An Incremental framework for a Thai-English Machine Translation System using a LFG tree structure as an Interlingua

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***Abstract*—Developing a machine translation system which can correctly translate any sentence from one language to another is a formidable and challenging task. This suggests that such a system should be implemented incrementally in order to cope with new sentences that have previously not been successfully translated. This paper proposes a new framework to develop Thai to English machine translation incrementally. It is based on the Interlingua approach, which uses syntactic representation of Lexical Functional Grammar (LFG) or an LFG tree structure as Interlingua. The system development is an iterative process that adds more complex grammar rules into the system. Each iteration of the process consists of four phases: syntactic analysis, building Thai LFG tree, mapping a Thai LFG-tree into an English c-structure tree and, lastly, English sentence generation. According to experiment results, this framework has proven to be effective in building and designing a machine translation system.** *(Abstract)*

Keywords Incremental Processing System, Interlingua structure, Left Corner Parsing, LFG grammar, Machine Translation System.

I. INTRODUCTION

Machine translation (MT) aims to automatically translate text from one natural language (source language) to an equivalent text (target language) in another language [37]. The machine translation systems can help people to read texts written in foreign languages or to communicate with others with different natural languages. Although there are many successful machine translation systems in several languages, most research covering Thai-English machine translation was done on English-to-Thai translation but not the other way around [23] [24] [25]. Therefore, the objective of the research for this paper is to develop a Thai-to-English machine translation system.

There are a number of research studies on machine translation that use Interlingua as an intermediate representation for the translation. Interlingua examples previously used are tree structure [18], semantic frame [19], framework [20], and case frame [22]. LFG is a generative grammar [1] developed by Joan Bresnan and Ronald M. Kaplan. The parsing of a sentence using LFG grammar creates multiple structures, for instance, c(onstituent)-structure, f(unctional)-structure, a(rgument)-structure and so on. The main structures are c-structure and f-structure. The c-structure represents the syntactic pattern of a sentence in a form of phrase structure tree, while f-structure - in a form of attribute-value matrices - models grammatical functions and features of a phrase or sentence such as information about subject, object, tense etc. Because of its expressiveness, LFG and its structures have been used in many natural language processing research projects [2][3] [4] [5] [6] [7], hence, they are also used in this research. The essential and first task for machine translation is parsing.

The well-known methods of parsing are top-down and bottom-up approaches [8]. The top-down approach starts by building a parse tree from the root to leaves. This approach may encounter left-recursion problems where the leftmost symbol on the right side of a grammar rule is the same as the symbol on the left side of the rule e.g. $A \rightarrow Aa \mid b$. The bottom-up approach starts by building a parse tree from leaves to the root. It tries to combine words or constituents of a right hand side of a grammar rule to a larger constituent appearing at the left hand side of the rule. This approach may encounter empty rule problems where a wrong decision can lead to a dead end and backtracking, resulting in a wasted effort. A better approach than the two mentioned is left-corner parsing. The key idea of left corner parsing is to combine top-down processing with bottom-up processing. It starts with a top-down prediction that limits a set of rules to pursue, then takes a bottom-up step, and then alternates between top-down and bottom up steps until a parse tree is successfully created. The advantage of this approach is that it can avoid wrong decisions in the ways that are prone to occur in the pure top-down and pure bottom-up parsing techniques. Because of its advantage, left-corner parsing is chosen as the approach for parsing a Thai sentence in the proposed Thai-to-English machine translation system.

