ASIC DESIGN FOR HEALTHINESS RECOGNITION OF AGRICULTURE

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DEDICATION

This thesis is dedicated to my mother, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main supervisor, Dr. Suhaila Isaak, for encouragement, guidance, critics and friendship. Without her continuous support and interest, this thesis would not have been the same as presented here.

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My fellow postgraduate friends should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members as well.

ABSTRACT

The purpose of this study is to develop the application of healthiness recognition of agriculture plant module and then develop the module into ASIC design. Plant disease is a common issue which leads to decrease in the food production in the crop agriculture sector. The main factor of plant disease is caused by microorganism which include bacteria, fungi and virus. Nitrogen play an important role in the yield of plant. Excess of or lacking in nitrogen may affect the deficiency in crop. There are few methods for nitrogen detection in the leaf such as colour analysis using image processing, remote sensing and neural network etc. In this project, HSV colour model is used for colour analysis through image processing that able to separate the colour portion from the intensity. Before the colour analysis, median filter is used as pre-processing step to remove unwanted salt and pepper noise in the image and preserver the edge of the leaf in the image. After pre-processing step and colour, linear SVM classification is used as classification step. Linear SVM classification, able to classify the plant into healthy and unhealthy categories by determine the concentration of nitrogen in the leaf with 95.36 % accuracy. The algorithm of recognition module is verified through Matlab software simulation. After that, HLS is used to translate the high-level language into hardware description language. The tool can handle complex image processing algorithm and floating point in the algorithm. Unrolled factor for for-loop and pipeline is combined and implemented into the design to obtain the best hardware utilization resource and timing result at netlist level. Lastly, the Verilog netlist of image recognition system is implemented into ASIC. The benefit of ASIC design, that is closer to hardware descript language, and able to minimize the latency and increase the efficiency. ASIC design has been produced successfully with 24.2 mW of power consumption, 0.039 mm^2 area and able to operate at 250 MHz clock frequency.

ABSTRAK

Tujuan kajian ini adalah untuk mengembangkan aplikasi pengiktirafan kesihatan modul tanaman pertanian dan kemudian mengembangkan modul tersebut menjadi reka bentuk ASIC. Penyakit tanaman adalah masalah umum yang menyebabkan penurunan pengeluaran makanan di sektor pertanian tanaman. Faktor utama penyakit tumbuhan disebabkan oleh mikroorganisma yang merangkumi bakteria, kulat dan virus. Nitrogen memainkan peranan penting dalam pengeluaran tanaman. Lebihan atau kekurangan nitrogen boleh mempengaruhi kekurangan tanaman. Terdapat beberapa kaedah untuk pengesanan nitrogen pada daun seperti analisis warna menggunakan pemprosesan gambar, penginderaan jauh dan rangkaian saraf dll. Dalam projek ini, model warna HSV digunakan untuk analisis warna melalui pemprosesan gambar yang dapat memisahkan bahagian warna dari intensiti . Sebelum analisis warna, penapis median digunakan sebagai langkah pra-pemprosesan untuk menghilangkan bunyi garam dan lada yang tidak diingini dalam gambar dan menjaga tepi daun dalam gambar. Selepas langkah dan warna pra-pemprosesan, klasifikasi SVM linear digunakan sebagai langkah klasifikasi. Klasifikasi Linear SVM, dapat mengklasifikasikan tanaman menjadi kategori sihat dan tidak sihat dengan menentukan kepekatan nitrogen dalam daun dengan ketepatan 95.36 %. Algoritma modul pengenalan disahkan melalui simulasi perisian Matlab. Selepas itu, HLS digunakan untuk menterjemahkan bahasa peringkat tinggi menjadi bahasa penerangan perkakasan. Alat ini dapat menangani algoritma pemprosesan gambar yang kompleks dan titik terapung dalam algoritma. Faktor yang tidak terkawal untuk gelung dan saluran paip digabungkan dan diterapkan ke dalam reka bentuk untuk mendapatkan sumber penggunaan perkakasan dan masa yang terbaik pada peringkat netlist. Terakhir, sistem pengecaman imej senarai bersih Verilog dilaksanakan ke ASIC. Manfaat reka bentuk ASIC, yang lebih dekat dengan bahasa deskripsi perkakasan, dan dapat meminimumkan kependaman dan meningkatkan kecekapan. Reka bentuk ASIC telah berjaya dihasilkan dengan penggunaan kuasa 24.2 mW, kawasan 0.039 mm^2 dan dapat beroperasi pada frekuensi jam 250 MHz.

