Chapter 2

Ancient Sri Lankan Inscriptions and Optical Character Recognition

2.1 Introduction

The importance of this project is highlighted in the previous chapter along with the aim, objectives and the resource requirements.

This chapter is written entirely base on the conducted literature survey. This includes the approaches that have been conducted by other researchers. The literature survey for this project was conducted through two directions. A thorough study was done to capture the domain knowledge about the ancient Sri Lankan inscriptions. And on the other hand the technologies that were used for optical character recognition were studied.

2.2 Ancient Sri Lankan Inscriptions

The major source for this study was based on the books that were published by the Sri Lanka National Museum. Following illustrate the knowledge that was captured by those books.

The book Sinhala Lekhana Kalaawa (Sinhala Art of Writing) presents the evolution of the Sinhala characters during various time periods [21]. As described in this book the first characters in Sri Lankan history are known as Brahmi characters which had a direct relationship with the Asoka Brahmi characters in India. It state that the Sri Lankan Brahmi alphabet in initial stages had limited number of non-curve characters. This book also explains about the significant changes that occurred to the initial Brahmi alphabet during different time stages. For example new characters were added to the alphabet as a result of the relationship that had with other countries. This book also highlights how the non-cursive form of the initial Brahmi characters has move to the cursive nature. Basically this book is written in order to provide a rough idea about the evolution of the Sinhala art of writing.

A detail study has been conducted about the ancient Sri Lankan pillar inscriptions in the book Sri Lanka Shilaalipi Sanniwedanaya (Sri Lanka Inscription Communication)

[22]. This book contains the wordings in the pillar inscriptions along with their meanings. It also slightly explains about other inscription types such as cave inscriptions, slab inscriptions and rock inscriptions.

The book Sri Lankeeya Brahmi Ahkshara Malawehi Arambaya (The beginning of the Sri Lankan Alphabet) [12] mainly focus on the Brahmi characters that is found in the ancient clay pots. It describes the evolution of the ancient Brahmi characters and their relationship with the ancient Indian characters. Most importantly this book introduces a new concept to describe the ancient Brahmi characters using the eight directions.

2.3 Optical Character Recognition – The State of Art

Research in optical character recognition has identified two board areas, namely handwritten character recognition and printed character recognition.

2.3.1 Hand Written Character Recognition

Below explain some of the research conducted for the hand written character recognition.

The paper "Off-line Sinhala Handwriting Recognition using Hidden Markov Models", by S. Hewavitharana and her colleagues presents a method to recognize the offline Sinhala characters using Hidden Markov Models [11]. As the initial step of the recognition process sample hand writings were collected using pre-formatted A4 sized paper. This document is binarized using adaptive thresholding techniques. After going through the segmentation and the classification processes, the feature vectors will be created for horizontal and vertical directions of a particular character and passed to the Hidden Markov Model for recognition. Even though the accuracy of the classification for the top three choices is 92.1%, for the first choice the accuracy rate is 64.3%.As future modifications the research team is planning to modify the feature vector by the orientation selective method such as Gabor filtering. And also the future version of this system are planned to cater for the full Sinhala alphabet.

Buddika Jayasekara and Lanka Udawatta have presented an evolutionary computation based alphabet training approach to recognize the Sinhala scripts [13]. The proposed approach consists of 2 phases, alphabet training using the genetic algorithms and script recognition based on correlation based mapping. During the training phase, the

training character set will under-go some pre-processing steps in order to convert the RGB characters to binary thinned characters. In this paper the horizontal and the vertical distance in a thinned character image are considered as an important feature. Therefore a separate genetic algorithm is used to train the distance feature values of one character image row. In the recognition stage, horizontal and the vertical projection profiles are used to segment the Sinhala characters which are written in the pre-formatted document. The segmented characters are grouped using three layered structure of the line and the core character is mapped with the trained alphabet using the correlation. Although the proposed approach has a high recognition rate for the characters with unique distinct shapes there is a considerable amount of drop off when recognizing the confusing shapes that occur due to the abnormal writing.

Alexander J. Faaborg has proposed an adaptive character recognition system using neural network [8]. This paper briefly describes the Unistroke recognition algorithms where the user has to adapt to the device. The method proposed by J. Faaborg to recognize handwriting was reliable, comfortable and highly adaptable. For this research he has taken several sample hand writings, analyze them by a java application and convert into a Mathlab vector. This vector is send through a neural network which uses the back propagation algorithm. Although the network was able to handle the changes in the rotation and the position of the characters, the variations in the letter sizes has diminished accuracy rate of the system. This paper also states some of the limitations of the neural network by highlighting the long training time and the processor intensive activity.