Number of machine translation systems employed different pattern matching methods to guide the translation, for instance: [9] application of example-based pattern with transfer driven for a spoken language, [10] development of a framework for

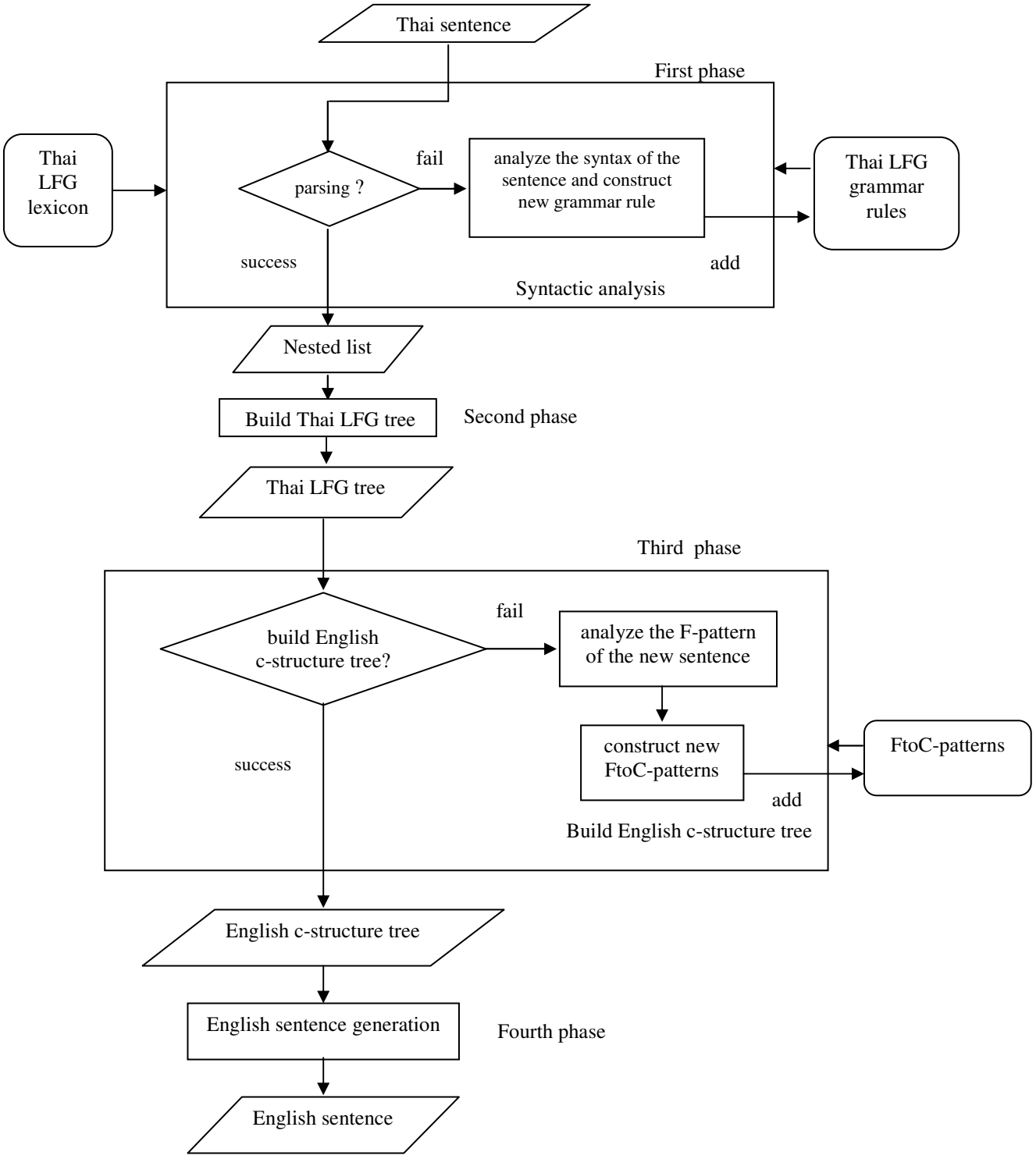
the translation based on the analogy principle, [11] use of a mixed rule-based and example-based approach, [12] presentation of flexible translation through integrated linguistic rules and examples, [13] use of similarity for pattern matching, and so on [14] [15] [16] [17].

For the proposed machine translation system, a pattern matching technique is employed to translate the Interlingua into a corresponding English sentence. An LFG tree structure is translated into the corresponding English C-structure tree using a set of predefined patterns. The process of pattern matching and transformation is performed from root to the leaves in top down fashion.

