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Research Article

Design of a Robotic Humanoid for Surveillance Application

David O. Agbo*, Jonathan A. Enokela, Goshwe Y. Nentawe

Department of Electrical/Electronic Engineering, Federal University of Agriculture Makurdi, P.M.B. 2373, Nigeria

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**Corresponding author:*
E-mail: agbo.david@gmail.com

ABSTRACT

The evolution of robotics and their control systems have made the placement of arms, their motion, grasping of objects, as well as exploring their immediate environments a very important area of research. The electronic design and implementation of the humanoid which involves the keypad and graphical user interface (GUI) to track the movement of the humanoid robot as well as control the humanoid robot in performing the tasks of avoidance of obstacles and picking of objects is achieved. The system is made of two units: the remote controller unit and the humanoid control unit. The remote controller unit is of two types namely; the keypad and the GUI. The keypad uses the buttons to control or direct the humanoid while the GUI does the control using PC. The GUI has the additional function of viewing the picture taken by the humanoid, if the arrangement of an obstacle is not included among the sixteen obstacle avoidance algorithms considered. The humanoid control unit makes the humanoid walk and avoid obstacles autonomously. The simulation of robotic humanoid and hardware results also show that the hardware implementation can be embedded into the humanoid frame for surveillance applications.

Keywords: *Surveillance, Camera, GUI, Control, Keypad, and Humanoid Robot*

Introduction

Robots are increasingly being integrated into tasks to replace humans. They are currently used in many fields of applications including office, military tasks, hospital operations, industrial automation, security systems, dangerous environment and agriculture [31]. Several types of mobile robots with different dimensions are designed for various robotic applications. The robot in this work has been designed for the purpose of surveillance.

Many related researches have been done in humanoid design and applications: In [7], the humanoid (HRP-2P) with biped locomotion controller that can find a target object by vision and to carry the object with the assistance of human voice commands was used. The human voice is use to control the arms of the robot. This is done using force/torque sensor on the wrists while the robot is walking. Humanoid robot was used to assist socially in a smart home environment (for receiving information) [4]. In

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[3], HRP-2 humanoid robot was developed for table carrying task and height stabilization using vision. The iCub humanoid robot was used to pick and place objects [6]. In [10, 13 and 1], a humanoid was developed for entertainment and competition (FIRA) for Robot soccer using Webots simulation tool. In [12], a small size humanoid robot was designed for monocular SLAM, capable of image feature detection, good feature selection, and image depth calculation and feature state estimation using; Speeded up Robust Features (SURF), Kalman filter-based estimation algorithm and computation schemes of visual SLAM. In [11], a small humanoid was developed to help children affected by autism spectrum disorder (ASD). In [2], the effect of appearance of robot to children was used with autism. In [9], MATLAB based object detection technique was used. They used arduino board to create an iROBOT with the MATLAB algorithm to make the robot control the state of the output pins of Arduino. In [5], review was done on humanoid robot and their effect on children with autism. In [8], PR2 humanoid robot was used to teach the humanoid new skills (training the humanoid). The robotic humanoids mentioned in the reviews were designed for various non-surveillance applications; the research in this paper focuses on surveillance applications.

Methods

a. *Overview of the proposed Design*

Figure 1 shows the proposed physical design of the robot humanoid. The materials used in this research consist of both software and hardware. The software design is the GUI design, while the hardware design consists of the electronic components. The block diagram of the system is divided into two sections. Figure 2a shows the remote controller unit, where Figure 2a (i) is the GUI control section that views the pictures that the humanoid is sends to the PC. The control of the humanoid can also be done from the GUI to perform some certain tasks. Figure 2a (ii) shows the mobile keypad remote controller unit that can still access the information sent by the humanoid and also control the humanoid to perform same task like the GUI, but has no function of viewing the image taken by the humanoid. Figure 2b is the electronic section that drives the humanoid to walk autonomously and to perform other functions directed to it by GUI or keypad commands.

