [wordasso('เชื่อ', ['2-9-1', '2-9-4']), wordasso('เชื่อว่า', ['2-9-2'])]).
entry(belong_with, [wordasso('เป็นส่วนหนึ่งของ', ['6-9'])]).
entry(big, [wordasso('ใหญ่', ['13-8-1-2']), wordasso('โต', ['13-8-1-1'])]).
entry(biggest, [wordasso('ใหญ่ที่สุด', ['13-8-1-2']), wordasso('โตที่สุด', ['13-8-1-1'])]).
entry(bird, [wordasso('นก', ['1-1-1-2-1-2']), wordasso('สัตว์ปีก', ['1-1-1-2-1-2'])]).
entry(born, [wordasso('เกิด', ['2-1-1-16-1'])]).
entry(bright, [wordasso('สว่าง', ['13-12-2']), wordasso('สดใส', ['13-10']),
wordasso('สด', ['13-8-5-2-1']), wordasso('ฉลาด', ['13-10-6'])]).
entry(broken, [wordasso('ชำรุด', ['13-8-5'])]).
entry(brown, [wordasso('สีน้ำตาล', ['13-8-5-2']), wordasso('ทำให้เป็นสีน้ำตาล',
['2-1-1-8'])]).
entry(but, [wordasso('แต่', ['r10']), wordasso('นอกจาก', ['r11'])]).
entry(by, [wordasso('โดย', ['r40', 'r41']), wordasso('ด้วย', ['r4']), wordasso('ทาง',
['r42']),
wordasso('ข้างๆ', ['r43']), wordasso('ตาม', ['r45']), wordasso('ภายใน', ['r44']),
wordasso('ก่อน', ['13-17-5']), wordasso('ทีละ', ['r46'])]).
entry(call, [wordasso('เรียก', ['2-1-3-1-3']), wordasso('ประกาศ', ['2-1-3-1-7']),
wordasso('ตะโกน', ['2-1-3-1-1']),
wordasso('โทรศัพท์', ['2-1-3-1-6', '1-1-2-1-1-3-4-1']), wordasso('เสียงตะโกน',
['4-1-1-1'])]).
wordasso('เรียกว่า', ['2-33-1'])]).
entry(came, [wordasso('มา', ['2-1-5-6']), wordasso('มาถึง', ['2-37']),
wordasso('กลายเป็น', ['2-1-1-1'])]).
entry(came_over_to, [wordasso('ตรงมาที่', ['2-1-5-6'])]).
wordasso('ห้องน้ำ', ['1-1-2-1-1-2-3'])]).
entry(cat, [wordasso('แมว', ['1-1-1-2-1-1'])]).
entry(chase, [wordasso('ไล่', ['2-1-6']), wordasso('การตามล่า', ['2-2-1-1'])]).
entry(children, [wordasso('เด็กๆ', ['1-1-1-1-1-4']), wordasso('ลูกๆ',
['1-1-1-1-1-3-5'])]).
entry(come, [wordasso('มา', ['2-1-5-6']), wordasso('มาถึง', ['2-37']),
wordasso('กลายเป็น', ['2-1-1-1'])]).
entry(corner, [wordasso('มุม', ['1-1-2-1-3-1']), wordasso('จุนมุม', ['2-11'])]).
entry(cottage, [wordasso('กระท่อม', ['1-1-2-1-1-2-2'])]).
entry(could, [wordasso('สามารถ', ['9']), wordasso('ได้', ['a7', 'a8'])]).
entry(countryside, [wordasso('ชนบท', ['1-1-2-1-3-2-2-1'])]).
entry(cover, [wordasso('คลุม', ['2-1-19-2']), wordasso('ปิด', ['2-1-19-1']),
wordasso('ปกคลุม', ['2-1-18-2']),
wordasso('ครอบคลุม', ['6-4']), wordasso('หน้าปก', ['1-1-2-1-1-5-1-2'])]).
entry(crack, [wordasso('แตก', ['2-1-1-12-1']), wordasso('ตอก', ['2-1-1-13-1-2']),
wordasso('รอยร้าว', ['2-3-11-1']), wordasso('ร้าว', ['2-1-1-12-2-1']),

```

```

wordasso('แกะ', ['2-1-1-13-1-1']), wordasso('ปรี', ['2-1-1-12-2-2'])).
entry('crack_open', [wordasso('ปริแตกออก', ['2-1-1-12-2-2'])]).
entry(cried, [wordasso('ร้องไห้', ['2-1-3-1-2']), wordasso('ร้อง', ['2-1-3-1-1'])]).
entry(cucumber, [wordasso('แตงกวา', ['1-1-1-3-1-3-1', '1-1-2-1-2-1-2-1'])]).
entry(day, [wordasso('วัน', ['2-4-2-3', '2-4-3-1-2']), wordasso('กลางวัน',
['2-4-3-1-1'])]).
entry(decided, [wordasso('ตัดสินใจ', ['2-12']), wordasso('ตกลงใจ', ['2-12'])]).
entry(did, [wordasso('ทำ', ['2-34'])]).
entry(do, [wordasso('ทำ', ['2-34'])]).
entry(does, [wordasso('ทำ', ['2-34'])]).
entry(door, [wordasso('ประตู', ['1-1-2-1-1-2-1-1'])]).
entry(dream, [wordasso('ฝัน', ['2-1-8-2-1', '2-6']), wordasso('ความฝัน',
['2-5-1-2'])]).
entry(duck, [wordasso('เปิด', ['1-1-1-2-1-2-1', '1-1-2-1-2-1-2-4-1']),
wordasso('กุ่ม', ['2-1-5-2']), wordasso('จับตกลง', ['2-1-5-4-1']),
wordasso('ฆ่าลีนินขาว', ['1-1-2-1-1-1'])]).
entry(duckling, [wordasso('ลูกเปิด', ['1-1-1-2-1-2-1'])]).
entry(each, [wordasso('แต่ละ', ['r58'])]).
entry(early, [wordasso('เร็วกว่าที่กำหนด', ['13-14-1']), wordasso('ตอนต้น',
['13-14-2'])]).
entry(edge, [wordasso('ขอบ', ['1-1-2-1-3-2-4']), wordasso('เขยิบ', ['2-1-5-5'])]).
entry(egg, [wordasso('ไข่', ['1-1-2-1-2-1-2', '1-3-1']), wordasso('กระตุ่น',
['2-1-7'])]).
entry(evening, [wordasso('เวลาเย็น', ['2-4-3-1-1'])]).
entry(ever, [wordasso('เคย', ['13-15-1'])]).
entry(farmyard, [wordasso('ลานติดโรงนา', ['1-1-2-1-1-4'])]).
entry(fat, [wordasso('อ้วน', ['13-8-2']), wordasso('ไขมัน', ['1-1-2-1-2-5'])]).
entry(feather, [wordasso('ขนนก', ['1-4-1-2-3'])]).
entry(feeling, [wordasso('ความรู้สึก', ['2-5-3']), wordasso('รู้สึก', ['2-6-'])]).
entry(find, [wordasso('หาให้พบ', ['2-16'])]).
entry(fine, [wordasso('ดีเลิศ', ['13-10']), wordasso('งดงาม', ['13-10-7']),
wordasso('ปลอดโปร่ง', ['13-12-1']), wordasso('สบายดี', ['13-11']),
wordasso('ปรับ', ['2-1-3-4-1']), wordasso('คำปรับ', ['2-1-3-3-1']),
wordasso('ทำให้บริสุทธิ์', ['2-1-1-10']), wordasso('บาง', ['13-8-5']),
wordasso('ทำให้ละเอียดขึ้น', ['2-1-1-11'])]).
entry(fish, [wordasso('ปลา', ['1-1-1-2-1-3-1', '1-1-2-1-2-1-2-3'])]).
entry(fishing, [wordasso('ตกปลา', ['2-2-1-3-1']), wordasso('การประมง',
['2-2-1-1-3-2'])]).
entry(five, [wordasso('ห้า', ['2-4-1'])]).
entry(flesh, [wordasso('เนื้อ', ['1-4-1-3-1']), wordasso('ร่างกาย', ['1-1-2-1-4-2'])]).
entry(flew, [wordasso('บิน', ['2-1-18-1-4-1', '2-1-5-1'])]).
entry(flock, [wordasso('ฝูง', ['8-3-2']), wordasso('กลุ่ม', ['8-2']),
wordasso('เส้นใย', ['1-1-2-1-2-3-4'])]).
entry(for, [wordasso('สำหรับ', ['r24', 'r33']), wordasso('แทน', ['r34']),
wordasso('เนื่องจาก', ['r32']), wordasso('เป็นเวลา', ['r35']), wordasso
('เป็นระยะ', ['r36']), wordasso('ในเรื่อง', ['r37'])]).

```

```

entry(friend,[wordasso('เพื่อน',[ '1-1-1-1-1' ]),wordasso('ผู้สนับสนุน',[ '1-1-1-1-1-6' ])]).
entry(from,[wordasso('จาก',[ 'r65-1' ]),wordasso('ตั้งแต่',[ 'r65-2' ])]).
entry(gather,[wordasso('รวบรวม',[ '12' ]),wordasso('จับกลุ่ม',[ '2-1-3-5' ])]).
entry(geese,[wordasso('ห่าน',[ '1-1-1-2-1-2-1' ])]).
entry(gleaming,[wordasso('เป็นประกาย',[ '13-12-2' ])]).
entry(go,[wordasso('ไป',[ '2-1-5-1' ]),wordasso('กลายเป็น',[ '2-1-1-1' ])]).
entry(graceful,[wordasso('อ่อนช้อย',[ '13-10-4' ])]).
entry(gray,[wordasso('สีเทา',[ '13-8-5-2' ])]).
entry(hatch,[wordasso('ฟัก',[ '2-1-1-16-2', '2-1-8-1' ]),wordasso('คิด',[ '2-1-8-2' ]),wordasso('ฟาดพิศทองทองเรือ',[ '1-1-2-1-1-2-1-1' ])]).
entry(he,[wordasso('เขา',[ '7-1-1' ])]).
entry(head,[wordasso('หัว',[ '1-4-1-1-1' ])]).
entry(heard,[wordasso('ได้ยิน',[ '2-6' ])]).
entry(hen,[wordasso('ไก่',[ '1-1-1-2-1-2-2', '1-1-2-1-2-1-2-4-1' ])]).
entry(her,[wordasso('ของเธอ',[ 'r7-1-2' ]),wordasso('เธอ',[ '7-1-2' ])]).
entry(here,[wordasso('ที่นี่',[ '1-1-2-1-3-1' ])]).
entry(herself,[wordasso('ตัวเธอเอง',[ '7-1-2' ])]).
entry(hid,[wordasso('ได้ซ่อน',[ '2-10-1' ]),wordasso('ได้ปิดบัง',[ '2-10-2' ])]).
entry(hide,[wordasso('ซ่อน',[ '2-10-1' ]),wordasso('ปิดบัง',[ '2-10-2' ])]).
entry(hidden,[wordasso('ซ่อน',[ '2-10-1' ]),wordasso('ปิดบัง',[ '2-10-2' ])]).
entry(him,[wordasso('เขา',[ '7-1-1' ])]).
entry(himself,[wordasso('ตัวเขาเอง',[ '7-1-1' ])]).
entry(his,[wordasso('ของเขา',[ 'r7-1-1' ])]).
entry(home,[wordasso('บ้าน',[ '1-1-2-1-1-2-2' ]),wordasso('ที่อยู่อาศัย',[ '1-1-2-1-3-1-1' ])]).
entry(hungry,[wordasso('หิว',[ '5-4-2' ]),wordasso('กระหาย',[ '2-6-2-8', '5-4-2' ])]).
entry(i,[wordasso('ฉัน',[ '7-1' ])]).
entry(ice,[wordasso('น้ำแข็ง',[ '1-1-2-1-2-6-1' ])]).
entry(if,[wordasso('ถ้า',[ 'r54' ]),wordasso('แม้ว่า',[ 'r55' ])]).
entry(in,[wordasso('ใน',[ 'r25-1', 'r26', 'r27', 'r28' ]),wordasso('เข้ามา',[ '2-3-6-4' ]),wordasso('เข้าไป',[ '2-3-6-3' ]),wordasso('อย่าง',[ 'r29' ]),wordasso('ด้วย',[ 'r2', 'r4' ])]).
entry(into,[wordasso('เข้าไป',[ 'r19' ]),wordasso('เป็น',[ 'r20' ])]).
entry(it,[wordasso('มัน',[ '7-2' ])]).
entry(its,[wordasso('ของมัน',[ 'r7-1-3' ])]).
entry(make,[wordasso('ทำ',[ '2-1-8', '2-34' ]),wordasso('ทำให้',[ '2-1-1-17' ]),wordasso('ยี่ห้อ',[ '2-5-1-6-1-1' ])]).
entry('make_fun_of',[wordasso('เยาะเย้ย',[ '2-1-3-2-1' ])]).
entry(many,[wordasso('มาก',[ '2-4-5' ]),wordasso('หลาย',[ '2-4-5-1' ])]).
entry(neck,[wordasso('คอ',[ '1-4-1-1-2' ]),wordasso('กอดจูบ',[ '2-1-18-1-1' ])]).
entry(nest,[wordasso('รัง',[ '1-1-2-1-4' ]),wordasso('ทำรัง',[ '2-1-8-6' ])]).
entry(never,[wordasso('ไม่เคย',[ '13-15-2' ])]).
entry(new,[wordasso('ใหม่',[ '13-7-2' ])]).
entry(no,[wordasso('ไม่',[ 'a3' ]),wordasso('ไม่มี',[ 'a4' ])]).
entry(no_one,[wordasso('ไม่มีใคร',[ 'a5' ])]).

```

entry(not, [wordasso('ไม่', ['a2']), wordasso('ไม่มี', ['a4'])]).
 entry(of, [wordasso('ของ', ['r7']), wordasso('ทำด้วย', ['r8']), wordasso('ใน', ['r9'])]).
 entry(open, [wordasso('เปิด', ['2-1-1-1', '2-1-16']), wordasso('เริ่ม', ['2-1-17'])]).
 entry(or, [wordasso('หรือ', ['r16'])]).
 entry(other, [wordasso('อื่น', ['r17'])]).
 entry(others, [wordasso('อื่นๆ', ['r18'])]).
 entry(out, [wordasso('ออกมา', ['2-3-6-1']), wordasso('ออกไป', ['2-3-6-2']), wordasso('ออกจาก', ['2-3-8-1']), wordasso('ข้างนอก', ['1-1-2-1-3-2-1'])]).
 entry(out_of, [wordasso('ออกจาก', ['r64'])]).
 entry(plump, [wordasso('อวบ', ['13-8-2'])]).
 entry(pond, [wordasso('แอ่งน้ำ', ['1-1-2-1-6-2'])]).
 entry(proudly, [wordasso('อย่างภาคภูมิใจ', ['13-12-3'])]).
 entry(purr, [wordasso('เพอร์', ['4-1-1-2'])]).
 entry(quack, [wordasso('ควัก', ['4-1-1-2']), wordasso('หมอเถื่อน', ['13-5-1'])]).
 entry(ran, [wordasso('วิ่ง', ['2-1-5-9']), wordasso('ดำเนิน', ['2-1-13-1-1'])]).
 entry(ran_after, [wordasso('ไล่ตาม', ['2-1-5-10'])]).
 entry(red, [wordasso('สีแดง', ['13-8-5-2']), wordasso('คอมมิวนิสต์', ['1-1-1-1-1-7-1'])]).
 entry(reed, [wordasso('คันนก', ['1-1-1-3-1-2-1']), wordasso('ขลุ่ย', ['1-1-2-1-1-3-1-2'])]).
 entry(room, [wordasso('ห้อง', ['1-1-2-1-1-2-3']), wordasso('ที่ว่าง', ['2-21-3'])]).
 entry(salad, [wordasso('สลัด', ['1-1-2-1-2-1-1-1'])]).
 entry(sat, [wordasso('นั่ง', ['6-2'])]).
 entry(seen, [wordasso('เห็น', ['2-6'])]).
 entry(several, [wordasso('หลาย', ['2-4-5-1'])]).
 entry(she, [wordasso('เธอ', ['7-1-2'])]).
 entry(should, [wordasso('ควร', ['a12'])]).
 entry(shout, [wordasso('ตะโกน', ['2-1-3-1-1']), wordasso('การตะโกน', ['2-15-1-6-1'])]).
 entry(sister, [wordasso('พี่สาวน้องสาว', ['1-1-1-1-1-3-3']), wordasso('นางชี', ['13-5-1'])]).
 entry(sky, [wordasso('ท้องฟ้า', ['1-1-2-1-3-2-3'])]).
 entry(so, [wordasso('ดังนั้น', ['r30']), wordasso('อย่างนั้น', ['2-4-8'])]).
 entry(weak, [wordasso('อ่อนแอ', ['13-21-1', '13-10-3'])]).
 entry(went, [wordasso('ไป', ['2-1-5-1']), wordasso('กลายเป็น', ['2-1-1-1'])]).
 entry(what, [wordasso('อะไร', ['7-2-1']), wordasso('สิ่ง', ['7-2'])]).
 entry(wheat, [wordasso('ข้าวสาลี', ['1-1-1-3-1-2-1-1'])]).
 entry(when, [wordasso('ที่ไหน', ['7-3']), wordasso('ที่ซึ่ง', ['r14'])]).
 entry(white, [wordasso('สีขาว', ['13-8-5-2']), wordasso('คนขาว', ['13-6-1'])]).
 entry(yellow, [wordasso('สีเหลือง', ['13-8-5-2'])]).
 entry(you, [wordasso('คุณ', ['7-1'])]).

