DESIGN AND IMPLEMENTATION OF EMBEDDED TRACKING SYSTEM USING SPATIAL PARALLELISM ON FPGA FOR ROBOTICS

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بِسْمِ اللهِ الرَّحْمنِ الرَّحِيم

وَيَرَى الَّذِينَ أُوتُوا الْعِلْمَ الَّذِي أُنزِلَ إِلَيْكَ

مِن رَّبِّكَ هُوَ الْحَقَّ وَيَهْدِي إِلَى صِرَاطِ الْعَزِيزِ الْحَمِيدِ

صَدَقَ اللهُ الْعَظِيم

{ سبأ ٦}

The first thanking is to the first giver "glorious ALLAH"

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LIST OF ABBREVIATIONS

ADAS	Advanced Driver Assistance Systems
ADC	Analog to Digital Converter
ASIC	Application Specific Integrated Circuit
CAD	Computer Aided Design
CNG	Circular Navigation Guidance
CPU	Control Processor Unit
DSP	Digital Signal Processor
EEPROM	Electrically Erasable Programmable Read-Only Memory
FPGA	Field Programmable Gate Array
GPS	Global Positioning System
GPU	Graphic Processing Unit
HDL	Hardware Description Language
HGFMD	Hierarchical Grey-Fuzzy Motion Decision
I/O	Input / Output
IP	Intellectual property
IR	Infrared
I2C	Inter-Integrated Circuit
JTAG	Joint Test Action Group
LRF	Laser Range Finder
TOF	Time Of Flight
PLL	Phase Locked Loop

PWM	Pulse Width Modulation
RAM	Random Access Memory
ROM	Read-only memory
RTL	Register Transfer Level
SBC	Single Board Computer
SDA	Serial Data Line
SDRAM	Synchronous Dynamic Random Access Memory
SCL	Serial Clock Line
SMBus	System Management Bus
SOC	System On Chip
SRAM	Static Random Access Memory
SSH	Secure Socket Shell
TOBJ	Temperature Object
USB	Universal Serial Bus
US	Ultrasonic Sensor
VHDL	VHSIC (Very High Speed Integrated Circuit) Hardware Description language
VNC	Virtual Network Computing
WCSP	Wafer Chip-Scale Package

REKABENTUK DAN IMPLIMENTASI SISTEM PENGESANAN BERASASKAN KESELARIAN SPATIAL MENGGUNAKAN FPGA UNTUK ROBOTICS

ABSTRAK

Sistem pengesanan robot adalah salah satu jenis sistem yaung digunalean pada robot mudah alih dan biasanya digunakan sebagai sebahagian daripada pelbagai perspektif, sebagai contoh, keselamatan atau ketenteraan. Dalam projek ini, sistem pengesanan robot yang aktif dan pasif digunakan pada platform FPGA yang dilaksanakan. Robot tersebut boleh mengenal pasti dan mengesan objek dengan menggunakan sensor inframerah (IR) dan haba. Persepsi pendekatan dan perancangan gerakan adalah bahagian yang paling penting dalam projek ini. Dua sensor IR jarah jauh dan dua sensor suhu sentuh (TMP007) digunakan dalam proses pengesanan untuk membezakan sebarang objek yang bergerak mana uala sensor sensor ultrasonik bertindak sebagai sensor pengelalk halangan. Platform projek tersebut adalah papan DE0-Nano, dan ciri-ciri FPGA menawarkan kebolehan penyusunan semula program dan membuat kan ia lebih mudah untuk melaksanakannya pada platform robot mudah alih yang berbeza. Sensor dan platform robot telah disepadukan dengan papan DE0-Nano. Pengekodan struktur VHDL digunakan untuk reka bentuk sistem pengesanan robot dan Quartus ll 13.0sp1 pula digunakan sebagai alat pembangunan CAD. Pelaksanaan sistem pengesanan kompleks dengan platform FPGA (DE0-Nano) wujud kerana la kaya dengan unsur-unsur logic. ujian khas terhadap cin-cin sensor dan katakilan robot telah dijalankan untuk menguasai sensor dan robot. Hasil untuk projek ini telah menunjukkan frekuensi DE0-nano yang mencapai sehingga 1.3 GHz, juga jumlah unsur-unsur logik yang telah digunakan untuk projek ini iaitu 8045 dan ditunjukkan bahawa voltan output bacaan sensor IR mempunyai pemantulan tinggi untuk objek warna putih berbanding warna lain seperti biru dan hitam,serta jarak pengesanan untuk sensor sentuh adalah 15cm. oleh yang demikian, prestasi sistem yang telah dilakeanakan telah bertamlaah baik dengan penggunaan teknologi FPGA.

