DEVELOPMENT AND ANALYSIS OF EMBEDDED FACE RECOGNITION SYSTEM USING RASPBERRY PI

by

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LIST OF ABBREVIATIONS

2D	Two-dimensional space
3D	Three -dimensional space
AC3	Audio codec
ARM	Advanced RISC Machine
ASF	formerly "Advanced Streaming Format"
AVI	Audio Video Interleaved
BSP	Board support package
CMOS	Complementary Metal–Oxide–Semiconductor
CPU	Central Processing Unit
CSI	Camera Serial Interface
DivX	Brand name of products created by "DivX, LLC."
DV	Digital Video format
EFM	Enhanced Fisher Model
EHMM	embedded hidden Markov model
ext3	Third Extended Filesystem
fat32	File Allocation Table 32
FLDA	Fisher's Linear Discriminant analysis
FRRP	Face Recognition using Raspberry Pi
HCI	Human–computer interaction
HD	High-Definition
HDMI	High-Definition Multimedia Interface
HMM	hidden Markov model
HW	Hardware
I/O	input/output
ID	identification

IEEE	Institute of Electrical and Electronics Engineers
JPEG	Joint Photographic Experts Group
MIPI	Mobile Industry Processor Interface
MP3	MPEG-1 or 2 Part 3
MPEG	Moving Picture Experts Group
OGG	Ogging
OpenCV	open source computer vision
OS	Operating System
PCA	principal component analysis
PDAs	personal digital assistant
PIL	Python Imaging Library
PKG	Packaging
RAM	Random-access memory
RGB	RGB color space(RGB)
RPi	RASPBERRY PI
RTOS	real-time operating systems
S5	camera connector socket in Raspberry Pi
SBC	Single Board Computer
SD	Secure Digital
SDHC	SD High-Capacity
SDIO	Secure Digital Input Output,
SDSC	Secure Digital Standard Capacity
SDXC	Secure Digital eXtended Capacity
SW	Software
TIFF	Tooth Interior Fatigue Fracture
TS	Technologic system
TV	Television

USB	Universal Serial Bus
VGA	Video Graphics Array
wpa_gui	WPA Graphical User Interface
XML	Extensible Markup Language

Pembangunan dan Analisis Sistem Terbenam Wajah menggunakan Raspberry Pi

ABSTRAK

Wajah manusia adalah bahagian yang paling ketara yang boleh digunakan untuk mengenali seseorang. Terdapat banyak sistem yang tersedia untuk mengenali wajah di pasaran, tetapi ianya besar, mahal, dan monopoli. Pelaksanaan teknik pengecaman wajah dalam sistem embedded adalah aspek yang sangat penting. Dalam projek ini akan membahaskan tentang reka bentuk yang tepat pada masanya, mudah alih, kos rendah sistem pengenalan wajah. Tujuan-tujuan yang boleh diperolehi dengan menggunakan system embedded, yang merupakan sistem komputer tujuan khas yang berupaya untuk melaksanakan set yang sangat kecil dari aktiviti-aktiviti yang ditetapkan. Dalam kajian ini, tahap pembangunan yang terdiri daripada Satu Papan Komputer (SBC, Raspberry Pi (Model A) sebagai proses menyatukan, GNU / Linux berasaskan system operasi Embedded Raspbian sebagai platform pembangunan aplikasi. Projek ini memberi tumpuan untuk menerapkan algoritma pengecaman wajah yang sesuai dengan Raspberry Pi (Model A) sistem yang dicadangkan diimplementasikan menggunakan pemproses ARM11 dan memori yang tidak cekap pada Raspberry Pi (Model A) lembaga, untuk mendapatkan prestasi yang boleh diterima dari sistem, gambar yang ditangkap pada resolusi (320 × 240), sistem perlu ≈2.1 saat untuk memproses imej yang ditangkap, system embedded dapat ditingkatkan apabila teknik pengesanan gerakan diterapkan.