Appendix D

Types, Their Features and Their Value Types

This appendix illustrates some types defined in our grammars as discussed in section 6.1.1.2. Their features and their value types are also provided.

Type	Features/Type of value	Immediate Supertype
sign	$\left[\begin{array}{ll} \text{SYNSEM} & \text{synsem} \\ \text{QSTORE} & \text{set_quant} \end{array} \right]$	entity
phrase	...	sign
word	...	sign
synsem	$\left[\begin{array}{ll} \text{LOC} & \text{loc} \\ \text{NONLOCAL} & \text{nonlocal} \end{array} \right]$	mod_synsem
pre_mod_synsem		synsem
post_mod_synsem		synsem
loc	$\left[\begin{array}{ll} \text{CAT} & \text{cat} \\ \text{CONT} & \text{cont} \\ \text{CONX} & \text{conx} \end{array} \right]$	entity
conx	$\left[\text{BACKGR} \quad \text{set_psoa} \right]$	entity
cat	$\left[\begin{array}{ll} \text{HEAD} & \text{head} \\ \text{SPR} & \text{list_synsem} \\ \text{SUBJ} & \text{list_synsem} \\ \text{COMPS} & \text{list_synsem} \\ \text{MARKING} & \text{marking} \end{array} \right]$	entity
cont		entity
nom_obj	$\left[\begin{array}{ll} \text{MODE} & \text{mode} \\ \text{INDEX} & \text{ind} \\ \text{RESTR} & \text{set_psoa} \end{array} \right]$	cont

Type	Features/Type of value	Immediate Supertype
quant	[DET sem_det RESTIND nom_obj]	cont
forall exists the ind	[IGENN gend INUM num IPER per]	sem_det sem_det sem_det entity
it there ref psoa	[QUANTS list_quantsem_det NUCLEUS qfpsoa]	ind ind ind cont
qfpsoa	[SURFACE surface WORDASSO wordasso]	entity
property un_relation bin_relation tri_relation control_qfpsoa lang eng thai head	[INSTANCE ref]	qfpsoa qfpsoa qfpsoa qfpsoa qfpsoa entity lang lang entity
subst	[PRD boolean MOD mod_synsem]	head
noun	[CASE case WORDASSOI wordasso]	subst
verb	[VFORM vform INV boolean AUX boolean NEG boolean]	subst
adj prep reltvz clas case nom acc akol		subst subst subst subst entity case case entity

Type	Features/Type of value	Immediate Supertype
agr	[GENN gend NUM num PER per]	entity
masc		gend
fem		gend
neut		gend
sg		num
pl		num
first		per
second		per
third		per
bse		vform
fin		vform
pas		nform
func	[spec synsem]	head
mark		func
det	[count boolean]	func

Appendix E

Lexical Rules

This appendix contains the lexical rules discussed in section 6.1.1.3. Our lexical rule is adapted from the lexical rule which was provided by Gerald Penn [Penn 1993] and Colin Matheson [Matheson 1996]. Lexical rules 1-6 are used for deriving the third singular verb, simple past verb, present participle verb, passive verb and plural noun for English lexical entries. Lexical rule 6 is used to form the simple past verb for Thai.

1. The 3rd-singular verb lexical rule

$$\left[\begin{array}{ll} \text{PHON} & X \\ \text{HEAD} & \left[\begin{array}{ll} \text{VFORM} & \text{bse} \\ \text{AUX} & \boxed{1} \text{ minus} \\ \text{LANG} & \text{eng} \end{array} \right] \\ \text{SUBJ} & \langle \text{NP [nom]} \rangle \end{array} \right] \Rightarrow \left[\begin{array}{ll} \text{PHON} & X \rightarrow (X.s) \text{ or } (X.y) \rightarrow (X.i.es) \\ \text{HEAD} & \left[\begin{array}{ll} \text{VFORM} & \text{fin} \\ \text{AUX} & \boxed{1} \\ \text{LANG} & \text{eng} \end{array} \right] \\ \text{SUBJ} & \langle \text{NP [nom. sg]} \rangle \end{array} \right]$$

2. The simple-past verb lexical rule

$$\left[\begin{array}{ll} \text{PHON} & X \\ \text{HEAD} & \left[\begin{array}{ll} \text{VFORM} & \text{bse} \\ \text{AUX} & \boxed{1} \text{ minus} \\ \text{LANG} & \text{eng} \end{array} \right] \end{array} \right] \Rightarrow \left[\begin{array}{ll} \text{PHON} & X \rightarrow (X.ed) \text{ or } (X.y) \rightarrow (X.i.ed) \\ & \text{or } (X.e) \rightarrow (X.ed) \text{ or other irregular} \\ & \text{forms.} \\ \text{HEAD} & \left[\begin{array}{ll} \text{VFORM} & \text{fin} \\ \text{AUX} & \boxed{1} \\ \text{LANG} & \text{eng} \end{array} \right] \end{array} \right]$$

3. The present-participle lexical rule

$$\left[\begin{array}{cc} \text{PHON} & X \\ \text{HEAD} & \left[\begin{array}{cc} \text{VFORM} & \text{bse} \\ \text{AUX} & \boxed{1} \text{ minus} \\ \text{LANG} & \text{eng} \end{array} \right] \end{array} \right] \Rightarrow \left[\begin{array}{cc} \text{PHON} & X \rightarrow (X.\text{ing}) \text{ or } (X.\text{c}) \rightarrow (X.\text{ing}) \\ \text{HEAD} & \left[\begin{array}{cc} \text{VFORM} & \text{prp} \\ \text{AUX} & \boxed{1} \\ \text{LANG} & \text{eng} \end{array} \right] \end{array} \right]$$

4. The passive lexical rule

$$\left[\begin{array}{cc} \text{PHON} & X \\ \text{HEAD} & \left[\begin{array}{cc} \text{VFORM} & \text{bse} \\ \text{AUX} & \boxed{1} \text{ minus} \\ \text{LANG} & \text{eng} \end{array} \right] \\ \text{COMPS} & \left(\left[\begin{array}{cc} \text{CAT} & \boxed{2} \text{ [HEAD noun]} \\ \text{CONX} & \boxed{3} \mid \boxed{4} \end{array} \right] \right) \end{array} \right] \Rightarrow \left[\begin{array}{cc} \text{PHON} & X \\ \text{HEAD} & \left[\begin{array}{cc} \text{VFORM} & \text{pas} \\ \text{AUX} & \boxed{1} \text{ minus} \\ \text{LANG} & \text{eng} \end{array} \right] \\ \text{SUBJ} & \left(\left[\begin{array}{cc} \text{CAT} & \boxed{2} \text{ [HEAD noun]} \\ \text{CONX} & \boxed{3} \end{array} \right] \right) \\ \text{COMPS} & \boxed{4} \end{array} \right]$$

5. The plural noun formation

$$\left[\begin{array}{cc} \text{PHON} & X \\ \text{CAT} & \text{HEAD} \left[\begin{array}{cc} \text{noun} & \\ \text{AGR} & \text{sg} \\ \text{LANG} & \text{eng} \\ \text{SPR} & \boxed{1} \end{array} \right] \\ \text{CONT} & [\text{INDEX} [\text{NUM} \text{ sg}]] \end{array} \right] \Rightarrow \left[\begin{array}{cc} \text{PHON} & X \rightarrow (X.\text{s}) \text{ or other irregular forms.} \\ \text{CAT} & \text{HEAD} \left[\begin{array}{cc} \text{noun} & \\ \text{AGR} & \text{pl} \\ \text{LANG} & \text{eng} \\ \text{SPR} & \boxed{1} \end{array} \right] \\ \text{CONT} & [\text{INDEX} [\text{NUM} \text{ pl}]] \end{array} \right]$$

6. The Thai simple_past lexical rule

$$\left[\begin{array}{cc} \text{PHON} & X \\ \text{HEAD} & \left[\begin{array}{cc} \text{VFORM} & \text{bse} \\ \text{AUX} & \boxed{1} \text{ minus} \\ \text{LANG} & \text{thai} \end{array} \right] \end{array} \right] \Rightarrow \left[\begin{array}{cc} \text{PHON} & X \rightarrow ('1\text{๓}', X) \text{ or } X \rightarrow (X, '๒๓') \\ \text{HEAD} & \left[\begin{array}{cc} \text{VFORM} & \text{fin} \\ \text{AUX} & \boxed{1} \\ \text{LANG} & \text{thai} \end{array} \right] \end{array} \right]$$

It is noted that the Thai verb does not have an inflection resulting from verb agreement (see section 4.1). The words แล้ว (lɛ́ɛw) and ได้ (dâj) are added to the verb to indicate past tense. แล้ว (lɛ́ɛw) appears immediately after the verb whereas ได้ (dâj) immediately precedes the verb.

Appendix F

SL and TL Grammars

This appendix contains the English and Thai grammars discussed in section 6.1.1.6. Our grammar is a modification to the grammars which were provided by Gerald Penn [Penn 1993] and Colin Matheson [Matheson 1996].

F.1 English Grammar

1. Subject_Head Rule

$$\text{subj-hd-ph} \Rightarrow \left[\begin{array}{ll} \text{SUBJ-DTR} & [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} \boxed{1}] \\ \text{HD-DTR} & [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{SUBJ} \boxed{1}] \end{array} \right]$$

2. Head_Complement rule

$$\text{hd-comp-ph} \Rightarrow \left[\begin{array}{ll} \text{HD-DTR} & \left[\begin{array}{l} \text{word} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} | \text{COMP} \end{array} \begin{array}{l} \langle \boxed{1}, \boxed{2}, \dots, \boxed{n} \rangle \end{array} \right] \\ \text{NON-HD-DTRS} & \langle [\text{SYNSEM} \boxed{1}], [\text{SYNSEM} \boxed{2}], \dots, [\text{SYNSEM} \boxed{n}] \rangle \end{array} \right]$$

3. Coordination rule

$$\text{coordination-ph} \Rightarrow \left[\begin{array}{l} \text{CONJUNCT-DTR1} \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM | LOC | CAT } [1] \end{array} \right] \\ \text{COORDINATE-DTR} \left[\text{SYNSEM | LOC | CAT | HEAD } \text{conj} \right] \\ \text{CONJUNCT-DTR2} \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM | LOC | CAT } [1] \end{array} \right] \end{array} \right]$$

4. Head_Subject_Complement Rule

$$\text{hd-subj-comp-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \left[\begin{array}{l} \text{word} \\ \text{SYNSEM | LOC | CAT } \left[\begin{array}{l} \text{HEAD } [\text{INV } \text{yes}] \\ \text{SUBJ } [4] \\ \text{COMPS } \langle [1], [2], \dots, [3] \rangle \end{array} \right] \end{array} \right] \\ \text{SUBJ-DTR} \left[\text{SYNSEM | LOC | CAT | SUBJ } [4] \right] \\ \text{NON-HD-DTRS } \langle [\text{SYNSEM } [1]], [\text{SYNSEM } [2]], \dots, [\text{SYNSEM } [3]] \rangle \end{array} \right]$$

5. Specifier_head_Rule

$$\text{spr-hd-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \quad [2] \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM | LOC | CAT | SPR } [1] \end{array} \right] \\ \text{SPEC-DTR} \quad [1] \left[\text{SYNSEM | LOC | CAT | HEAD | SPEC } [2] \right] \end{array} \right]$$

6. Adjunct_head and Head_adjunct rules

$$\text{adjunct-hd-ph} \Rightarrow \left[\begin{array}{l} \text{ADJUNCT-DTR} \quad [\text{SYNSEM | LOC | CAT | HEAD | MOD } [2], \text{pre_mod_synsem}] \\ \text{HD-DTR} \quad [2] \left[\text{phrase} \right] \end{array} \right]$$

$$\text{hd- adjunct-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \quad [2] \left[\text{phrase} \right] \\ \text{ADJUNCT-DTR} \quad [\text{SYNSEM | LOC | CAT | HEAD | MOD } [2], \text{post_mod_synsem}] \end{array} \right]$$

F.2 Thai Grammar

1. Subject_Head Rule

$$\text{subj-hd-ph} \Rightarrow \left[\begin{array}{ll} \text{SUBJ-DTR} & [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} \boxed{1}] \\ \text{HD-DTR} & [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{SUBJ} \boxed{1}] \end{array} \right]$$

2. Head_Complement rule

$$\text{hd-comp-ph} \Rightarrow \left[\begin{array}{ll} \text{HD-DTR} & \left[\begin{array}{l} \text{word} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} | \text{COMP} \end{array} \left(\boxed{1}, \boxed{2}, \dots, \boxed{n} \right) \right] \\ \text{NON-HD-DTRS} & \langle [\text{SYNSEM} \boxed{1}], [\text{SYNSEM} \boxed{2}], \dots, [\text{SYNSEM} \boxed{n}] \rangle \end{array} \right]$$

3. Coordination rule

$$\text{coordination-ph} \Rightarrow \left[\begin{array}{ll} \text{CONJUNCT-DTR1} & \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} \boxed{1} \end{array} \right] \\ \text{COORDINATE-DTR} & [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} \text{ conj}] \\ \text{CONJUNCT-DTR2} & \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} \boxed{1} \end{array} \right] \end{array} \right]$$

4. Head_specifier Rule

$$\text{hd-spr-ph} \Rightarrow \left[\begin{array}{ll} \text{HD-DTR} & \boxed{2} \left[\begin{array}{l} \text{phrase} \\ \text{SYNSEM} | \text{LOC} | \text{CAT} | \text{SPR} \boxed{1} \end{array} \right] \\ \text{SPEC-DTR} & \boxed{1} [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} | \text{SPEC} \boxed{2}] \end{array} \right]$$

5. Adjunct_head and Head_adjunct rules

$$\text{adjunct-hd-ph} \Rightarrow \left[\begin{array}{l} \text{ADJUNCT-DTR} \quad [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} | \text{MOD} \boxed{2}, \\ \text{HD-DTR} \quad \boxed{2} [\text{phrase}] \end{array} \begin{array}{l} \text{pre_mod_synsem} \\ \end{array} \right]$$

$$\text{hd- adjunct-ph} \Rightarrow \left[\begin{array}{l} \text{HD-DTR} \quad \boxed{2} [\text{phrase}] \\ \text{ADJUNCT-DTR} \quad [\text{SYNSEM} | \text{LOC} | \text{CAT} | \text{HEAD} | \text{MOD} \boxed{2}, \\ \text{post_mod_synsem}] \end{array} \right]$$

Appendix G

Intelligibility and Fidelity Evaluation

This appendix contains the evaluation of ALMT with respect to *intelligibility* and *fidelity* as outlined in Chapter 8.