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LIST OF ABBREVIATIONS

WFP	-	World Food Program
FPGA	-	Field Programmer Gate Array
ASIC	-	Application Specific Integrated Circuit
ALU	-	Arithmetic Logic Unit
CPU	-	Central Processing Unit
KNN	-	K-nearest neighbours
CNN	-	Convolution Neural Network
VLSI	-	Very Large-Scale Integration
SVM	-	Support Vector Machine
RGB	-	Red, Green and Blue
HSV	-	Hue, Saturation and Value
SYN	-	Synthesis
PNR	-	Place and Route
STA	-	Static Timing Analysis
FF	-	Flip-flop
LUT	-	Look-up Table
LVS	-	Layout versus Schematic
QoR	-	Quality of Report

LIST OF SYMBOLS

º	-	Degree
%	-	Percentage

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Plant disease is defined as “anything that prevents a plant from performing to its maximum potential” [1] Plant disease can be classified into abiotic or non-infectious and biotic or infectious. Non-infectious means that the disease cannot be spread from the sick plants to the nearby plants. It is caused by the external conditions their living environment and those non-living agents, the temperature, oxygen level, water level, soil composition, wind, air pollution toxicity etc which may affect the health of the plant.

While biotic or known as infectious are caused by living organisms and can be spread from one plant to another plant. It will infect the leaves, shoots, stems, crowns, roots and fruits of the plants.

The root causes of these diseases are the environment, host and pathogen as shown in Figure 1.1 [2] When these three components happen at the same time, plant disease happen. Environmental factor is referring to the temperature, light or moisture of the air, while Host is referring to various types of living organism such as butterflies and insects. Pathogen is referred to an organism that causes the plant disease.

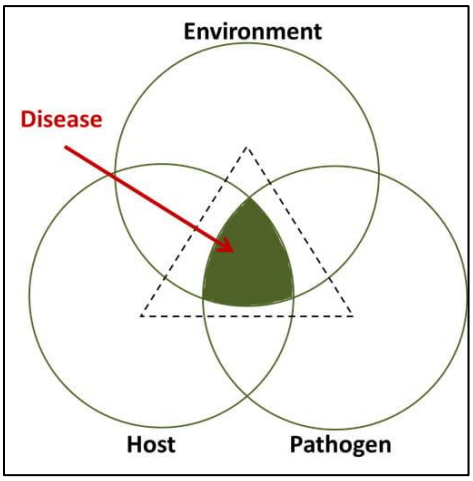

Figure 1.1: Ven-diagram of Disease Triangle [1]

Plant disease is a common threat that leads to decrease in food production in the agriculture field. According to the world food program (WFP), there around 795 million of people faced problem with not able to have a proper food [3]. Bacteria, fungi and virus as well as climate change and the reduction of pollinator are the main factors that cause plant disease. Some of the diseases are hard to be recognised through our human eyes, or the disease symptoms are only recognisable when it is too late to act such as providing plant disinfectant. The symptoms are usually observable on their leaves or stem but difficult to recognised through naked eye. It require professional with years of experience those symptoms [4].

An automatic plant disease recognition system can be used by farmers to monitor the health their crops easily through smart devices. In future, drones can be used as an automatic plant disease device for surveying and taking care of hectares of farm. Besides that, home gardeners can use the automatic plant disease recognition on a mobile platform.

The automatic plant disease recognition system includes a firebase system and a computing unit to process the image. According to researcher [5],[6] reported that there are relations between leaf colour and the nitrogen status in the leaf. An automatic plant disease recognition system can be performed with the help of image processing. Recently, application-specific integrated circuit (ASIC) design chip is one of the promising computing chip which contain its own structure of logic, arithmetic logic

(ALU) and able to meet the requirement of area, performance or power. [7] Besides that, ASIC design which design using Verilog coding that able to perform up to 851% faster than c-code as shown in Figure 1.2. Figure 1.2 shows the execution time both FPGA or ASIC and C-code running on 20 symbols and 50 simulations. ASIC design able to perform faster than my available processing units in the market such as embedded or computer processing [8]–[10].