A new framework for developing Thai to English machine translation system is also used. The system is built incrementally in terms of capabilities to translate more complex sentences. The LFG grammar used in syntactical analysis and the set of predefined patterns used in interlingua translation step as mentioned above, are incrementally added into the system to enable it to handle more complex sentences. According to the experiments the incremental framework has proven to be effective for developing a very complex system such as the machine translation system.

II. THE FRAMEWORK FOR DEVELOPING THE SYSTEM

The framework is divided into four phases, as depicted in Fig. 1



Figures 1 The framework for developing the system

A. First phase: Thai syntactic analysise

GFU-LAB [38], which is software package written in Prolog that performs syntactical analysis using LFG, was modified to parse Thai sentences into Interlingua. The modified software uses the Left-Corner parsing method and requires two sets of data as follows,

- Thai LFG grammar rules

  Thai LFG grammar rules were developed [26][27][28] through grammar analyses following IC (Immediate constituent) theory. The analyses were performed on 200 noun phrases, verb phrases, preposition phrases and simple sentences from the Orchid Corpus [39]. During the analyses each phrase or sentence is repeatedly divided into successive constituents until the smallest constituents - consisting of only a word or meaningful part of a word - are determined. Each step of the constituent division can then be translated into a corresponding Thai grammar rule in a context-free format. Finally, the Thai grammar rules are transformed into c-structure forms of LFG grammar.

- Thai LFG lexicon

  There are a number of structural differences between Thai and English language [29]. English is an inflectional language where morphemes can be changed inside or affixed so that information - such as gender, quantity, tense and so on - can be expressed inside the morphemes. or example:

  'cars' Quantity = plural.

  'ran' Tense = past simple.

Thai is not an inflectional language and so its morphemes cannot be changed inside. In order to express such information on a morpheme, other morphemes must be accompanied with it, thus forming a compound word. Each word in the Thai LFG lexicon [30][31][32][33][34][35][36] consists of information about the word, for example:

คอมพิวเตอร์ (computer) = NOUN

head = **คอมพิวเตอร์**

pred = computer

type = NCMN

ontology = computer.

The output of the first phase after a given Thai sentence or phrase has been parsed is a nested list structure. The list consists of two structures of LFG, namely c-structure and f-structure. If the Thai sentence or phrase can be parsed successfully, the output of that Thai sentence or phrase is forwarded to the second phase. Alternatively, the syntax of the Thai sentence or phrase is analyzed using IC theory and new Thai grammar rules founded by the analyses will be added to the system so that the sentence or phrase can be successfully parsed. Fig. 2 shows an example of the output of the syntactic analysis for a Thai phrase "**โครงการ เครือข่ายคอมพิวเตอร์**"

[[modi=[sem=[pred=computer network, type=NCMN, ontology=network], wordtype=NOUN, head= **เครือข่ายคอมพิวเตอร์**], wordtype=NOUN, head= **โครงการ**, sem=[pred=project, type=NCMN, ontology=plan, modifier=[pred=computer network, type=NCMN, ontology=network]]]

Figure 2. An example of output resulting from syntactic analysis

B. Second Phase: Building a Thai LFG tree structure

In this phase the output from the first phase in nested list format is converted into a general tree structure. For example, the output of Fig. 2 is converted into a corresponding Thai LFG tree structure as shown in Fig. 3

