

**USING MULTI AGENT TECHNOLOGY FOR
AUTOMATIC MACHINE TRANSLATION**

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Thesis submitted in partial fulfillment of the requirements for the degree
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Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The above candidate has carried out the research for the PhD thesis under my supervision.

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Prof. Asoka S. Karunananda

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14.07.2020

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.....

Prof. George Rzevski

Date:

Dedicated to

This thesis is dedicated

...to my beloved mother and father

...to my wife and son

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Abstract

Machine translation is a cost-effective, quick, and widely accepted automated language translation method that has become essential in the modern and ever more globalized world. Machine translation can be done with one or more different approaches, including dictionary-based, rule-based, example-based, phrase-based, statistical, or neural-linguistic approaches. Nevertheless, most of the existing machine translation systems show a quality gap when compared with human translation. Thus, human translation has been considered as the best language translation method so far. Human language translation is a complex and opportunistic process depends on human memory. This human language translation process has been described through a few theories. Among them, the garden path model and the constraint satisfaction model are two fundamental approaches available for human language translation, especially concerning sentence parsing with meaning. These two theoretical models demonstrate how to select suitable words in the phrase of a sentence to generate accepted meanings. Based on these two theories, a hybrid approach to machine translation has been proposed. This proposed approach is stimulated by how people parse and translate a sentence by putting available phrases together with accepted meaning. According to the approach, translation is done in three stages. In the first stage, the system analyses the given sentence by considering the morphology, syntax, and semantics of the source language. Then, the system uses phrase-based translation and translates each phrase into the target with multiple solutions. The phrase translation is done considering the four factors of psycholinguistic parsing techniques, such as phrase structure, semantic features, thematic roles, and probability. Finally, considering all the translated phrases, the system should be capable of identifying suitable target language phrases to take accepted meanings, considering subject-verb and object-verb agreements. After the subject-verb-object agreement, other available phrases in the sentence should be capable of re-arranging according to the accepted subject, object, and verb phrases.

This approach has been simulated with the multi-agent system named EnSiMaS, which translates English text into Sinhala. The EnSiMaS was implemented on the MaSMT framework, which was specially developed for agent-based machine translation. The EnSiMaS comprises of 26 language processing agents on both source and target languages. These agents were clustered into six agent swarms considering morphological, syntactical, and semantical concerns of the source and the target languages. In addition to these language-processing agents, the system should be able to create an agent dynamically for each source language phrase. These dynamically created phrase agents should be capable of communicating with other relevant phrases and taking the accepted solutions.

The EnSiMaS was tested with 85 sample English sentences. For each English sentence, three different translations were taken. According to the evaluation result, the system shows an 8.77% word error rate, a 6.72% inflexion error rate, and a 5.37% sentence error rate for the first, second, and third translations. In addition, calculated BLUE scores show 0.89160756, 0.52009204, and 0.43581893 for the first, second, and third translations. Then randomly selected 25 samples sentences are used to calculate the adequacy and fluency of the EnSiMaS. Adequacy and fluency rates were taken from 55 human evaluators considering the human-translated reference sentences. The Kendal's Tau correlation coefficient shows that there is a weak positive association between adequacy levels of human translations vs EnSiMaS system translations and moderate positive association between fluency levels of human translation and EnSiMaS system translation. Further, according to the Fleiss Kappa coefficient method, there is a significant fair agreement on raters for adequacy and fluency ratings.

Keywords: Machine Translation, Multi-agent systems, Human Language Processing, MaSMT, EnSiMaS

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List of Abbreviations

AI	- Artificial Intelligence
ARGM	- Agent Role Group Model
BCE	- Before the Current Era
BEES	- Bilingual Expert for English to Sinhala
CE	- Current Era
CAT	- Computer Assisted Translation
CYK	- Cocke–Younger–Kasami
CSM	- Constraint Satisfaction Model
EMA	- English Morphological Analysis
ESA	- English Syntax Analysis
ESMTS	- English to Sinhala Machine Translation System
EnSiMaS	- English to Sinhala Multi-Agent System
EBMT	- Example Based Machine Translation
FIPA	- Foundation for Intelligent Physical Agents
GNMT	- Google’s Neural Machine Translation
GPM	- Garden Path Model
HAMT	- Human-assisted (-aided) machine translation
IER	- Inflexion Error Rate
JADE	- Java Agent DEvelopment Framework
KQML	- Knowledge Query and Manipulation Language
LSTM	- Long Short Term Memory
LL	- Left-to-right, Leftmost derivation
LR	- Left-to-right, Rightmost derivation
MWE	- Multi-Word Expressions
MAS	- Multi-Agent System
MT	- Machine Translation
MaSMT	- Multiagent System for Machine Translation
NMT	- Neural Machine Translation
NLTK	- Natural Language Toolkit
NPMT	- Neural Phrase-based Machine Translation

NLP	- Natural Language Processing
PPO	- Preposition Phrase Order
RBMT	- Rule-based Machine Translation System
RTT	- Round-trip Translation
SL	- Source Language
SMT	- Statistical Machine Translation
SER	- Sentence Error Rate
SMG	- Sinhala Morphological Generation
SSG	- Sinhala Syntax Generation
SOV	- Subject Object Verb
SVO	- Subject Verb Object
SPADE	- Smart Python multi-Agent Development Environment
TAG	- Tree Adjoining Grammar
TL	- Target Language
WER	- Word Error Rate