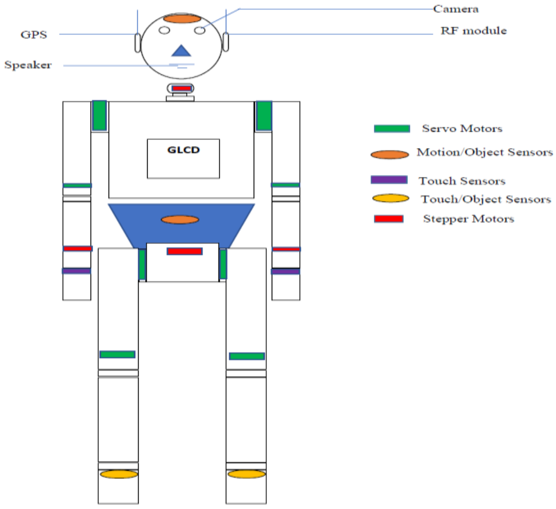
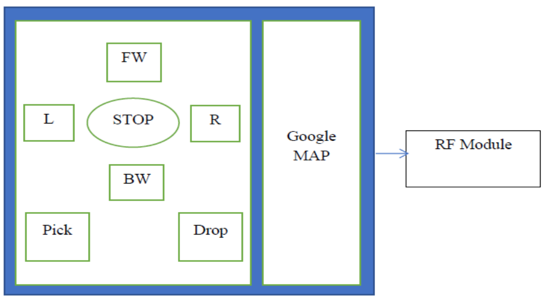
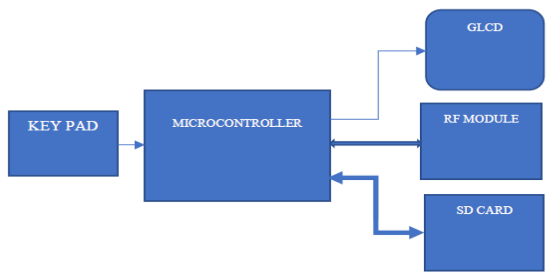


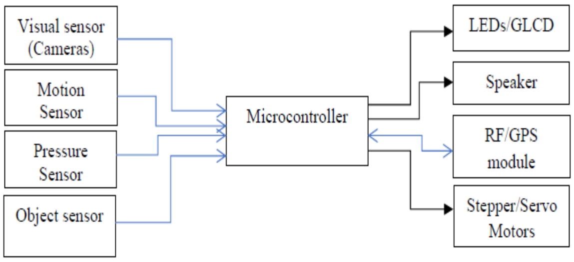
Figure 1. Physical Diagram of the Proposed Humanoid Robot



(i): GUI controller Unit



(ii.): Keypad controller Unit
(a): Remote controller system



(b): HUMANOID

Figure 2. Block Diagram of the supervised Robotic Human for Surveillance Applications

b. *Operation of the Remote-Controlled Robotic Humanoid*

The remote controller section is made of two units. Figure 3 shows the key pad remote controller unit that is made up of five buttons with graphical liquid crystal display (GLCD) [26] as display unit and uses RF module [22] for communication while Figure 4 shows the GUI [27] remote controller unit displaying icons which are used to control the humanoid robot as well. The center button of the keypad unit is the menu button which is used to select the mode that the humanoid robot is to operate whenever the remote controller unit receives a Help call from the humanoid robot. The humanoid operates in two modes: walking mode and picking and placing mode. In the walking mode the robotic humanoid needs to avoid obstacles while walking, using obstacle avoidance tree. If the arrangement of an obstacle is not included among the sixteen obstacle avoidance algorithms considered, the humanoid gets information about the obstacles it needs via the camera unit shown in figure 5. The operator uses this information to aid the human in avoiding the obstacles. Figure 5 shows the OV7670 camera [23] and storage device (SD) card [28] interfaced with Arduino uno [29]. The camera is used in taking pictures every 3 seconds and these pictures can be stored in the SD card or sent to the remote controller unit via the RF module by the PIC18F4520 microcontroller [19] which can also access the SD card. Figure 6 shows the humanoid controller unit that consists of many components controlled by the PIC18F8722 microcontroller [20]. All these components interact to make the humanoid walk smoothly. Each leg has three servo motors [17] on it to make it move using forward kinematics.