Development and Analysis of Embedded Face Recognition System using Raspberry Pi

ABSTRACT

Human Face is the most visible part which can be used to recognize persons. There are many available systems for face recognition in the market, but they are bulky and expensive. The implementation of face recognition techniques in an embedded system is a very important aspect. This project involves design of a real-time, portable, low embedded cost face recognition system. Implementation and analysis of face recognition techniques on an embedded system, the development phase consists of Single Board Computer (SBC, Raspberry Pi (Model A) as process unite, and GNU/Linux based Embedded Raspbian Operating system is used as application development platform. This project focuses to apply the face recognition algorithm that is suitable with Raspberry Pi (Model A) The proposed system is implemented using ARM11 processor and inefficient memory on Raspberry Pi (Model A) board, to get an acceptable performance of the system, the images are captured at resolution (320×240), the system needs ≈ 2.1 sec to process the captured images, The performance of the embedded system is done by evaluating detection time and recognition time (is 1.75 sec, between 0.29 sec to 0.74 sec) respectively, together with CPU utilization and RAM utilization (33%, 17.75%) for detection and (36.5%, 22%) for recognition. Results obtained shows that the overall performance on the embedded system can be increased when motion detection techniques is applied.

CHAPTER 1

INTRODUCTION

1.1 Overview

Over the years, face recognition systems have been developed in order to be used in different applications such as security systems (e.g., controlling the access of the people to specific buildings, identifying the criminals in public places, etc.). The system should be able to detect face image, extract its features, and recognize it (Parmar and Mehta, 2013). Face detection and recognition algorithms have been developed rapidly in terms of performance and speed, but most of the researches and improvements have been directed towards software algorithms and their implementation. Many real-time face recognition algorithms have been successfully implemented; however, they require expensive hardware to operate (Theocharides, 2006). The application domains extend to portable environments, therefore, an accurate real-time face recognition system that can facilitate commercial needs is desirable.

1.2 Problem Statement

There are many available systems for face recognition in the market, but they are bulky, expensive, and monopoly (Mehrab et. al., 2012). Making face recognition systems ubiquitous require substantially reduction in the system complexity, size, and price (Sun, 2007). These aims can be obtained by using an embedded system, which is a special purpose computer system that is capable of performing very small sets of designated activities. Embedded systems have many characteristics such as small size, real-time operation, lightweight, portable, and low cost. Some embedded systems have been designed to perform the face recognition process using a Single Board Computer (SBC) TS-5500 and iris detection algorithm (Ahmad, 2010; Shuhaizar, 2010). There are various SBC provider and each board is different from the other in the design, hardware, and its operating system. Therefore, aiming for an improved performance, other SBC boards can be suggested to be used for implementing and performing the face recognition process in the embedded system. In addition, other face recognition algorithm can be chosen to be implemented on the suggested board.

1.3 Research Objectives and Aim

1) To design and implement a specific system capable of performing real time face recognition process using a new SBC board.
2) To select and modify face detection and recognition algorithms that can be used with the selected board.
3) To evaluate the suggested and implemented face recognition system in real time.

1.4 Research Scope

This research focuses on developing an embedded system for face recognition process using a Single Board Computer (SBC) called Raspberry Pi (Raspberry Pi Foundation, 2014). The work in the hardware part includes preparing the hardware components, setting connected devices, selecting the packages and libraries that will be used, and installing them onto the GNU/Linux Operating System (OS). For the software implementation, the Haar Feature-based Cascade Classifier (Lienhart and Maydt, 2002) and the Fisherface algorithm (Belhumeur et al., 1997) are chosen to perform the face detection, tracking, and identifying tasks.

1.5 Thesis Outline

The remaining part of the thesis is organized as follows:

- Chapter 2: presents the literature review for the project consisting of embedded systems, Single Board Computers (SBC), and face recognition systems.
- Chapter 3: explains the methodology process used to implement the embedded system prototype and discusses the configuration of its two main parts (i.e., the hardware part and the software part).
- Chapter 4: covers the software development.
- Chapter 5: shows the results obtained from the experimental prototype and the efficiency of the developed system.
- Chapter 6: presents the conclusions of the research and some recommendations for the future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The high growth in the technology and the augmentation of the integrated circuit technology opened new challenges and development of advanced embedded system for different applications. One of the applications that have attracted interest is the embedded system for the face recognition process. This chapter presents background information and reviewing techniques that are related to the topic of this research. Next section provides the background information about embedded systems and their specifications. Then embedded operating system and GNU/Linux are explained. Thereafter, face recognition systems and techniques are reviewed.

