TRACKING SYSTEM USING NEURAL NETWORK

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TRACKING SYSTEM USING NEURAL NETWORK

by

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ANN	Artificial Neural Network
CNN	Convolutional Neural Network
EEPROM	Electrically Erasable Programmable Read-Only Memory
FPGA	Field Programme Gate array
IO	Input and Output
LED	Light Emitting Diode
ML	Machine Learning
MLP	Multilayer Perceptron
MSE	Mean Square error
RNN	Recurrent Neural Network
SDRAM	Synchronous Dynamic Random-Access Memory
SOC	System on Chip
SPI	Stateful Packet Inspection
UART	Universal Asynchronous Receiver/ Transmitter
USB	Universal Serial Bus
Verilog HDL	Verilog Hardware Description Language

SISTEM PENJEJAKAN DENGAN MENGGUNAKAN RANGKAIAN NEURAL

ABSTRAK

Pengguna kerusi roda mungkin menghadapi kesukaran untuk membawa bagasi mereka semasa melakukan perjalanan. Penyelesaian yang dicadangkan telah diperkenalkan demi mengatasi masalah yang dinyatakan. Pengikut kereta yang mengunakan sensor visual telah dicadangkan demi memudahkan mobiliti kerusi roda apabila membawa bagasi. Kereta itu akan menjejaki dan mengikuti kerusi roda dalam jarak yang sesuai. Kamera berfungsi sebagai input untuk membiarkan kereta dapat mengesan dan mengikuti kerusi roda. Sensor Visi (Pixy CMUcam5) telah digunakan untuk mengesan corak warna yang telah ditetapkan. Sensor berasaskan visual mengumpul maklumat papan corak warna yang terletak di belakang kerusi roda dan mengumbulkan maklumat-maklumat yang diperlukan. Maklumat yang dikumpulkan akan dilatihkan dengan rangkaian neural demi mendapatkan maklumat kedudukan relatif, seperti jarak dan sudut condong. Nilai MSE yang diperoleh ialah 0.14007. Rangkaian neural akan dilaksanakan ke dalam FPGA. Pelaksanaan rangkaian neural pada FPGA boleh dilakukan melalui konfigurasi perisian dan perkakasan. Nilai ralat untuk jarak keluaran kurang daripada 0.8000 manakala nilai ralat untuk sudut keluaran kurang dari 0.3000 semasa simulasi.

TRACKING SYSTEM USING NEURAL NETWORK

ABSTRACT

Wheelchair users might face difficulty to carry their luggage when traveling. A proposed solution is introduced based on the problem stated. A visual-based sensor cart follower is proposed to ease the mobility of a wheelchair in carrying their luggage. The cart will track and follow the wheelchair in a suitable distance. A Camera acts as input to let cart able to track and follow the wheelchair, Vision sensor (Pixy CMUcam5) is used to detect the predefined colour pattern in this project. The visually based sensor gathered the information of the colour pattern board which situated behind the wheelchair and translate the gathered information into relative position information, such as distance and skew angle which helps the cart in following the wheelchair. This translation can be done in the neural network. The Mean Squared Error (MSE) value obtained is 0.14007. The neural network can be implemented in the Field Gate Programmable Array (FPGA). The implementation of the neural network on the FPGA can be done through software and hardware configuration. The error value in predict the distance is less than 0.8000 while the error value in predict the skew angle is less than 0.3000.

CHAPTER 1

INTRODUCTION

1.1 Research Background

The term “artificial intelligence” was first introduced by John McCarthy in 1956 when he held the first academic conference on the subject [1]. Five years later Alan Turing wrote a paper on the notion of machines being able to react like human beings and the ability to do intelligent things, such as play Chess [2]. Artificial intelligence (AI) is a core key technology in the field of computer science. Artificial means human-made while intelligence means the thing able to learn and react. The aim of artificial intelligence is creating and developing a machine that able to learn and react like a human. Artificial intelligence is incorporated into a variety of technology and widely used in different area. Examples of artificial intelligence technology are automation, machine vision, machine learning, etc.

Autonomous is one of the branches of the field of artificial intelligence. An autonomous robot is a robot which able to perform tasks (assigned by the programmer) in an environment without outside control or guidance [3]. Therefore, autonomous robot vehicles can be understood as vehicles that able to move independently and intelligently. The autonomous vehicle is currently being concerned topic. It is helpful for use as reconnaissance or aid vehicles in the field of planetary exploration, land and undersea environments, remote repair and maintenance, and even intelligent wheelchairs for the disabled [4].

Visual tracking is recently being studied as it is a key component in fields of dynamic computer vision. It is a fundamental technology which supports in developing computer vision applications such as human tracking and identification, object tracking in an environment, and intelligent motion robot vehicle [5]. Visual tracking vehicle is one of the key technologies in an intelligent transport system. However, visual tracking for an outdoor vehicle is still a challenging issue in accurately tracking the target [6]. The visual tracking system can be improved by gathering the sensory information regarding the current environment to come out of a suitable decision and action. The sensory information may come from vision, ultrasonic range, etc. Vision sensor may provide richer information than other sensors [7].