The angles and delay time are created at each particular stance of the robotic gait to complete a walking or gait cycle. The gait cycle is made of two stances; the double support stance (DSS) and the single support stance (SSS) or swing stance where the leg's hip, knee and ankle angles change with delay time as the leg moves. A complete gait cycle is made of ten phases. The DSS takes 30% of the gait cycle while SSS takes 70% of the gait cycle. The gait cycle is divided into two, the first half gait cycle and the second gait cycle. Each half gait cycle consists of one DSS and four SSS: DSS is 15% while SSS is 35%. Phase 1 to 2, 5 to 6 and 9 to 10 are DSS while 2 to 5 and 6 to 9 are SSS. For the right stance phase where the right leg makes the first move, the phase is between 1 to 6 and the left stance phase where the left leg makes the first move; the phase is between 5 to 10. The humanoid commences walking with double stance with either right leg making the first move then the left leg follows. The angle selections as the humanoid walks are shown in table 2. These processes enable the humanoid to use servo motors to walk. While walking the humanoid avoids obstacles using the ultrasonic sensors on its legs (two per leg) and are connected at 45^0 and 90^0. The PIR sensor [18] enables the humanoid to know if the obstacle is a human or animal; with that knowledge the humanoid can easily avoid such obstacles. When the humanoid controller requests for help it switches the SD card from the Arduino to PIC to access the pictures taken and it then asks for Help for directions from the remote controller center via RF module. Stepper motors are used at the neck, waist and hands. The neck has the capability of moving from angle 0^0 to 360^0 with stepping of 1.8^0. The stepper motor [30] placed at the waist is to enable the waist move from 20^0 to 180^0 with stepping of 1.8^0 or nearest degree. The hand has stepper motor to control it to avoid crushing of object while grasping. Pressure sensors [16] are placed at each hand to serve as feedback to the stepper motor. There are also pressure sensors at the feet of each humanoid to send feedback to the controller to indicate that the feet have made contact with the floor so that the next stance can begin. GPS [14] are connected to enable the controller track the positions of the humanoid and these positions are displayed on the GLCD of the remote controller unit or the GUI on the PC to compare the pathway the humanoid is following with the waypoints fed into it.