2.2 Embedded Systems

Embedded system is a combination of hardware and software, which is designed to perform specific tasks. Early use of the embedded systems returns to the 1960s where it has been used for controlling the electromechanical telephone switches (Ahmad, 2010). Nowadays, the embedded systems are used in different fields such as military fields, medical fields, and many others. Examples on uses of the embedded systems are as follows (Ahmad, 2010):

- Network equipment such as firewall, router, and switches.
- Consumer equipment such as MP3 players, cell phones, PDAs, digital cameras, and camcorders.
- Household appliances such as microwaves and washing machines.

The operating systems required for Embedded system is unlike that for the fully featured personal computers. Embedded systems are restricted with small memory footprint and a fraction of the processing power that is usually available in desktop personal computers; therefore, it requires a different kind of operating system specifically built for embedded system environment. Design of the embedded system consists of designing the hardware and the software in parallel. The life cycle of designing the embedded system passes through some specific phases as illustrated in Figure 2.1 (Berger, 2002).

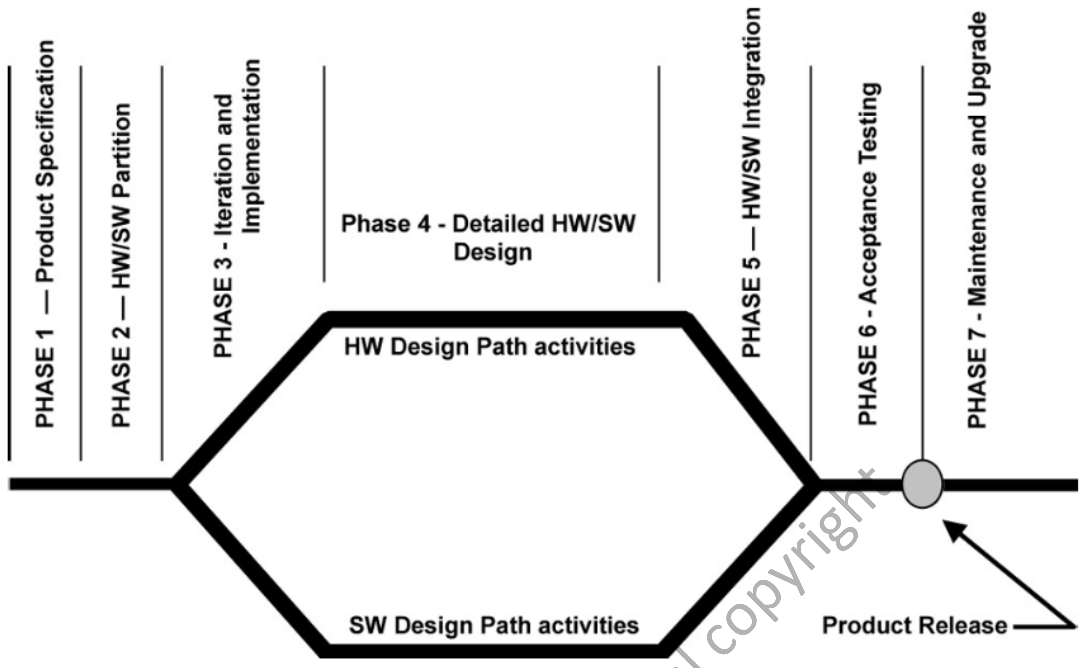

Figure 2.1: A schematic Representation Of The Embedded Design Fife Cycle (Berger, 2002).

The seven phases shown in Figure 2.1 are as follows (Berger, 2002):

1. Product specification and requirements.
2. Partitioning of the design into its software (SW) and hardware (HW) components.
3. Iteration and improvement of the partitioning.
4. Independent hardware and software design tasks.
5. Combination of the hardware and software components.
6. Product testing, evaluation, and release.
7. On-going maintenance and upgrading.

The economics and the reality of a design requirement usually force the decisions to be made before the designers of the embedded system can consider the best design trade-offs. Therefore, the designer looks for the prospect of obtaining a design in which the requirement constraints are minimal and can be strictly specified in terms of performance and cost goals.

