Chapter 5

Analysis and Design of Recognition of Ancient Sri Lankan Inscriptions

5.1 Introduction

This chapter contains the design overview of the proposed solution. It includes a diagram that present the top level architecture of the system. And each and every module displayed in the top level architecture diagram is explained.

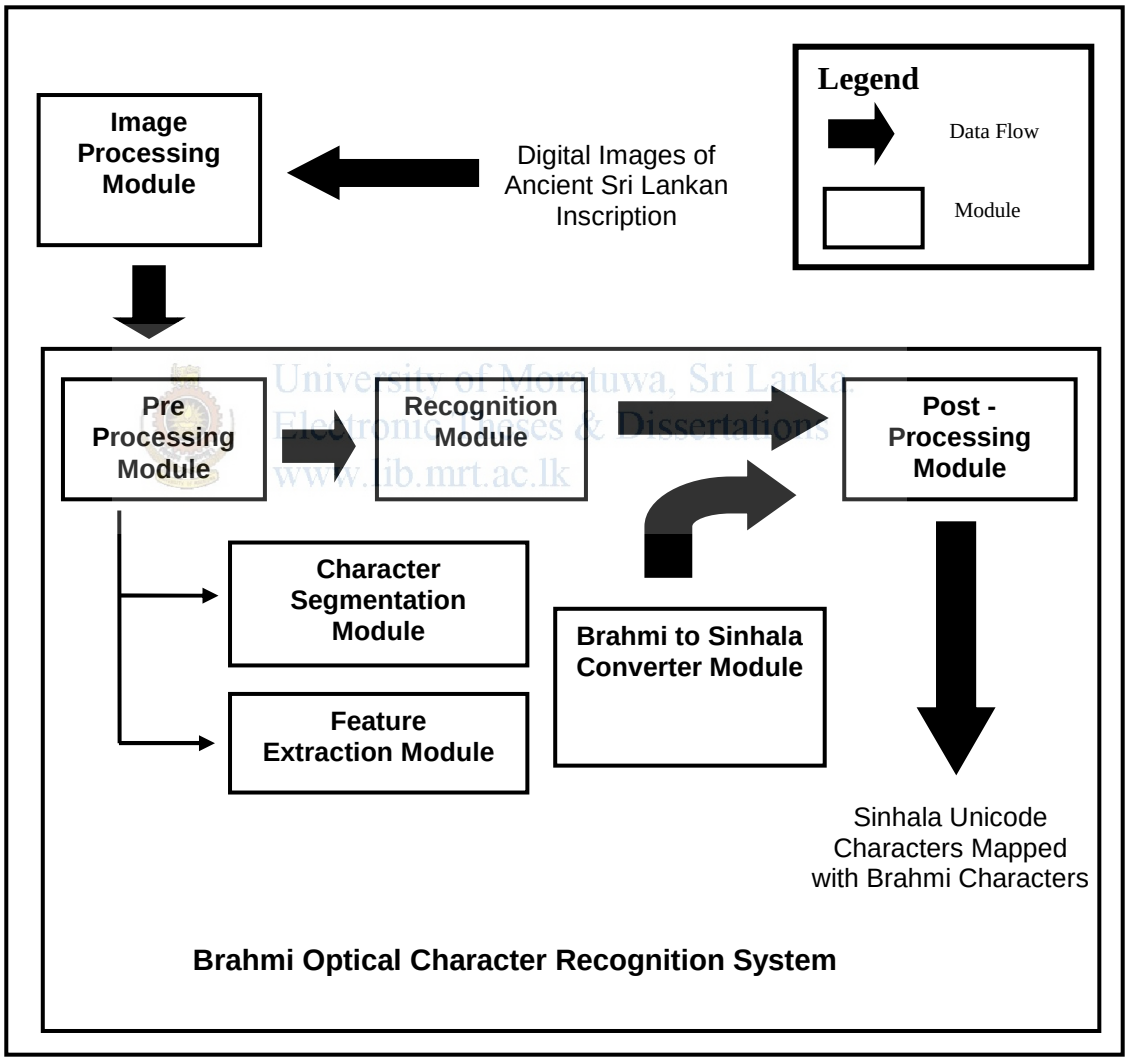

Figure 5.1 : High Level Design Diagram of Ancient Sri Lankan Inscription Recognition System

This system consists of four major modules namely, Pre Processing Module, Recognition Module, Post Processing Module and the Brahmi to Sinhala Converter Module. Figure 5.1 shows the interconnection between these modules.