Seerla Sasi and his colleagues has propose a method to recognize the hand written characters by combining the wavelet packet transform with neuro-fuzzy approach [18]. In this research the feature extraction of the character is done by taking the wavelet packet transform of the character image using best basis algorithm for a desired number of multi-resolution levels. The neuro – fuzzy technology is used to analyze the features of the characters, classify and recognize the particular character. Fuzzy sets are created for each wavelet component with name of the component, the membership value in the range, and the name of the range. The output from the fuzzy classifier is used for train the neural network in order to memorize the patterns. According to the results the combinations of wavelet packet transform and neuro-

fuzzy approach had produce accurate results on pixel level rather than using only fuzzy logic.

The paper “Fuzzy based approach to recognition of multi-font numerals” describes a schema for off-line recognition of multi-font numerals [10]. It proposes the fuzzy logic technology to identify the multi-font numerals based on the extracted features. As the initial step of the recognition process the numerals will undergo through a pre processing stage which will resize and convert the numerals into one pixel wide thinned digit. For an unknown numeral, 24 distance features are extracted by the Box method approach. The mean and the variance of these features are adapted using two structural parameters. The membership function which is based on normalized vector distance is selected to recognize the numerals. Although the recognition rate is 96% it has been improved up to 98.67% by modifying the fuzzification function on the basics of the value of variance.

M. Blumenstein and his colleagues have proposed a novel feature extraction technique to recognize the segmented characters [5]. Two feature extraction techniques were discussed in this paper namely, direction feature and the transition feature and this paper use neural network technology to recognize the characters. As the initial step the non-cursive/printed characters are located sequentially by using character component analysis. Then the vertical boundaries of each character are defined by using heuristic segmenter. During the pre-processing stage the character will be thinned and the boundaries of the characters will be extracted. As the first step of the directional feature extraction process the starting point and the intersection points will be determined. The starting points will be identified by the first black pixel in the lower left hand side of the image and the intersection points will be recognize from the pixels that have more than two foreground pixel as their neighbours. As the second step, the individual line segments will be recognized by an algorithm which will capture the intersection points and perform a search in a clockwise direction to determine the starting and the end points of the line segment. After locating the line segments it is coded with direction information namely, Vertical line segment - 2, Right diagonal line - 3, Horizontal line segment - 4 and Left diagonal line - 5. The marked line segments are normalized with the values belonging to each direction in order to discard the error pixels. Then these characters direction information is zoned into windows of equal size. Then specific information such as line segment direction,

length, intersection points is extracted from the each individual window. This extracted information is used to fill out the components of the input vector. The transition feature extraction technique which was explained next in the paper is based on the calculation and location of transition features from background to foreground pixels in the vertical and horizontal directions. Two neural networks was design to recognize the uppercase and the lower case letters with the neural classifiers Back-Propagation and Radial Basis Function networks. According to experimental results higher recognition rate was recorded when the patterns were not resized. This paper compares the back propagation and the radial basis function network based on the recorded experimental results.

2.3.2 Printed Character Recognition

The research performed for printed character recognition is illustrated subsequently.

Nadia Ben Amor and his colleague Najoua Essoukri has propose an optical character recognition system for Arabic characters [4]. Due to the recursive nature of Arabic characters, the optical character recognition has become a challenging task. This paper presents a hybrid approach that was used to recognize the multi-font Arabic characters. As the initial step, during the pre-processing stage the characters are converted to single line drawing image and edges are identified using the Canny Edge detector. The features that are necessary for classification are captured using Hough Transform technique which identifies the particular shapes such as straight lines, curves and circles within the given character image. To classify the characters by using the identified features this paper explains an approach by combining the Hidden Markov Model and Neural Network architecture. This system was experiment using 85000 samples in five different fonts that are most commonly used in Arabic writing. The overall recognition rate has been recorded as 97.36%.

Eric W. Brown has design an algorithm by using feature point extraction method to recognize the characters [7]. As described in the paper “Feature Point” is a point where human are interested in the image, basically this points act a major role to identify a letter. This algorithm is a slight modification of Euclidean distance which is designed to recognize eight by eight printed English characters. By this algorithm a selected pixel is examined to check whether it is on the “On” state. If the selected pixel is in the “On” state its eight neighbouring pixels are also checked. Therefore

there will be 256 possible enumerations of neighbourhoods for a particular pixel if it is on the “On” state. Likewise the feature points of a particular image could be identified. This research paper explains about a character dictionary where the characters are stored with their associated features. The unknown characters are identified by using the extracted feature points and the character dictionary. This algorithm was tested in two different font types (Ult and Alt Character Sets) and other font type (CBM Character Set) is used as the reference. However the overall result of this algorithm was not in very satisfactory level since there were considerable amount of wrong guesses for both the tested font types. As future improvements it was suggested to construct logic that would resolve the ambiguities based upon the other surrounding feature points. And it was also suggested to examine the space between individual feature points to determine whether they were connected by contiguous straight lines.

