

Autonomous Lawnmower using FPGA implementation.

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Abstract. Nowadays, there are various types of robot have been invented for multiple purposes. The robots have the special characteristic that surpass the human ability and could operate in extreme environment which human cannot endure. In this paper, an autonomous robot is built to imitate the characteristic of a human cutting grass. A Field Programmable Gate Array (FPGA) is used to control the movements where all data and information would be processed. Very High Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL) is used to describe the hardware using Quartus II software. This robot has the ability of avoiding obstacle using ultrasonic sensor. This robot used two DC motors for its movement. It could include moving forward, backward, and turning left and right. The movement or the path of the automatic lawn mower is based on a path planning technique. Four Global Positioning System (GPS) plot are set to create a boundary. This to ensure that the lawn mower operates within the area given by user. Every action of the lawn mower is controlled by the FPGA DE1 Board Cyclone II with the help of the sensor. Furthermore, Sketch Up software was used to design the structure of the lawn mower. The autonomous lawn mower was able to operate efficiently and smoothly return to coordinated paths after passing the obstacle. It uses 25% of total pins available on the board and 31% of total Digital Signal Processing (DSP) blocks.

1. Introduction

Autonomous lawn mower is the robot which can perform desired tasks in unstructured environments without control by human being. Different type of autonomous lawn mower have different abilities of operating in relative environment but have the similar objective which is to mow the entire lawn. Advance and high performance robot is particularly desirable in fields such as unstructured environment or extreme landscape, where obstacle and interruptions are unavoidable. Besides that, it also has standard used benefit from having some level of autonomy, like cleaning floors, vacuum robot, and waste water treatment. Some modern factory lawn mower are "autonomous" within their direct environment. An autonomous lawnmower may also learn or gain new capabilities like adjusting strategies for accomplishing its tasks which is to cut the grass or adapting the changing surroundings.

The autonomous lawn mower is applying the ability on how managing its movement to complete its task. Field covers a large space of area thus it need high cost, energy and time in order to mow the entire field. Some other places have more than one field such as campus area, sport complex, and



schools. As the result, extra workers are needed to do routine maintenance over those exceeding fields. In addition, lawn mowing is not suitable to be done by workers especially in hot weather. The weather in this country is too hot for a man to stay in the middle of field as the Ultraviolet (UV) light is penetrating the body skin and the high temperature will lead to heat stroke which is very dangerous for workers. Thus it is not suitable for workers to mow in the middle of the field especially in the afternoon.

The existing autonomous lawn mowers are using random path planning which is not effective and caused a lot waste of energy and time. The device is perhaps not aligned with proper tyre adjustment and the same power management towards its two motors to drive the lawn mower into a straight path. This method would make the lawn mower to navigate itself towards the same track. It consumed a huge amount of energy, money and time to mow the entire grassy area on the field. An autonomous lawn mower is needed in order to reduce the cost of maintenance service. Compared with other commercial autonomous robotic lawn mowers like Honda Miimo, Husqvarna Automower 265 ACX and Robomow RS630, this proposed design use a difference platform by using FPGA with the similar specifications. FPGA offers high speed, flexibility, low power, low cost and development time.

The autonomous lawn mower is implemented using Field Programmable Gate Array (FPGA) which act as its brain to control movement, detect obstacle and turn 180 degree when it reaches the end of the boundary area. The autonomous lawn mower is capable of analysing where it is and plan its path. It is also capable of recalculate the path to be taken after facing some obstacle. However, this robot may also needed to understand its limitation boundary working space to complete up its goal. This robotic lawnmower has the hardware and software that work together to fulfil the desired task. One of the best feature of the robot is that it will cut grass in a parallel line and working in serpentine mode with Global Positioning System (GPS) navigation system. The GPS module helps the lawnmower to recognize the limitation boundary of working space programmed before the start up. Two direct current (DC) motors control the movements of the robot while operating. With the help of a sensor this autonomous lawnmower intelligently cut a lawn without supervision. The sensor used is an ultrasonic sensor. It emits sound wave and send the signal to the FPGA to be analysed when it detect an obstacle. The FPGA is programmed to give some instruction to the DC motor to avoid the obstacle by making the suitable movement.

2. Hardware Development

Hardware development involve with the mechanical and electronic parts that are assembled together to build part of project, for this case an autonomous lawnmower robot. Both of the aspects need to be functioned well as it needs to work together simultaneously to perform a task.