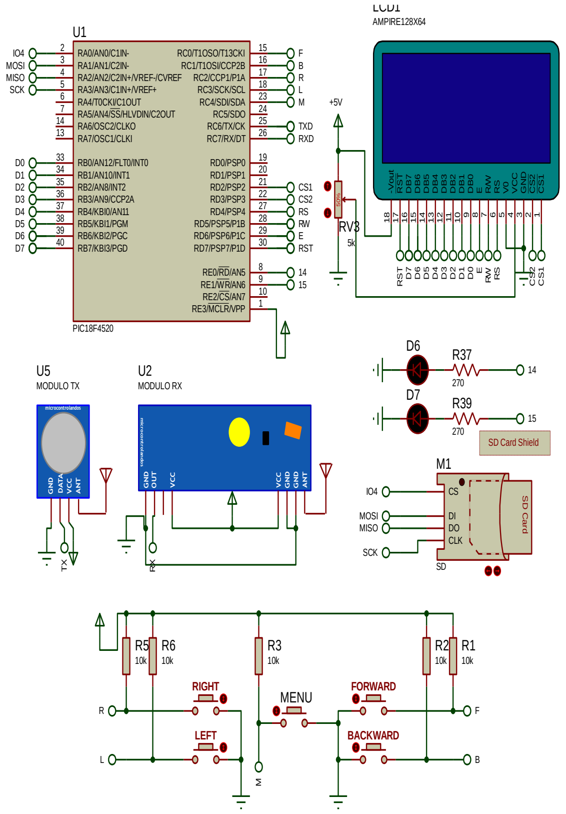


Figure 3. Keypad Remote Controller Unit

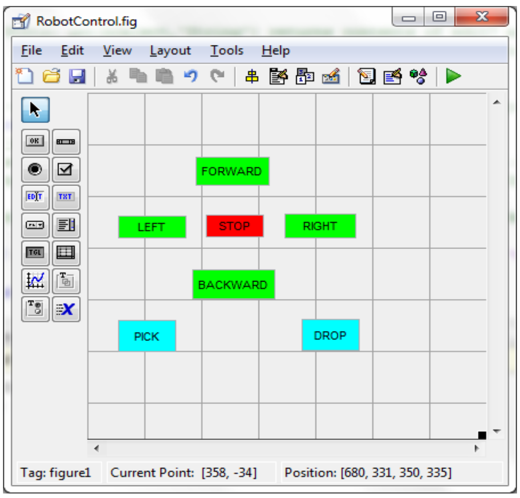


Figure 4. GUI Remote Controller Unit

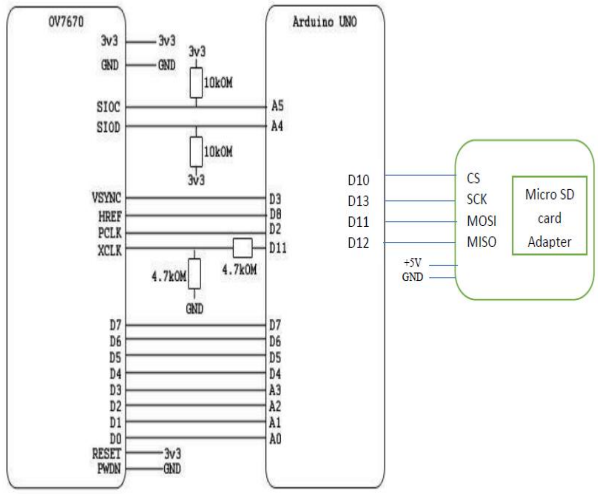


Figure 5. Arduino Uno interfaced with OV7670 Camera and SD card

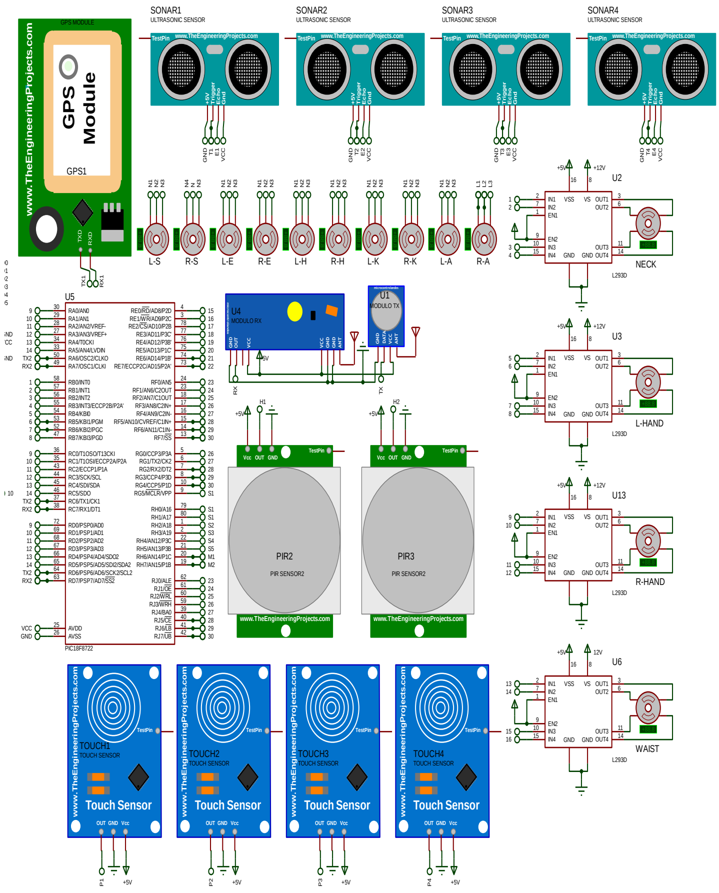
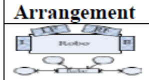
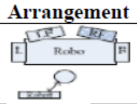
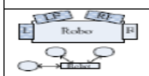
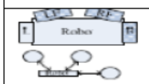
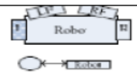
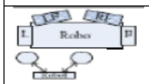
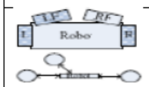
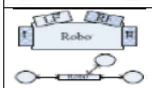
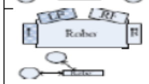