5.2 Image Processing Module

In this module digital images in ancient Sri Lankan inscriptions under go through a noise removal session which is executed by the human user manually. The image processing techniques such as blurring, threshold techniques are applied to the original image in-order to minimize the noise. Since these images processing procedures are performed by a separate image processing tool this module could be categorize as a module which is external to the system.

5.3 Pre – Processing Module

The input for this module is an ancient Sri Lankan inscription which is processed in the image processing module. This module could be categorize into two sub modules namely, Character Segmentation Module and the Feature Extraction module. In the character segmentation module the horizontal and vertical projection graphs are produced by analyzing the black pixels in the rows and the columns. Based on the horizontal projection graph the lines that could contain characters are identified. By analyzing the vertical projection graph of a particular line segment, the system marks the possible character segmentation locations of the line segment image. However the system marked location might not exactly separate characters it might represent the noise patches that is available in the inscription image. Therefore the line segments with the marked locations are provided to the human user for the character segmentation. The marked locations are represented by black lines and the user has given the facility to select the lines by ticking a checkbox. These isolated characters are resized into 30 x 30 pixels image. These characters are used in the feature extraction module.

Following features were extracted without any further processing.

1. Total number of black pixels in the image.
2. Maximum number of horizontal black pixels in the image
3. Maximum number of vertical black pixels in the image.

Then the 30 X 30 pixel character image is divided into nine boxes and following features were extracted.

1. Total number of black pixels in square 01 to square 09.
2. Maximum number of horizontal black pixels in square 01 to square 09.
3. Maximum number of vertical black pixels square 01 to square 09.

And finally the character image is segmented into horizontal wise three layers and total number of black pixels in each layer is calculated.

In addition to the above features system converts the segmented character images into black and white image and assigns 1 and 0 respectively. These values are also considered as a feature of the character.

5.4 Recognition Module

This module contains an artificial neural network which represents the ANN agent in the multi agent solution. The neural network is designed as a multi layer perceptron which is layered feed forward network typically trained with static back propagation.

Numbers of hidden layers of the neural network was decided by experimentally increasing the hidden layers and analyzing the output.

No of Hidden Layers	Recognition Rate
10	48%
5	55%
3	70%
1	80%

Table 5.1 : Output with Different Number of Hidden Layers

Base on the recognition rates presented in Table 5.1, highest recognition rate was recorded when 1 hidden layer was used. Therefore the neural network was designed has a 3 layer network that consists of 1 hidden layer, 1 input layer and 1 output layer.

The neural network is trained with the extracted character features of the feature extraction module. The input layer of the neural network contains 914 neurons to

represent all the 14 features of a Brahmi character and rest of the 900 neurons represent the colour of the each and every pixel in the 30 X 30 character image. The output layer consists of 1 neuron to represent the recognized character.

5.5 Post Processing Module

The ancient inscriptions that are carved in the rocks have been damaged due to long term human activities, climate etc. Therefore recognizing the characters using only neural network is an impossible task since sometimes the patches would also recognize as characters and characters itself would incorrectly recognized due to cracks and patches that resides on the character itself. Therefore it is crucial to rectify the output given by the neural network. The post processing module has been introduced for this purpose.