Machine learning is also a subfield of artificial intelligence that aims to develop the machine, especially a computer system that capable of learning without being explicitly programmed. It assumes that systems can learning based on example, identify the patterns, and make decisions with minimal human intervention. Computers can be trained with different algorithms that can map the consequent output from input data. This means that learning algorithms can completely make data-driven decisions or predictions by building models based on the input data [8].

Artificial neural network (ANN) is defined as an operation of a biological neural network system [9]. It makes the computer being able to a human in processing the data and behave some of its intelligence in some ways like pattern recognition. It gathered all the information, detecting the pattern based on the input data, and produce a result through a set of rules. ANN is related to learning and decision making of a machine. The production of ANN can be concluded as a process that gathered enough knowledge to produce a correct sequence of the rule to produce a model that satisfies the expected condition.

The first Field Programmable Gate Array (FPGA) was introduced by Xilinx in 1985 [10]. It contains the arrays of logic blocks which are programmable. FPGAs are pre-fabricated silicon devices that can be programmed in the field of digital circuit or system [11]. FPGAs have greatly enhanced efficiency, performance and power consumption.

1.2 Problem Statement

Disable people, especially wheelchair users might face the difficulty of carrying their luggage along, especially when traveling around from one place to another place. Wheelchair users need to use both their hand to control their wheelchair. It may cause an accident if the luggage is heavy and the wheelchair may lose balancing when making a turn. Hence, a luggage carrying cart follower is required. Similar research had been done in 2015. In the research, the cart follower is proposed by interfacing the microcontroller with ultrasonic sensor. Ultrasonic sensors are used to identify and follow the target object [12]. However, ultrasonic sensor has some limitations. Instance, ultrasonic sensor has difficulty in reading reflections from soft, curved, thin and small objects. Besides that, the detection accuracy of the ultrasonic sensor on an irregular ground surface was greatly affected by the measuring distance due to its wide beam width [13]. Hence, another method is suggested in predicting the perpendicular distance and skew angle between the wheelchair and cart. A tracking system using neural network is proposed so that the cart follower able to predict the movement and position of the wheelchair.

1.3 Objectives

The objectives of this project are as follows:

i) To identify the distance and skew angle of the object by using neural network.

ii) To simulate the neural network in FPGA.

1.4 Scope of Project

This research has covered the studies of developing an ANN for the tracking system. Tracking system helps the luggage carrying cart follower track and following the wheelchair in an appropriate distance as follow to the laws of the traffic. The system is trained by an artificial neural network in estimating the distance and skew angle between the luggage carrying cart follower and wheelchair with higher accuracy. This research also covered the implementation of neural network in FPGA in hardware configuration and software configuration.

1.5 Thesis Outline

This thesis consists of five chapters. They are the introduction, literature review, methodology, result, and conclusion.

Chapter 1 is about the introduction of the research on developing an ANN in a tracking system. It concludes the background of the research and the focus of the project.

Chapter 2 is the literature review of the research. It is the summary of articles from a journal that related to the research field. It provides information and understanding of the study of the research.

Chapter 3 is about the methodology of developing of neural network for a tracking system. It defines the design of experiment, project flow, and uses of the methods and tools.

Chapter 4 is about the result and discussion of the neural network model's performance. The results will be tabulated in the table.

Chapter 5 is concluding the developing and performance of the neural network m. It also covers the future improvement of the system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will review the existing work which is related to the tracking system such as visual based tracking system. It also includes the introduction of machine learning (ML) and theoretical concepts of artificial neural network (ANN). Lastly, it also involves the study of the implementation of neural network in Field Programmable Gate Array (FPGA).

2.2 Visual Based Tracking System

Robot manipulator needs enough knowledge to make the right decision and action based on the information regarding the current environment. Vision sensors play an important role by providing the quantity information to track a moving object [14]. The visual based tracking system can be dividing into three basic stages as shown in Figure 2-1.

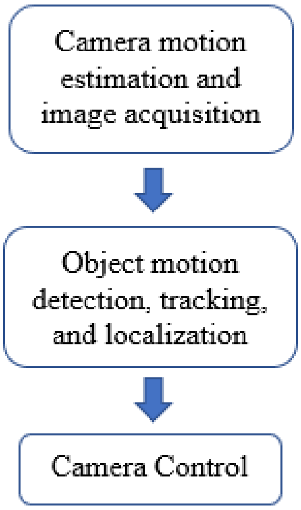
Camera motion estimation and image acquisition
Object motion detection, tracking, and localization
Camera Control

Figure 2-1: Three basic stages for visual-based tracking system

The first step for many computer vision algorithms is the estimation of camera motion. This step manipulates the camera movement to identify the direction of the camera motion. This means that the motion can be done automatically and no signal from the servo is needed [15]. Before processing and analyzing the images, the step must be taken is to capture the image. This is called an Image Acquisition. Image Acquisition is achieved by using a suitable camera [16]. The distance of the camera from the ground should keep the same level as the object as shown in Figure 2-2.