Figure 6. Circuit Diagram of Controlled Robotic Humanoid on Proteus 8.9 IDE

c. Decision Tree of the Obstacle Avoidance and the Flow Chart of the System

Obstacle avoidance for a walking robotic humanoid is very essential. It is paramount that when the humanoid is walking, it should be able to avoid obstacle and other humans. So, a pattern of obstacle avoidance was created for it as shown in Figure 7 using ultrasonic object detector. Figure 8 shows the flowchart of the remote controller unit that begins with start. The system initializes and waits for Help Call from the humanoid. If there is no Help Call, the system continues to wait for it. If a Help Call comes in, the system checks the type of Help Call. If the Help call is to assist in obstacle avoidance, the user goes to the required commands for obstacle avoidance. If the Help call is to pick and place an object, the users goes to the required commands for pick and place the object and the process continues all over again. Figure 9 shows the ultrasonic sensor flowchart that follows the obstacle avoidance decision tree. The system initializes the ultrasonic sensor and the sensor then checks for objects. If no object is detected the sensor continues to check for object as the humanoid is moving along a path. If an object is detected along the path, the system checks the obstacle avoidance decision tree to know the category of the obstacle placement and follows the programme to avoid the obstacle(s). Figure 10 shows the PIR/camera sensor flowchart. The system initializes the PIR and camera sensor. If the humanoid detects an object while moving along the path, it uses the PIR sensor to check if it is human or animal. If the obstacle is human or animal it snaps and sends the picture to the remote controller unit; if the object is a lifeless object, it uses the object decision tree to avoid the object. If the object cannot be avoided, the humanoid sends Help call message to the remote controller unit for guidance.

Sensors Arrangement	Commands	Sensors Arrangement	Commands
	Call For HELP		Maneuver Left
	Turn 90 Degree Right		Go Straight
	Turn 90 Degree Left		Go Straight
	Turn 90 Degree Left		Go Straight
	Slip Right		Go Straight
	Slip Left		
	Maneuver Right		
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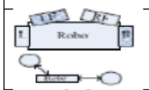
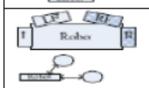
	Slip Right		
	Maneuver Right		
	Maneuver Left		