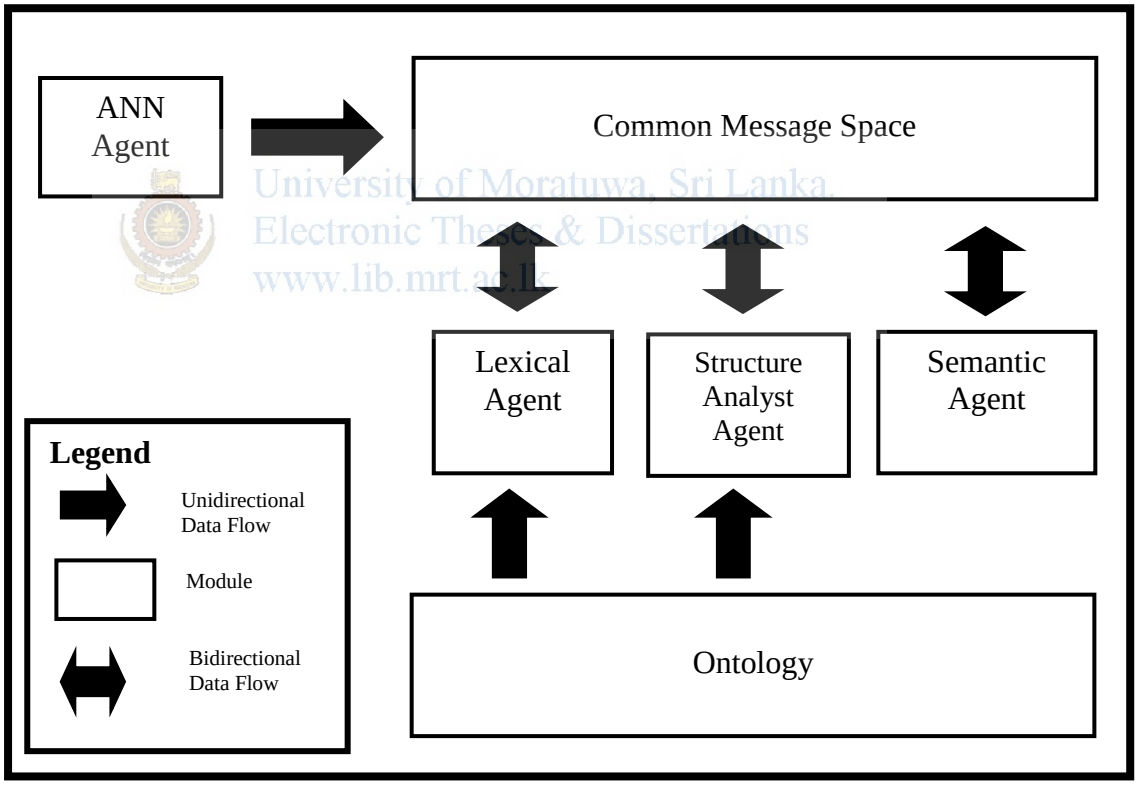

Figure 5.2 : Design Diagram of Post Processing Module

Figure 5.2 illustrates the design diagram of the post processing module. The artificial neural network which is the main component in the recognition module acts as the Artificial Neural Network (ANN) Agent in the multi agent solution. The ANN agent which acts as the request agent provides the recognized character string to the common message space.

5.5.1 Lexical Agent

The lexical agent captures the recognized character string in the message space. This character string could contain characters which are incorrectly identified due to noise. Lexical agent analyzes the character string and come-up with the suggestions for the incorrectly recognized words base on the dictionary that is available in the ontology. Then the lexical agent generates sentences by forming combination of suggestions along with the other words. These generated messages also are verified against the variations that exist in the Sinhala language such as Kombuwa, Aela Pilla , Al Lakuna etc and modifications are done accordingly, to the generated sentences. These modified messages are written to the message space for the reference of the other agents.

5.5.2 Structure Analyst Agent

Structure Analyst Agent further processes the sentence generated by the lexical agent and assigns marks for the words base on the located positions of the words in the sentence. If the mark achieved by the sentence is higher than the threshold mark those sentences are considered as valid sentences. If the sentence is valid, the Structure Analyst Agent accepts the sentence else Structure Analyst Agent rejects the sentence.

5.5.3 Semantic Agent

Semantic agent is a human agent who selects the sentences base on the context. The semantic agent is provided with the sentence which lexical agent has identified and the response of the Structure Analyst Agent. Base on the validity of the sentence the Semantic Agent accepts or reject the sentence.

Base on the agent responses that were achieved through negotiation and communication the final output for the selected inscription is identified and presented to the users.

5.5.4 Common Message Space

The Common Message Space acts as a bulletin board for agents. Agents can publish common messages on common message space. These messages are displayed to all the agents in the multi agent system. The relevant agent could use these messages as

and when they are needed. In this system the ANN agent publish recognized character string in the common message space and the lexical agent process the recognized character string and publish the sentence that is generated by the combinations of suggestions. Structure Analyst agent read the message space to find out the sentence that is suggested by the lexical agent and process it to discover the validity of the sentence. Base on the validity of the sentence structure analyst agent provide its answer and it is also published in the message space. Semantic agent could find out both the responses of the lexical agent and the structure analyst agent in the message space. The semantic agent also publishes its response also in the message space. Likewise the common message space is actively used by the agents in this multi agent system.

5.5.5 Ontology

The ontology plays a major role in multi agent systems; it acts as the main medium to store the knowledge of the agents. The ontology in this system contains a two word dictionaries, one dictionary contain Sinhala words and the other dictionary contains the Sinhala words represent in English letters. In addition the ontology also consists of knowledge about the word statistics. For example for a particular word what is the percentage that word could exists in the beginning of the sentence , middle of the sentence and end of the sentence.