Source Text:

Sentence 1- 76: The ugly duckling version written by Ronne Randall (1987).

Sentence 77- 90: Newspapers and Articles.

Translators:

HM1: Thai Linguist

HM2: Thai Student (Graduate School)

Legends:

- ☐ Inappropriate word usage: This word does not distort the meaning of the expression but it is inappropriate.
Incorrectly translated word: This word is incorrectly translated. It causes the sentence to be meaningless or the sentence conveys a different meaning from the original.
- ↖ Misplaced word: The word is wrongly placed and it affects the meaning of the sentence. It should be moved in the direction of the arrow.
- ↗ Misplaced word: The word is wrongly placed and it affects the meaning of the sentence. It should be moved in the direction of the arrow.

1. SL: It was a warm sunny day.
 TC: มัน (it) เป็น (was) วัน (day) ที่ (which) สดใส (sunny) อุ่นๆ (warm) วัน (classifier) หนึ่ง (a)
 HM1: ใน เข้า วัน ที่ อากาศ อุ่นๆ แสงแดด จัดจ้าน หนึ่ง
 HM2: วัน ที่ แสงแดด จัดจ้าน
 No repair required.
2. SL: A mother duck sat on her nest at the edge of a pond waiting for her eggs to hatch.
 TC: แม่ (mother) เป็ด (duck) ตัว (classifier) หนึ่ง (a) ไถ่ (sat) บน (on) รัง (nest) ของเธอ (her) ที่ (at) ขอบ (edge) ขอบ (classifier) นั้น (the) ของ (of) แ่งน้ำ (pond) แอ่ง (classifier) หนึ่ง (a) รอ (waiting) สำหรับ (for) ไข่ (egg) หลาย (plurality) ของเธอ (her) ที่จะ (to) ฟักตัว (hatch)
 HM1: แม่ เป็ด ตัว หนึ่ง กไข่ ของมัน อยู่ใน รัง ข้างๆ สระน้ำ มัน กำลัง รอ ให้ ไข่ ฟักตัว
 HM2: แม่ เป็ด หนึ่ง กไข่ บน รัง ของมัน ที่ ริม บึง เพื่อ รอ ให้ ไข่ ฟัก
 No repair required.
3. SL: one_by_one, the eggs began to crack_open.
 TC: ทีละหนึ่ง (one_by_one), ไข่ (egg) หลาย (plurality) ฟอง (classifier) นั้น (the) ได้ เริ่ม (began) ที่จะ (to) แตกออก (crack_open)
 HM1: ไข่ แต่ละใบ ค่อยๆ แตก เป็ดออก ออก
 HM2: ไข่ เริ่ม ฟัก ทีละใบ ทีละใบ
 I misplaced word.
4. SL: Peep, Peep, said each little yellow duckling as it poked out its head and looked around.
 TC: เป็ด (peep), เป็ด (peep), ลูกเป็ด (duckling) สีเหลือง (yellow) เล็ก (little) แต่ละ (each) ตัว (classifier) พูด (said) ดังที่ (as) มัน (it) ได้ไม่ลื้ม (poked) ออกมา (out) หัว (head) ของมัน (its) และ (and) ไต่มอง (looked) รอบๆ (around)
 HM1: เป็ด เป็ด เสียง เจ้า ลูกเป็ด ตัวเล็กๆ สีเหลือง พวกมัน ส่งเสียงร้อง ขณะที่ พวกมัน ไต่ หัว พวก เป็ดออกไข่ และ มอง ไปรอบๆ
 HM2: เป็ด เสียงร้อง จาก ลูกเป็ด สีเหลือง แต่ละ ตัว ขณะที่ มัน ไต่ หัว และ มอง ไปรอบๆ
 I misplaced word, I incorrectly translated word.
5. SL: Quack, quack, said the mother duck feeling very pleased with herself.
 TC: แควก (quack), แควก (quack), แม่ (mother) เป็ด (duck) ตัว (classifier) หนึ่ง (the) พูด (said) ความรู้สึก (feeling) พอใจ (pleased) มากๆ (very) กับ (with) ตัวเธอเอง (herself)
 HM1: แควก แควก แม่ เป็ด ร้อง มัน ดีใจ ที่ ได้เห็น ลูกๆ

HM2: แม่ เบ็ด ร่อง ภายๆ ด้วย ความ ดีใจ
I incorrectly translated word.

6. SL: The biggest egg hatched last of all

TC: ไช้ (egg) ที่ (which) ใหญ่ที่สุด (biggest) ไค้ฟัก (hatched) สุดท้าย (last) ของ (of) ทั้งหมด (all)

HM1: ไช้ ที่ ใหญ่ที่สุด ฟัก ตัว เป็น ใบสุดท้าย

HM2: ไช้ ใบ ใหญ่ที่สุด ฟัก ตัว เป็น ใบสุดท้าย

Grammatically incorrect.

7. SL: But the duckling that poked out his head was not little and yellow like the others

TC: แต่ (but) ลูกเป็ด (duckling) ตัว (classifier) นั้น (the) ที่ (that) ไค้โผล่ (poked) ข้างนอก (out) หัว (head) ของเขา (his) ไม่ (not) เล็ก (little) และ (and) สีเหลือง (yellow) เหมือน (like) หัวอื่นๆ (the others) ๓

HM1: แต่ เจ้า ลูกเป็ด ที่ โผล่ หัว ออกมา นั้น ตัว ไม่ เล็ก นึก และ ไม่ใช่ สีเหลือง เหมือน ตัวอื่นๆ

HM2: แต่ ลูกเป็ด ตัว นั้น ไม่ ได้ ตัว เล็ก และ สีเหลือง เหมือน ตัวอื่นๆ

I misplaced word, 2 incorrectly translated words.

8. SL: He was big and gray and ugly

TC: เขา (he) โต (big) และ (and) สีเทา (gray) และ (and) ชีเห่ร (ugly)

HM1: มัน กลับ ตัว ใหญ่ มี สีเทา และ ดู น่าเกลียด

HM2: มัน กลับ ตัว ใหญ่ สีเทา และ ดู น่าเกลียด

No repair required.

9. SL: Quack, said the mother duck

TC: แควก (quack), แม่ (mother) เป็ด (duck) ตัว (classifier) นั้น (the) พูด (said)

HM1: แควก แม่ เบ็ด ร่อง

HM2: แม่ เบ็ด ร่อง ออกมา ก้าน

No repair required.

10. SL: You are the ugliest duckling I have ever seen

TC: คุณ (you) เป็น (are) ลูกเป็ด (duckling) ที่ (which) ชีเห่รที่สุด (ugliest) มัน (I) เคย (have ever) เห็น (seen)

HM1: แก เป็น ลูกเป็ด ที่ น่าเกลียดที่สุด เท่าที่ ฉัน เคย เห็น

HM2: แก เป็น ลูกเป็ด ที่ น่าเกลียดที่สุด ที่ ฉัน เคย เห็น

Grammatically incorrect.

11. SL: The mother duck led her ducklings into the water.

TC: แม่ (mother) เบ็ด (duck) ตัว (classifier) นั้น (the) ได้นำ (led) ลูกเบ็ด (duckling) หลาย (plurality) ตัว (classifier) ของเธอ (her) เข้าไปใน (into) น้ำ (water) นั้น (the)

HM1: แม่ เบ็ด พา ลูกๆ ของมัน ลงไป ใน สระน้ำ

HM2: แม่ เบ็ด พา ลูก ลงไป ใน น้ำ

No repair required, I inappropriate word usage.

12. SL: The other ducks gathered around.

TC: เบ็ด (duck) ตัวอื่น (the other) หลาย (plurality) ตัว (classifier) ได้จับกลุ่ม (gathered) รอบๆ (around)

HM1: เบ็ด ตัวอื่นๆ ใน สระ ้วย เข้ามา ใกล้ๆ แม่เบ็ด และ ลูกๆ

HM2: เบ็ด ตัวอื่นๆ เริ่ม รวมตัว กัน

No repair required.

13. SL: what lovely children you have, they told her.

TC: เด็กๆ (children) ที่ (which) น่ารัก (lovely) อะไร (what) คุณ (you) มี (have), พวกเขา (they) ไดบอก (told) เธอ (her)

HM1: เจ้า มี ลูกๆ ที่ น่ารัก จจริงๆ เบ็ด เหล่านั้น พูด กับ แม่ เบ็ด

HM2: ลูกๆ เธอ น่ารัก ทั้งนั้น เลยนะ เบ็ด ตัวอื่น พร้อมกัน บอก เธอ

2 misplaced words.

14. SL: But when they saw the big gray duckling, they began to laugh.

TC: แต่ (but) เมื่อ (when) พวกเขา (they) ได้เห็น (saw) ลูกเบ็ด (the) สีเทา (gray) โต (big) ตัว (classifier) นั้น (the), พวกเขา (they) ได้เริ่ม (began) ที่จะ (to) หัวเราะ (laugh)

HM1: แต่ เมื่อ เบ็ด พวกนั้น ได้เห็น ลูกเบ็ด สีเทา ตัวใหญ่ พวกมัน พากัน หัวเราะ

HM2: แต่ เมื่อ มองเห็น ลูกเบ็ด สีเทา ตัวใหญ่ พวกมัน ทั้งหมด พากัน หัวเราะ

No repair required.

15. SL: That one is not lovely, they said

TC: ว่า (that) หนึ่ง (one) ไม่ (not) น่ารัก (not), พวกเขา (they) พูด (said)

HM1: เจ้า ตัว นี้ ไม่ น่ารัก เอาเลย เบ็ด เหล่านั้น พูด

HM2: มี ตัว นี้แหละ ที่ ไม่ น่ารัก

2 incorrectly translated words.

16. SL: what an ugly duckling he is !

TC: ลูกเป็ด (duckling) ที่ (which) ซี้เหว่ (ugly) ตัว (classifier) หนึ่ง (an) อะไร (what) เขา (he) เป็น (is) เช่นนั้น (I)

HM1: ลูกเป็ด อะไร นะ น่าเกลียด จังจิง

HM2: ลูกเป็ด อะไร นะ น่าเกลียด จังจิง

2 misplaced words.

17. SL: The mother duck took her ducklings to the farmyard.

TC: แม่ (mother) เป็ด (duck) ตัว (classifier) หนึ่ง (the) ไดเอา (took) ลูกเป็ด (duckling) หลาย (plurality) ตัว (classifier) ของเธอ (her) ไปที่ (to) ลานคตโรงนา (farmyard) แห่ง (classifier) นั้น (the)

HM1: แม่ เป็ด พา ลูกๆ ของมัน ไปยัง ลานในฟาร์ม แห่ง หนึ่ง

HM2: แม่ เป็ด พา ลูกๆ ไปยัง สวน แห่ง หนึ่ง

No repair required, 1 inappropriate word usage.

18. SL: When the other animals saw the big gray duckling, they all began to shout.

TC: เมื่อ (when) สัตว์ (animal) หลาย (plurality) ตัว (classifier) ตัวอื่น (the other) ได้เห็น (saw) ลูกเป็ด (duckling) ที่ (which) สีเทา (gray) โต (big) ตัว (classifier) นั้น (the), พวกเขา (they) ทั้งหมด (all) ได้เริ่ม (began) ที่จะ (to) ตะโกน (shout)

HM1: ครั้น สัตว์ ตัวอื่นๆ เห็น ลูกเป็ด สีเทา ตัว ใหญ่ พวกมัน พวก ตะโกน ลั่น

HM2: เมื่อ สัตว์ อื่น เห็น ลูกเป็ด สีเทา ก็ พวก หัวเราะ แล้วให้

1 misplaced word.

19. SL: What an ugly duckling he is ! they said.

TC: : ลูกเป็ด (duckling) ที่ (which) ซี้เหว่ (ugly) ตัว (classifier) หนึ่ง (an) อะไร (what) เขา (he) เป็น (is) เช่นนั้น (I) พวกเขา (they) ได้พูด (said)

HM1: ลูกเป็ด อะไรกันนี้ น่าเกลียด จังจิง พวกมัน พูดขึ้น

HM2: ลูกเป็ด อะไรนะ น่าเกลียด จังจิง

2 misplaced words.

20. SL: He does not belong with us.

TC: เขา (he) ไม่ (not) ใช้ส่วนหนึ่งของ (belong with) พวกเรา (us)

HM1: แก ไม่ใช่ พวกเดียว กับ เรา

HM2: มัน เข้าพวก กับ เรา ไม่ได้หรอก

No repair required.

21. SL: The geese and the turkeys ran_after the duckling and tried to chase him away.

TC: พวกห่าน (geese) นั้น (the) และ (and) ไก่จวง (turkey) หลาย (plurality) ตัว (classifier) มัน (the) ได้ไล่ตาม (tried) ลูกเป็ด (duckling) ตัว (classifier) นั้น (the) และ (and) ได้พยายาม (tried) ที่จะ (to)ไล่ (chase) เขา (him) ห่างไป (away)

HM1: ห่าน และ ไก่จวง พวกมัน รังไล่ ลูกเป็ด และ พยายาม มัน ออกจาก ฝูง

HM2: ห่าน และ ไก่จวง ต่าง รังไล่ มัน ให้ ออกไป

Grammatically incorrect.

22. SL: Even his own brothers and sisters joined_in and called_him_names.

TC: แม้แต่ (even) พี่ชายน้องชาย (brother) หลาย (plurality) คน (classifier) ของเขา (his) เอง (own) และ (and) พี่สาวน้องสาว (sister) หลาย (plurality) คน (classifier) เข้าร่วม (joined_in) และ (and) ตั้งฉายาเขาต่างๆ (called_him_names)

HM1: กระทั่ง ลูกเป็ด ที่ เป็น พี่น้อง ของมัน เอง ยังช่วย พวกมัน ขับไล่ และ คำว่า มัน

HM2: แม้แต่ พี่น้อง ของมัน ก็เอาด้วยนะ ล้อ ต่างๆนาๆ

Grammatically incorrect.

23. SL: The ugly duckling hid in a corner of the farmyard and cried.

TC: ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ (ugly) ตัว (classifier) นั้น (the) ได้ซ่อน (hid) ใน (in) มุม (corner) มุม (classifier) หนึ่ง (a) ของ (of) ลานคอกโรงนา (farmyard) แห่ง (classifier) นั้น (the) และ (and) ได้ร้องไห้ (cried)

HM1: เจ้าลูกเป็ด ขี้เหร่ เข้าไป แอบ อยู่ที่ มุม หนึ่ง ของ ฟาร์ม และ เริ่ม ร้องไห้

HM2: ลูกเป็ด ขี้เหร่ ที่ น่าเกลียด เลยซ่อน ตัว ที่ มุม หนึ่ง ของ ฟาร์ม แล้ว มัน ร้องไห้

No repair required.

24.1. SL: The next morning,

TC: เช้า (morning) วัน (classifier) ถัดไป (next) นั้น (the)

HM1: เช้า วัน ต่อมา

HM2: เช้า วัน รุ่งขึ้น

No repair required.

24.2. SL: The ugly duckling decided to run_away

TC: ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ (ugly) ตัว (classifier) นั้น (the) ได้ตัดสินใจ (decided) ที่จะ (to) หนีจากไป (run_away)

HM1: ลูกเปิด ชีห์เร่ ตัดลิ้นใจ ที่จะ หนีไป
HM2: ลูกเปิด ชีห์เร่ ตัดลิ้นใจ ที่จะ หนีไป

No repair required.