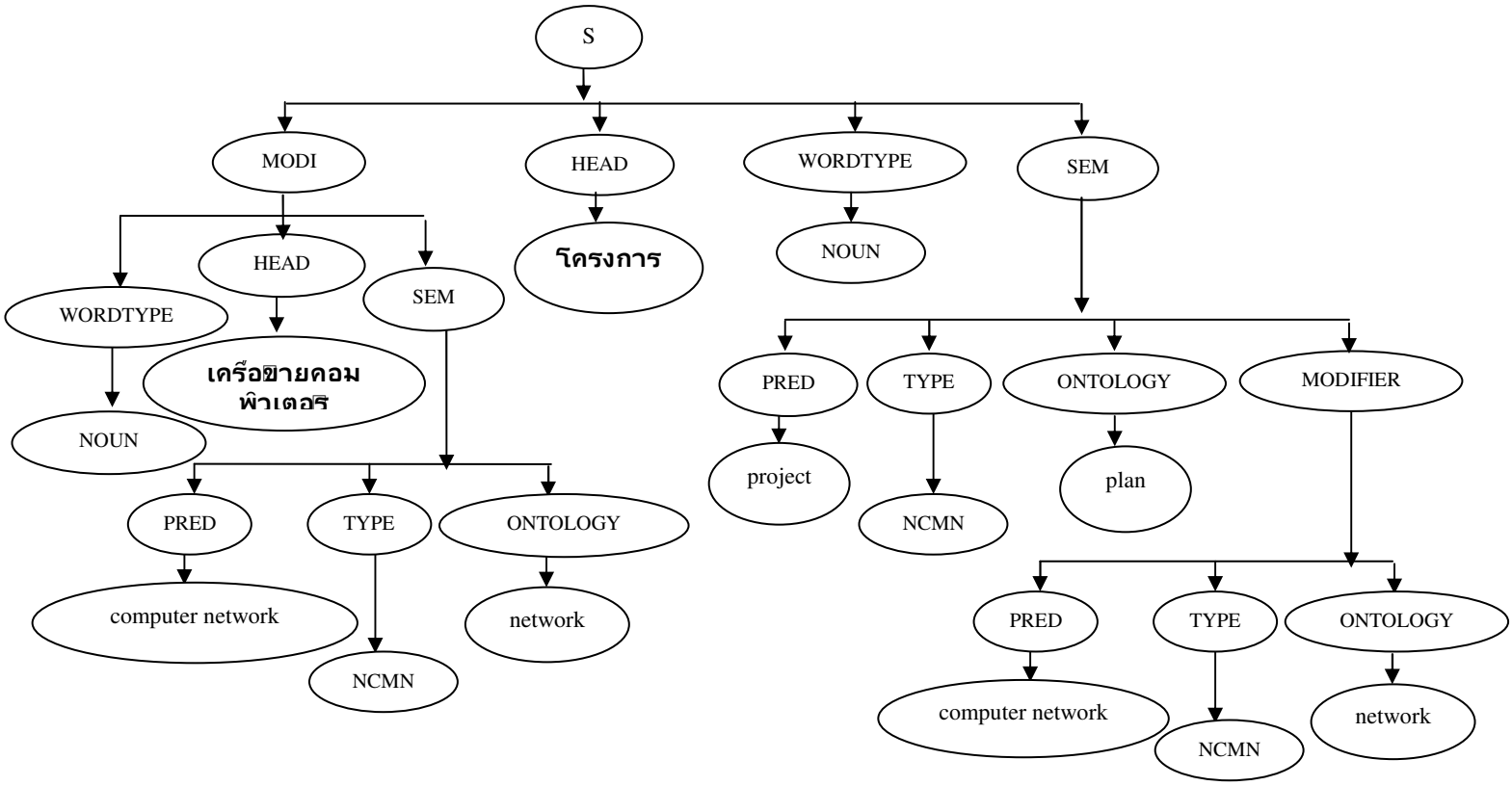


Figure 3. An example of Thai LFG tree (Interlingua)

C. Third Phase: Building English c-structure tree

In this phase, an English c-structure equivalent to the Thai LFG tree structure derived from phase 2 is created. There are two steps in this phase. The first step matches the child nodes of the root representing the sentence level of the Thai LFG-tree against a set of predefined patterns. If a match is found, the child nodes are reordered and converted into the equivalent nodes of English c-structure at the sentence level. The predefined patterns are called FtoC patterns. The second step is performed recursively at each lower level or the phrase levels. For each of the lower levels, phase-level transformation is performed. The phase-level transformation involves matching the current node and its children against the predefined set of phase level FtoC patterns. If a match is found, necessary reordering and conversion takes place. The conversion process is performed recursively from the root to the leaves of the Thai LFG tree structure until the whole tree structure is processed. Each of the FtoC patterns consists of a sequence of constitutes at the right hand side of a Thai LFG grammar rule.

