A NOVEL DESIGN OF A HUMAN-ROBOT FINGER CONTROLLER

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Abstract

Over the years, robots have been used in many areas of our lives. Robots are used for assistance at home, office, hospital, industrial plant, educational institution and waste disposal facility, among other places. Many of these working robots are either self-guided without human interference (autonomous) or human-operated with a remote controller (tele-operated). Many of these robots do not have dual operational modes that allow effective human-robot interactions. The objective of this study was to provide a unique and novel perspective for designing and building a human-robot finger controller that has dual operational modes for controlling the robot. The finger controller is a custom-made controller that is capable of controlling the robot using only two fingers on the left hand and two fingers on the right hand. Commands are communicated wirelessly to control a robot through an Arduino microcontroller and an XBee shield.

In this paper, the authors present three applications of robots controlled by the custom-made finger controller with an emphasis on the Finger-Controller's wireless communication from the transmitter to a receiver and vice versa. The three robotic applications are: Flexible Robot, Line-Following Robot and Solar Rechargeable Robot.

Introduction

Robots have evolved over the years to help people perform repetitive and dangerous tasks, which humans prefer not to do or are unable to do due to size limitations. For instance, robots have provided assistance in performing under extreme conditions and in dangerous environments such as the deep sea and in outer space. However, these robots do not collaborate with humans. In the proceedings of the 2009 4th ACM/IEEE International Conference on Human Robot Interaction, Astride Weiss stated that "effective collaboration between robots and humans is not only a question of interface design and usability, but also of user experience and social acceptance" [1]. This shows that humans are fine with the idea of working with a humanoid robot, as long as there is a clear distinction between the human and the robot in terms of tasks and working procedures.

Many human-robot interactions are done in either tele-operated or autonomous mode. In the tele-operated mode, many robots are either controlled by joysticks, keyboards, virtual GUI (graphical user interface) screens, through voice recognition or Microsoft Kinect motion-capture systems. Unlike these commonly used controllers, the finger controller is a custom-made human-robot controller that is capable of controlling many different robots. It is performed by two fingers on the left hand and two fingers on the right hand. It offers the flexibility of switching from tele-operated to autonomous mode or vice versa. Thus, the finger controller provides a unique and novel design of human-robot interactions that will help to enhance the collaboration between human and robot.

Sensors and the Finger Controller

The human hand has five fingers. The names of the five fingers are defined in Figure 1.

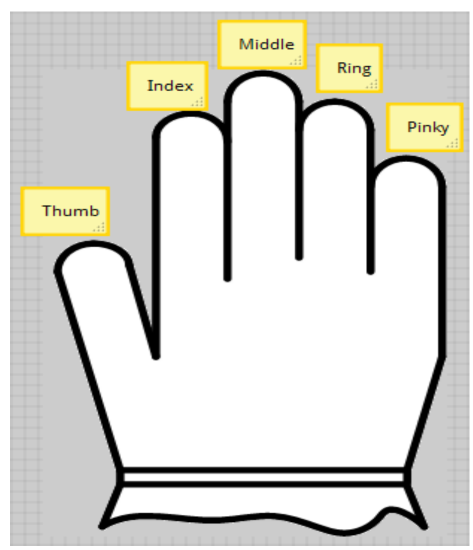

Figure 1. Right Hand

The index and middle fingers from the left and right hands are used as part of the finger controller. To make the finger controller flex with the real human fingers, the 4.5-inch flex sensor [2] would be an ideal scenario for this application. As the flex sensor is bent and flexed, as shown in Figure 2, the resistance across the sensor increases.

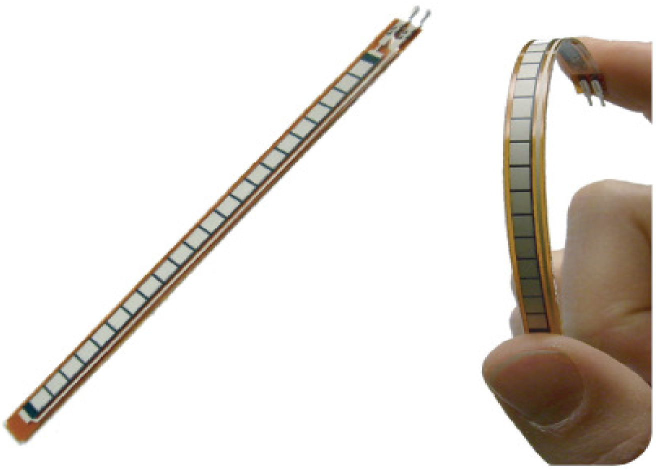

Figure 2. 4.5-inch Flex Sensor

If the flex sensor is flat, the nominal resistance is at 10K Ohms. When the flex sensor is bent, it has a range of 60K to 110K Ohms with a tolerance of ±30%.