25. SL: I will find a place where no_one will make_fun_of me, he said to himself.

TC: ฉัน (I) จะ (will) หาไหน (find) ที่ (place) ที่ (classifier) หนึ่ง (a) ที่ซึ่ง (where) ไม่มีใคร (no_one) จะ (will) เอาเย้ย (make_fun_of) ฉัน (me), เขา (he) ได้พูด (said) กับ (to) ตัวเขาเอง (himself)

HM1: ฉัน จะ ไปอยู่ ที่อื่น ที่ๆ ไม่มีใคร หัวเราะเยาะ ฉัน ได้อีก ลูกเปิด นอก กับ ตัวเอง

HM2: ฉัน จะ หา ที่ ลึก ที่ หนึ่ง ที่ ไม่มีใคร เอาเย้ย ฉัน มัน พูด กับ ตัวเอง

No repair required.

26. SL: He left the farmyard and ran to the great marsh where the wild ducks lived.

TC: เขา (he) ได้จาก (left) ลานติดโรงนา (farmyard) แห่ง (classifier) หนึ่ง (the) และ (and) ได้วิ่ง (ran) ไปที่ (to) หนองน้ำ (marsh) ใหญ่มาก (great) หนอง (classifier) หนึ่ง (the) ที่ไหน (where) เป็ด (duck) ป่า (wild) หลาย (plurality) ตัว (classifier) นั้น (the) ได้อาศัยอยู่ (lived)

HM1: มัน ออกจาก ฟาร์ม และ ตรงไปยัง บึง ใหญ่ แห่ง หนึ่ง ที่ มี เป็ด ป่า อาศัยอยู่

HM2: มัน ออกจาก ฟาร์ม แล้ว วิ่งไป ที่ ทุ่งเปียๆ ที่ เป็ด ป่า อาศัยอยู่

1 incorrectly translated word.

27. SL: Perhaps they will be kind to me, he said sadly.

TC: บางที (perhaps) พวกเขา (they) จะ (will) ใจดี (kind) กับ (to) ฉัน (me), เขา (he) ได้พูด (said) อย่างเศร้าสร้อย (sadly)

HM1: บางที พวกนั้น อาจจะ ดี กับ ฉัน ก็ได้ มัน พูด กับ ตัวเอง อย่างเศร้าสร้อย

HM2: บางที พวกเขาอาจจะ ดี กับ เรา ก็ได้ มัน พูด ด้วยความเศร้าสร้อย

No repair required.

28. SL: But the wild ducks were not kind.

TC: แต่ (but) เป็ด (duck) ป่า (wild) หลาย (plurality) ตัว (classifier) นั้น (the) ไม่ (not) ใจดี (kind)

HM1: แต่ เจ้า เป็ด ป่า ไม่ได้ ดี กับ มัน เลย

HM2: แต่ เป็ด ป่า กลับ ไม่ ใจดี

No repair required.

29. SL: You are very ugly, they said.

TC: คุณ (you) ชีห์เร่ (ugly) มากๆ (very), พวกเขา (they) พูด (said)

HM1: แก มั่น นำเกลียด พวกมัน พูด
HM2: แก นะ นำเกลียด จริงๆ

No repair required.

30. SL: You are certainly not one of us
TC: คุณ (you) เป็น (are) อย่างแน่นอน (certainly) ไม่ (not) หนึ่ง (one) ของ (of) พวกเรา (us)
HM1: แก ไม่ใช่ พวกเรา แน่ๆ
HM2: แก ไม่ใช่ หนึ่ง ของพวกเรา แน่ๆ

2 misplaced words.

31. SL: And the wild ducks laughed at the duckling
TC: และ (and) เบ็ด (duck) ป่า (wild) หลาย (plurality) ตัว (classifier) นั้น (the) ได้หัวเราะเยาะ (laughed_at) ลูกเบ็ด (duckling) ตัว (classifier) นั้น (the)
HM1: แล้ว เบ็ด ป่า ก็ พากัน หัวเราะเยาะ ลูกเบ็ด ซี่เห่
HM2: เบ็ด ป่า ก็ หัวเราะเยาะ ลูกเบ็ด

No repair required

32. SL: So the ugly duckling left the marsh.
TC: ดังนั้น (so) ลูกเบ็ด (duckling) ที่ (which) ซี่เห่ (ugly) ตัว (classifier) นั้น (the) ได้จาก (left) หนองน้ำ (marsh) หนอง (classifier) นั้น (the)
HM1: ลูกเบ็ด ซี่เห่ จึง ออกไป จาก บึง แห่ง นั้น
HM2: ลูกเบ็ด ซี่เห่ จึง ออกจาก พุงเปียๆ นั้น

No repair required

33. SL: the wind was blowing and it was cold.
TC: ลม (wind) นั้น (the) กำลัง (continuous tense) พัด (blow) และ (and) มัน (it) หนาว (cold)
HM1: มี กระแสลม พัดมา และ มัน อากาศ เริ่ม เป็น ลม
HM2: ลม ก็ แรง และ มัน ก็ หนาว

No repair required.

34. SL: Winter was coming
TC: ฤดูหนาว (winter) กำลัง (continuous tense) มา (come)

39. SL: An old woman lived in the cottage with a fat black cat and a plump brown hen.

TC: ผู้หญิง (woman) แก่ (old) คน (classifier) หนึ่ง (an) ได้อาศัยอยู่ (lived) ใน (in) กระท่อม (cottage) หลัง (classifier) นั้น (the) ด้วย (with) แมว (cat) สีดำ (black) อ้วน (fat) ตัว (classifier) หนึ่ง (a) และ (and) ไก่ (hen) สีนํ้าตาล (brown) อวบ (plump) ตัว (classifier) หนึ่ง (a)

HM1: มี หญิงชรา อาศัยอยู่ ใน กระท่อม นาง อยู่ กับ แมว ตัว อ้วน สีดำ และ แม่ ไก่ ตัว ใหญ่ สีนํ้าตาล

HM2: หญิงชรา อาศัยอยู่ ใน กระท่อม กับ แมว สีดำ ตัว อ้วน และ ไก่ สีนํ้าตาล ตัว อวบ

I incorrectly translated word.

40. SL: The old woman did not mind the ugly duckling but the cat and the hen wanted him to leave.

TC: ผู้หญิง (woman) แก่ (old) คน (classifier) นั้น (the) ไม่ (not) รังเกียจ (mind) ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ (ugly) ตัว (classifier) นั้น (the) แต่ (but) แมว (cat) ตัว (classifier) นั้น (the) และ (and) ไก่ (hen) ตัว (classifier) นั้น (the) ได้ต้องการ (wanted) เขา (him) กับ (to) จาก (leave)

HM1: หญิงชรา ไม่ รังเกียจ เจ้า ลูกเป็ด ขี้เหร่ แต่ แมว และ ไก่ ของนาง ต้องการ ให้ เขา ลูกเป็ด ออกไป จาก กระท่อม

HM2: หญิงชรา ไม่ได้ ว่า อะไรแต่ แมว และ ไก่ ต้องการ ให้ มัน ออกไป

I incorrectly translated word.

41. SL: Can you purr ? asked the cat

TC: คุณ (you) สามารถ (can) ทำเสียงพ้องแมว (purr) ได้ไหม (?) แมว (cat) ตัว (classifier) นั้น (the) ได้ถาม (asked)

HM1: แก ร้องอย่างแมว ได้ไหม แมวถามขึ้น

HM2: เออ ร้องอย่างแมว ได้ไหม

No repair required.

42. SL: No, said the ugly duckling.

TC: ไม่ (no), ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ (ugly) ตัว (classifier) นั้น (the) ได้พูด (said)

HM1: ไม่ได้หรอก ลูกเป็ด ขี้เหร่ ตอบ

HM2: ไม่ได้หรอก ลูกเป็ด ขี้เหร่ บอก

No repair required.

43. SL: Can you lay eggs ? asked the hen.

TC: คุณ (you) สามารถ (can) วาง (lay) ไข่ (egg) หลาย (plurality) ฟอง (classifier) ได้ไหม (?) ไก่ (hen) ตัว (classifier) นั้น (the) ได้ถาม (asked)

HM1: แก วาง ไข่ ได้ไหม แม่ ไก่ ถาม นาง

HM2: แก ออก ไข่ ได้มั๊ย

No repair required.

HM1: ฤดูหนาว กำลัง จะ มาถึง
HM2: หน้าหนาว กำลัง จะ มาถึง

No repair required.

35. SL: The ugly duckling was very tired.

TC: ลูกเป็ด (duckling) ที่ (which) ซี้เหว (ugly) ตัว (classifier) นั้น (the) เหนื่อย (tired) มากๆ (very)

HM1: ลูกเป็ด ซี้เหว รู้สึก เหนื่อย เหลือเกิน

HM2: ลูกเป็ด ซี้เหว เริ่ม เหนื่อยแล้ว

No repair required.

36. SL: He had to find a place to stay where he could be warm and safe.

TC: เขา (he) ต้อง (had_to) หาที่พบ (find) ที่ (place) ที่ (classifier) หนึ่ง (a) ที่จะ (to) อยู่ (stay) ที่ซึ่ง (where) เขา (he) จะได้ (could_be)อุ่น (warm) และ (and)ปลอดภัย (safe)

HM1: มัน ต้อง หา ที่พัก สักแห่ง ที่ๆ อบอุ่น และ ปลอดภัย

HM2: มัน ต้อง หา ที่อยู่ ที่ให้ ความอบอุ่น และ ปลอดภัย

No repair required.

37. SL: One evening, he came to a little cottage.

TC: หนึ่ง (one) เย็น (evening), เขา (he) ได้มา (came) กับ (to) กระโจม (cottage) เล็ก (little) หลัง (classifier) หนึ่ง (a)

HM1: เย็น วัน หนึ่ง ลูกเป็ด เดิน มา ถึง กระโจม เล็กๆ หลัง หนึ่ง

HM2: เย็น วัน หนึ่ง มัน มา ถึง กระโจม เล็ก หลัง หนึ่ง

I misplaced word, I incorrectly translated word.

38. SL: The door was opened and he went inside.

TC: ประตู (door) ประตู (classifier) นั้น (the) ถูก (passive voice) เปิด (open) และ (and) เขา (he) ได้ไป (went) ข้างใน (inside)

HM1: ประตู กระโจม เปิด อยู่ มัน จึง เข้าไป ข้างใน

HM2: ประตู เปิด อ้า อยู่ มัน จึง เดิน เข้าไป

No repair required.

44. SL: No, said the ugly duckling
 TC: ไม่ (no), ลูกเป็ด (duckling) ที่ (which) ชีห์เร่ (ugly) ตัว (classifier) นั้น (the) ได้พูด (said)
 HM1: ก็ไม่ได้อีกเหมือนกัน ลูกเป็ดชีห์เร่ตอบ
 HM2: ไม่ได้หรอก ลูกเป็ด ชีห์เร่ บอก
 No repair required.
45. SL: Then you must go, said the cat and the hen.
 TC: ในตอนนั้น (then) คุณ (cat) ต้อง (must) ไป (go), แมว (cat) ตัว (classifier) นั้น (the) และ (and) ไก่ (hen) ตัว (classifier) นั้น (the) ได้พูด (said)
 HM1: อ่าฉัน เก ออกไป เลย ไป แมว และ แม่ไก่ ตะโกน ไล่
 HM2: อ่าอย่างนั้น เธอ ต้อง ไป นะ แมว และ แม่ไก่ พูด
 Convey different meaning from the original.
46. SL: They chased the ugly duckling out of the cottage and would not let him in again.
 TC: พวกเขา (they) ได้ไล่ (chased) ลูกเป็ด (duckling) ที่ (which) ชีห์เร่ (ugly) ตัว (classifier) นั้น (the) ออกจาก (out of) กระโจม (cottage) หลัง (classifier) นั้น (the) และ (and) จะ (will) ไม่ (not) ปล่อยให้ (let) เขา (him) เข้ามา (in) อีกครั้ง (again)
 HM1: พวกมัน พาฉัน ไล่ ลูกเป็ด ชีห์เร่ ออกจาก กระโจม และ ไม่ยอม ให้ มัน กลับ เข้าไป อีก
 HM2: แมว และ แม่ไก่ เลยไล่ ลูกเป็ด ชีห์เร่ ให้ ออกไป จาก กระโจม และ ไม่ยอม ให้ เข้ามา อีก
 I inappropriate word usage.
47. SL: The ugly duckling wandered through the countryside for many days.
 TC: ลูกเป็ด (duckling) ที่ (which) ชีห์เร่ (ugly) ตัว (classifier) นั้น (the) ได้เดินไปเดินมา (wandered) ผ่าน (through) ชนบท (countryside) แห่ง (classifier) นั้น (the) เป็นเวลา (for) หลาย (many) วัน (day)
 HM1: ลูกเป็ด ชีห์เร่ ตระเวนไป จนทั่ว ท้องถิ่น แถบนั้น เป็น เวลา หลาย วัน
 HM2: ลูกเป็ด ชีห์เร่ เดินทาง ร่อนเร่ ตาม ชนบท อยู่ หลาย วัน
 Grammatically incorrect.
48. SL: No one would give him a home.
 TC: ไม่มีใคร (no one) จะ (would) ให้ (give) เขา (him) บ้าน (home) หลัง (classifier) หนึ่ง (a)
 HM1: ไม่มีใคร ให้ มัน อาศัยอยู่ ด้วย
 HM2: ไม่มีใคร ยอมให้ อยู่ ที่ บ้าน ด้วย
 I incorrectly translated word.

49. SL: No one would be his friend.
 TC: ไม่มีใคร (no_one) จะ (would) เป็น (be) เพื่อน (friend) ของเขา (his)
 HM1: ไม่มีใคร เป็น เพื่อน กับ มัน
 HM2: ไม่มีใคร อยาก เป็น เพื่อน กับ ด้วย
 No repair required.
50. SL: All the birds and animals said that he was ugly
 TC: นก (bird) ทั้งหมด (all) นั้น (the) และ (and) สัตว์ (animal) หลาย (plurality) ตัว (classifier) ได้พูด (said) ว่า (that) เขา (he) ชี้เหร่ (ugly)
 HM1: นก และ สัตว์ ทุก ตัว ต่าง พากัน พูด ว่า มัน เป็น สัตว์ ที่ น่าเกลียด
 HM2: นก และ สัตว์ อื่นๆ พากัน บอก ว่า มัน น่าเกลียด
 No repair required.
51. SL: He grew more and more sad and more and more tired
 TC: เขา (he) ได้สูงขึ้น (grew) อีก (more) และ (and) เศร้า (sad) มากขึ้น (more) และ (and) เหนื่อย (tired) มากขึ้น (more)
 HM1: ลูกเบ็ด ชี้เหร่ ค่อยๆ ตัว โตขึ้น มัน ดูเศร้าซึม และ อ่อนล้า ยิ่งกว่า เดิม
 HM2: มัน เริ่ม เศร้ามากขึ้น และ เหนื่อยมากขึ้น
 Convey different meaning from the original.
52. SL: at last he stopped to rest by a lake that was covered with ice.
 TC: ในที่สุด (at_last) เขา (he) ได้หยุด (stopped) เพื่อที่จะ (to) พัก (rest) โดย (by) ทะเลสาบ (lake) แห่ง (classifier) หนึ่ง (a) ว่า (that) ถูก (passive voice) ปกคลุม (cover) ด้วย (with) น้ำแข็ง (ice)
 HM1: แล้ว ในที่สุด มัน ก็ หยุด เร่ร่อน และ หาย ที่พัก อยู่ ใกล้ๆ ทะเลสาบ ที่ ปกคลุม ด้วย น้ำแข็ง
 HM2: ในที่สุด มัน ก็ หยุดพัก ที่ ทะเลสาบ ที่ ปกคลุม ด้วย น้ำแข็ง แห่งหนึ่ง
 2 incorrectly translated word.