Examples of FtoC patterns at a sentence level are shown in Table I, while examples of FtoC patterns at a phrase level are shown in Table II. The symbols used in the table are as follows: V1, V2, and Vs represent finite verbs, while V3 denotes a participle verb. NP represents a noun phrase and PP denotes a preposition phrase. Like the grammar rules used in the first phase, the FtoC patterns and corresponding reordering and conversions are built incrementally. If an equivalent English c-structure is constructed successfully, the output English c-structure will be forwarded to the next phase. Otherwise, syntactical structure of the sentence or phrase is analyzed and new corresponding FtoC patterns - along with necessary ordering/conversions - are added into the system, enabling the equivalent English c-structure to be successfully constructed.

TABLE I. EXAMPLES OF SENTENCE LEVEL FtoC-PATTERNS

	Thai Patterns				English Patterns			
PASSIVE VOICE	SUBJECT (NP)	VERB	OBLIQUE PHRASE (PP)		SUBJECT (NP)	VERB (is + V_3) (are + V_3)	OBLIQUE PHRASE (PP)	
FUTURE	SUBJECT (NP)	VERB (ADJUNCT + V)	OBJECT (NP)		SUBJECT (NP)	VERB (will + V_1) (shall + V_1)	OBJECT (NP)	
PAST	SUBJECT (NP)	VERB (ADJUNCT + V)	OBJECT 1 (NP)	OBJECT 2 (NP)	SUBJECT (NP)	VERB (V_2)	OBJECT 2 (NP)	OBJECT 1 (NP)
PRESENT	SUBJECT (NP singular) VERB (V + Modifier) OBJECT (NP) SUBJECT (NP plural) VERB (V + Modifier) OBJECT (NP)				SUBJECT (NP singular) VERB (Vs + Modifier) OBJECT (NP) SUBJECT (NP plural) VERB (V_1 + Modifier) OBJECT (NP)			

TABLE II. EXAMPLES OF PHRASE LEVEL FtoC-PATTERNS

	Thai Patterns			English Patterns				
Noun Phrase	MODIFIER (Classifier)	NOUN (Proper Noun)		The	MODIFIER (Classifier)	of	NOUN (Proper Noun)	
	NOUN (Common Noun)	MODIFIER (Ordinal Number)		The	MODIFIER (Ordinal Number)	NOUN (Common Noun)		
	MODIFIER (Common Noun)	NOUN (Proper Noun)		The	MODIFIER (Common Noun)	of	NOUN (Proper Noun)	
	MODIFIER1 (Common Noun)	MODIFIER2 (Common Noun)	NOUN (Proper Noun)	The	MODIFIER2 (Common Noun)	MODIFIER1 (Common Noun)	of	NOUN (Proper Noun)
	NOUN (Common Noun)	MODIFIER (Common Noun)			MODIFIER (Common Noun)	NOUN (Common Noun)		
Preposition Phrase	PREPOSITION	OBJECT (Noun phrase)			PREPOSITION	OBJECT (Noun phrase)		
Verb phrase	NEGATOR	VERB	OBJECT (Noun phrase)		DO + NOT	V_1	OBJECT (Noun phrase)	

According to the examples of FtoC patterns shown above, the system must be able to perform subject-verb matching and also perform necessary conversions to handle functional features such as tense, voice, article, singular or plural noun etc.

D. Fourth Phase: Generating an English sentence

To generate the equivalent English sentence, the system traverses an English c-structure tree and prints out all English words of the leaf nodes in a left to right direction. The output from this fourth phase will be the English phrase/sentence translated from the given Thai sentence.

III. Building a system prototype

To verify whether the framework can be used effectively for building the Thai-to-English machine translation system, a system prototype is built according to the framework. Two stages of building the prototype are implemented as the prototype is constructed incrementally according to the framework.