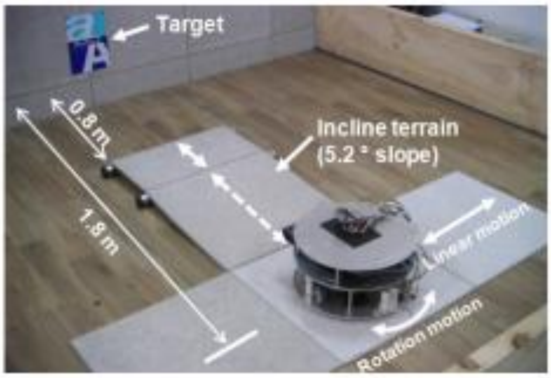

Figure 2-2: Camera Motion Estimation and Image Acquisition

The important step for visual-based tracking system is object motion detection, tracking, and localization. In general, detection of movement, classification of target objects, and tracking of moving object are considered distinct areas of research [17]. Object tracking plays an important role in many applications such as video surveillance, image search, and medicine. However, it is still an open problem in tracking an object. This is due to fast objects' motion may cause an unstructured shape of objects or scenes. One of the ways is tracking the object via colour detection. It detects and isolating the colour of the object [18]. Figure 2-3 shows the vision tracking system via colour detection. Detecting and localizing the object accurately is important for initializing a tracking system [19].

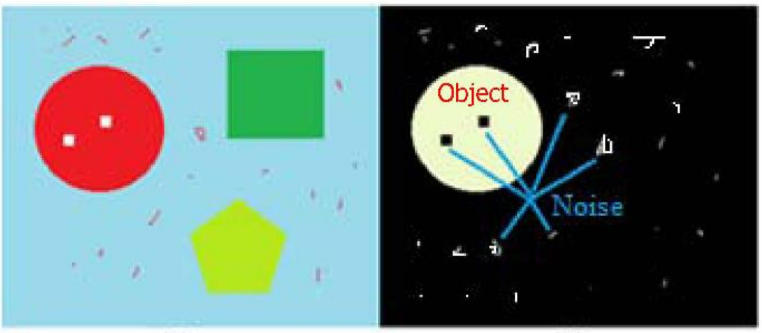

Figure 2-3: Vision Tracking System Via Colour Detection

General, unrestricted environment including the moving objects increase the difficulty of correction identification [20]. In order to keep track of objects, camera control is required to perform monitoring tasks.

A project, “Colour tracking technique by using pixy CMUcam5 for wheelchair luggage follower” is proposed in 2017 [21]. This project involves Pixy CMUcam, ultrasonic sensor, and servo motor. The maximum error on the ultrasonic sensors is 2.00%. The percentage error for the servo motor without a load is 1.58% while with a load is 15.74%. In order to improve the performance of the tracking system, a neural network can be used in the project so that the cart will track and follow the wheelchair with high accuracy.

2.3 Following Mobile Robot

Robots can be fixed robots or mobile robots. Mobile Robots are robots with a mobile ability which move freely in the environment. The basic function of the following mobile robot is simple: it can track the target object and following the target object. It goes forward as the target object go forward; goes backward as target object go backward; turns left/right as target object turn left/right. When the target object stops moving, it stops as well. Figure 2-4 shows the object following robot.

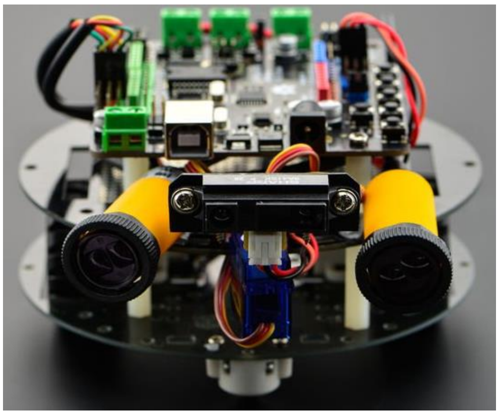

Figure 2-4: Object Following Robot

Another advanced mobile robot is the Line Follower Robot. Line Follower Robot is designed using artificial intelligence to follow a path and avoiding the obstacles. The path can be a black line on the white floor (visible) or multiple colour lines. Every line has different colors as their identities. This robot will able to identify the lines and choose its desired path [22]. Figure 2-5 shows the line following robot.