The block diagram of the autonomous lawnmower robot is shown in Figure 1. This figure portrays the connection of the mechanical components and the control system. Both DC motors were connected to the FPGA. The FPGA will control the speed of both motors by controlling the Pulse Width Modulation (PWM). In addition, ultrasonic sensor is also connected with the FPGA. The ultrasonic sensor will send the signal and the FPGA will decide what is the step that needs to be done depending on the situation faced. GPS module is also connected to the FPGA. This is to give the exact boundary coordinate that the autonomous lawnmower need to be operated.

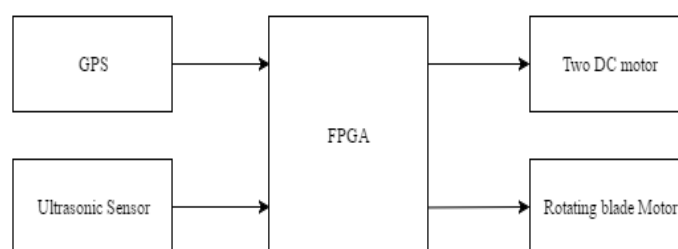


Figure 1. Block diagram of hardware architecture

In order to make a prototype of the autonomous lawnmower, a model is sketched using Sketch Up Software. This software has the ability of showing up the model in 3 dimension view. Any adjustment can be made whether it is at the front, back, upper site, or under the body part of the robot. As the result, it is easy to see if there is any miss aligned or unconnected area. From this method also, it is easy to build a real model of autonomous lawn mower.

There are two wheels attached at the back of the lawn mower. The two wheels at the back of the autonomous lawn mower is directly connected with DC motors. Both of the DC motors functioned to manage the movement whether for moving frontward, backward, left and right. Figure 2 shows the mechanical design of autonomous lawn mower (front).



Figure 2. Mechanical design of autonomous lawn mower (front)

One small wheel is also being added at the front of the outer body of the lawn mower. This is to make the lawn mower move easily. Altera DE1 board is placed at the upper side of the lawn mower. DE1 board acts as the brains to control all the hardware in the lawn mower. The FPGA board control the signal to each of the hardware while the robot is operating. The bottom site of the body is where the blade for cutting is placed. This blade is connected with DC motor to spin and cut the grass. To ensure that the spinning blade is perfectly cut the grass, some measurement need to be calculated in order to get perfect grass cutting. Figure 3 shows the upward view of the lawnmower and Figure 4 shows the bottom view of the lawnmower.

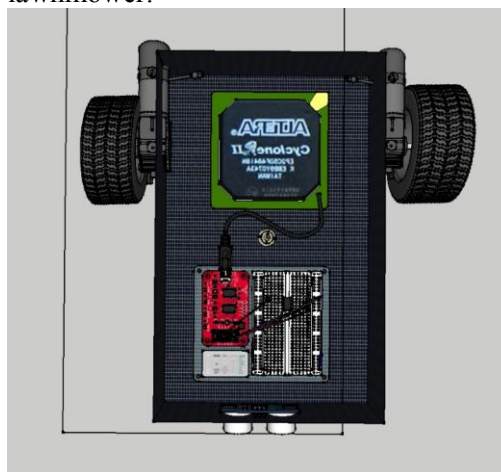


Figure 3. Upward view of the lawn mower

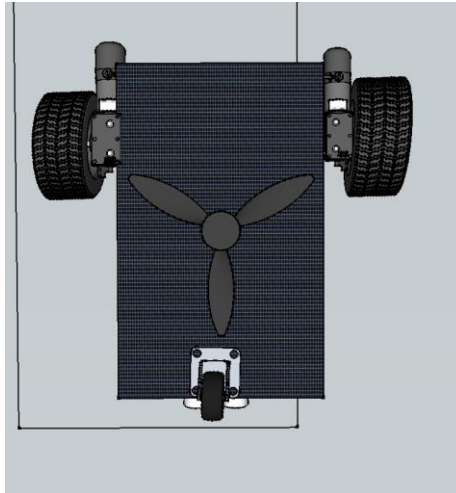


Figure 4. Bottom view of the lawn mower

3. Software Development

Altera Quartus II V15 design software is used and provides the multiplatform design environment that easily adapts to specific design needs. It is a comprehensive environment for system-on-a-programmable-chip (SOPC) design. Thus, the FPGA is acting as the brain for the autonomous lawnmower to control every signal sent by the sensors such as ultrasonic sensor and GPS module. The FPGA is then give the instructions to the autonomous lawn mower hardware such as the DC motor to make some appropriate movement to finish up the task.