53. SL: He stayed there all winter, hidden in the reeds.
 TC: เขา (he) ได้อยู่ (stayed) ที่นั่น (there) ตลอด (all)ฤดูหนาว (winter), ซ่อน (hidden) ใน (in) ต้นกก (reed) หลาย (plurality) ต้น (classifier) นั้น (the)
 HM1: มัน อาศัย อยู่ ที่นั่น ตลอด ฤดูหนาว และ ซ่อน ตัว อยู่ ใต้ ต้นกก
 HM2: มัน อาศัย ที่นั่น ตลอดทั้ง หนาวหนาว ซ่อน ตัว ใน พงหญ้า
 No repair required.

54. SL: He was cold and hungry and very lonely.

TC: เขา (he)หนาว (cold) และ (and) หิว (hungry) และ (and) เหงา (lonely) มากๆ (very)

HM1: ลูกเปิด ตัวหนาว สิ้น และ รู้สึก ว่าเหว

HM2: มันหนาว หิว และ ว่าเหว มาก

No repair required.

55. One bright morning in early spring, when all the ice had melted, a flock of beautiful birds came to the lake.

TC: หนึ่งใน (one)ที่ (which)สว่าง (bright) เช้า (morning) ใน (in) ตอนต้น (early)ฤดูใบไม้ผลิ (spring), เมื่อ (when)น้ำแข็ง (ice)ทั้งหมด (all)นั้น (the)ได้ (had)ละลาย (melt)นก (bird)ที่ (which)สวย (beautiful)ของ (of)ฝูง (flock)ตัว (classifier)หนึ่ง (a)หลาย (plurality)ได้มา (came)ถึง (to)ทะเลสาบ (lake)แห่ง (classifier)นั้น (the)

HM1: จวบกระทั่ง เขา ที่ สดใส วันหนึ่ง ตอน ฤดูใบไม้ผลิ เมื่อ น้ำแข็ง ใน ทะเลสาบ ละลาย ไปหมด ฝูง นก ที่ สวยงาม ฝูง หนึ่ง ได้ บิน มา ยัง ทะเลสาบ

HM2: เข้า แจ่มใส วันหนึ่ง ใน ต้น ฤดูใบไม้ผลิ เมื่อ น้ำแข็ง ได้ ละลายหมด แล้ว ฝูง นก สวยงาม ฝูง หนึ่ง บิน มา ยัง ทะเลสาบ

Grammatically incorrect.

56. SL: They had gleaming white feathers and long graceful necks

TC: พวกเขา (they)มี (had)ขนนก (feathers)ที่ (which)เป็นประกาย (gleaming)สีขาว (white)หลาย (plurality)เส้น (classifier)และ (and)คอ (neck)ที่ (which)ยาว (long)อ่อนช้อย (graceful)หลาย (plurality)คอ (classifier)

HM1: พวกมัน มี ขน สีขาว มันระยับ และ ลำคอ ที่ ระหง งดงาม

HM2: พวกเขา มี ขน สีขาว สะท้อนแสง และ คอ ที่ ยาว สง่า

No repair required.

57. SL: The ugly duckling watched them from his hiding place in the reeds.

TC: ลูกเปิด (duckling)ที่ (which)ชั่วเหว (ugly)ตัว (classifier)นั้น (the)ได้เฝ้าดู (watched)พวกเขา (them)จาก (from)สถานที่ (place)การซ่อน (hiding)ของเขา (his)ใน (in)ต้นกก (reed)หลาย (plurality)ต้น (classifier)นั้น (the)

HM1: ลูกเปิด ชั่วเหว เฝ้ามอง พวกนั้น จาก ที่ซ่อน ของมัน ได้ ต้นกก

HM2: ลูกเปิด ชั่วเหว แอมมอง นก สวยงาม เหล่านั้น จาก พงศาว

I incorrectly translated word.

58. SL: They are the most beautiful birds I have ever seen, he thought.

TC: พวกเขา (they)เป็น (are)นก (bird)ที่ (which)สวย (beautiful)ที่สุด (most)หลาย (plurality)ตัว (classifier)ฉัน (I)เคย (have_ever)เห็น (seen), เขา (he)ได้คิด (thought)

HM1: นก พวกนี้ สวยที่สุด ตั้งแต่ ฉัน เคย เห็น มา มัน คิด อยู่ ในใจ
 HM2: พวกเขา เป็น นก ที่ สวยที่สุด ที่ ฉัน เคย เห็น มา มัน คิด อยู่ ในใจ

Grammatically incorrect.

59. SL: If only I could be like them.

TC: ถ้า (if) เพียงแต่ (only) ฉัน (I) สามารถ (could) ชอบ (like) พวกเขา (them)

HM1: ถ้า ฉัน สวย อย่าง พวกนี้ บาง ก็ คง จะ ดี ชี นะ

HM2: ถ้า ฉัน ได้ เป็น อย่าง พวกเขา

I incorrectly translated word.

60. SL: the beautiful birds saw the ugly duckling.

TC: นก (bird) ที่ (which) สวย (beautiful) หลาย (plurality) ตัว (classifier) นั้น (the) ได้เห็น (saw) ลูกเป็ด (duckling) ที่ (which) ชี้เหร่ (ugly) ตัว (classifier) นั้น (the)

HM1: นก ที่ สวยงาม ฝูง นั้น มองเห็น ลูกเป็ด ชี้เหร่

HM2: นก ที่ สวย นั้น มองเห็น ลูกเป็ด ชี้เหร่

No repair required.

61. SL: The biggest one came over to him

TC: ตัว (one) ที่ (which) โดดที่สุด (biggest) ตรงมาที่ (came_over_to) เขา (him)

HM1: นก ตัว ที่ ใหญ่ที่สุดใน ฝูง บิน เข้ามา หา มัน

HM2: นก ตัว ใหญ่ที่สุด เข้ามา หา

No repair required.

62. SL: The ugly duckling tried to hide

TC: ลูกเป็ด (duckling) ที่ (which) ชี้เหร่ (ugly) ตัว (classifier) นั้น (the) ได้พยายาม (tried) ที่จะ (to) ซ่อน (hide)

HM1: ลูกเป็ด ชี้เหร่ พยายาม จะ ซ่อน ตัว

HM2: ลูกเป็ด ชี้เหร่ พยายาม จะ หลบ

No repair required.

63. SL: He was sure that the bird would make_fun_of him or try to chase him away
 TC: เขา (he) แน่ใจ (sure) ว่า (that) นก (bird) ตัว (classifier) นั้น (the) จะ (would) เยาะเย้ย (make_fun_of) เขา (him) หรือ (or) พยายาม (try) กับ (to)ไล่ (chase) เขา (him) ห่างไป (away)

HM1: มัน เชื่อ แน่ ว่า นก พวกนี้ ต้อง หัวเราะเยาะ หรือ ไม่ ก็ ขบไล่ มัน อีก

HM2: มัน แน่ใจว่า นก ตัว ใหญ่ ตัว นั้น จะ ต้อง เยาะเย้ย และ ไล่ มัน ไป ให้ พัน

I incorrectly translated word.

64. SL: But the lovely white bird said, what a fine young swan you are !

TC: แต่ (but) นก (bird) ที่ (which) สีขาว (white) น่ารัก (lovely) ตัว (classifier) นั้น (the) ได้พูด (said), หงส์ (swan)หนุ่ม (young) งดงาม (fine) ตัว (classifier) นั้น (a) อะไร (what) คุณ (you) เป็น (are) เช่นนั้น (!)

HM1: แต่ นก สีขาว ที่ สวยงาม กลับ พูด ว่า เจ้า เป็น หงส์ น้อย ที่ สวยงาม มาก

HM2: แต่ นก ตัว สวย สีขาว พูด ว่า เธอ ข้าง เป็น หงส์ หนุ่มที่ สวย จริงๆ

3 misplaced words.

65. SL: You should not be here all_by_yourself.

TC: คุณ (you) ไม่ (not) ควร (should) อยู่ (be) ที่นี่ (here) โดยลำพัง (all_by_yourself)

HM1: เจ้า ไม่ น่า อยู่ ที่นี้ ตามลำพัง หรือ กะ

HM2: เธอ ไม่ ควร อยู่ ที่นี้ ตามลำพัง

No repair required.

66. SL: The ugly duckling could not believe what he had heard.

TC: ลูกเป็ด (duckling) ที่ (which) ชีเหฺร (ugly) ตัว (classifier) นั้น (the) ไม่ (not) สามารถ (could) เชื่อ (believe) อะไร (what) เขา (he) ได้ (had) ได้ยิน (heard)

HM1: ลูกเป็ด ชีเหฺร แหบ ไม่ เชื่อ คำพูด ที่ มัน ได้ยิน

HM2: ลูกเป็ด ชีเหฺร ไม่ ยาก จะ เชื่อ สิ่ง ที่ มัน ฟัง ได้ยิน

I incorrectly translated word.

67. SL: He looked at his reflection in the water

TC: เขา (he) ได้มอง (looked) ไปที่ (at) ภาพสะท้อน (reflection) ของเขา (his) ใน (in) น้ำ (water) นั้น (the)

HM1: มัน มองดู เงา ของ ตัวเอง ใน น้ำ

- HM2: มัน มอง เจา ของ มัน ใน น้ำ
No repair required.
68. SL: It was true
TC: มัน (it) จริง (true)
HM1: จริงๆ ด้วย
HM2: จริงๆ ด้วย
No repair required.
69. SL: His feathers were white and gleaming.
TC: ขนนก (feathers) หลาย (plurality) เสน (classifier) ของเขา (his) สีขาว (white) และ (and) เป็นประกาย (gleaming)
HM1: ขน ของมัน สีขาว และ เป็น มันระยับ
HM2: ขน ของมัน เป็น สีขาว และ สะท้อนแสง เงาม
- No repair required.
70. SL: his neck was long and graceful
TC: คอ (neck) ของเขา (his) ยาว (long) และ (and) อ่อนช้อย (graceful)
HM1: คอ ของมัน ยาว และ สวยงาม
HM2: คอ ของมัน ยาว และ สง่า
No repair required.
71. SL: He had grown into a handsome swan
TC: เขา (he) ได้ (had) เติบโต (grown) เป็น (into) หงส์ (swan) รูปงาม (handsome) ตัว (classifier) หนึ่ง (a)
HM1: มัน กลายเป็น หงส์ ที่ สง่างาม ตัว หนึ่ง
HM2: มัน ได้ เติบโต เป็น หงส์ หนึ่ง ที่ สง่างาม ตัว หนึ่ง
I inappropriate word usage.
72. SL: Come with us, said the swan.
TC: มา (come) กับ (with) พวกเรา (us), หงส์ (swan) ตัว (classifier) หนึ่ง (the) ได้พูด (said)
HM1: มา กับ พวกเรา ซิ หงส์ ตัว หนึ่งเอ๋ย ปาก ขวาน
HM2: มา กับ พวกเรา ซิ

No repair required.

73. SL: The ugly duckling spread his wings and rose_into the sky

TC: ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ (ugly) ตัว (classifier) นัน (the) กาง (spread) ปีก (wing) หลาย (plurality) ปีก (classifier) ของเขา (his) และ (and) ขึ้นสู่ (rose_into) ท้องฟ้า (sky) นัน (the)

HM1: ลูกเป็ด ขี้เหร่ คลี ปีก ของมัน ออก และ โผ ขึ้น สู่ ท้องฟ้า

HM2: ลูกเป็ด ขี้เหร่ กาง ปีก ออก และ บิน ขึ้น ไป บน ท้องฟ้า

No repair required.

74. SL: I never dreamed that i could_be so happy, he said, and he flew off proudly with his new friends.

TC: ฉัน (I) ไม่เคย (never) ได้ฝัน (dreamed) ว่า (that) ฉัน (I) จะได้ (could_be) ตั้งนั้น (so) เป็นสุข (happy), เขา (he) ได้พูด (said), และ (and) เขา (he) ได้บิน (flew) ออกไป (off) อย่างภาคภูมิใจ (proudly) ด้วย (with) เพื่อน (friend) ใหม่ (new) หลาย (plurality) ตัว (classifier) ของเขา (his)

HM1: ฉัน ไม่เคย คิดเลย ว่า จะ มี ความสุข อย่างนี้ มัน พุด กับ ตัวเอง และ บิน ไป ใน ท้องฟ้า อย่าง ล่าพองใจ กับ เพื่อน ใหม่ ของมัน

HM2: ฉัน ไม่เคย คิด มาก่อน เลย ว่า จะ มี ความสุข ขนาดนี้ มัน พุด และ บิน ไป ด้วย ความภูมิใจ พร้อม กับ เพื่อนๆ ใหม่

2 incorrectly translated words.

75. SL: The ugly duckling

TC: ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ (ugly) ตัว (classifier) นัน (the)

HM1: ลูกเป็ด ขี้เหร่

HM2: ลูกเป็ด ขี้เหร่

No repair required

76. SL: Written by Ronne Randall

TC: เขียน (written) โดย (by) รอนนี่_แรนเดล (Ronne_Randall)

HM1: เขียน โดย รอนนี่ แรนเดล

HM2: เขียน โดย รอนนี่ แรนเดล

No repair required.

77. SL: The wheat was yellow

TC: ข้าวสาลี (wheat) นัน (the) สีเหลือง (yellow)

HM1: ข้าวสาลี ออก สีเหลืองอร่าม

HM2: ข้าวสาลี สีเหลือง

No repair required.

78. SL: Here the stork marched about on his long red legs talking Egyptian.

TC:ที่นี่ (here) นกกระสา (stork) ตัว (classifier) นั้น (the) เดินไปมา (marched about) บน (on) ขา (leg) สีแดง (red) ยาว (long) หลาย (plurality) ขา (classifier) ของเขา (his) พูด (talking) คนอียิปต์ (Egyptian)

HM1: ดูนะ นกกระสา เชื่องช้า ด้วย ขา สีแดง ยาวๆ ของมัน พวกมัน พูด ภาษาอียิปต์

HM2: นกกระสา พวกมัน เดิน บน ขา ที่ ยาว สีแดง ของมัน ค่อยๆ กัน เป็น ภาษาอียิปต์

2 incorrectly translated words.

79. SL: When I was an ugly duckling, he thought, I never dreamed I could be so happy.

TC:เมื่อ (when) ฉัน (I) เป็น (was) ลูกเป็ด (duckling) ที่ (which) ที่เหว (ugly) ตัว (classifier) นั้น (an), เขา (he) ได้คิด (thought), ฉัน (I) ไม่เคย (never) ได้ฝัน (dreamed) ฉัน (I) จะได้ (could be) ดังนั้น (so) เป็นสุข (happy),

HM1: เมื่อครั้งที่ ฉัน เป็น ลูกเป็ด ที่เหว มัน ครุ่นคิด อยู่ในใจ ฉัน ไม่เคย ฝัน ว่า จะ มี ความสุข มาก เท่านี้

HM2: ตอนที่ ฉัน เป็น ลูกเป็ด ที่เหว มัน คิด ฉัน ไม่เคย คิด ฝัน เลย ว่า ฉัน จะ มี ความสุข ขนาดนี้

I incorrectly translated word.