2.2.1 Single Board Computer (SBC)

Single board computer (SBC) is an example of the embedded system that has recently attracted a lot of interest. A single board computer is any electronic system with at least a microprocessor, memory, and I/O that fits on a single circuit board (SBC Information and Resources, 2014). There exist different SBC provider companies and each board is different in the design, the hardware, and the operating system. Examples of the SBC boards are Raspberry Pi (RPi) (RASPBERRY PI, 2014), BeagleBone Black (BeagleBone Black, 2014), Parallela (Parallela, 2014), ODROID-XU3 (ODROID Platforms, 2014), Hackberry (Miniand Products, 2014), UDOO (UDOO Features, 2014), APC Rock, Cubieboard2, Marsboard, A13-OLinuXino (Open Source Hardware Boards, 2014), and Technologic Systems (TS7800) (Technologic Systems, 2014). The choice of the SBC board depends on the targeted application, the cost limitations, and the preferred performance. Table 2.1 lists SBC boards that have been mentioned in this section with some of their specifications (i.e., CPU, RAM, OS, I/O ports, and the storage unit).

Table 2.1: Specifications Of Some SBC Types

SCBs	Specifications	
	Components	**description**
Raspberry Pi	Chip	Broadcom BCM2835 SoC full HD multimedia applications processor
	CPU	700 MHz Low Power ARM1176JZ-F Applications Processor
	GPU	Dual Core VideoCore IV®Multimedia Co-Processor
	Memory	256MB SDRAM (model A) or 512SDRAM (model B)
	I/O ports	USB2.0, Ethernet (model B), HDMI, RCA, Audio jack and GPIO
	Onboard Storage	SD, MMC, SDIO card slot
	Operating System	ARM Linux distributions supporting ARMv6.Two main OS supported: Debian and Arch Linux ARM
	Components	**description**
BeagleBone Black	Chip	Based on Sitara XAM3359AZCZ100 processor
	CPU	AM335x 1GHz ARM® Cortex-A8
	GPU	PowerVR SGX530
	Memory	512MB DDR3 RAM
	I/O ports	USB2.0, Ethernet, HDMI, and GPIO
	Onboard Storage	2GB eMMC & micro SD card slot
	Operating System	ARM Linux distribution.2 main OS supported: Ubuntu and Angstrom
	Components	**description**
Cubieboard2	Chip	Based on the AllWinnerTech SOC A20
	CPU	ARM @Cortex™-A7 Dual-Core ARM 1GHz
	GPU	ARM® Mali400MP2, Complies with OpenGL ES 2.0/1.1
	Memory	1GB DDR3 @480M
	I/O ports	USB2.0, Ethernet, HDMI, GPIO and IR
	Onboard Storage	NAND+MicroSD or TSD+ MicroSD or 2*MicroSD
	Operating System	Mac, Linux, windows

Table 2.1: Continued

SCBs	Specifications	
Parallella	**Components**	**description**
	Chip	Based on the Epiphany 16-core CPU E16G301
	CPU	Xilinx Zynq Dual-core ARM A9 XC7Z020 1GHz
	GPU	16 or 64-core Epiphany Multicore Accelerator
	Memory	1 GB DDR3
	I/O ports	USB2.0, Ethernet, HDMI and GPIO
	Onboard Storage	Micro-SD
	Operating System	ARM Linux distribution.2 main OS supported: Ubuntu
UDOO	**Components**	**description**
	Chip	Based on the Freescale i.MX 6
	CPU	ARM Cortex-A9 CPU Dual/Quad core 1GHz
	GPU	GPU Vivante GC 2000 for 3D + Vivante GC 355 for 2D (vector graphics) + Vivante GC 320 for 2D
	Memory	RAM DDR3 1GB
	I/O ports	USB2.0, Ethernet, HDMI,LDVS, and GPIO
	Onboard Storage	Micro-SD (boot device) and SATA (Only Quad-Core version)
	Operating System	Android 4.3 Jelly Bean and ARM Linux distribution Ubuntu
TS 7800	**Components**	**description**
	Chip	Marvell MV88F5182
	CPU	ARM9 CPU 500MHz
	GPU	Non
	Memory	128MB DDR-RAM
	I/O ports	USB2.0, Ethernet, RS-485 , ADC, DIO, LCD, and GPIO
	Onboard Storage	SD, MMC, SDIO card slot
	Operating System	Kernel 2.6 and Debian Linux

2.2.2 Embedded Operating System (OS)

Embedded OS is an operating system specified for embedded computer systems. These operating systems are designed to be fast, lightweight, reliable, efficient at resource usage, and uses relatively few resources. In addition, discarding from many functions and service that non-embedded OS provide, which may not be used in the