A. The First Stage: Building an intermediate system

In this stage, about 100 Thai phrases and simple sentences (no serial verb constructions) are selected from the Orchid Corpus and then Thai grammar rules are developed according to the phrase and sentences using the IC-theory. A Thai LFG lexicon based on the Thai phrases and simple sentences is also created. Following the framework, each of the phrases/sentences is entered into the prototype system, one at a time. The grammar rules and FtoC patterns were built incrementally. After the completion of the first stage, the prototype can handle the translation of phrases and simple sentences. Hence, the prototype can be used as an intermediate system open to extension, enabling it to eventually handle translations of more complex sentences.

B. The Second Stage: Enhancing the intermediate system

An additional 100 more complex sentences (no serial verb constructions) were selected from the corpus and then processed in the same way as in the first stage. Again, the grammar rules and FtoC patterns associated with each of the additional sentences were added into the system. As more sentences were input into the prototype, the prototype became more capable and some sentences could be translated successfully without any changes or modifications to the system.

To evaluate the quality of the translation of the prototype, three senior master students of the School of Language and Communication of National Institute of Development Administration (NIDA), Thailand, who had taken courses in translation theory, were presented with the 200 input phrase/sentences as well as the corresponding results of the machine translations from the prototype. The students were asked to assess and classify the quality of the translation into three levels. The first level - with a score of 3 - is given to a translation that is acceptable, i.e. the output sentence could be understood and had the same meaning as the source sentence.

The second level - with a score of 2 - is given to a translation that is moderately acceptable. This means that the output sentence might have small errors but could still be understood and carried the same meaning as the source sentence.

The third level - with a score of 1- is given to a translation that is not acceptable or has to be rejected outright. This means that the output sentence could not be understood or did not carry the same meaning as the source sentence. The scores given by the three students are summarized in Table III.

TABLE III. THE SUMMARY OF SCORES GIVEN BY THE THREE STUDENTS

	Acceptable (3) (%)	Moderate (2) (%)	Rejected (1) (%)
First student	22	57	21
Second student	31.5	48	20.5
Third student	32.5	37.5	30
Average percentages	28.7	47.5	23.8
Average Score	2.05		

Table III shows that most of the translations (about 76.2 %) from the prototype are either acceptable or moderately acceptable. The remainder - about 23.8 % - are rejected. The average score given by the three students was 2.05.

These figures demonstrate that the prototype built according to the framework can be an effective tool for Thai to English machine translation, although there are still improvements required to be made in the future.

IV. CONCLUSIONS AND FUTURE WORK USING THE TEMPLATE

This paper introduces a new framework for developing Thai to English machine translation system incrementally. Thai LFG grammar rules were derived directly from given Thai sentences/phrases using IC-theory. A Thai sentence is first translated into an Interlingua of Thai LFG tree structure. A process of pattern matching the Thai LFG tree nodes and transforming them into equivalent nodes of English LFG c-structure tree is proposed. The English LFG c-structure can then be easily transformed to an English sentence/phrase.

A prototype of the machine translation system was built according to the framework. The prototype system was able to achieve a certain degree of success in terms of the quality of the translations. However, more progresses need to be made in the future so that the system can handle more

complex sentences, tenses, voices and articles. Automatic tools to learn Thai grammar rules from corpus and to learn patterns of Thai LFG tree structure and their transformations from a given translation may be used to assist the development of a fully functioning system.

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REFERENCES

[1] Y. N. Falk, Lexical-Functional Grammar:An Introduction to Parallel Constraint-Based Syntax, California: Center for the study of Language and Informantion Stanford, 2001.

[2] L. Clément, and A. Kinyou., "XLFG-an LFG parsing scheme for Frenc," In Proceedings of the LFG01 Conference, University of Hong Kong, Hong Kong, Miriam Butt and Tracy Holloway King, 2001.

[3] Z. Güngördü, and K. Of Lazer, "Parsing Turkish using the Lexical Functional Grammar Formalism," In Proceedings of the 15th conference on Computational linguistics, Kyoto, Japan, 1994, pp. 494 – 500.