80. SL: You can take a fish to school but you can not make them think.

TC:คุณ (you) สามารถ (can) เอา (take) ปลา (fish) ตัว (classifier) นั้น (a) ไปที่ (to) ฝูงปลา (school) แต่ (but) คุณ (you) ไม่ (not) สามารถ (can) ทำ (make) พวกเขา (them) คิด (think)

HM1: คุณ อาจจะ พา คนไป ไป โรงเรียน ได้ แต่ คุณ สอน ให้ เขา คิด ไม่ได้

HM2: คุณ พา ปลา ตัว หนึ่ง ไป โรงเรียน ได้ แต่ ทำ ให้ มัน คิด ไม่ได้

2 incorrectly translated word.

81. SL: Five days before the trout are released.

TC:ห้า (five) วัน (day) ก่อน (before) ปลาเทราท์ (trout) ตัว (classifier) นั้น (the) ถูก (passive voice) ปล่อย (release)

HM1: ห้า วัน ก่อน ที่ ปลาเทราท์ จะ ถูก ปล่อย

HM2: อีก ห้า วัน ที่ ปลาเทราท์ จะ ถูก ปล่อย

Grammatically incorrect.

82. SL: I rent a room from Mrs Jones.

TC:ฉัน (I) ค่าเช่า (rent) ห้อง (room) ห้อง (classifier) นั้น (a) จาก (from) นาง (Mrs) โจนส์ (Jones)

HM1: ฉัน เช่า ห้อง จาก มิสซิส โจนส์

HM2: ดัน เข้า ห้อง จาก คุณ โจนส์

I incorrectly translated word.

83. SL: She was rending her hair out in anger

TC: เธอ (she) กำลัง (continuous tense) ฉีก (rend) ผม (hair) ของเธอ (her) ออกมา (out) ใน (in) โกรธ (anger)

HM1: หลอน กำลัง ทั้ง ผม ตัวเอง ด้วย ความโกรธ

HM2: เธอ กำลัง ทั้ง ผม ตัวเอง ด้วย ความโกรธ

3 incorrectly translated words.

84. SL: Algebraic symbols are used when you do not know what you are talking about.

TC: สัญลักษณ์ (symbols) ทางพีชคณิต (algebraic) หลาย (plurality) ตัว (classifier) ถูก (passive voice) ใช้ (use) เมื่อ (when) คุณ (you) ไม่ (not) รู้ (know) อะไร (what) คุณ (you) กำลัง (continuous tense) พูด (talk) เกี่ยวกับ (about)

HM1: สัญลักษณ์ ทางพีชคณิต จะ ถูก ใช้ เมื่อ คุณ ไม่ รู้ ว่า จะ พูด เกี่ยวกับ อะไร

HM2: สัญลักษณ์ ทางพีชคณิต ถูก ใช้ เมื่อ คุณ ไม่ รู้ ว่า กำลังพูด เรื่อง อะไร อยู่

I misplaced word.

85. SL: Before he went fishing, John took the worms

TC: ก่อน (before) เขา (he) ได้ไป (went) ตกปลา (fishing), จอห์น (John) ได้เอา (took) ไส้เดือน (worm) หลาย (plurality) ตัว (classifier) นั้น (the)

HM1: ก่อน ที่ เขา จะ ไป ตกปลา จอห์น เอา ตัวหนอน ไป ด้วย

HM2: ก่อน เขา จะ ไป ตกปลา จอห์น เอา หนอน ไป ด้วย

Grammatically incorrect.

86. SL: The ugly duckling hides his head under his wing

TC: ลูกเป็ด (duckling) ที่ (which) ชีเหร่ (ugly) ตัว (classifier) นั้น (the) ซ่อน (hide) หัว (head) ของเขา (his) ใต้ (under) ปีก (wing) ของเขา (his)

HM1: ลูกเป็ด ชีเหร่ ซุก หัว ของมัน ไว้ ใต้ ปีก

HM2: ลูกเป็ด ชีเหร่ ซ่อน หัว ของมัน ที่ ใต้ ปีก

No repair required.

87. SL: The beautiful Egyptian talked about her dream

TC: คนอียิปต์ (Egyptian) ที่ (which) สวย (beautiful) คน (classifier) นั้น (the) ได้พูด (talked) เกี่ยวกับ (about) เธอ (her) มั่น (dream)

HM1: สิวสวย ชาวอียิปต์ เล่า ถึง ความฝัน ของหลอน
 HM2: คนอียิปต์ คน สวย พูดถึง ความฝัน ของเธอ
 I misplaced word, 2 incorrectly translated words.

88. SL: The countryside is very green in spring
 TC: ชนบท (countryside) แห่ง (classifier) นั้น (the) เขียวขุ่น (green) มากๆ (very) ใน (in) ฤดูใบไม้ผลิ (spring)
 HM1: ถิ่นชนบท มี สีเขียวขุ่น ใน ฤดูใบไม้ผลิ
 HM2: ชนบท นั้น เป็น สีเขียว ใน ฤดูใบไม้ผลิ
 No repair required.

89. SL: A green salad has only green vegetables such as lettuce and cucumber
 TC: สลัด (salad) สีเขียว (green) หนึ่ง (a) มี (has) เท่านั้น (only) ผัก (vegetable) ที่ (which) สีเขียว (green) หลาย (plurality) อย่าง (classifier) ตัวอย่างเช่น (such_as)
 ผักกาดแก้ว (lettuce) และ (and) แตงกวา (cucumber)
 HM1: สลัด สีเขียว มี แค่ ผัก สีเขียว เช่น ผักกาดแก้ว และแตงกวา
 HM2: สลัด สีเขียว ก็มี แค่ ผัก สีเขียว เช่น ผักกาดแก้ว และแตงกวา
 I misplaced word.

90. SL: The spirit is willing but the flesh is weak.
 TC: วิญญาณ (spirit) นั้น (the) พร้อม (willing) แต่ (but) ร่างกาย (flesh) นั้น (the) อ่อนแอ (weak)
 HM1: จิตวิญญาณ นั้น กล้าแกร่ง หาก ภาย กลับ อ่อนล้า
 HM2: จิตวิญญาณ นั้น พร้อม หาก ร่างกาย กลับ อ่อนล้า
 I incorrectly translated word.

Appendix H

Comprehensibility Evaluation

This appendix contains the evaluation of ALMT with respect to *comprehensibility* as outlined in Chapter 8.

Source Text:

Sentence 1- 76: The ugly duckling version written by Ronne Randall (1987).

Sentence 77- 90: Newspapers and Articles.

Evaluators:

HM3: Thai Linguist

HM4: Thai Student (Grade 7, Age 12)

HM5: Thai Student (Grade 4, Age 9)

Legends:

- ↑ Additional word required: The word, when installed, will make the sentence complete and correct in terms of meaning and grammar.
- ☐ Inappropriate word usage: This word does not distort the meaning of the expression but it is inappropriate.
- Meaningless word: This word renders the sentence meaningless.
- / Unnecessary word: This word is not needed nor used in spoken language.
- ↖ Misplaced word: The word is wrongly placed and it affects the meaning of the sentence. It should be moved in the direction of the arrow.

- **Misplaced word:** The word is wrongly placed and it affects the meaning of the sentence.
It should be moved in the direction of the arrow.

1. SL: It was a warm sunny day.
 TC: มัน (it) เป็น (was) วัน (day) ที่ (which) สดใส (sunny) อุ่น (warm) วัน (classifier) หนึ่ง (a)
 HM3: comprehensible
 HM4: comprehensible
 HM5: comprehensible
 comprehensible
2. SL: A mother duck sat on her nest at the edge of a pond waiting for her eggs to hatch.
 TC: แม่ (mother) เป็ด (duck) ตัว (classifier) หนึ่ง (a) ไค่นั่ง (sat) บน (on) รัง (nest) ของ (her) ที่ (at) ขอบ (edge) ขุด (classifier) หนึ่ง (the) ของ (of) แอ่งน้ำ (pond) แอ่ง (classifier) หนึ่ง (a) รอ (waiting) สำหรับ (for) ไข่ (egg) หลาย (plurality) ฟอง (classifier) ของ (her) ที่จะ (to) ฟักตัว (hatch)
 HM3: incomprehensible
 HM4: incomprehensible
 HM5: incomprehensible
 incomprehensible
3. SL: one_by_one, the eggs began to crack_open.
 TC: ทีละหนึ่ง (one_by_one) . ไข่ (egg) หลาย (plurality) ฟอง (classifier) นั้น (the) ได้เริ่ม (began) ที่จะ (to) แตกออก (crack_open)
 HM3: comprehensible, inappropriate word order, not colloquial Thai.
 HM4: comprehensible, inappropriate word order, not colloquial Thai.
 HM5: comprehensible, inappropriate word order, not colloquial Thai..
 comprehensible, word order is inappropriate, not colloquial Thai.
4. SL: Peep, Peep, said each little yellow duckling as it poked out its head and looked around.
 TC: เป็ด (peep), เป็ด (peep), ลูกเป็ด (duckling) สีเหลือง (yellow) เล็ก (little) แต่ละ (each) ตัว (classifier) พูด (said) ดังที่ (as) มัน (it) ได้โผล่ (poked) ออกมา (out) หัว (head) ของมัน (its) และ (and) ไข่มอง (looked) รอบๆ (around)
 HM3: incomprehensible, 1 additional word required, 1 meaningless word, 1 word misplaced.
 HM4: incomprehensible, 1 additional word required, 1 inappropriate word usage, 1 meaningless word, 1 word misplaced.
 HM5: comprehensible
 incomprehensible
5. SL: Quack, quack, said the mother duck feeling very pleased with herself.
 TC: แควก (quack), แควก (quack), แม่ (mother) เป็ด (duck) ตัว (classifier) หนึ่ง (the) พูด (said) ความรู้สึก (feeling) พอใจ (pleased) มากๆ (very) กับ (with) ตัวเธอเอง (herself)
 HM3: incomprehensible, 1 meaningless word.

HM4: incomprehensible, 1 meaningless word.

HM5: comprehensible

incomprehensible

6. SL: The biggest egg hatched last of all

TC: ไช้ (egg) ไช้ (which) ไช้ที่สุด (biggest) ไช้ฟัก (hatched) ไช้สุดท้าย (last) ของ (of) ทั้งหมด (all)

HM3: incomprehensible, 1 additional word required.

HM4: incomprehensible, 2 additional words required.

HM5: incomprehensible, 2 additional words required.

incomprehensible

7. SL: But the duckling that poked out his head was not little and yellow like the others

TC: แต่ (but) ลูกเป็ด (duckling) ตัว (classifier) นั้น (the) ที่ (that) โด่โผล่ (poked) ข้างนอก (out) หัว (head) ของเขา (his) ไช้ (not) เล็ก (little) และ (and) สีเหลือง (yellow) เหมือน (like) หัวอื่นๆ (the others)

HM3: incomprehensible, 2 meaningless words, 1 word misplaced.

HM4: incomprehensible, 2 meaningless words, 1 word misplaced, 2 additional words required.

HM5: comprehensible

incomprehensible

8. SL: He was big and gray and ugly

TC: เขา (he) โต (big) และ (and) สีเทา (gray) และ (and) ชีเหร่ (ugly)

HM3: incomprehensible, 1 additional word required.

HM4: incomprehensible, 1 additional word required, 1 unnecessary word.

HM5: incomprehensible, 1 additional word required.

incomprehensible

9. SL: Quack, said the mother duck

TC: แควก (quack), แม่ (mother) เป็ด (duck) ตัว (classifier) นั้น (the) พูด (said)

HM3: comprehensible

HM4: comprehensible

HM5: comprehensible

comprehensible

10. SL: You are the ugliest duckling I have_ever seen
 TC: คุณ (you) เป็น (are) ลูกเป็ด (duckling) ที่ (which) ซ้ำห่วยที่สุด (ugliest) ^๑ ฉัน (I) เคย (have_ever) เห็น (seen)
 HM3: incomprehensible, 1 additional word required.
 HM4: incomprehensible, 1 additional word required.
 HM5: incomprehensible, 1 additional word required.
 incomprehensible
11. SL: The mother duck led her ducklings into the water.
 TC: แม่ (mother) เป็ด (duck) ตัว (classifier) นั้น (the) ได้นำ (led) ลูกเป็ด (duckling) หลาย (plurality) ตัว (classifier) ของเธอ (her) เข้าไปใน (into) น้ำ (water) ^๒ (the)
 HM3: incomprehensible, 1 unnecessary word .
 HM4: incomprehensible, 1 unnecessary word .
 HM5: incomprehensible, 1 unnecessary word .
 incomprehensible
12. SL: The other ducks gathered around.
 TC: เป็ด (duck) ตัวอื่น (the other) หลาย (plurality) ตัว (classifier) ได้จับกลุ่ม (gathered) รอบๆ (around)
 HM3: comprehensible
 HM4: comprehensible
 HM5: comprehensible
 comprehensible
13. SL: what lovely children you have, they told her.
 TC: เด็ก ๆ (children) ที่ (which) น่ารัก (lovely) อะไร (what) ^๓ คุณ (you) มี (have), พวกเขา (they) ได้บอก (told) เธอ (her)
 HM3: incomprehensible, 1 inappropriate word usage, 1 additional word required, 2 words misordered.
 HM4: incomprehensible, 1 additional word required, 2 words misordered.
 HM5: comprehensible, 1 additional word required, 2 words misordered.
 incomprehensible
14. SL: But when they saw the big gray duckling, they began to laugh.
 TC: แต่ (but) เมื่อ (when) พวกเขา (they) ได้เห็น (saw) ลูกเป็ด (the) สีเทา (gray) โต (big) ตัว (classifier) นั้น (the), พวกเขา (they) ได้เริ่ม (began) ^๔ ที่จะ (to) หัวเราะ (laugh)
 HM3: comprehensible.

HM4: comprehensible, 1 additional word required.
HM5: comprehensible.

comprehensible

15. SL: That one is not lovely, they said

TC: ว่า (that) ~~หนึ่ง~~ (one) ไม่ (not) น่ารัก (not), พวกเขา (they) พูด (said)

HM3: incomprehensible, 2 meaningless words.

HM4: incomprehensible, 2 meaningless words.

HM5: incomprehensible, 2 meaningless words.

incomprehensible

16. SL: what an ugly duckling he is !

TC: ลูกเป็ด (duckling) ที่ (which) ~~ที่~~ เทว (ugly) ~~ตัว~~ (classifier) ~~หนึ่ง~~ (an) อะไร (what) เขา (he) เป็น (is) เช่นนั้น (!)

HM3: incomprehensible, 2 unnecessary words , 2 words misordered.

HM4: incomprehensible, 2 unnecessary words , 2 words misordered.

HM5: incomprehensible, 2 unnecessary words , 2 words misordered.

incomprehensible

17. SL: The mother duck took her ducklings to the farmyard.

TC: แม่ (mother) เป็ด (duck) ตัว (classifier) นั้น (the) ได้เอา (took) ลูกเป็ด (duckling) หลาย (plurality) ตัว (classifier) ของเธอ (her) ไปที่ (to)

ลานคตโรงนา (farmyard) แห่ง (classifier) นั้น (the)

HM3: comprehensible.

HM4: comprehensible, 2 unnecessary words , 1 inappropriate word usage.

HM5: comprehensible.

comprehensible

18. SL: When the other animals saw the big gray duckling, they all began to shout.

TC: เมื่อ (when) สัตว์ (animal) ~~หลาย~~ (plurality) ~~ตัว~~ (classifier) ตัวอื่น (the other) ได้เห็น (saw) ลูกเป็ด (duckling) ที่ (which) สีเทา (gray) โต (big) ตัว (classifier) นั้น (the), พวกเขา (they) ทั้งหมด (all) ได้เริ่ม (began) ที่จะ (to) ตะโกน (shout)

HM3: incomprehensible, 2 unnecessary words .

HM4: incomprehensible, 2 unnecessary words .

HM5: comprehensible.