DESIGN AND IMPLEMENTATION OF EMBEDDED TRACKING SYSTEM USING SPATIAL PARALLELISM ON FPGA FOR ROBOTICS

ABSTRACT

The robot tracking system is one type of utilization system on a mobile robot and generally utilized as a part of numerous perspectives, for example, security or military. In this project, an active and passive robot tracking system used FPGA platform was implemented. The robot can identify and track objects by using Infrared (IR) and thermal sensors. Perception approach and motion planning is the most essential part in this project .Two long range IR sensors utilized for the tracking process to distinguish any moving object and two contactless temperature sensor (TMP007) for detected the temperature objects while a ultrasonic sensor as the obstacle avoidance sensor . The project platform was the DE0-Nano board and the characteristic of FPGA offer programmability and makes it easier to implement on different mobile robot platforms. Sensors and robot platform was integrated with the DE0-Nano board. A structure VHDL coding was used for design the robot tracking system and Quartus II 13.0sp1 as a development CAD tool. The implementation of complex tracking system with FPGA platform (DE0-Nano) was possible because of the rich logic elements, a specific sensors characteristics testing and robot stability was carried out to master those sensors and robot. The result for this project was shown the frequency for DE0-nano achieved up to 1.3 GHz, also the total logic elements were used for this project is 8,045 and shown the output reading voltage of the IR sensor is high reflectivity for the white colour object compared to another colours like blue and black, also the detection distance for contactless sensor was 15cm. Hence, using the FPGA technology improved the performance of implemented system.

CHAPTER 1

INTRODUCTION

1.1 Overview

The field of robotics was seeing a massive impact on daily life. The robots were invented for overcoming the problem related to insufficient resources. Moreover, they are able to accomplish the tasks which are highly risk for the humans. The robot tracking system was designed and implemented on FPGA. Nowadays, robotics has been widely applied in the areas of security, service etc. The robot tracking system helps us carry out several tasks successfully.

On the other hand, some of the important problems in the robot tracking system include object discovery, path planning and avoiding obstacles are explored. Two long-range Infrared (IR) beams were used for tracking any type of object; while two temperature sensors were used for detect thermal objects. Using these sensors was able to resolve the object detection and the tracking issues. Furthermore, also resolved the obstacle avoidance issue by using the ultrasonic sensor, and the DE0 Nano board was selected for mastering all sensors and controlling the robot motors through L293D chip to let the robot moved in different directions.

The DE0 Nano refers to a compact-sized FPGA development platform; which is more suited for the portable designing projects like a robot. The configurable logic block used in the FPGA helps in updating the design easily. Also, the DE0 Nano platform consists of rich I/O pins, and enables it to simultaneously handle huge data volume and achieve higher data processing speeds with frequency up to 1.3GHz. The DE0 Nano platform solves the problems related to a low processing speed and I/O and resource limitation. The DE0 Nano platform was interfaced with the sensors and the robot. Thereafter, the VHDL and such Mega function modules were used for overcoming the design-based challenges. The Quartus II 13.0sp1 CAD tool software acted as the designing tool for simulating the VHDL coding or the block diagram for validating the performance of this design

The project aim was to improve and develop the performance of the robot tracking system using the FPGA technology. Also wanted to reduce the resource consumption and improve sensing IR, contactless temperature and the acoustic sensors. It was shown that the FPGA is proper platform for improving the technology and benefit the whole society.