Figure 3 illustrates the finger controller that contains the flex sensors on the index and middle fingers of the left-hand and right-hand gloves. The use of the flex sensors is a unique way for human-robot interactions because it is the first step to haptic robotics. Haptic means tactile feedback or physical feedback from a device or a robot [3]. For instance, the haptic feedback in a Sony Playstation 2 console has a vibrating remote controller in a shooting game. It sends feedback to the user that an event (in this case, shooting) is triggered. It is a step toward a more humane robot. In the case of the finger controller, it provides tactile feedback to the user for controlling different robotic applications.

The finger controller is designed to control a combination of two DC motors, such as Tetrix DC motors, Servo motors or CIM motors. It is designed to be used as a transmitter to send the data to the receiver. For instance, depending on the robotic application, the flex sensors on the two index fingers are controlled by the forward and backward motions of the robot. And the two middle fingers are controlled by the left and right turns of the robot.

Finger Controller and Wireless Communication

As illustrated in Figure 3, the finger controller has four flex sensors. Each hand has two flex sensors connected to the index and middle fingers. Also, each hand has one microcontroller. This is to prevent the congestion of data between the XBees and wireless data transmission interference. Also, the two XBees provide better redundancy against failure. Each flex sensor connects to the analog pin of the Arduino microcontroller [4]. The analog values from the flex sensors are based on a voltage divider between two resistance values. These values then transmit two one-way communications wirelessly to the receiver. The wireless Xbee communication radio transmits information byte by byte [5]. Each byte consists of 8 bits or 2 nibbles. All of the standard ASCII characters can be sent byte by byte. A byte looks like this, in binary, 00000000 which represents 0 in decimal or 0x00 in hexadecimal. The highest decimal possible in a byte is represented 0xFF in hexadecimal, 255 in decimal and 11111111 in binary [6]. Thus, the wireless communication can send information in numerical or character form from 0 to 255.

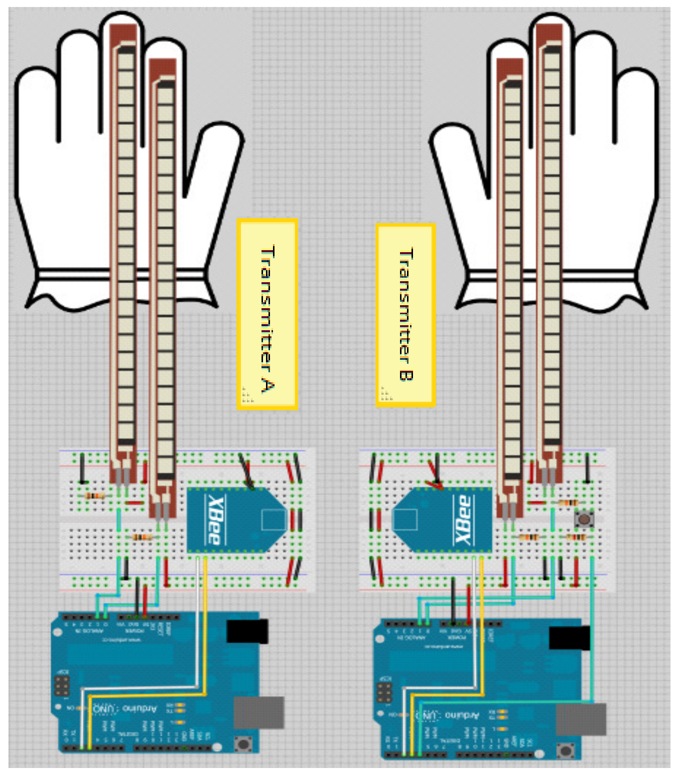

Figure 3. 3D Finger-Controller Layout

In addition to the flex sensors integrated with the finger controller, a push-button switch is implemented on the right hand of the finger controller. The push-button switch allows the user to alternate from tele-operated to autonomous mode and vice versa. Each time the user pushes the switch, the switch produces either a HIGH or a LOW signal. This HIGH or LOW signal transmits one byte (either 11111111 or 00000000) to the receiver. Thus, the finger controller is a unique and novel controller for human-robot interactions.

Prototyping of the Finger Controller

Based on the 3D layout shown in Figure 3 and 2D schematic shown in Figure 4, the design of the finger controller can be seen in Figure 5. Note that the schematic of Figure 4 is a duplicate of Figure 3. However, Figure 4 provides a clear schematic layout as a guide to complete the Finger-Controller circuit in Figure 5.

Robotic Applications

Three robotic applications are presented in this section; the Flexible Robot, Line-Following Robot and Solar Rechargeable Robot. All three robots have different characteristics and are controlled by the finger controller. To make the finger controller adapt to different robotic tasks, the high-level programming source codes were created and uploaded to the Arduino microcontroller. The source codes were developed using the following software flowchart.