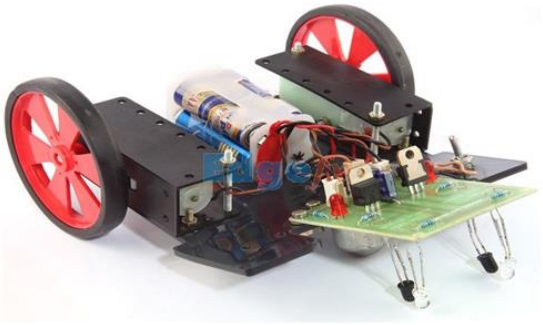

Figure 2-5: Line Following Robot

2.4 Machine Learning

Machine learning is a kind of artificial learning while deep learning is a kind of machine learning. This is the relationship between artificial intelligence, machine learning, and deep learning. Machine learning is data-driven modeling. This means that machine learning builds a “model” based on the “data” [23]. Sets of data are used to train the system while model provides a mathematical framework for learning [24].

The learning process begins with the training data. The purpose of the learning process is to allow the computers to learn automatically with minimum human intervention or assistance and makes better decisions in the future based on the examples. Machine learning algorithms are basically categorized as supervised or unsupervised. Below is some machine learning method:

- **Supervised machine learning algorithms**

  Supervised learning explained a scenario in which the “experience”. It has been learned in the past and applies to new data to predict future data. The “experience”, a training example, contains the required information. It is like the learner is supervised by a teacher with providing the labeled information [25]. The learning algorithm produces an inferred function to make predictions about the output values by a known training dataset. The learning algorithm can also compare its output with the correct output and figure out errors.

- **Unsupervised machine learning algorithms**

  Unsupervised learning is used when the information used to train is neither classified nor labeled. Unsupervised learning can draw inferences from input data to describe a hidden structure from unlabeled data. The system doesn’t figure out the right output, but it explores the data and can draw a reasoned conclusion from datasets. In unsupervised learning, there is no distinction between training data and test data.

- **Semi-supervised machine learning algorithms**

  The small amount of data is labeled but a large amount of data is unlabeled cause a mixture of supervised and unsupervised techniques is used. Semi-supervised learning is in between supervised and unsupervised learning since they use both labeled and unlabeled data for training.

- **Reinforcement machine learning algorithms**

  Reinforcement learning is considered a variation of supervised learning as it continuously analyzes the difference between the response produced by the network and the corresponding desired output [26].

Supervised learning can be further group into two categories, which are classification model and regression model. A classification model is used when the output variable is a category. For example, prediction of the gender of a person by handwriting styles. For good performance, a large amount of testing examples is required, and training error cannot too high. Figure 2-6 shows the good and bad result of the classification model.

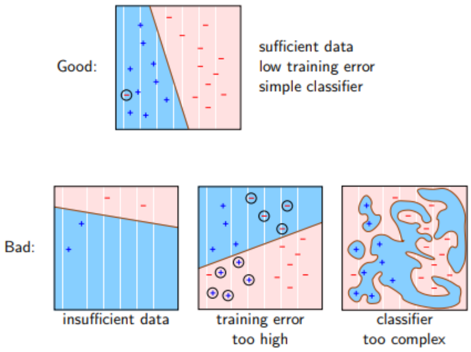

Figure 2-6: Good and Bad Result of Classification Model

A regression model is used when the output variable is a real or continuous value. Two types of model can be used, one is linear regression while another one is non-linear regression. The simplest method is linear regression. The regression tasks can be predicting the age of a person. Figure 2-7 shows the graph of the regression model.

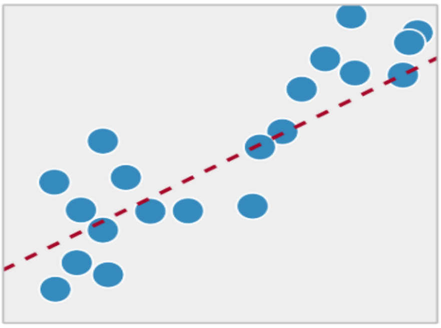

Figure 2-7: Graph of the Regression Model

Unsupervised learning can be further group into two categories, which are the clustering model and associate model. Association rules describe commonly seen patterns found in large binary data sets. Clustering finds groups of similar points according to some similarity metric, generally distance [27].

2.5 Artificial Neural Network

Artificial neural networks (ANNs) are biologically inspired computer programs designed to simulate the way in which the human brain processes information [28]. ANN is one of the main tools used in machine learning. A simple neuron consists of three layers, which are the input layer, hidden layer, and output layer [29]. Figure 2-8 shows s simple neuron architecture.