1.2 Problem Statement

In order to implement tracking system for robotics needs to know how to deal with the target and how to detect it for long range and track the target with high accuracy. In addition, it must be able to avoid obstacle automatically when it's moving directly to the target.

Active robot tracking system is one kind of utilization of tracking system on a mobile robot. With the widespread of application of robot tracking system, it is necessary that the development of this robot tracking system that facilitate future enhancement. However, problem of detecting the object, planning path and avoiding obstacles during tracking the object is an important issue in mobile robot tracking system (Yee et al., 2016).

Robot does not have sensing ability and unable to perceive its environment .Therefore, robot tracking system has two types; passive and active. An active sensor emits the energy and measure the environment with the reflected energy, and passive sensor measure the emissions of object's energy within sensor coverage area. However, active sensors have certain limitation, it may affect the characteristic of object that attempt to measure and also interfered when the signal beyond its control. Active ranging sensors output can be interpreted easily with the measurement of distance and direction of the object from the robot.

Therefore, FPGA technology can solve the perception issue with the support of active and passive sensors. In addition tracking system using spatial parallelism is required to fulfil all these problems.

1.3 Objectives

Two following objectives were carried:

1) To develop and implement an embedded robot tracking system with the help of a spatial parallelism of FPGA
2) To enhance the robot tracking system using the long-range IR and contactless temperature sensors (TMP007), and also avoid the obstacles using an ultrasonic sensor.

1.4 Scope

For resolving the problems observed in the currently-used robot tracking systems, like the decision-making, resource limitation, power processing etc., it was made use of the positive factors of the FPGA board (DE0 Nano) for improving the functionality and the performance of the tracking system. Furthermore, though the techniques used for solving the perception and the sensing range problems in the current robot tracking system are very advanced, they do consume many resources. Therefore, the long-range IR and temperature sensors for object detection were used and for decreasing the resource consumption. Also an acoustic sensor was used for improving the accuracy of obstacles detection. A difference in the arrangement of the sensors yielded different results; hence, several arrangements for optimising the sensor functions were carried out.

The vision-based robot tracking system was one of the most efficient systems as it behaved like humans and could track the objects using an object feature. However, this feature cannot be achieved easily by the system that uses an IR sensor. Based on the energy output, it becomes very difficult to gauge the shape, colour and such features of the object. As stated earlier, the acoustic sensor helps in improving the accuracy of obstacle detection. An acoustic or an ultrasonic sensor is one of the most effective sensors for avoiding obstacles and has been widely used in the field of robot tracking system. This sensor was used in a different mode, solely for avoiding objects.

1.5 Project Organisation

The project has been divided into many Chapters, each of which covers a different feature .Here, 5 chapters were presented and discussed.

Chapter 2 presents the literature review of many published articles, conference proceedings, website-based information etc. also cited many articles published in the field of robot tracking system. Furthermore, and explained the perception or the sensing approach which is currently used in the robot tracking systems. Additionally, certain platforms like the

Arduino, Raspberry Pi and FPGA was discussed and their limitations were stated. Finally, some of the analysis and the tracking techniques were discussed.

Chapter 3 presents the research methodology that was used. Here, the architecture and the platform characteristics which would be further used were discussed. Also the procedures and the methodologies that used were presented.

Chapter 4 described the compilation and the in-system memory readings results. Furthermore, the estimated sensor characteristics and displayed the robot motor interface were presented. Finally, the main results were presented.

In Chapter 5, an overall summary of the study was discussed. All the results and the observations were mentioned in brief. Also assessed the results and presented the conclusions. Finally, the future recommendations and the work to be carried out related to the proposed robot tracking system was presented

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Today, the robot tracking system is widely used in all societies. Hence, research and further development of this system were seen to be important and the researchers have been able to develop new robot tracking systems having different configurations and sensing capacities. One basic functions of the mobile robot includes object tracking. With this regards, several researchers have proposed different platforms and sensing techniques for improving the object tracking. The active and the passive robot tracking system includes active or passive sensors that emit energy for detecting the moving objects that enter sensing range and generate a response after following the movement of the objects. For accomplishing all the assigned objectives, the robot has to detect the moving objects which enter its sensing range, after which it has to move properly, without crashing and must track the moving object.