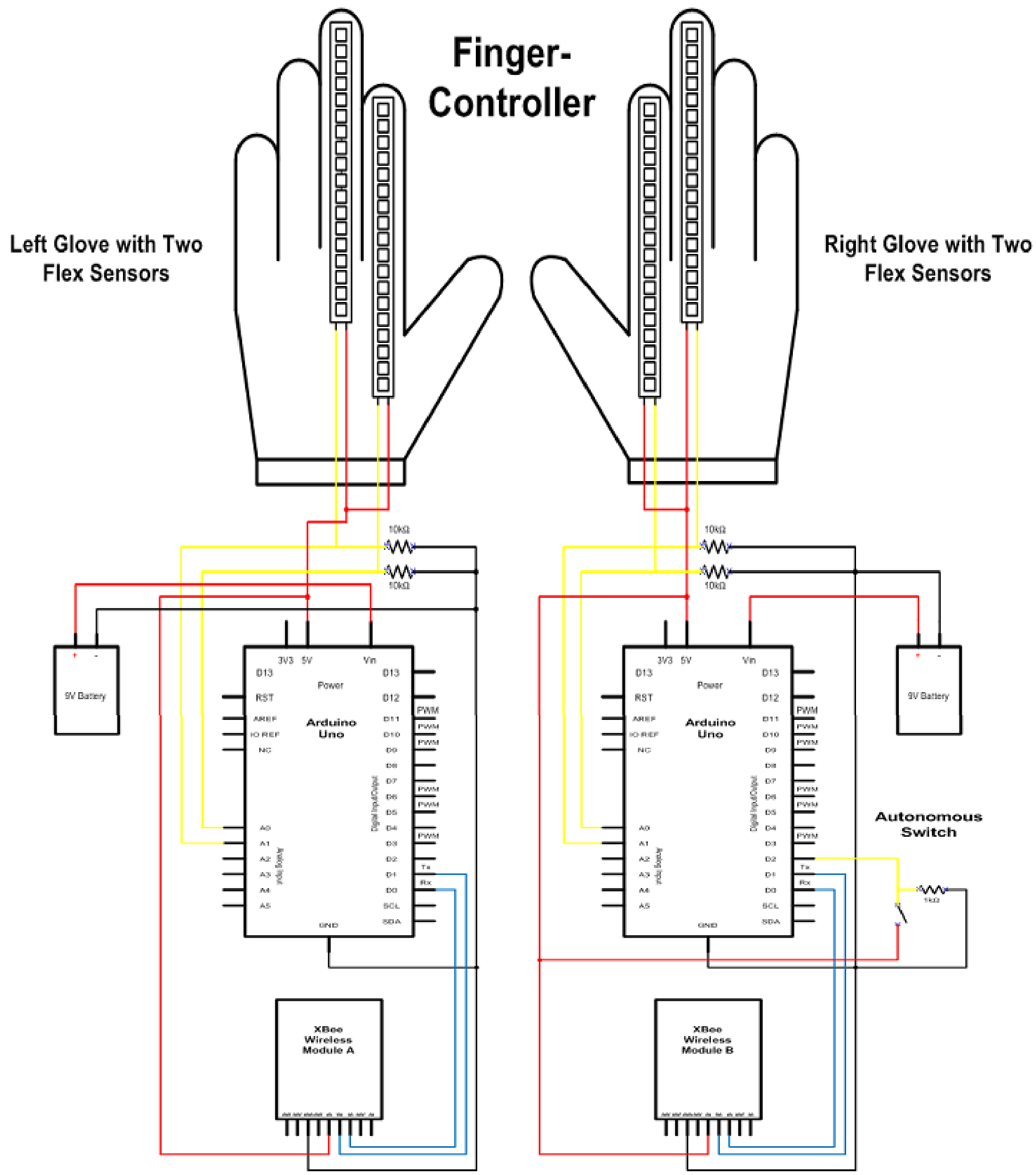

Figure 4. 2D Schematic of the Finger Controller

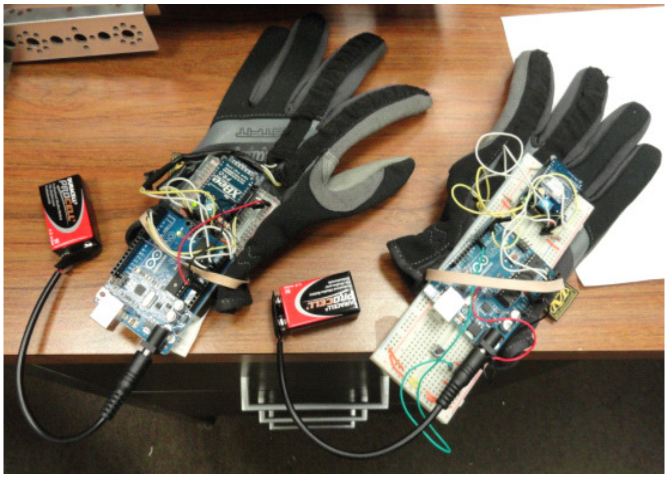

Figure 5. Prototype of the Finger Controller

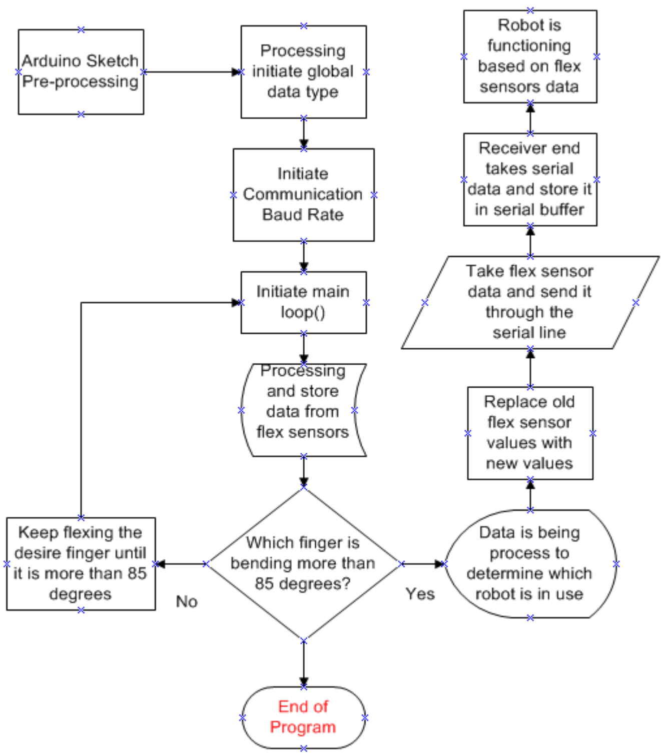

Figure 6. Finger-Controller Software Flowchart

Figure 6 is a software flowchart that is used to create the source codes for the finger controller. The user has to decide which robot is going to be used. Then, the user has to bend one of his or her four fingers (left middle, left index, right index or right middle) more than 85 degrees to select the desired robot. Each finger represents one robot application, as seen in Table 1. After the selection has been made, the robot is now controlled by the finger controller, either in tele-operated or autonomous mode.

Table 1. Robot Applications