incomprehensible

19. SL: What an ugly duckling he is ! they said.

TC: : ลูกเห็บ (duckling) ที่ (which) ชีเหร์ (ugly) ~~น่า~~ (classifier) ~~น่า~~ (an) อะไร (what) เขา (he) เป็น (is) เช่นนั้น (I) พวกเขา (they) ได้พูด (said)

HM3: incomprehensible, 2 unnecessary words , 2 words misordered.

HM4: incomprehensible, 2 unnecessary words , 2 words misordered.

HM5: incomprehensible, 2 unnecessary words , 2 words misordered.

incomprehensible

20. SL: He does not belong with us.

TC: เขา (he) ไม่ (not) ใ้ส่วนหนึ่งของ (belong_with) พวกเรา (us)

HM3: comprehensible.

HM4: comprehensible.

HM5: comprehensible.

comprehensible

21. SL: The geese and the turkeys ran after the duckling and tried to chase him away.

TC: พวกห่าน (geese) ~~นั้น~~ (the) และ (and) ไก่จวง (turkey) หลาย (plurality) ตัว (classifier) นั้น (the) ได้ไล่ตาม (tried) ลูกเห็บ (duckling) ตัว (classifier) นั้น (the) และ (and) ไคพยายาม (tried) ที่จะ (to) ไล่ (chase) เขา (him) ~~↑~~ หนีไป (away)

HM3: comprehensible, 1 unnecessary word, 1 additional word required.

HM4: incomprehensible, 1 unnecessary word, 1 additional word required.

HM5: comprehensible.

comprehensible

22. SL: Even his own brothers and sisters joined in and called him names.

TC: แม้แต่ (even) พี่ชายน้องชาย (brother) หลาย (plurality) คน (classifier) ของเขา (his) เอง (own) และ (and) พี่สาวน้องสาว (sister) หลาย (plurality) คน (classifier) ~~รวม~~ เข้ารวม (joined_in) และ (and) ตั้งฉายาเขาต่างๆ (called_him_names)

HM3: comprehensible, 1 additional word required.

HM4: comprehensible, 1 additional word required.

HM5: comprehensible.

comprehensible

23. SL: The ugly duckling hid in a corner of the farmyard and cried.
 TC: ลูกเป็ด (duckling) ที่ (which) ซึ่เหว (ugly) ตัว (classifier) นั้น (the) ได้ซ่อน (hid) ใน (in) มุม (corner) มุม (classifier) หนึ่ง (a) ของ (of) ลานติดโรงนา (farmyard) แห่ง (classifier) นั้น (the) และ (and) ได้ร้องไห้ (cried)
 HM3: comprehensible.
 HM4: comprehensible, 1 inappropriate word usage.
 HM5: comprehensible.
 comprehensible
- 24.1. SL: The next morning,
 TC: เขา (morning) วัน (classifier) ถัดไป (next) นั้น (the)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible
- 24.2. SL: The ugly duckling decided to run_away
 TC: ลูกเป็ด (duckling) ที่ (which) ซึ่เหว (ugly) ตัว (classifier) นั้น (the) ได้ตัดสินใจ (decided) ที่จะ (to) หนีจากไป (run_away)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible
25. SL: I will find a place where no_one will make_fun_of me, he said to himself.
 TC: ฉัน (I) จะ (will) หา (find) ที่ (place) ที่ (classifier) หนึ่ง (a) ที่ (where) ไม่มีใคร (no_one) จะ (will) เยาะเย้ย (make_fun_of) ฉัน (me), เขา (he) ได้พูด (said) กับ (to) ตัวเขาเอง (himself)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible
26. SL: He left the farmyard and ran to the great marsh where the wild ducks lived.
 TC: เขา (he) ได้จาก (left) ลานติดโรงนา (farmyard) แห่ง (classifier) นั้น (the) และ (and) ได้วิ่ง (ran) ไปที่ (to) หนองน้ำ (marsh) ใหญ่มาก (great) หนอง (classifier) นั้น (the) ที่ไหน (where) เป็ด (duck) ป่า (wild) หลาย (plurality) ตัว (classifier) นั้น (the) ได้อาศัยอยู่ (lived)
 HM3: incomprehensible, 1 meaningless word.
 HM4: incomprehensible, 2 meaningless words.

HM5: incomprehensible, 2 meaningless words.

incomprehensible

27. SL: Perhaps they will be kind to me, he said sadly.

TC: บางที (perhaps) พวกเขา (they) จะ (will) ใจดี (kind) กับ (to) ฉัน (me), เขา (he) ได้พูด (said) อย่างเศร้าสร้อย (sadly)

HM3: comprehensible.

HM4: comprehensible.

HM5: comprehensible.

comprehensible

28. SL: But the wild ducks were not kind.

TC: แต่ (but) เป็ด (duck) ป่า (wild) หลาย (plurality) ตัว (classifier) นั้น (the) ไม่ (not) ใจดี (kind)

HM3: comprehensible.

HM4: comprehensible.

HM5: comprehensible.

comprehensible

29. SL: You are very ugly, they said.

TC: คุณ (you) ซึ่เหว (ugly) มากๆ (very), พวกเขา (they) พูด (said)

HM3: comprehensible.

HM4: comprehensible.

HM5: comprehensible.

comprehensible

30. SL: You are certainly not one of us

TC: คุณ (you) เป็น (are) อย่างแน่นอน (certainly) ไม่ (not) หนึ่ง (one) ของ (of) พวกเรา (us)

HM3: incomprehensible, 3 words misordered.

HM4: incomprehensible, 3 words misordered.

HM5: incomprehensible, 3 words misordered.

incomprehensible

31. SL: And the wild ducks laughed at the duckling

TC: และ (and) เป็ด (duck) ป่า (wild) หลาย (plurality) ตัว (classifier) นั้น (the) ได้หัวเราะเยาะ (laughed_at) ลูกเป็ด (duckling) ตัว (classifier) นั้น (the)

- HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible
32. SL: So the ugly duckling left the marsh.
 TC: ดังนั้น (so) ลูกเป็ด (duckling) ที่ (which) ซี้เหว่ (ugly) ตัว (classifier) นั้น (the) ไต่จาก (left) หนองน้ำ (marsh) หนอง (classifier) นั้น (the)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible
33. SL: The wind was blowing and it was cold.
 TC: ลม (wind) ~~มัน~~ (the) กำลัง (continuous tense) พัด (blow) และ (and) มัน (it) หนาว (cold)
 HM3: incomprehensible, 1 unnecessary word, 1 meaningless clause.
 HM4: incomprehensible, 1 unnecessary word, 1 meaningless clause.
 HM5: incomprehensible, 1 meaningless clause.
 incomprehensible
34. SL: Winter was coming
 TC: ฤดูหนาว (winter) กำลัง (continuous tense) มา (come)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible
35. SL: The ugly duckling was very tired.
 TC: ลูกเป็ด (duckling) ที่ (which) ซี้เหว่ (ugly) ตัว (classifier) นั้น (the) เหนื่อย (tired) มากๆ (very)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible

36. SL: He had_to find a place to stay where he could_be warm and safe.
 TC: เขา (he) ต้อง (had_to) หา(หา)ที่ไหน (find) ที่ (place) ที่ (classifier) หนึ่ง (a) ที่ จะ (to) อยู่ (stay) ที่ (where) เขา (he) จะ ได้ (could_be)อุ่น (warm) และ (and)ปลอดภัย (safe)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible
37. SL: One evening, he came to a little cottage.
 TC: หนึ่ง (one) เป็น (evening), เขา (he) ใดมา (came) กับ (to) กระท่อม (cottage) เล็ก (little) หลัง (classifier) หนึ่ง (a)
 HM3: incomprehensible, 1 word misplaced, 1 additional word required, 1 meaningless word.
 HM4: incomprehensible, 1 word misplaced, 1 additional word required, 1 meaningless word.
 HM5: incomprehensible.
 incomprehensible
38. SL: The door was opened and he went inside.
 TC: ประตู (door) ปรึะถู (classifier) หนึ่ง (the) ถูก (passive voice) เปิด (open) และ (and) เขา (he) ได้ไป (went) ข้างใน (inside)
 HM3: comprehensible, not colloquial Thai.
 HM4: comprehensible, not colloquial Thai.
 HM5: comprehensible, not colloquial Thai.
 comprehensible, not colloquial Thai.
39. SL: An old woman lived in the cottage with a fat black cat and a plump brown hen.
 TC: ผู้หญิง (woman) แก่ (old) คน (classifier) หนึ่ง (an) ได้อาศัยอยู่ (lived) ใน (in) กระท่อม (cottage) หลัง (classifier) หนึ่ง (the) ด้วย (with) แมว (cat) สีดำ (black) อ้วน (fat) ตัว (classifier) หนึ่ง (a) และ (and) ไก่ (hen) สีน้ำตาล (brown) อ้วน (plump) ตัว (classifier) หนึ่ง (a)
 HM3: incomprehensible, 1 inappropriate word usage.
 HM4: incomprehensible, 1 inappropriate word usage.
 HM5: comprehensible, 1 inappropriate word usage.
 incomprehensible.
40. SL: The old woman did not mind the ugly duckling but the cat and the hen wanted him to leave.
 TC: ผู้หญิง (woman) แก่ (old) คน (classifier) หนึ่ง (the) ไม่ (not) รั้งเกียจ (mind) ลูกเป็ด (duckling) ที่ (which) ชีเหร่ (ugly) ตัว (classifier) หนึ่ง (the) แต่ (but) แมว (cat) ตัว (classifier) หนึ่ง (the) และ (and) ไก่ (hen) ตัว (classifier) หนึ่ง (the) ใดต้องการ (wanted) เขา (him) กับ (to) จาก (leave)
 HM3: incomprehensible, 1 additional word required, 1 meaningless word.

HM4: incomprehensible, 1 additional word required, 1 meaningless word.
 HM5: incomprehensible, 2 meaningless word.

incomprehensible

41. SL: Can you purr ? asked the cat

TC: คุณ (you) สามารถ (can) ทำเสียงพื๊อย่างแมว (purr) ได้ไหม (?) แมว (cat) ตัว (classifier) นั้น (the) ได้ถาม (asked)

HM3: comprehensible.

HM4: comprehensible.

HM5: comprehensible.

comprehensible

42. SL: No, said the ugly duckling.

TC: ไม่ (no), ลูกเป็ด (duckling) ที่ (which) ชี้เห่ (ugly) ตัว (classifier) นั้น (the) ได้พูด (said)

HM3: comprehensible.

HM4: comprehensible.

HM5: comprehensible.

comprehensible

43. SL: Can you lay eggs ? asked the hen.

TC: คุณ (you) สามารถ (can) วาง (lay) ไข่ (egg) หลาย (plurality) ฟอง (classifier) ได้ไหม (?) ไก่ (hen) ตัว (classifier) นั้น (the) ได้ถาม (asked)

HM3: comprehensible.

HM4: comprehensible.

HM5: comprehensible.

comprehensible

44. SL: No, said the ugly duckling

TC: ไม่ (no), ลูกเป็ด (duckling) ที่ (which) ชี้เห่ (ugly) ตัว (classifier) นั้น (the) ได้พูด (said)

HM3: comprehensible.

HM4: comprehensible.

HM5: comprehensible.

comprehensible

45. SL: Then you must go, said the cat and the hen.

TC: ในตอนนั้น (then) คุณ (cat) ต้อง (must) ไป (go), แมว (cat) ตัว (classifier) นั้น (the) และ (and) ไก่ (hen) ตัว (classifier) นั้น (the) ได้พูด (said)

HM3: comprehensible, but does not convey the intended meaning.
 HM4: comprehensible, but does not convey the intended meaning.
 HM5: comprehensible
 comprehensible

46. SL: They chased the ugly duckling out_of the cottage and would not let him in again.
 TC: พวกเขา (they) ได้ไล่ (chased) ลูกเป็ด (duckling) ที่ (which) ซึ่งเหว (ugly) ตัว (classifier) นั้น (the) ออกจาก (out_of) กระท่อม (cottage) หลัง (classifier) นั้น (the) และ (and) จะ (will) ไม่ (not) ปล่อยให้ (let) เขา (him) เข้ามา (in) อีกครั้ง (again)
 HM3: comprehensible, 1 inappropriate word usage.
 HM4: comprehensible, 1 inappropriate word usage.
 HM5: comprehensible
 comprehensible

47. SL: The ugly duckling wandered through the countryside for many days.
 TC: ลูกเป็ด (duckling) ที่ (which) ซึ่งเหว (ugly) ตัว (classifier) นั้น (the) ได้เดินไปเดินมา (wandered) ผ่าน (through) ชนบท (countryside) แห่ง (classifier) นั้น (the) เป็นเวลา (for) หลาย (many) วัน (day)
 HM3: comprehensible.
 HM4: comprehensible, 2 inappropriate word usage.
 HM5: comprehensible
 comprehensible

48. SL: No one would give him a home.
 TC: ไม่มีใคร (no_one) จะ (would) ให้ (give) เขา (him) บ้าน (home) หลัง (classifier) หนึ่ง (a)
 HM3: incomprehensible, 1 meaningless word.
 HM4: incomprehensible, 1 meaningless word.
 HM5: incomprehensible, 1 additional word required.
 comprehensible

49. SL: No one would be his friend.
 TC: ไม่มีใคร (no_one) จะ (would) เป็น (be) เพื่อน (friend) ของเขา (his)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible
 comprehensible

50. SL: All the birds and animals said that he was ugly
 TC: นก (bird) ทั้งหมด (all) นั้น (the) และ (and) สัตว์ (animal) หลาย (plurality) ตัว (classifier) ได้พูด (said) ว่า (that) เขา (he) ที่เหว (ugly)
 HM3: comprehensible, not colloquial Thai.
 HM4: comprehensible, not colloquial Thai.
 HM5: comprehensible, not colloquial Thai.
 comprehensible, not colloquial Thai.
51. SL: he grew more and more sad and more and more tired
 TC: เขา (he) ได้สูงขึ้น (grew) อีก (more) และ (and) เศร้า (sad) มากขึ้น (more) และ (and) เหนื่อย (tired) มากขึ้น (more)
 HM3: comprehensible, but does not convey the intended meaning, not colloquial Thai.
 HM4: comprehensible, but does not convey the intended meaning, not colloquial Thai.
 HM5: comprehensible, but does not convey the intended meaning.
 comprehensible
52. SL: at last he stopped to rest by a lake that was covered with ice.
 TC: ในที่สุด (at last) เขา (he) ได้หยุด (stopped) เพื่อที่จะ (to) พัก (rest) โดย (by) ทะเลสาบ (lake) แห่ง (classifier) หนึ่ง (a) ว่า (that) ถูก (passive voice) ปกคลุม (cover) ด้วย (with) น้ำแข็ง (ice)
 HM3: incomprehensible, 2 meaningless words.
 HM4: incomprehensible, 2 meaningless words.
 HM5: incomprehensible, 2 additional words required.
 comprehensible
53. SL: He stayed there all winter, hidden in the reeds.
 TC: เขา (he) ได้อยู่ (stayed) ที่นั่น (there) ตลอด (all) ฤดูหนาว (winter), ซ่อน (hidden) ใน (in) ต้นกก (reed) หลาย (plurality) ต้น (classifier) นั้น (the)
 HM3: comprehensible, not colloquial Thai.
 HM4: comprehensible, not colloquial Thai.
 HM5: comprehensible, not colloquial Thai.
 comprehensible, not colloquial Thai.