It is evident from the literature that high recognition rate for optical character recognition systems was achieved by using the technology artificial neural network. Therefore we can stress out the artificial Neural Networks technology is the best approach for optical character recognition.

According to the Table 2.1 it seems that considerably higher recognition rates were achieved by using the neural network technology .Therefore we can stress out the Neural Network technology is the best approach for optical character recognition.

Research	**Technology**	**Comments**
Off-line Sinhala Handwriting Recognition using Hidden Markov Models	Hidden Markov Models	Recognition rate recorded as 92.1%.
Evolutionary computation based alphabet training approach to recognize the Sinhala scripts	Genetic Algorithms	Accuracy drops off when recognizing the confusing shapes.
Using Neural Network to Create an Adaptive Character Recognition System	Neural Networks	Able to handle changes in rotation and position of characters.
Wavelet Packet Transform and Neuro-Fuzzy approach to hand written character recognition	Neuro-Fuzzy	Accurate results than using fuzzy logic only.

Fuzzy based approach to recognition of multi-font numerals	Fuzzy Logic	Recognition rate recorded as 98.67%
Multifont Arabic Characters Recognition using Hough Transform and HMM/ANN Classification	Hidden Markov Model and Neural Networks	Recognition rate recorded as 97.36%
A Novel Feature Extraction Technique for the Recognition of Segmented Handwritten Characters	Neural Networks	High recognition rate was recorded.
Character Recognition by Feature Extraction	Feature Point Extraction Algorithm	Results were not in satisfactory level

Table 2.1 : Comparison on Technologies used in Optical Character Recognition Research Projects

However this system distinguishes from other optical character recognition systems due to the high noise percentage in the given input. Therefore it is essential to rectify the output given by the neural network since the neural network output could contain letters that is incorrectly identified. Following a real world scenario this issue could be resolved by performing a discussion among the experts for particular areas.

The below literature survey was conducted to discover how the multi agent systems could use to solve problems as in the real world problem solving scenarios.

2.4 Multi Agent Systems in Problem Solving

The paper “A Multi-Agent System for Enterprise Integration” proposes an agent-based framework for intelligent enterprise integration [16]. It addresses the problem where manufacture would face to explore the market opportunities in a timely fashion. A set of agents with specialized expertise are designed to quickly collect the relevant information and knowledge, to cooperate with each other and with other management systems and human managers and analysts to arrive at timely decisions in dealing with various enterprise scenarios. However the work presented in this paper represents the first step for the agent-based manufacturing integration

M. S. Uppin have proposed a Supply Chain for Information Sharing system base on the Multi Agent System [20]. Information sharing plays a major role for the effective

functioning of supply chains. The proposed multi agent solution comprise of several agents such as Stock Agent, Product Data Agent, Agent for Bill of Material. Each and every agent is performs a specific function of the organization and share the information with other agents. By sharing information among agents the most important requirement of the supply chain is achieved.

Alexander and his colleagues present a test bed for multi agent system for Road Traffic Management [6]. This system consists of two major process namely, traffic process and traffic control process. The motorists and other traffic participants are involved in the traffic process. The decisions to perform dynamic traffic management measures in order to optimize the traffic process are executed in the traffic control process. A traffic simulation suite is used to define the traffic network and simulated traffic. In order to demonstrate the concept behind this project the researchers have developed a scenario where three ramps join to the main road. If congestion occurred in one of the ramp the multi agent system is able to communicate with each other and perform the rational action in order to solve the current congestion problem and avoid future congestions. In a similar scenario like this multi agent system controls the number of vehicles that approach in the particular ramps. Even though this system has the capability to handle dynamic traffic it has opportunities for further extension. For example this system could be extended to handle the traffic in the ramps and also it could expand to handle different traffic control instruments.