Left Middle	Left Index	Right Index	Right Middle
Not In Use	Flexible Robot	Line Following Robot	Solar Rechargeable Robot

Note that the receiver end of the finger controller can be set up with different robotic wheel configurations and different drive systems.

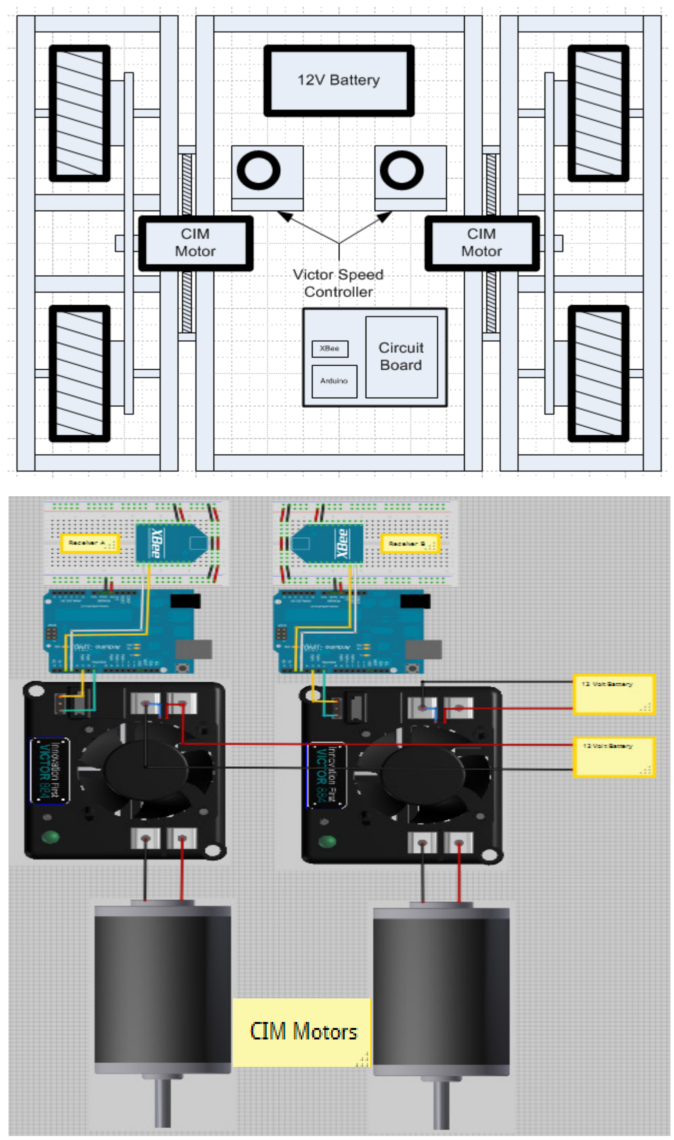

Figure 7. Conceptual Design and Schematic Layout of the Flexible Robot

Flexible Robot

The Flexible Robot has unique and innovative features for unconventional means in mobility through different environments. The concept is essentially a robot that can be controlled wirelessly through tele-operated or autonomous mode with a programmable microcontroller. At the same time, the mechanical design of the Flexible Robot has the capability of moving effectively over rough terrain that would otherwise stop conventional robots.