Figure 1.3 show that FPGA is faster time to market, low non-recurring engineering and simple design then ASIC. ASIC design is cheaper on unit cost, able to perform high performance with low power consumption and per unit size. The complex design in ASIC design can be solve by using HLS. High level language can be programmed through HLS platform and transform it into Hardware description language.

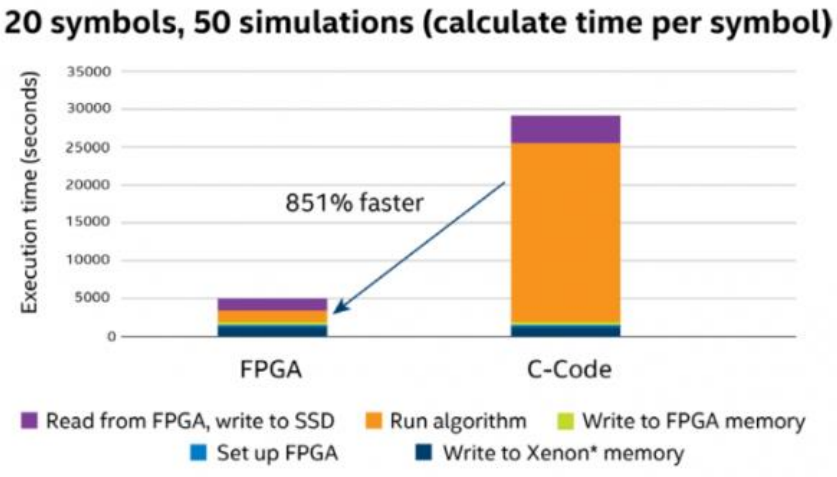

Figure 1.2: Execution Time using different programming language [7]

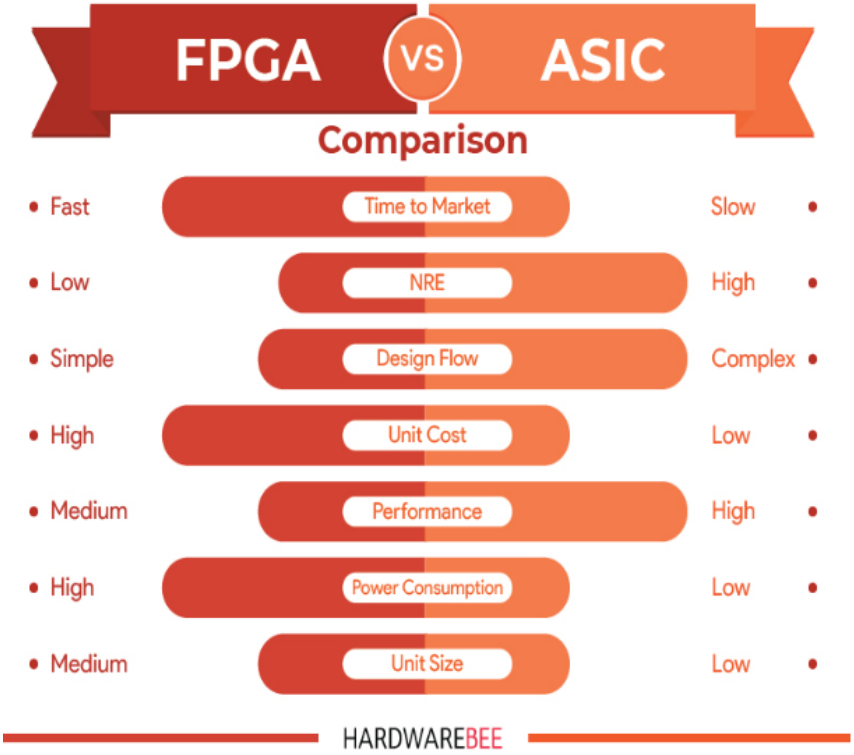

Figure 1.3: FPGA versus ASIC [7]

1.2 Problem Statement

One of the plants of interest is the tomato which is a prominent place in the Algerian agriculture economy. In 2016, tomato crops was affected by late blight disease, which causes dramatic losses in agriculture economy in that year [11]. In a few areas of farm, there is a tan of healthy and unhealthy plants. To determine the health of plants, it require an experienced workers or professional farmers to recognise and determine the plant healthiness. It is very difficult and time to those workers and farmers to scan through each plant leaves one by one. Meanwhile the weakness of human eye which unable to recognise accurately of each healthiness of plant. With the help of image processing on plant leaves, it is able to detect the plant disease automatically and accurately [12].