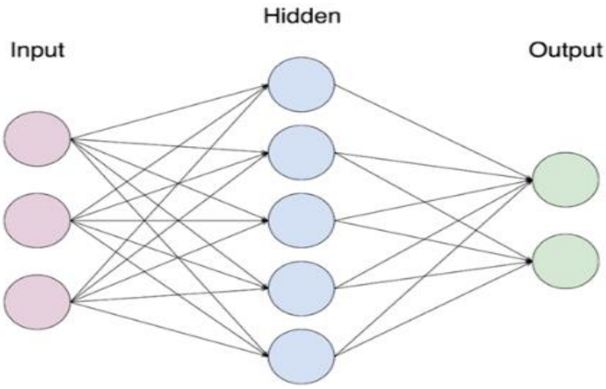

Figure 2-8: Simple Neuron Architecture

- Input layer: This layer is responsible for receiving information (data), signals, features, or measurements from the external environment. These inputs are usually normalized within the limit values produced by activation functions.
- Hidden layer: These layers are composed of neurons which are responsible for extracting patterns associated with the processor system being analysed. It transforms the input into something that the output layer can use.
- Output layer: This layer is responsible for producing and presenting the final network outputs, which result from the processing performed by the neurons in the previous layers.

There are three basic types of neural network. According to hidden layer number, Multilayer Perceptron (MLP) which usually comprised of one or more layers of neurons. Data is fed to the input layer, there may be one or more hidden layers providing levels of abstraction, and predictions are made on the output layer. MLP is suitable for regression prediction problems where a real-valued quantity is predicted given a set of inputs. Judged from the operations executed by the neural network, there is a Convolutional Neural Network (CNN) which mainly perform its function through convolutional operation. The hidden layers of a CNN typically consist of convolutional layers, pooling layers, fully connected layers, and normalization layers. CNN is designed to map image data to an output variable. In terms of the direction of data flow, there are Recurrent Neural Network (RNN) where there is a data flow between adjacent cells in the same layer. RNN is designed to work with sequence prediction problems.

There are two main procedures in design neural networks which are forward process and backward process. Feedforward neural network is known as data-driven. It defines the number of layers, the number of neurons in each layer, what kind of training method and activation function are selected, and then passes input data through the network. Backpropagation neural network is known as goal-driven. It defines the loss function to calculate the gap between the prediction value and the labelled values. It looks for the minimum value of the error function in weight space using gradient descent [30]. The weights will get updated to optimum weights. One feed forward and back propagation process can be called as one epoch and a trained neural network model need hundreds or thousands of epochs.

2.5.1 Training Algorithm

It is very difficult to know which training algorithm will be the fastest and better for a given problem. The complexity of the problem, the number of training data, the number of weights and biases in the network, and the goal can impact the performance of the neural network system. Table 2-1 shows the list of the training algorithm.

Table 2-1: List of Training Algorithm

Algorithm	**Description**
Trainb	Batch Training with Weight & Bias Learning Rules
Trainbfg	Bfgs Quasi-Newton
Trainbr	Bayesian Regularization
Trainc	Cyclical Order Incremental Training W/Learning Functions
Traincgb	Conjugate Gradient with Powell/Beale Restarts
Traincgf	Fletcher-Powell Conjugate Gradient
Traincgp	Polak-Ribiére Conjugate Gradient
Traingd	Gradient Descent Backpropagation

Algorithm	Description
Traingdm	Gradient Descent with Momentum Backpropagation
Traingda	Gradient Descent with Adaptive Lr Backpropagation
Traingdx	Variable Learning Rate Backpropagation
Trainlm	Levenberg-Marquardt
Trainoss	One Step Secant Backpropagation
Trainr	Random Order Incremental Training W/Learning Functions
Trainrp	Resilient Backpropagation (Rprop)
Trains	Sequential Order Incremental Training W/Learning Functions
Trainscg	Scaled Conjugate Gradient Backpropagation

2.5.2 Activation Function

Activation function is a function used to map the input data into an output signal in a neuron. Activation functions are used in the hidden layer as well as the output layer. Activation functions bring the weighted sum of inputs plus a bias as input to the function and then perform the necessary computation to produce the outputs in a layer as shown in Figure 2-9.

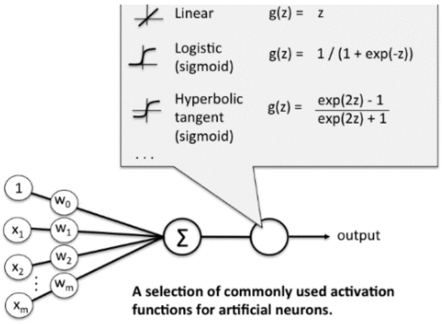
Linear g(z) = z
Logistic (sigmoid) g(z) = 1 / (1 + exp(-z))
Hyperbolic tangent (sigmoid) g(z) = (exp(2z) - 1) / (exp(2z) + 1)
...
1
x1
x2
xm
w0
w1
w2
wm
Σ
output
A selection of commonly used activation functions for artificial neurons.