The Flexible Robot is a tank-drive robot that runs on four wheels. Each set of two wheels runs on a single CIM motor [7]. Therefore, there are two CIM motors for the entire four-wheeled robot. Figure 7 shows the process of conceptual design to build the electrical schematic layout.

Figure 8 shows the prototype of the Flexible Robot and the preliminary testing of the Flexible Robot controlled by the finger controller. The CIM motors in Figures 7 and 8 are controlled and powered by a Victor 884 [8] speed controller. There is one speed controller for every CIM motor. This Victor 884 speed controller can control the speed and direction of the motor. The left finger controller on the transmitter controls the left set of wheels, while the right finger controller controls the right set of wheels. The index fingers of the finger controller control the forward motion of the robot, and the middle fingers control the reverse motion of the robot. The variation of speed and direction are dependent on how much the flex sensors are bent.

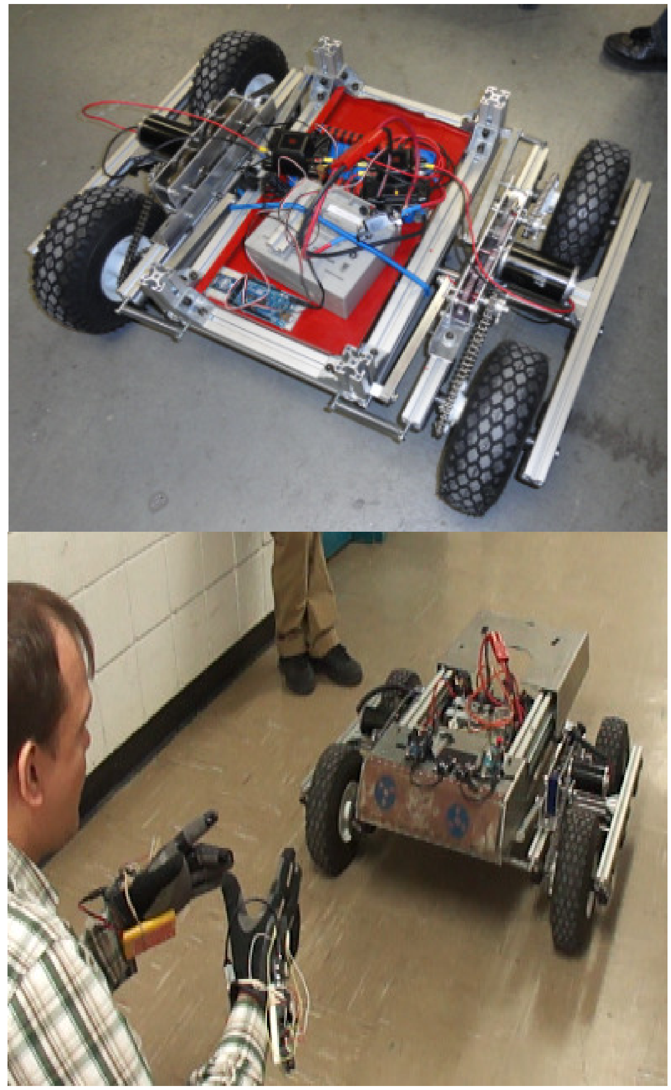

Figure 8. Flexible Robot and Finger Controller

Line-Following Robot

The Line-Following Robot has a unique feature of following lines when the robot is either in autonomous or tele-operated mode. The lines must be formed by using black electrical tape. For instance, the robot can follow any pattern of unknown mazes that are designed using the electrical black tape.

Unlike the Flexible Robot, the Line-Following Robot runs on two small DC motors that use a lower voltage supply of 5V. It does not use the Victor 844 speed controller but rather a low-cost, 16-pin Quadruple Half H-Bridge Driver (SN754410) IC [9]. The internal circuit setup of the H-Bridge Driver is similar to the Victor 844 speed controller. The single chip Quadruple H-Bridge IC can control two DC motors of the Line-Following Robot. Figure 9 shows the process of conceptual design to build the electrical schematic layout of the Line-Following Robot. Based on the information of Figure 9, the prototype was made and is illustrated in Figure 10.

The Line-Following Robot in Figure 10 can operate either in autonomous or tele-operated mode to follow any pattern of lines that are made out of pieces of black electrical tape. When it is in the autonomous mode, the robot has five infrared sensors activated to follow the lines of tape. The infrared sensors are off when it is switched to tele-operated mode by pressing the push-button switch on the transmitter side of the finger controller. Thus, this is an innovative feature of the finger controller for controlling the Line-Following Robot.

Solar Rechargeable Robot

The objective of the Solar Rechargeable Robot is to have the solar panel collect energy from the sun and store it in the rechargeable battery. This rechargeable battery provides the entire power source to run the Solar Rechargeable Robot during night time and on cloudy days. In other words, the robot itself functions through the power source from the solar panel during sunny days while at the same time it can charge the rechargeable battery. This rechargeable battery can then be stored for later use during night times and on cloudy days.