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The paper “A Multi Agent Home Automation System for Power Management” proposes a system that adapts power consumption to available power resources according to the user comfort and cost criteria [1]. Each agent is embedded into a power resource or an equipment, which may be an environment such as thermal-air, thermal-water, ventilation, luminous or a service such as washing, cooking. These agents cooperate and coordinate with each other in order to find acceptable near-optimal solution. Base on the weather forecast and the other energy resource information resource agent calculates the available power resources and the equipment agent predict the power consumption by determining the future power needs base on the user behaviour. Base on these predictions and the user specified constraints the power management plan is design by negotiating with other agents. This system also provides facility for real time amendments for the power plan base on the modified or new requirements. This is achieved by the cooperation between agents. This system was tested under thermal air environment. The system consists of three heaters where the room temperature is fixed. By the use of this system, heaters

communicate with each other and maintain the room temperature in user satisfied level while balancing the energy consumption of the heaters.

Sevan and his colleagues has design a configurable and extensible open-source system for usage of research community in order to investigate multi-agent decision making [9]. This system was named as Colored Trails (CT) test-bed. This is a multi agent game environment that could be played by humans, computer agents, or a mixture of the two. CT can involve any number of players and supports one-shot and repeated games, games with simultaneous and sequential decision making, and games with imperfect and incomplete information. The players may act as individuals or within teams. This system was build to operate in parameters to provide facility to study variety decision-making scenarios. This game is played on a board of colored squares. Each player has a piece on the board as well as a collection of colored chips that can be used to move the piece on the board. Player pieces can move only to adjacent squares; to move a piece to an adjacent square, a player must turn in a chip of the same colour as the square. One or more of the board squares are designated as goal squares, and the objective of each player is to move her piece as close as possible to an appropriate goal square. A player may lack certain chips needed to reach a goal square, but another player may have these needed chips. Players have to negotiate with each other to exchange chips. Thus, the CT framework provides a situated environment where each player has objectives, tasks that must be performed to meet an objective, and resources. The computer agents are constructed to formulate behaviour of the human model. This test bed provides the opportunity to view how the agents negotiate and communicate with each other to solve the problems.

The paper “A Multi – Agent Platform for Auction Based Allocation of Loads in Transportation Logistics” describes an agent based platform for allocation of loads in distributed transportation logistics [14]. This system consists of set of agents bidding for transportation loads to be distributed from central depot in the Netherlands to different locations across Germany. The platform supports both human agents such as transportation planners, who can bid through specialized planning and bidding interfaces, as well as automated, software agents. This system consists of 3 major agents, human agent who represents the carrier role, automated bidding agent and the auctioneer agent. Human agents are provided guidance by an automated decision

support system to plan to load the trucks. Automated bidding agent place bids based on the current industry prices. This agent is responsible to simulate the market and stabilize the simulated market. The auctioneer agent distributes the transportation orders on behalf of one or more shippers. This system was evaluated by simulating a real world scenario where bidders bid against each other in an environment where the agents also act as the bidders. The experiment was in a successful stage where the convergence of the prices was in a realistic level. However, in order to ensure that the profit rates actually match current practice, the pricing scheme and other parameters require some further refinement.

Cornel Turcu has developed a multi agent system to solve train ticket booking problem [19]. Booking for a non – direct connection between departure and destination places is identified as a main problem in the train booking system. The propose system consists of two major components namely, agent model and the network model. At the network level the coordination is achieved by a specialized agent known as yellow page agent. The newly created agents are registered with the yellow page agent providing information such as their net address , the service that they occur. The yellow page agent also responds to the registration requests from other agents by providing the required information. This system provides functionalities such as handling customer requests, routes planning, routes notification, routes confirming /cancelling and booking. Three types of agents are defined in this system namely, CustomerAg , CFRAg , CoordinatorAg. CustomerAg collaborate with other agents in order to facilitate the customer access to the resources. CFRAg responds to the CustomerAg with a notification about the requested services. CoordinatorAg act as backup in a case CFRAg fails. These agents exchange messages in order to perform the required functionality. By communication and the coordination within the agents in multi agent system all the expected functionalities of the system is achieved. Base on the tests that have performed the response time was very low and the customer satisfaction was very high.

Our literature survey relieves that multi agent solutions could be used solve problems using the features in multi agent systems such as communication, negotiation etc. Therefore we suggest implementing this system using both the technologies, Neural Networks and Multi Agent systems.

2.5 Summary

This chapter illustrate the exposure of the research area - optical character systems with the used technologies. It also highlights the limitations along with the achieved results. According to the conducted literature survey it was planned to develop the recognition phase using artificial neural network and recertify the output of the artificial neural network via Multi Agent technology.

The next chapter discuss about the neural network and multi agent technologies in detail.