When a sentence with new words is accepted by the multi agent solution, the system updates the ontology with the new words. These newly added words could be used by the lexical agent in future sentence building process.

5.5.6 Interaction between Agents

The Communication between agents has played a major role in the post processing module. Figure 5.3 presents the sequence flow of message passing between agents. The explanation of each and every sequence number displayed in the Figure 5.3 is described in the Table 5.2.

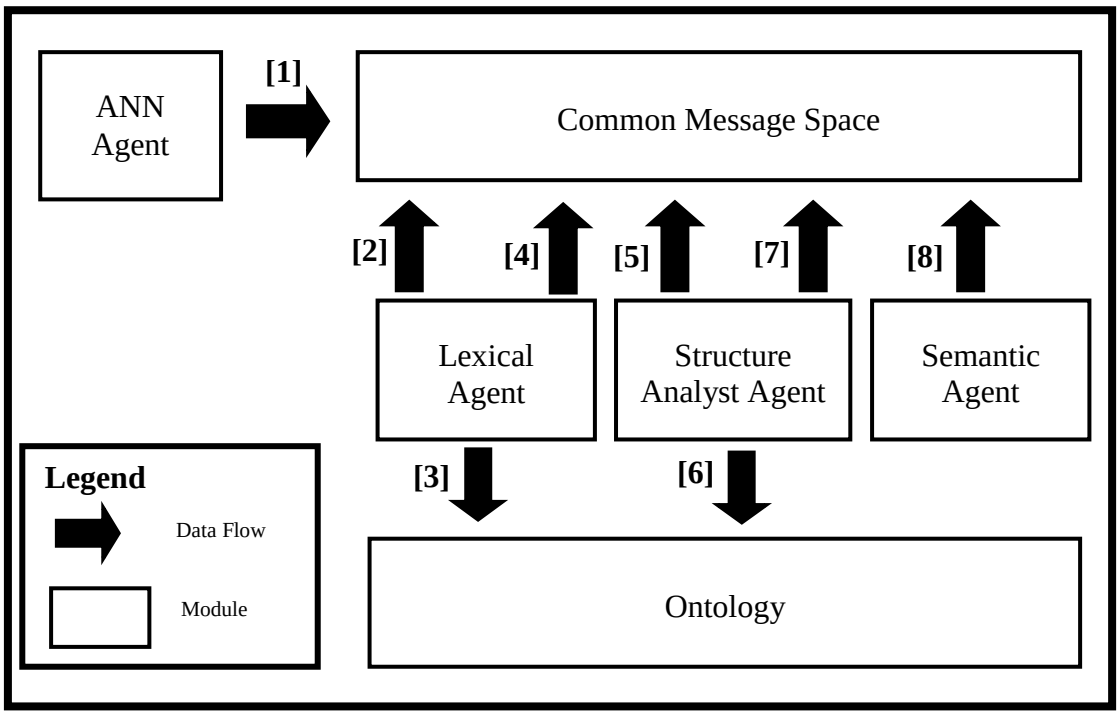

Figure 5.3 : AUML Collaboration Diagram

Sequence Number	Description
1	The ANN acts as a request agent and writes the recognized input string to the common message space.
2	The lexical agent reads the common message space and captures the input string that was written by the ANN agent.
3	The lexical agent queries the dictionary that is located in the ontology.
4	After processing the input string the lexical agent writes the results (sentences) to the common message space.
5	The Structure Analyst Agent reads the message space and captures the sentences written by the lexical agent.
6	The Structure Analyst Agent queries the statistics database in the ontology.
7	After processing the structure analyst agent writes the response (accept / reject) to the common message space
8	Semantic Agent reads the common message space to read the sentences that is written by lexical agent / structure analyst agent.

Table 5.1 : Interaction Order

5.6 Brahmi to Sinhala Converter Module

A domain knowledge database with the mapping between the Brahmi characters to Sinhala Unicode characters is maintained. This knowledge is gained from experts and by literature review. After the lexical agent create sentences in English representation the English letter by letter is converted to Sinhala Unicode characters formed standard Sinhala words.

5.7 Summary

This chapter was mainly focused on the design of the chapter. It explains the functionalities of each and every module in the system and the interactions among them. The next chapter elaborates how these functionalities are implemented.