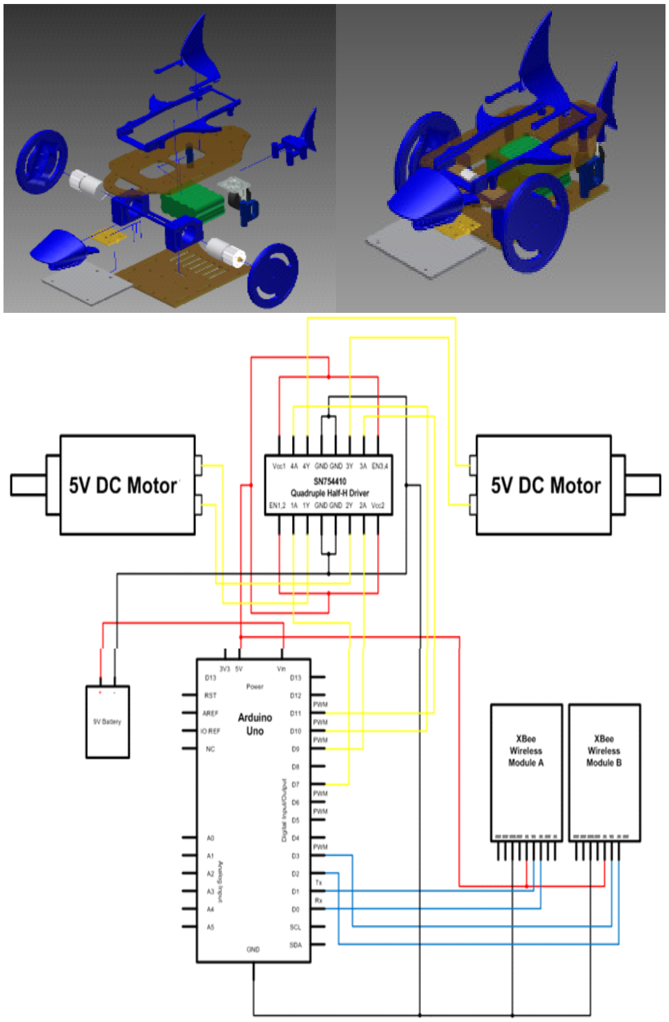

Figure 9. Conceptual Design and Schematic Layout of the Line-Following Robot

The Solar Rechargeable Robot is different from the previous two robots. Figure 11 shows a complete layout of the robot with the finger controller. It uses a steering system instead of a tank drive. The steering system is controlled by the Servo motor [10]. The Servo motor can control how much the motor turns but does not control speed. Also, the Servo motor has different variations such as 90-degree turns, 180-degree turns or full 360-degree turns.