4. Control System

Initially, the lawnmower is in a stop position while it is acquiring the GPS coordinate. After some analyses are done in acquiring the GPS coordinate, the autonomous lawn mower starts to move forward. The lawnmower is moving forward until it detects an obstacle (if present). If there is an obstacle detected by the ultrasonic sensors, the lawnmower will stop in order to avoid the obstacle.

The lawnmower will continue to move forward until it reaches the limit boundary set by using the GPS coordinate. The forward movement is guided by the proportional–integral–derivative controller (PID controller) to make sure there is no error between the two DC motors and eventually driving the robot into straight line. If the lawnmower reached the boundary, it will turn to 360 degree to continue on mowing the grass in serpentine mode. The lawnmower will stop on mowing after reaching the final dot of the coordinate. Figure 5 shows the process flow of the control system for the autonomous lawn mower.

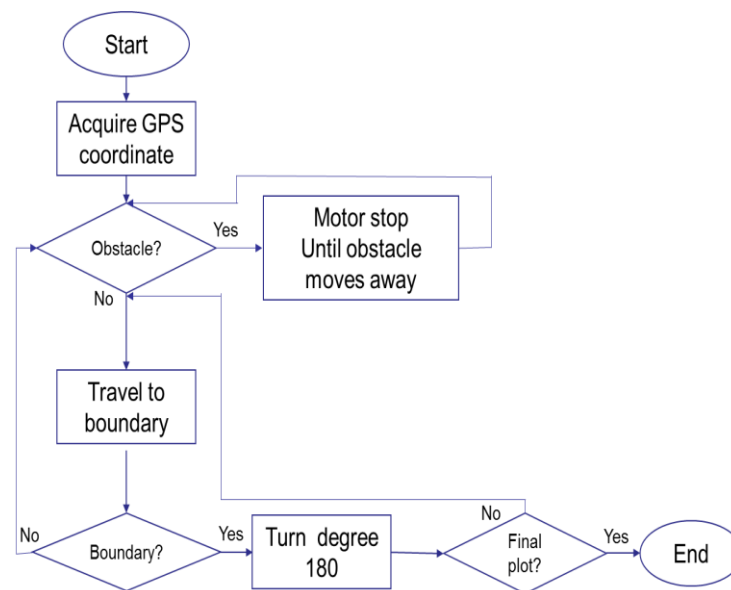


Figure 5. Process Flow of the control system

5. Simulation and Evaluation Results

The system specification of the autonomous lawn mower is listed as in Table 1.

Table 1. System specification of the autonomous lawn mower.

Item	Specification
Processing clock speed (FPGA)	50 MHz
Input voltage	3.3V
Motor voltage (rear)	12V
Motor current (rear)	7A
Motor voltage (blade)	5V
Motor current (blade)	2A
Number of motors	3

The Autonomous Lawnmower system is successfully designed, where the autonomous lawn mower was able to move the two tires at the same time when it had given instruction to move forward. Figure 6 shows the functional simulation of the top level entity. Figure 7 illustrates the timing simulation of the top-level entity.



Figure 6. Functional simulation of toplevel entity

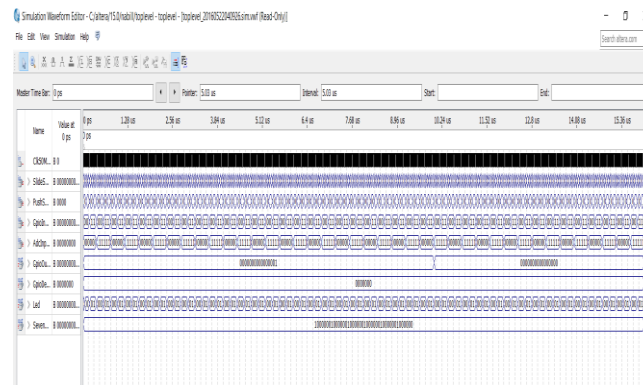


Figure 7. Timing simulation of top-level entity

Lawnmower controller FPGA has occupied 2% (726/32070) of the logic utilization and 715 of total register. The high amount of logic resources usage is due to mainly there are many built in mega function of floating point modules is used. The autonomous lawn mower is using high amount of total pins which are 25% (114/457).