[4] A. B. Borra, E. A. O. Chan, C. I. R. Lim, R. B. S. Tan, and M. C. N. Tong, "LFG-Based Machine Translation Engine for English and Filipino," 4th National Natural Language Processing, Research Symposium Philippine Languages and Computation De La Salle-College of Saint Benilde Hotel , Angelo King International Center ,Estrada corner Arellano St., Manila , 2007.

[5] Y. Graham, A. Bryl, and J. V. Genabith, "F-structure transfer-based statistical machine translation," In Proceedings of the LFG09 Conference. Miriam Butt and Tracy Holloway King (Editors), 2009.

[6] M. Dorna, A. Frank, Anette, G. V. Genabith, and M. C. Emele, "Syntactic and semantic transfer with f-structures," In Proceedings of the 17th international conference on Computational linguistics, Montreal, Quebec, Canada, 1998, pp: 341 – 347.

[7] R. M. Kaplan, K. Netter, J. Wedekind, and A. Zaenen., "Translation by structural correspondences," In Proceedings of the fourth conference on European chapter of the Association for Computational Linguistics. Manchester, England, 1989, pp. 272-281.

[8] A. V. Aho, R. sethi,and J. D. Ullman, Compilers: Principles, Techniques, and Tools, 2nd, United States of America: Addison-Wesley., 1988, pp.159-267.

[9] O. Furuse, and H. Iida, "Example-based Method for Transfer-driven Machine Translation," In Proceedings of the Fourth International Conference on Theoretical and Methodological Issues in Machine Translation, (1992), 1992, pp.139-149.

[10] M. Naga0., "A framework of a mechanical translation between Japanese and English by analogy principle," In Proceedings of the international NATO symposium on Artificial and human intelligence Lyon, France, 1984, pp: 173 – 180.

[11] S. Shirai, F. Bond, and Y. Takahashi, "A hybrid rule and example based method for machine translation." In the Natural Language Processing Pacific Rim Symposium (NLPRS-97), Phuket, Thailand, 1997, pp.49-54.

[12] A. Franz, K. Horiguchi, D. Lei, D. Ecker, E. Koontz, and K. Uchida, "An integrated architecture for example-based machine translation," In Proceedings of the 18th conference on Computational linguistics Saarbrücken, Germany, 2000, pp: 1031 – 1035.

[13] L. Cranias, H. Papageorgiou, and S. Piperidis, "A matching technique in Example-Based Machine Translation." In Proceedings of the 15th conference on Computational linguistics Kyoto, Japan , SESSION: Machine translation, 1994, pp: 100 – 104.

[14] K. Jung-jae, C. key-sun, and C.Young-soog, "Phrase-pattern-based Korean to English machine translation using two level translation pattern selection." In Proceedings of the 38th Annual Meeting on Association for Computational Linguistics Hong Kong, 2000, pp: 31 – 36.

[15] G. Tambouratzis, S. Sofianopoulos, V. Spilioti, M. Vassiliou, O. Yannoutsou, and S. Markantonatou, "Pattern Matching-Based System for Machine Translation (MT)," In Lecture Notes on Artificial Intelligence, Proceedings of the SETN-2006 Conference, May 18-20, Heraklion, Greece: Springer-Verlag, 2006, Vol. 3955, pp. 345-355.

[16] Y. Matsumoto, H. Ishimoto, and T. Utsuro, "Structural matching of parallel texts," In Proceedings of the 31st annual meeting on Association for Computational Linguistics Columbus, Ohio, 1993, pp: 23 – 30.

[17] K. Takeda, "Pattern-based context-free grammars for machine translation," In Proceedings of the 34th annual meeting on Association for Computational Linguistics Santa Cruz, California, 1996, pp: 144 – 151.

[18] B. Dorr, "UNITRAN: An Interlingual Approach to Machine Translation," In Proceedings AAAI-87 Sixth National Conference on Artificial Intelligence. Seattle, WA, 1987.

[19] Y. Lee, W. S. Yi. S. Seneff, and C. J. Weinstein, "Interlingua-Based Broad-Coverage Korean-to-English Translation in CCLINC," In Proceedings of the first international conference on Human language technology research, San Diego, 2001, pp.1-6.