Figure 2-9: Activation Function in neuron

The activation functions can be basically categories into 2 types:

1. Linear Activation Function

Linear Activation Function is a line or linear in a graph. It will not be confined to the range of output. If each layer is activated by a linear activation function, that activation, in turn, goes into the next level as input and the second layer calculates weighted sum on that input, then the final output of the last layer behaves the same way with the first input.

2. Non-linear Activation Functions (Sigmoid or Logistic)

   Non-linear activation function is a non-linear or s-curved in the graph. It can limit the range of outputs. If the hidden layer is activated by a sigmoid function, the number of hidden layer nodes is finite, and the gain of the output layer nodes is bounded, then the output layer nodes will have bounded output.

2.5.3 Performance Method

There are several functions to illustrate the performance of network such as MSE, SSE and etc. Mean squared normalized error performance function. It calculates the network's performance according to the mean of squared errors. If a very low MSE is got for training data, it means that the system is overfitting. While, if a very high MSE for test data, it means that the network is underfitting. Figure 2-10 shows the underfitted, good fit, and overfitted graph.

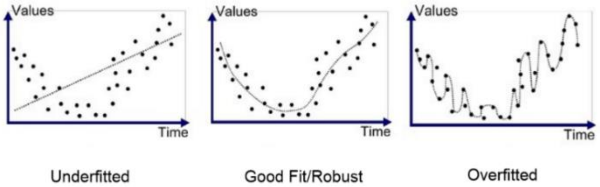

Figure 2-10: Underfitted, Good Fit, and Overfitted Graph

2.6 Field Programmable Gate Array

Field Programmable Gate Arrays (FPGA) are integrated circuits designed to be programmed by the user [31]. An FPGA contains a matrix of configurable logic blocks (CLB). CLB provides physical support for the program downloaded on FPGA [32]. It contains look-up tables, multiplexers, and flip-flops. Hence it supports the performance of complex combinatorial and sequential functions [33]. FPGA also contains a hierarchy of reconfigurable interconnects that allow the blocks to be connected together.

FPGA has a more flexible framework to implement algorithms as compared to CPU and GPU. The instructions in FPGA can be designed in a more efficient way without the constraint of fixed architectures. It is suitable for designers to explore the high-performance implement approaches in power or computing fields. Besides that, FPGA's clock frequency is slower than that of CPU or GPU. FPGA usually uses a few clock periods only when executes operations. This makes FPGA has a competitive advantage in real-time data processing and low power consumption design as CPU and GPU need dozens of instructions to execute one operation and higher frequency leads to higher power consumption.

Neural network implementation in FPGA is possible as it preserves the parallel architecture of the neurons in a layer and offers flexibility in reconfiguration. FPGA maintains high gate density which is needed to utilize the parallel computation in an ANN [34]. Most neural networks are implemented in software. A project, "Investigation on MLP Artificial Neural Network Using FPGA for Autonomous Cart Follower System" also is proposed in 2016 [35]. This project shows that the hardware floating-point acceleration block increases the logic element resource utilization. This project more focuses on the SOC design but not on hardware implementation. Software configuration has the advantage of being easy to implement, but with poor performance. Hardware configuration is generally more difficult and time-consuming to implement, but with better performance.

2.7 Chapter Summary

A visual-based mobile robot is more applicable in localization task as vision sensors able to provide the quantity information to track a moving object. Neural network is used to allow the machine to learn from the examples. Thus, machine able to make the decision automatically without human intervention. Besides, FPGA is chosen for implementation ANN as FPGA has a competitive advantage in real-time data processing and low power consumption design. One more reason is it can preserve the parallel architecture of the neurons in a layer and offer flexibility in reconfiguration. In this project, a tracking system with using neural network is built.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The step of developing the tracking system using a neural network is explained in detail in this chapter. MATLAB has Neural Network Design and Development Toolbox (NNTOOL) which is used extensively for designing of Neural Network. MATLAB tool is required as an intermediate tool to determine the suit model, the optimum weights and biases to train a neural network. Then the neural network model is written in Verilog HDL, and then is simulated in ModelSim to verify the system's performance.

3.2 Research Framework

This project is divided into three stages, which are data collection, training network, and neural network (NN) in FPGA. Figure 3-1 shows a block diagram of the overall project flow. The blocks that circled in red coloured rectangle are the parts where this project focus.