The coordinate of the GPS is determined by the Push switch [3...0]. The DC motor is then triggered when the Slide switch [9...0] is toggled on. Ultrasonic sensor emit it soundwave and received its echo when it detects an object. Ultrasonic trigger pulse send the information to the DC motor in order to avoid the obstacle. Right motor speed up for a little time and followed by the left side afterwards. The motor turn 180 degree when it reaches the boundary area.

The movement operation of the autonomous lawnmower is tested on the field. Four coordinate are transmitted using the GPS module to create a square boundary. This step are crucial to make sure that the autonomous lawnmower knows the region to be lawn. The lawnmower will automatically move from the first coordinate until it reaches the boundary line and eventually make a U-turn to continue. This steps are repeated all over again until it reaches the final coordinate. The autonomous lawnmower however will stops if the ultrasonic detected obstacle and will continue moving until the obstacle move away. This is to ensure the safety of people around and avoid accidentally collision that will break the robot. The Figure 8 illustrates the movement of the lawnmower.

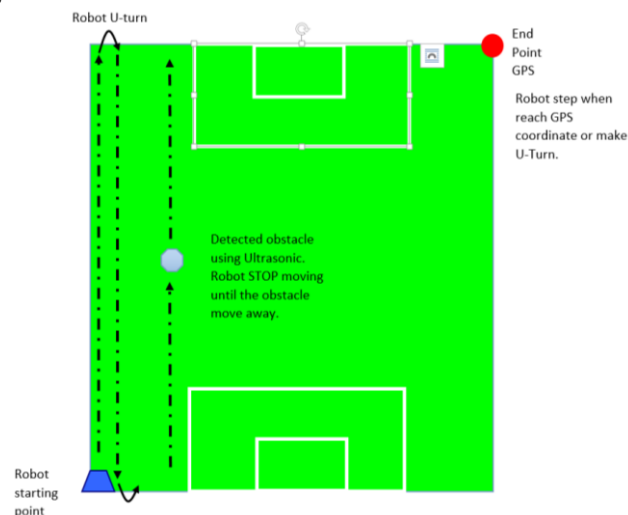


Figure 8. Movement of the lawn mower

Different type of cutters produced different results where it may not properly the grass. The paper cutter known as the pocket knife was used as the sample blade to cut the grass. The blade was able to

cut the grass. Figure 9 shows the result area after performing mowing action on a selected sample field.

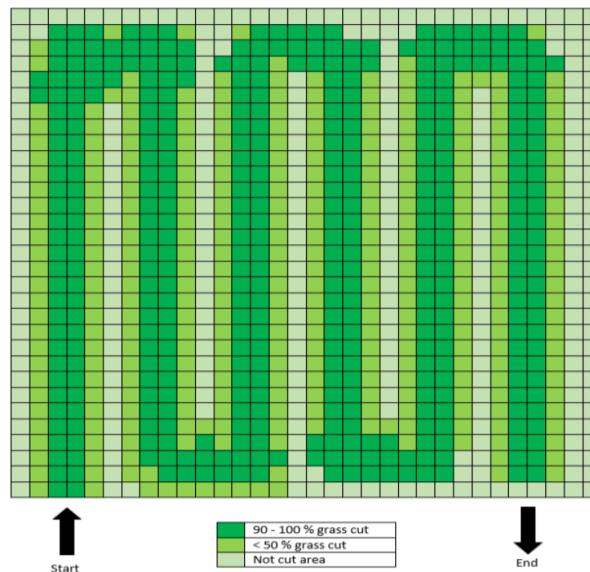


Figure 9. Block representation of the area of cutting output

The dark green area indicates the area of cutting being cut roughly 90 to 100 percent. The grass is cut to the desired height of mow height. For the middle green area show that the grass in that area were not cut fully by the lawn mower due to the design where the spinning blade was small in diameter which smaller compare to the size of the lawn mower itself. The grass was difficult to cut as it is located approximately to the circumference of the blade. This situation making it 50 percent chance to be cut. For the no cut area happen at the beginning and the continuous interval between sub separation widths. The beginning not cut area happen as the wheel was too big hence making that part cannot be cut. The only way to make sure that the entire field is fully mowed, the autonomous lawnmower need to be put at the non-mowed grass and continue its operation all over again.

6. Conclusions

This paper represent a design of an autonomous lawnmower using FPGA with GPS navigation. By applying the GPS coordinate given by the user to move inside the border according to the objective. The autonomous lawnmower is able to operate with the design that have been made and encounter no physical problem when moving. The structure build was user friendly and economically.

7. Acknowledgement

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