Figure 7. The behavior table of the decision tree

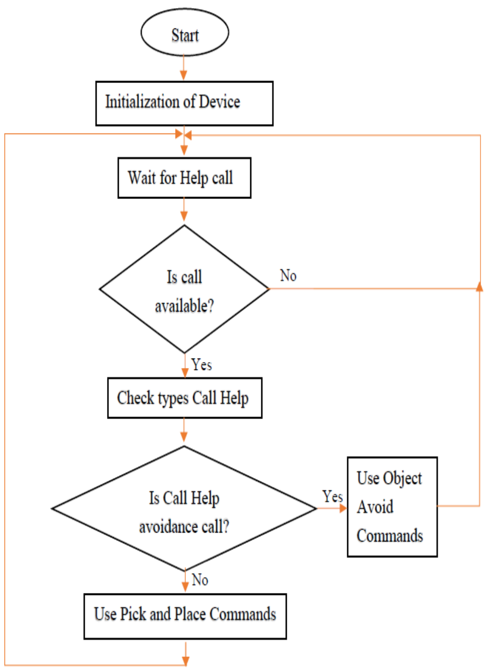


Figure 8. Remote Controller Flowchart

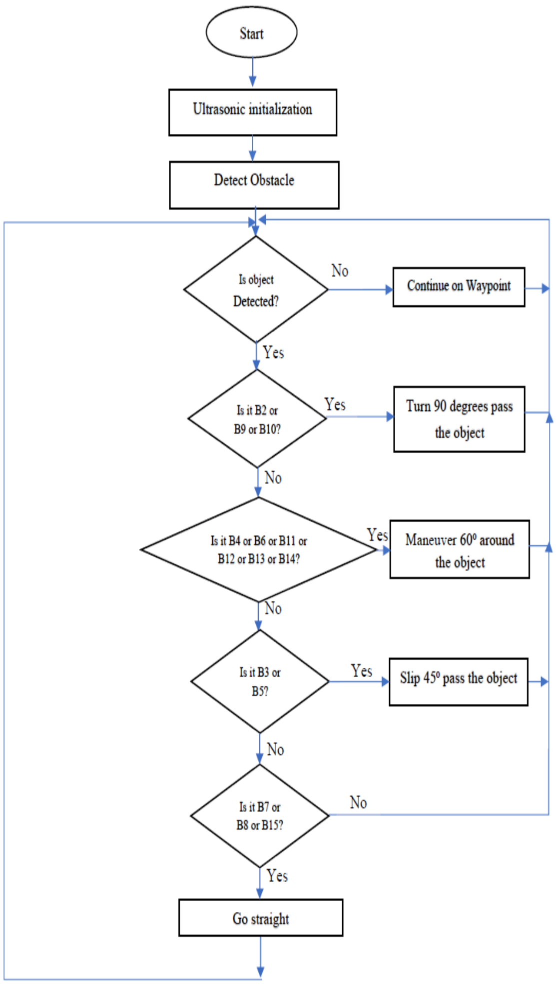


Figure 9: Ultrasonic Sensor Flowchart, Figure

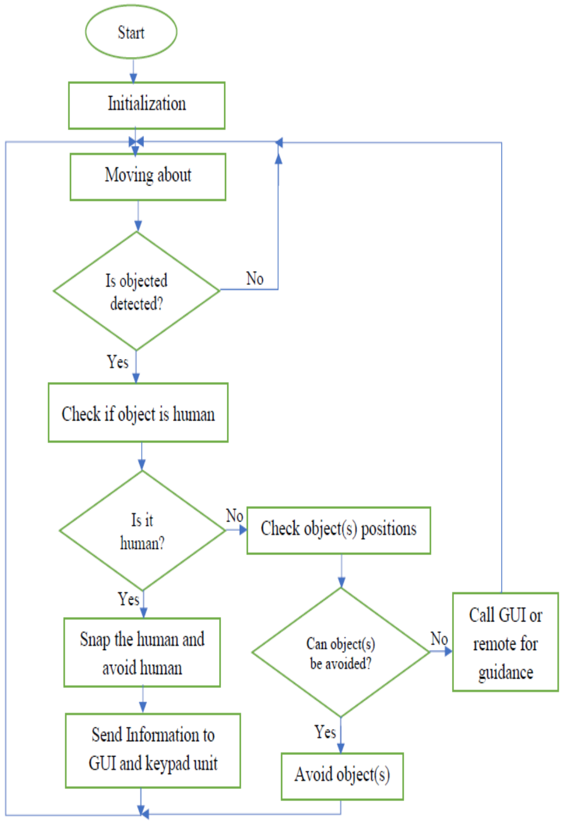


Figure 10. PIR/Camera Sensor Flowchart

Results and Discussions

The program for the microcontroller was written in C language and was then compiled into an executable file using the mickroC IDE [24]. Figure 11 shows the remote controller unit that displays the position of the robot. From the remote controller the user can override the movement of the robot by giving directive to the controller to follow. Figure 12 shows the camera unit of the humanoid control unit which is made up of a camera interfaced with Arduino microcontroller. Pictures from the camera can be stored in SD card or sent directly to another source on request or continuously sent to PC. Figures 13 and 14 show the pictures that have been taken by this Unit. The printed circuit board (PCB) [25] was designed for the PIC18F8722 microcontroller as shown in Figures 15 and 16, while other components are directly connected to the main board as shown in Figure 17.