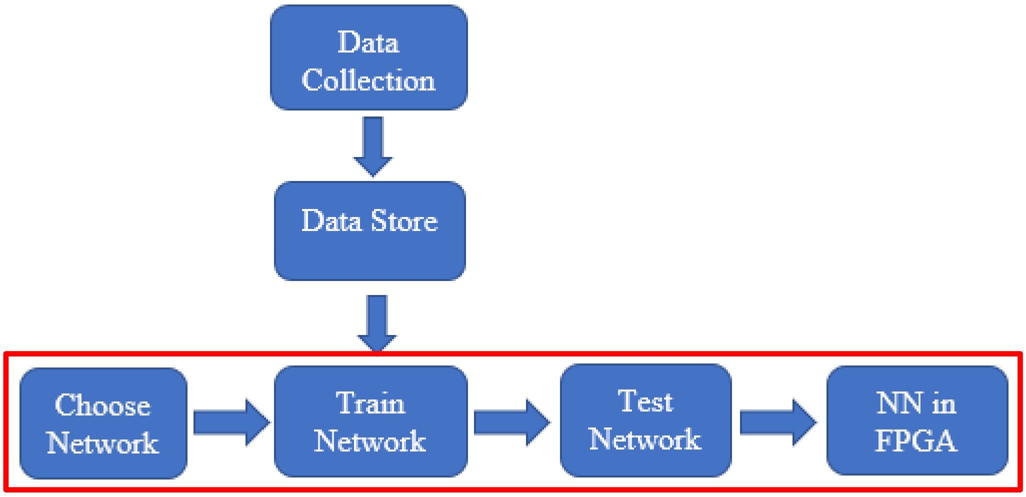

Figure 3-1: Block diagram of Overall Project Flow

Vision sensor (Pixy CMUcam5) is used to detect the predefined colour pattern. The visually based sensor gathered the information of the colour pattern board situated behind the wheelchair. The gathered information includes centroid x, centroid y, weight, and height. All of the information will be used to train the neural network. This task had been done in previous work. The architecture of network is chosen. For example, the number of hidden layers, the number of neurons in each layer, the used of activation function, and selecting the suitable training algorithm. Then, start to train the network. After training, the performance of the network is tested. After testing, the network can be implemented in FPGA.

3.3 Design of Experiment

The experiment is designed in to gather the data as shown in figure 3-2. The object colour pattern position will manipulate along the track. The object and the CMUcam5 are assumed at the same level which is 30cm above the ground level.

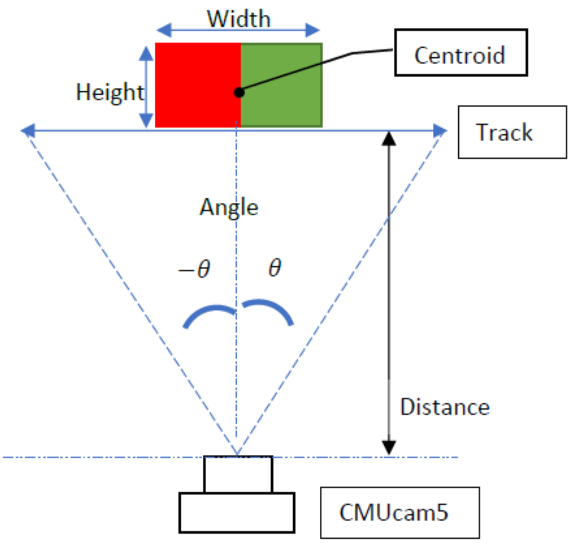

Figure 3-2: Overview of Experiment

The experiment is carried out by manipulating the perpendicular distance between the cart (illustrated by CMUcam5) and the wheelchair (illustrated by colour pattern) from

20cm to 69cm. The step size is 1cm. Another manipulated variable is the angle which is in the left and right view. The step size for the angle is 5 °. Table 3-1 shows the range of angle according to the distance.

Table 3-1: Range of angle According to the Distance

Distance (cm)	Angle (°)
20-29	-15 to 15
30-39	-20 to 20
40-49	-25 to 25
50-59	-30 to 30
60-69	-30 to 30

3.4 Data Collection with Arduino

The CMUcam5 is connected to Arduino to collect the centroid, width, and height of the object. The Arduino will initiate the Pixymon program to enable the colour pattern to be set as the object. There are two colours are used as the colour pattern in the project, the first colour is set and followed by the second colour. This is to enable the CMUcam5 to determine the object as a single object. Then, the Arduino will get the block data from CMUcam5 which contains the data of centroid x, centroid y, width, height, etc. Figure 3-3 shows the Pixymon program.

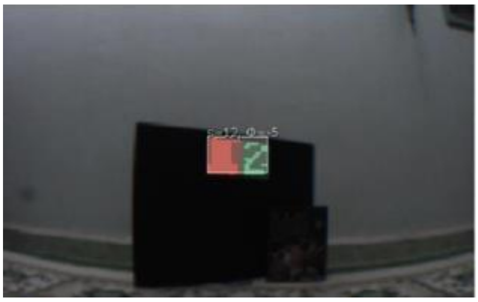

Figure 3-3: Pixymon Program

3.5 Neural Network Training in MATLAB

Figure 3-4 shows the flow chart of the developing of neural network in MATLAB Neural Network Toolbox (NNTOOL).