54. SL: He was cold and hungry and very lonely.
 TC: เขา (he) หนาว (cold) และ (and) หิว (hungry) และ (and) เหงา (lonely) มากๆ (very)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible

comprehensible

55. SL: One bright morning in early spring, when all the ice had melted, a flock of beautiful birds came to the lake

TC: หนึ่ง (one) ที่ (which) สว่าง (bright) เช้า (morning) ใน (in) ตอนต้น (early) ~~ฤดูใบไม้ผลิ~~ (spring), เมื่อ (when) น้ำแข็ง (ice) ทั้งหมด (all) นั้น (the) ~~ได้~~ (had) ได้ละลาย (melt) นก (bird) ที่ (which) สวย (beautiful) ~~ของ~~ (of)ฝูง (flock) ~~ตัว~~ (classifier) หนึ่ง (a) ~~หลาย~~ (plurality) โดนา (came) ถึง (to) ทะเลสาบ (lake) แห่ง (classifier) นั้น (the)

HM3: incomprehensible, 2 word misplaced, 1 additional word required, 4 unnecessary words

HM4: incomprehensible, 2 word misplaced, 1 additional word required, 4 unnecessary words.

HM5: incomprehensible

incomprehensible

56. SL: They had gleaming white feathers and long graceful necks

TC: พวกเขา (they) มี (had) นนท (feathers) ที่ (which) ~~เป็น~~ (plurality) สีขาว (white) ~~หลาย~~ (plurality) ~~ตัว~~ (classifier) และ (and) คอ (neck) ที่ (which) ยาว (long) ~~อ่อนช้อย~~ (graceful) หลาย (plurality) คอ (classifier)

HM3: incomprehensible, 4 unnecessary words.

HM4: comprehensible, not colloquial Thai.

HM5: comprehensible

comprehensible, not colloquial Thai.

57. SL: The ugly duckling watched them from his hiding place in the reeds.

TC: ลูกเป็ด (duckling) ที่ (which) ~~มี~~ (ugly) ตัว (classifier) นั้น (the) ได้ ~~เฝ้าดู~~ (watched) พวกเขา (them) จาก (from) สถานที่ (place) การซ่อน (hiding) ของเขา (his) ใน (in) ตกก (reed) หลาย (plurality) คน (classifier) นั้น (the)

HM3: incomprehensible, 1 meaningless word.

HM4: incomprehensible, 1 meaningless word.

HM5: comprehensible

incomprehensible

58. SL: They are the most beautiful birds I have ever seen, he thought.

TC: พวกเขา (they) เป็น (are) นก (bird) ที่ (which) สวย (beautiful) ที่สุด (most) หลาย (plurality) ตัว (classifier) ~~ฉัน~~ (I) เคย (have_ever) เห็น (seen), เขา (he) ได้คิด (thought)

HM3: incomprehensible, 1 additional word required.

HM4: incomprehensible, 1 additional word required.

HM5: incomprehensible, 1 additional word required.

incomprehensible, 1 additional word required.

59. SL: If only I could be like them.
 TC: ถ้า (if) เพียงแต่ (only) ฉัน (I) สามารถ (could) ชอบ (like) พวกเขา (them)
 HM3: comprehensible, but not in the meaning which it is intended.
 HM4: incomprehensible, I meaningless word.
 HM5: comprehensible.
 comprehensible.
60. SL: The beautiful birds saw the ugly duckling.
 TC: นก (bird) ที่ (which) สวย (beautiful) หลาย (plurality) ตัว (classifier) นั้น (the) ได้เห็น (saw) ลูกเป็ด (duckling) ที่ (which) ชี้เหร่ (ugly) ตัว (classifier) นั้น (the)
 HM3: comprehensible but it is not the way it is spoken in Thai.
 HM4: comprehensible but it is not the way it is spoken in Thai.
 HM5: comprehensible.
 comprehensible, it is not the way it is spoken in Thai.
61. SL: The biggest one came over to him
 TC: ตัว (one) ที่ (which) โตที่สุด (biggest) ตรงมาที่ (came_over_to) เขา (him)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible.
62. SL: The ugly duckling tried to hide
 TC: ลูกเป็ด (duckling) ที่ (which) ชี้เหร่ (ugly) ตัว (classifier) นั้น (the) ได้พยายาม (tried) ที่จะ (to) ซ่อน (hide)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible.
63. SL: He was sure that the bird would make fun of him or try to chase him away
 TC: เขา (he) แน่ใจ (sure) ว่า (that) นก (bird) ตัว (classifier) นั้น (the) จะ (would) เมาะเขี่ย (make_fun_of) เขา (him) หรือ (or) พยายาม (try) กับ (to)ไล่ (chase) เขา (him) หนีไป (away)
 HM3: incomprehensible, I meaningless word, I additional word required.

HM4: incomprehensible, 1 meaningless word, 1 additional word required.
 HM5: incomprehensible, 1 meaningless word, 1 additional word required.
 incomprehensible.

64. SL: But the lovely white bird said, what a fine young swan you are !

TC: แต่ (but) นก (bird) ที่ (which) สีขาว (white) น่ารัก (lovely) ตัว (classifier) นั้น (the) ได้พูด (said), หงส์ (swan) หนุ่ม (young) งดงาม (fine) ตัว (classifier) นั้น (a) อะไร (what) คุณ (you) เป็น (are) เขมม (!)

HM3: incomprehensible, 3 words misplaced.

HM4: incomprehensible, 3 words misplaced.

HM5: incomprehensible, 3 words misplaced.

incomprehensible.

65. SL: You should not be here all_by_yourself.

TC: คุณ (you) ไม่ (not) ควร (should) อยู่ (be) ที่นี่ (here) โดยลำพัง (all_by_yourself)

HM3: comprehensible.

HM4: comprehensible.

HM5: comprehensible.

comprehensible.

66. SL: The ugly duckling could not believe what he had heard.

TC: ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ (ugly) ตัว (classifier) นั้น (the) ไม่ (not) สามารถ (could) เชื่อ (believe) อะไร (what) เขา (he) ได้ (had) ได้ยิน (heard)

HM3: incomprehensible, 1 meaningless word, 1 additional word required, 1 unnecessary word.

HM4: incomprehensible, 1 meaningless word, 1 additional word required, 1 unnecessary word.

HM5: incomprehensible, 1 additional word required.

comprehensible.

67. SL: He looked at his reflection in the water

TC: เขา (he) ได้มอง (looked) ไปที่ (at) ภาพสะท้อน (reflection) ของเขา (his) ใน (in) น้ำ (water) นั้น (the)

HM3: comprehensible, 1 unnecessary word.

HM4: comprehensible, 1 unnecessary word.

HM5: comprehensible.

comprehensible.

68. SL: It was true
 TC: มัน (it) จริง (true)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible.
69. SL: His feathers were white and gleaming.
 TC: ขนนก (feathers) หลาย (plurality) เส้น (classifier) ของเขา (his) สีขาว (white) และ (and) เป็นประกาย (gleaming)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible.
70. SL: His neck was long and graceful
 TC: คอ (neck) ของเขา (his) ยาว (long) และ (and) อ่อนช้อย (graceful)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible.
71. SL: He had grown into a handsome swan
 TC: เขา (he) โต (had) สูงขึ้น (grown) เป็น (into) หงส์ (swan) รูปร่าง (handsome) ตัว (classifier) หนึ่ง (a)
 HM3: comprehensible, 1 inappropriate word usage.
 HM4: comprehensible, 1 inappropriate word usage.
 HM5: comprehensible.
 comprehensible.
72. SL: Come with us, said the swan.
 TC: มา (come) กับ (with) พวกเรา (us), หงส์ (swan) ตัว (classifier) นั้น (the) ได้พูด (said)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible.

73. SL: The ugly duckling spread his wings and rose into the sky
 TC: ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ (ugly) ตัว (classifier) นั้น (the) กาง (spread) ปีก (wing) หลาย (plurality) ปีก (classifier) ของเขา (his) และ (and) ขึ้นสู่ (rose_into) ท้องฟ้า (sky) นั้น (the)
 HM3: comprehensible, 2 unnecessary words.
 HM4: comprehensible, 1 inappropriate word.
 HM5: comprehensible.
 comprehensible.
74. SL: I never dreamed that i could_be so happy, he said, and he flew off proudly with his new friends.
 TC: ฉัน (I) ไม่เคย (never) ได้ฝัน (dreamed) ว่า (that) ฉัน (I) จะได้ (could_be) ตั้งนั้น (so) เป็นสุข (happy), เขา (he) ได้พูด (said), และ (and) เขา (he) ได้บิน (flew) ออกไป (off) อย่างภาคภูมิใจ (proudly) ด้วย (with) เพื่อน (friend) ใหม่ (new) หลาย (plurality) ตัว (classifier) ของเขา (his)
 HM3: incomprehensible, 2 meaningless words.
 HM4: incomprehensible, 2 meaningless words.
 HM5: incomprehensible.
 incomprehensible.
75. SL: The ugly duckling
 TC: ลูกเป็ด (duckling) ที่ (which) ขี้เหร่ (ugly) ตัว (classifier) นั้น (the)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible.
76. SL: Written by Ronne_Randall
 TC: เขียน (written) โดย (by) รอนนี่ แรนเดล (Ronne_Randall)
 HM3: comprehensible.
 HM4: comprehensible.
 HM5: comprehensible.
 comprehensible.
77. SL: The wheat was yellow
 TC: ข้าวสาลี (wheat) นั้น (the) สีเหลือง (yellow)
 HM3: comprehensible.

HM4: comprehensible, 1 unnecessary word .
 HM5: comprehensible.
 comprehensible .

78. SL: Here the stork marched_about on his long red legs talking Egyptian.

TC: ที่นี่ (here) นกกระสา (stork) ตัว (classifier) มัน (the) เดินไปมา (marched_about) บน (on) ขา (leg) สีแดง (red) ยาว (long) หลายน (plurality)

✓ (classifier) ของเขา (his) พูด (talking) คนอียิปต์ (Egyptian)

HM3: incomprehensible, 2 meaningless words.

HM4: incomprehensible, 2 meaningless words, 2 unnecessary words .

HM5: incomprehensible, 2 meaningless words, 2 additional word required.

incomprehensible.

79. SL: When I was an ugly duckling, he thought, I never dreamed i could be so happy.

TC: เมื่อ (when) ฉัน (I) เป็น (was) ลูกเป็ด (duckling) ที่ (which) ซึ่งเหว (ugly) ตัว (classifier) นั้น (an), เขา (he) ได้คิด (thought), ฉัน (I) ไม่เคย (never) ได้ฝัน (dreamed) ฉัน (I) จะได้ (could_be) ดังนั้น (so) เป็นสุข (happy),

HM3: incomprehensible, 1 meaningless word.

HM4: incomprehensible, 1 meaningless word, it is not a colloquial Thai.

HM5: incomprehensible, 1 meaningless word.

incomprehensible.

80. SL: You can take a fish to school but you can not make them think.

TC: คุณ (you) สามารถ (can) เอา (take) ปลา (fish) ตัว (classifier) นั้น (a) ไปที่ (to) ฝูงปลา (school) แต่ (but) คุณ (you) ไม่ (not) สามารถ (can) ทำ (make) พวกเขา (them) คิด (think)

HM3: incomprehensible, 1 meaningless word, 1 additional word required.

HM4: incomprehensible, 1 meaningless word, 1 additional word required.

HM5: incomprehensible, 1 meaningless word, 1 additional word required.

incomprehensible.

81. SL: Five days before the trout are released.

TC: ห้า (five) วัน (day) ก่อน (before) ปลาเทราต์ (trout) ตัว (classifier) นั้น (the) ถูก (passive voice) ปล่อย (release)

HM3: comprehensible, 1 additional word required.

HM4: comprehensible, 1 additional word required.

HM5: comprehensible.

comprehensible.

82. SL: I rent a room from Mrs Jones.
 TC: ฉัน (I) ค่าเช่า (rent) ห้อง (room) ห้อง (classifier) แห่ง (a) จาก (from) นาง (Mrs) โจนส์ (Jones)
 HM3: incomprehensible, 1 meaningless word, 1 additional word is required.
 HM4: incomprehensible, 1 meaningless word, 1 additional word is required.
 HM5: incomprehensible, 1 meaningless word, 1 additional word is required.
 incomprehensible .
83. SL: She was rending her hair out in anger
 TC: เธอ (she) กำลัง (continuous tense) ลืก (rend) ผม (hair) ของเธอ (her) ออกมา (out) ใน (in) โกรธ (anger)
 HM3: incomprehensible, 2 meaningless words.
 HM4: incomprehensible, 2 meaningless words, 1 inappropriate word usage.
 HM5: incomprehensible, 2 meaningless words.
 incomprehensible .
84. SL: Algebraic symbols are used when you do not know what you are talking about.
 TC: สัญลักษณ์ (symbols) ทางพีชคณิต (algebraic) หลาย (plurality) ตัว (classifier) ถูก (passive voice) ใช้ (use) เมื่อ (when) คุณ (you) ไม่ (not) รู้ (know) อะไร (what) คุณ (you) กำลัง (continuous tense) พูด (talk) เกี่ยวกับ (about)
 HM3: incomprehensible, 1 word misplaced.
 HM4: incomprehensible, 1 word misplaced.
 HM5: comprehensible.
 incomprehensible .
85. SL: Before he went fishing, John took the worms
 TC: ก่อน (before) เขา (he) ได้ไป (went) ตกปลา (fishing), จอห์น (John) ได้เอา (took) ไส้เดือน (worm) หลาย (plurality) ตัว (classifier) นั้น (the)
 HM3: comprehensible, inappropriate word order, not colloquial Thai.
 HM4: comprehensible, inappropriate word order, not colloquial Thai.
 HM5: comprehensible, inappropriate word order, not colloquial Thai.
 comprehensible, inappropriate word order, not colloquial Thai.
86. SL: The ugly duckling hides his head under his wing
 TC: ลูกเป็ด (duckling) ที่ (which) ชีเหร่ (ugly) ตัว (classifier) นั้น (the) ซ่อน (hide) หัว (head) ของเขา (his) ใต้ (under) ปีก (wing) ของเขา (his)
 HM3: comprehensible, 1 additional word required .
 HM4: comprehensible, 1 additional word required.

HM5: comprehensible.
comprehensible.

87. SL: The beautiful Egyptian talked about her dream

TC: คนอียิปต์ (Egyptian) ที่ (which) สวย (beautiful) คน (classifier) นั้น (the) ได้พูด (talked) เกี่ยวกับ (about) เธอ (her) ฝัน (dream)
HM3: incomprehensible, 2 meaningless words.
HM4: incomprehensible, 2 meaningless words.
HM5: incomprehensible, 2 meaningless words.
incomprehensible .

88. SL: The countryside is very green in spring

TC: ชนบท (countryside) แห่ง (classifier) นั้น (the) เขียวชอุ่ม (green) มากๆ (very) ใน (in) ฤดูใบไม้ผลิ (spring)
HM3: comprehensible, 1 additional word required .
HM4: comprehensible, 1 additional word required.
HM5: comprehensible.
comprehensible.

89. SL: A green salad has only green vegetables such as lettuce and cucumber

TC: สลัด (salad) สีเขียว (green) หนึ่ง (a) มี (has) เท่านั้น (only) ผัก (vegetable) ที่ (which) สีเขียว (green) หลาย (plurality) อย่าง (classifier)
ตัวอย่างเช่น (such_as) ผักกาดแก้ว (lettuce) และ (and) แตงกวา (cucumber)
HM3: incomprehensible.
HM4: incomprehensible, 1 meaningless word.
HM5: incomprehensible.
incomprehensible .

90. SL: The spirit is willing but the flesh is weak.

TC: จิตอาสา (spirit) นั้น (the) พร้อม (willing) แต่ (but) ร่างกาย (flesh) นั้น (the) อ่อนแอ (weak)
HM3: incomprehensible.
HM4: incomprehensible.
HM5: comprehensible.
incomprehensible.