Figure 11. The Remote Controller using RF Module

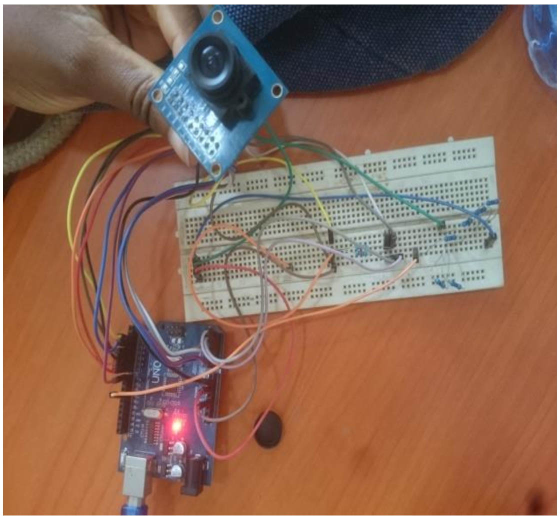


Figure 12. The Camera Unit using Arduino and OV7670 Camera

Figure 13. Images captured using OV7670 Camera from 3m away from the Camera

Figure 14. Images captured using OV7670 Camera 1.5m away from the Camera

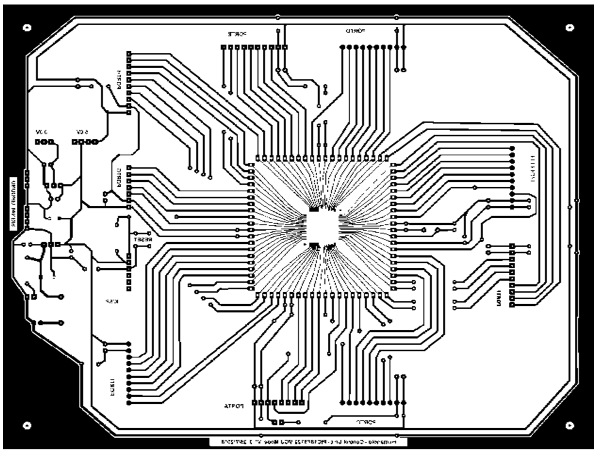


Figure 15. The PCB Board Design for PIC18F8722

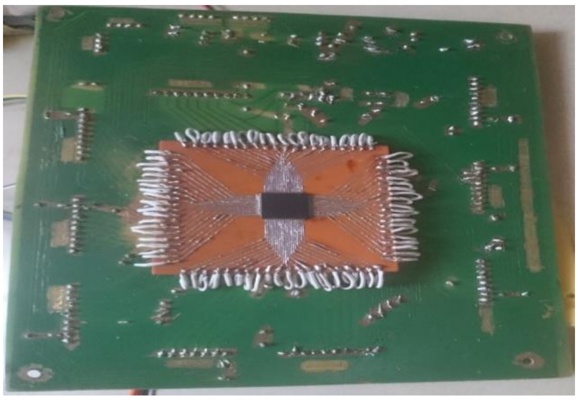


Figure 16. PIC18F8722 Boards

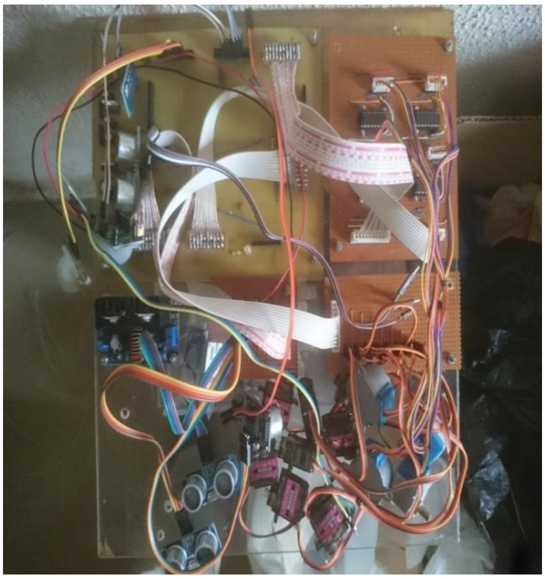


Figure 17. The Complete Connection of the Circuit

The electronic design was tested without the humanoid mechanical frame. The remote controller design shown in figure 11 was designed to get information about the position of the humanoid using RF and commands can be issue to the humanoid to follow (commands like: turn left or right, pick and drop). The controller unit comprises of figure 12 and 17. Figure 12 is used to take picture of the environment whenever the humanoid finds it difficult to navigate because of obstacle arrangement that is not in the avoidance decision tree, the humanoid calls for help from the remote controller unit. Figure 13 are pictures taken by the camera from 1m and 3m distance. Figure 17 shown is the controller unit that drive the humanoid to move. The ultrasonic and PIR sensors are used by the humanoid to avoid obstacles and humans. The servomotors are used to drive the joints of the humanoid (shoulders, elbows, hips and knees) while the stepper motors are used to drive the neck rotation, waist joint and hands joints. The pressure sensor are placed at the hands and feet of the humanoid to serve as feedback when the hand have grasp an object or when the feet have made contact with the ground.

Conclusions

The electronic design and implementation of the humanoid which involves the keypad and GUI to track the movement of the humanoid robot as well as control the humanoid robot in performing the task of avoidance of obstacles and picking of objects is achieved. The GUI has the additional function of viewing the pictures taken by the humanoid when in stranded state while it walks if the arrangement of an obstacle is not included among sixteen obstacle avoidance algorithms considered. The simulation of robotic humanoid and hardware results also shows that the hardware implementation can be embedded into the humanoid frame for surveillance applications.

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