One of the solutions for a proper implementation of the robot tracking system includes the fact that the robot has to determine the path and the space based on the movement of the object and then, must automatically avoid the object while moving towards its target, and also track the target. Hence, based on the available information, a successful implementation of the robot tracking system includes three basic factors – i.e., target detection, thermal object detection and obstacle avoidance.

2.2 Embedded System

The microprocessor-based systems are developed for controlling a specific function or a range of different functions and they are not designed for being user-controlled in the manner similar to a PC. These systems are known as the embedded system, and they are designed for carrying out a specific task, along with several other options and choices.

The embedded systems are seen to be used in daily life and are popular globally. It must be inexpensive and their memory must be the major component of the complete system, which would further decrease the total costs. The complexity and the performance requirements for the embedded systems are seen to rapidly grow, which would lead to further use of memory and more power usage (Li et al., 2016).

The embedded systems comprise of processing cores which are either digital signal processors or microprocessors. The microprocessors are known as a "chip" that can be packaged by themselves or along with other microcontrollers to form a hybrid of the Application Specific Integrated Circuits (ASIC). Generally, the input for the microprocessors comes from the detector or from sensors in the form of a specific word, while the output is passed on to the activator that could initiate or halt the operation of the whole operating system. The embedded system comprises of both the hardware and the software components.

Every embedded system is unique and uses specialised hardware which is to be used in the application domains. The hardware comprises of many microcontrollers, processors, IR sensors etc. On the contrary, the software components form the whole brain behind the embedded system and consist of different programming languages that enable the functioning of the hardware. Hence, the programming of the embedded system could be a huge learning experience. Block diagram for an Embedded System was presented in figure 2.1 (Technology and Khanal, 2014).