From past researches, there are lots of plant disease recognition system introduced using different methodologies such as software-based simulation, embedded system, deep learning and Android Apps as shown in Table 1.1.

Beside the software mentioned in Table 1.1, ASIC design based on its logic and able to execute in shorter time and reducing the connectivity time and increased the energy efficiency [8]–[10].

In the market product, there is one product named SPAD 502 Plus ChlorophyII Meter, which is able to classify the healthiness of plant by colour contain in leaf through wavelength. It costed around 2741 USD dollar, which costs more than ten thousand Ringgit Malaysia. For a farmer, a device that costs more than ten thousand Ringgit Malaysia, which is a heavy expense for farmer to invest on it to classify the healthiness of plant for few hectors of farm.

Table 1.1: Comparison of Different Method on Plant Diseases Classification

Past Research	Platform	Pros	Cons	Accuracy
Tomato Plant Disease Classification in Digital Image Using Classification [13]	Matlab	Computation visualization and programming	Software simulation (Installed in PC) [8]	97.3%
Plant Pathology Detection and Control Using Raspberry Pi [14]	Embedded System (microcontroller)	Smaller hardware size Computing simple and smaller size code [9]	Difficulty handle on bigger size code and complex algorithm such as Image processing, DSP, video, processing [9]	-
Plant Disease classification Using Deep Learning [15]	Deep Learning (CPU)	Higher accuracy	Complex neural network algorithm such as CNN, KNN Required higher performance hardware such as GPU/CPPU to execute [10]	88%-96%

.

1.3 Objective

The objectives for this project are:

(a) To develop image recognition module system based on concentration of nitrogen in the leaf to the detect healthiness of tomato plant

(b) To implement complex conversion algorithm of Red, Green and Blue (RGB) to Hue, Saturation and Value (HSV) into Verilog and apply utilization hardware resource to improve timing.

(c) To implement image recognition module into Application-specific Integrated Circuit (ASIC) design and evaluate its performance, timing and layout area.

1.4 Scope

For the scope of this project, on the plant of interest is tomato. Due to the time limitation given for this project, this project aims to recognise and classify the healthiness of tomato leaf with their image of 256 x 256 pixels sizes only. HSV algorithm of study for the recognition of the healthiness of tomato and verified the algorithm in Matlab. Online source of sample tomato leaf is taken as the input for training data and the threshold value to classify the healthiness of plant [16]. Verilog of HLS is import into Synopsys tools to perform ASIC design. Power, area and timing are been obtained from the ASIC design.

1.5 Outline of the Thesis

This thesis consists of five chapters. First chapter discusses the background study, problem statements, objective and scope of the project. Chapter 2 is presented the literature review on others works, including the plant disease classification and image processing on FPGA. In Chapter 3, the methodologies used in this project are

explained. Chapter 4 reports the results of this project and the discussion. Lastly, Chapter 5 discuss the future work of this project. Table 1.2 and table 1.3 show the Gantt chart for whole project

Table 1.2: Gantt Chart for Master Project I

Tasks	Sept 2019			Oct 2019				Nov 2019				Dec 2019		
	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3
Background study & Title Decide														
Literature Review														
Prepare RP1														
Searching and Understanding algorithm related to work														
Implementation of algorithm on Maltab														
Prepare for FYP1 Presentation Slide														
FYP1 Presentation														
FYP1 Report Writing														

Table 1.3: Gantt Chart for Master Project II

Tasks	Feb 2020				Mar 2020				Apr 2020				May 2020				Jun 2020			
	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4
Searching available platform for HLS																				
Implement of HSV algorithm on Vivado HLS																				
Validation of HLS result on Matlab																				
Learning Synosps Tools (DC, ICC & PT)																				
Import Verilog netlist into DC, ICC & PT																				
Final Tuning for the System																				
Thesis Writing																				
Prepare for FYP II Presentation Slide																				
FYP II Presentation																				

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