[20] Q. Xuan, Z. Huiping, and C. Huowang, "An Interlingua-Based Chinese-English MT System," Journal of Computer Science and Technology. Vol. 17(4), 2002, pp: 464 – 472, in press.

[21] D. Zeynep Hakkani, T. Gökhan, K. Oflazer, T. Mitamura, and E. H. Nyberg, An "English to Turkish Interlingual MT System. In Machine Translation and the Information Soup (MT in a growing field of language technologies)," Association for Machine Translation in the Americas (AMTA-98), 1998, pp.83-94.

[22] C. K. Turhan, "An English to Turkish Machine Translation System Using Structural Mapping," In ANLP 1997, 5th Applied Natural Language Processing Conference, March 31 - April 3, 1997, Marriott Hotel, Washington, USA, Proceedings, 1997, pp. 320-323.

[23] K. Naruedomkul , N. Cercone, "Generate and Repair Machine Translation," Journal Computational Intelligence, vol 18(3), 2002, pp. 254-269, in press.

[24] B. Sirinaovakul, K. Chancharoen, "English-Thai Structure-Based Machine Translation." Computational Intelligence, vol.18 (3), 2002, pp 294-312, in press.

[25] K. Chancharoen, N. Tannin, and B. Sirinaovakul, "Pattern-Based Machine Translation for English-Thai." In the 13th Pacific Asia Conference on Language, Information and Computation: Proceedings:Taiwan, R. 0. C. February 10-11, 1999.

[26] A. Prasithrathsint, Y. Hoonchamlong, and S. Savetamalya, Grammatical Theories. 2nd ed Bangkok: Chulalongkorn University Publishers, 2003.

[27] N. Bandhumedha, Thai Grammar, 3rd ed. Bangkok:Chulalongkorn University Publishers,2006.

[28] N. Kanchanawan, Analysis of Thai Structure., 2nd ed., Bangkok, Ramkhamhaeng University Publishers. 1999.

[29] W. Nathong, Contrastive Analysis of English and Thai, 1000, 13th ed. Ramkhamhaeng University. Bangkok, Publishers, 2003.

[30] W. A. Cook, Case Grammar Theory, Washington, D.C.: Georgetown University Press. 1989.

[31] D. Garden and S. Wannapok, Thai-English dictionary, 3rd ed. B.E. 2549. Bangkok: matichonbook. 2006.

[32] Human language Technology Laboratory of NECTEC, LEXITRON [online]. Retrieved August 13, 2004 from http://lexitron.nectec.or.th/

[33] P. Sungkhavon, "Semantic relationships between nouns and verbs in Thai sentences", M.S. thesis, Chulalongkorn University,Bangkok, Thailand, 1984.

[34] The Royal Institute Dictionary B.E. 2546. The Royal Institute Dictionary B.E. 2542, 1st ed. Bangkok: nanmeebooks. 2003.

[35] V. Sornlertlamvanish and M. Boriboon, Thai Concept Classification (Technical Report). Bangkok. Retrieved August 13, 2006 from http:// www.links.nectec.or.th/pub/tech/akotech.ps.g

[36] V. Sornlertlamvanish and W. Phantachat, Interlingual Expression for Thai Language (Technical Report). Bangkok. Retrieved August 13, 2006 from http://www.links.nectec.or.th/pub/tech/iltr.ps.gz

[37] D. Arnold, L. Balkan, S. Meijer, R.L. Humphreys, and S. Sadler, Machine Tranalation: An Introductory Guide, London: Blackwells-NCC. 1994.

[38] J. C. R. Anton (2004, Jan, 23). GFU-LAB. Retrieved August 13, 2004 from http://www3.uji.es/~ruiz/gfulab/

[39] V. Sornlertlamvanish, T. Charoenporn, and H. Isahara,Orchid Corpus. Retrieved August 13, 2004 from http://www.hlt.nectec.or.th/orchid/corpus/corpus.html.

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