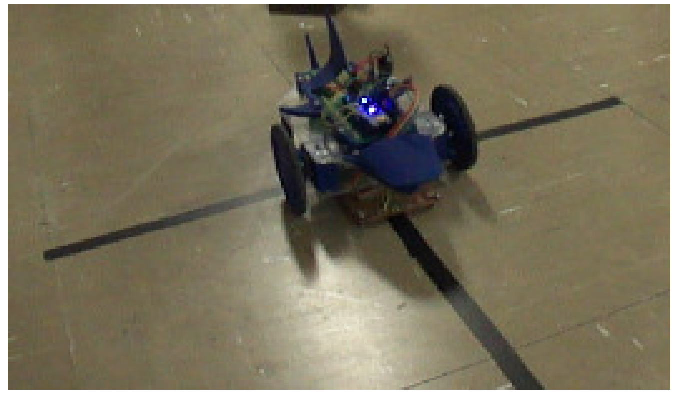

Figure 10. Prototype of the Line-Following Robot

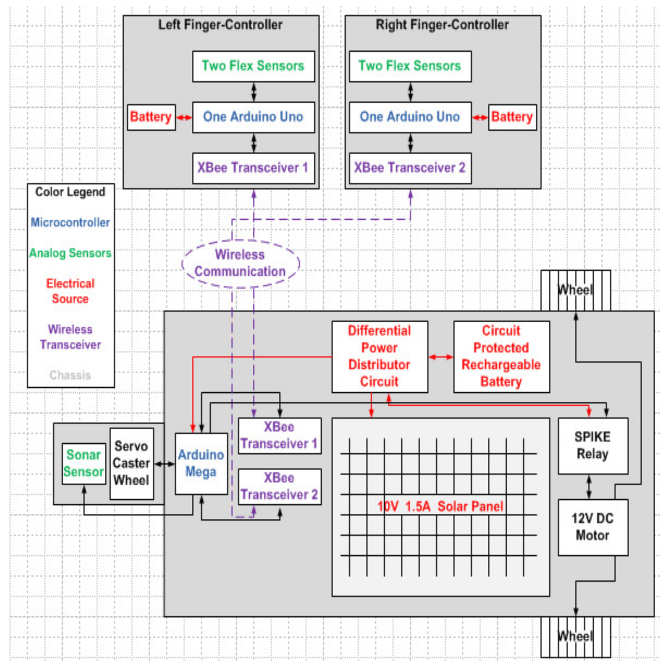

Figure 11. Layout of Solar Rechargeable Robot and Finger Controller

As seen in Figure 11, the left finger controller controls the steering while the right finger controller controls the forward and reverse rear wheels. For the rear drive system, a differential was also implemented to compensate for the turning when the steering is used. The rear drive system is a single 12-Volt Tetrix DC motor [11] controlled by a SPIKE [12], which is a device similar to a relay. The SPIKE logic can be seen in Table 2. The difference between a SPIKE and a speed controller or an H-Bridge Driver IC is that the SPIKE does not control speed, only direction. Although a speed controller can be used, the SPIKE was used to show that the finger controller can be used to only trigger the device on or off given certain thresholds.

Table 2. SPIKE Logic

Logic Signal One	Logic Signal Two	Direction
0	0	Stop
0	1	Forward
1	0	Reverse
1	1	Stop

Based on the information of Figure 11, the significant components of the Solar Rechargeable Robot are the Servo and Tetrix DC (with SPIKE) motors. The schematic layout for these components is shown in Figure 12. The Servo motor connects to the Arduino and receives 5 volts from the Arduino. Unlike the Servo, the Tetrix motor receives 12V from the external source. In addition, the Tetrix motor requires the use of SPIKE for power safety and to prevent damage to the Arduino. Also, both Servo and Tetrix motors work based on the data received from the finger controller through the XBee wireless communication system.

Figure 13 provides a complete schematic circuit of the Solar Rechargeable Robot. Note that the Ping sonar sensor is included for obstacle detection when the robot is in the autonomous mode. Also, while the robot is running by solar power, the power is then simultaneously charging the rechargeable battery. This makes the Solar Rechargeable Robot more energy efficient. The preliminary tests of the Solar Rechargeable Robot with the finger controller were successful. The finger controller was able to control the robot in tele-operated or autonomous modes. Additionally, the solar power provides the source to run the robot while it is charging the rechargeable battery. Figure 14 illustrates the preliminary tests of the Solar Rechargeable Robot and finger controller.

Since the solar power is important and crucial for running the Solar Rechargeable Robot, the voltage data were recorded before and after each preliminary test. Figure 15 shows the process of recording the data from the solar panel [13] to the rechargeable battery. Based on the preliminary data, the charging rate from the solar power to the rechargeable battery is approximately 0.05V per 30 minutes, while the robot is in use. If the robot is sitting still and not in use, the charging rate is about 0.5V per 30 minutes. The preliminary data did not take into account the temperature and intensity of the solar energy from the sun.