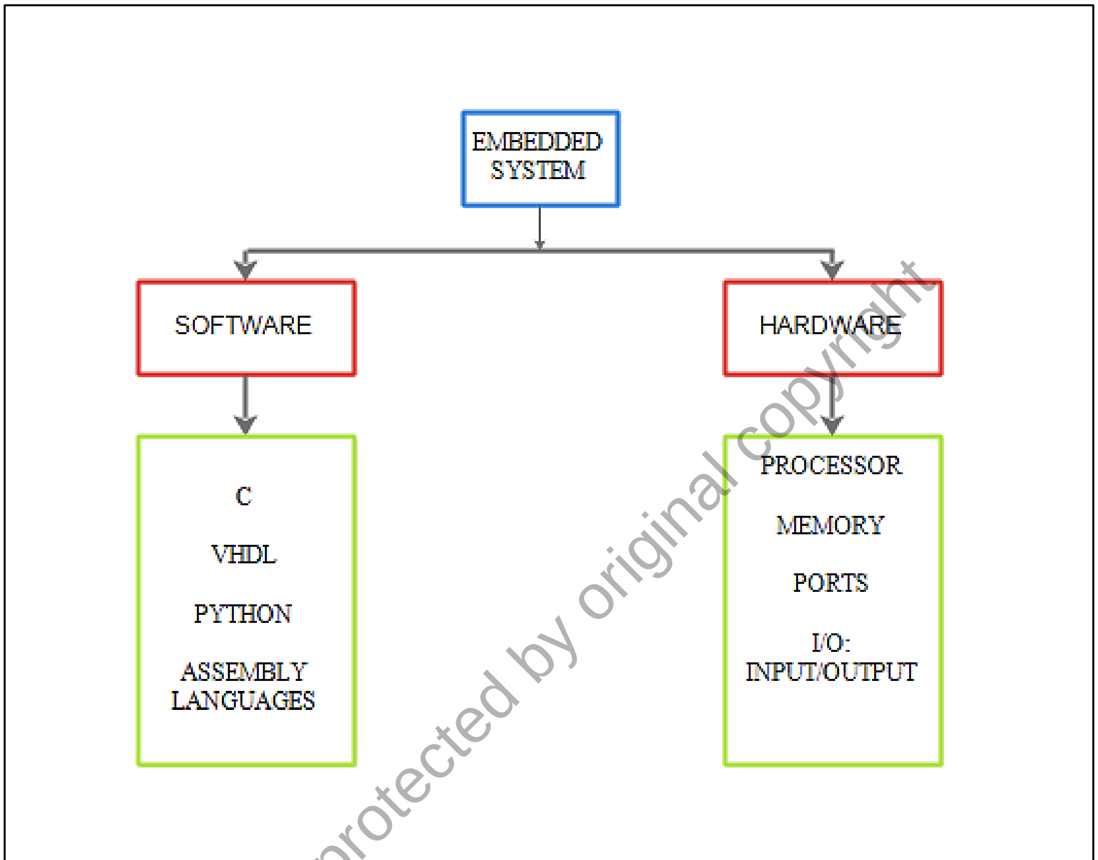

Figure 2.1: Block diagram for an Embedded System

2.3 Embedded System Challenges

The embedded system is made of many software components. However, the design of the complete system is not the form of a special software design. Several factors have to be considered while designing an embedded system, which are as follows:

1. All embedded systems have to be dependable, and the level of the dependability extends the general level for the PC-based systems.

2. Because of the efficiency targets, the software design in the embedded systems cannot be carried out independently, with any regards to the basic hardware. Hence, both the hardware and the software components have to be considered together while designing these systems. This can prove to be challenging as the integrated approaches are not generally taught at the educational institutes. Still, there is a lack of cooperation between the subjects like electric engineering and computer science. Mapping the hardware specifications is also seen to improve the energy efficiency. Moreover, carrying out hardware implementations is quite expensive and requires a longer designing time. Hence, the hardware design does not provide a required flexibility for changing the designs as needed. A compromise between the flexibility and the efficiency needs to be established.
3. All embedded systems have to also meet the non-functional requirements like energy/power efficiency, real-time constraints, and the dependability requirements. Several objectives have to be considered while designing these systems. Only capturing the non-functional requirements can prove to be difficult.
4. The actual embedded systems are seen to be very complicated and contain many components. It's more interested in a compositional design, which includes studying the combined effect of the components. For instance, if a GPS system can be added to the main information source in the car without overexerting the communicating bus (Marwedel, 2010).

In Table 2.1, the differences between the hardware used for an embedded and a PC-based system were shown.

Table 2.1: Scope of the mapping applications of the PC-like and Embedded System hardware (Marwedel, 2010)

	Embedded	PC-like
Architectures	Frequently heterogeneous Very compact	Mostly heterogeneous not Compact (x86 ect)
X86 compatibility	Less relevant	Very relevant
Architecture fixed?	Sometimes not	Yes
Model of computation (MoCs)	C+ multiple models (data flow, discrete events…)	Mostly von Neumann (C,C++,Java)
Optim. objectives	Multiple (energy, size,….)	Average performance dominates
Real-time relevant	Yes, very	Hardly
Application	Several concurrent apps.	Mostly single application
Apps. Known at design time	Most, if not all	Only some (e.g. WORD)

2.4 Robot Navigation

The robot navigation refers to the safe movement of the autonomous robot from one position to another. A general navigation problem is formulated as follows:

1. Where am I? An autonomous robot must know its position for making proper decisions. Determining the robot whereabouts is known as robotic localisation.
2. Where am I going? For carrying out certain tasks, the robot must know its destination. A particular goal has to be identified and this is called as goal recognition.
3. How do I get there? After the robot has determined its location and its destination, it must know how to reach there. Determining the way to reach the final destination is called as path planning.