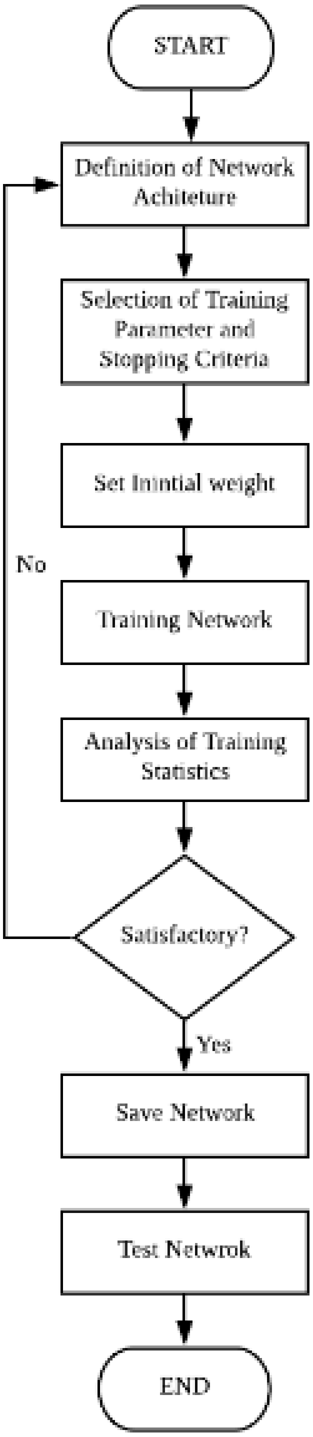
START
Definition of Network Achiteture
Selection of Training Parameter and Stopping Criteria
Set Inintial weight
No
Training Network
Analysis of Training Statistics
Satisfactory?
Yes
Save Network
Test Netwrok
END

Figure 3-4: Flow Chart of the Developing of Neural Network

The input data and target Data are fed into the network. Building a network involving the hidden layer number, the number of neurons in each layer, the used of activation function, and selecting the suitable training algorithm. Then, the training parameter and stopping criteria are set. Before the training starts, the initial weight is set. Training network will generate weight and bias. The weight and bias will be updated to the optimum value. This is to minimize the error in prediction. The training is consider done if the neural network reaches the specified level of accuracy. Then, saved the network. The network will be tested once the network is trained.

3.5.1 Data Processing

Data collected from CMUcam is provided into MATLAB. The values of distance and angle will set as target data, while the centroid x, centroid y, weight, and height will be set as predictor data. As the collected data in a huge quantity, hence only some of the training data are shown in Table 3-2.

Table 3-2: Training Data

Distance	Angle	x	y	w	h
20	-15	116	93	193	111
20	-15	116	93	193	111
.	.	.	.	.	.
.	.	.	.	.	.
41	-10	125	102	106	57
41	-10	125	102	106	57
41	-10	125	102	106	57
.	.	.	.	.	.
52	-15	104	102	81	45
52	-15	104	102	81	45
52	-15	104	102	81	45
.	.	.	.	.	.
59	-20	83	101	67	40

59	-20	83	101	67	40
59	-20	83	101	67	40
.	.	.	.	.	.
.	.	.	.	.	.
69	30	281	89	46	31
69	30	280	89	45	31
69	30	282	89	48	31
69	30	281	89	46	31

3.5.2 Artificial Neural Network Terminology

A simple neuron consists of two layers, one hidden layer, and one output layers. In each layer, it contains neurons and activation function. In each neuron, the input is multiplied with its corresponding weight before added together with bias. Then it generates a corresponding output through the activation function. Networks simulated are affected according to the number of neurons in their hidden layer. The neurons number in the hidden layer is 10 neurons as it is default number in MATLAB. The output layer has two neurons as it has two different outputs which are distance and angle. Figure 3-5 shows the artificial neural network terminology.

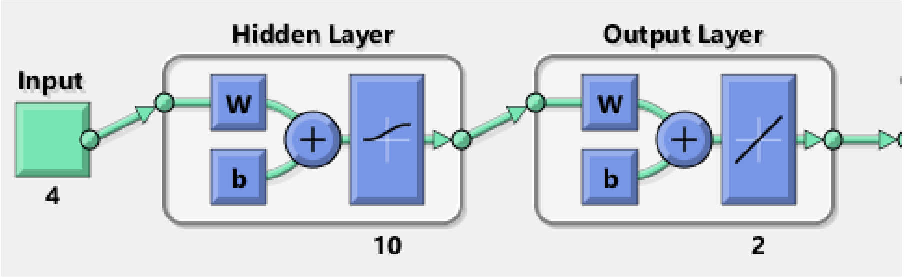

Figure 3-5: Artificial Neural Network Terminology

3.5.3 Training Algorithm

Levenberg-Marquardt Algorithm (trainlm) is used to train the neural network. Trainlm is one of the fastest backpropagation algorithms in the toolbox. It is highly recommended as a first-choice supervised algorithm. This weight and bias values are