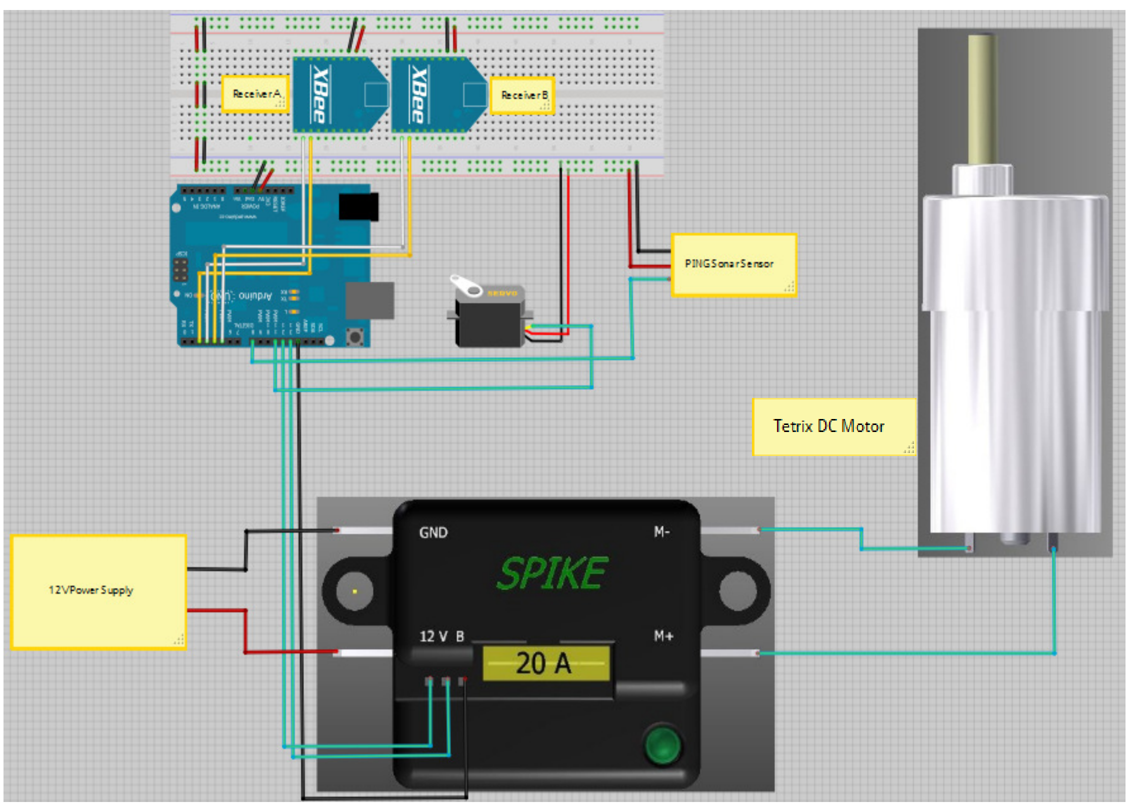

Figure 12. Schematic Layout of Servo and Tetrix motor, SPIKE, and Sonar Sensor

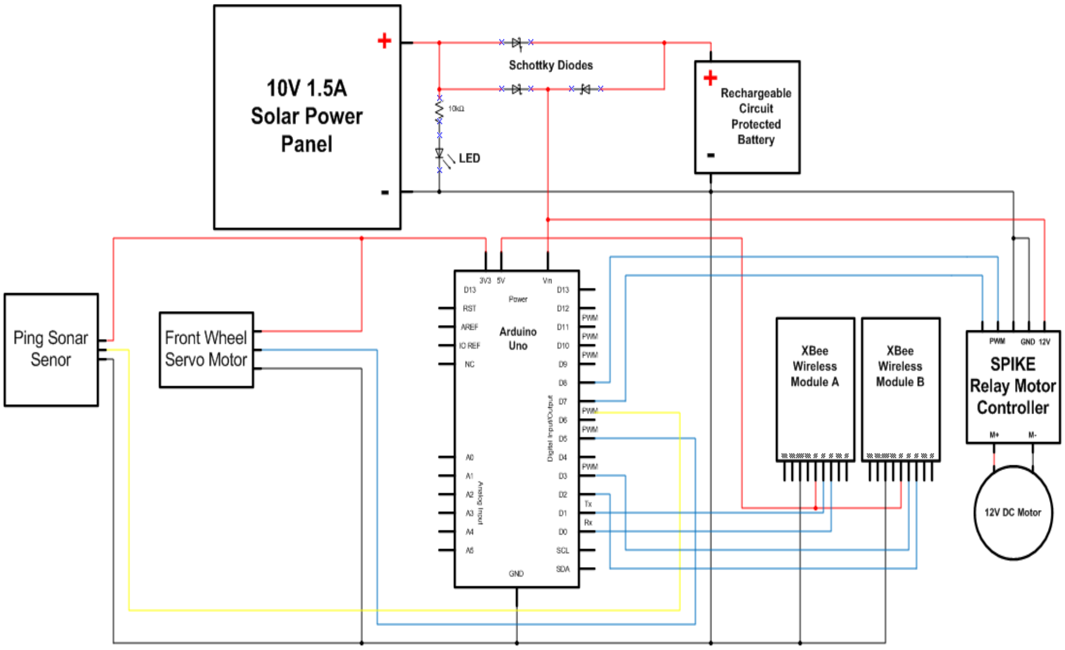

Figure 13. Schematic Circuit of Solar Rechargeable Robot

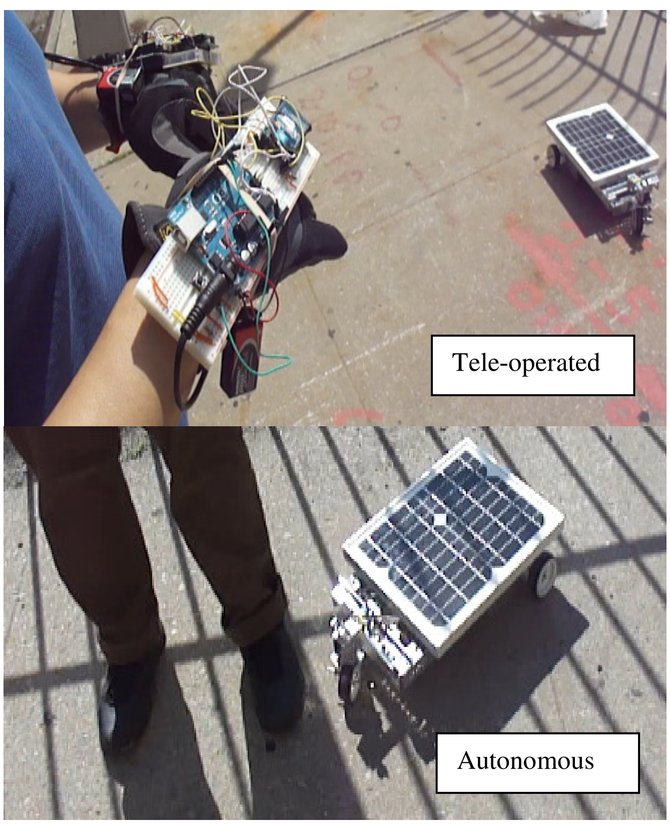

Figure 14. Testing Solar Rechargeable Robot with the Finger Controller

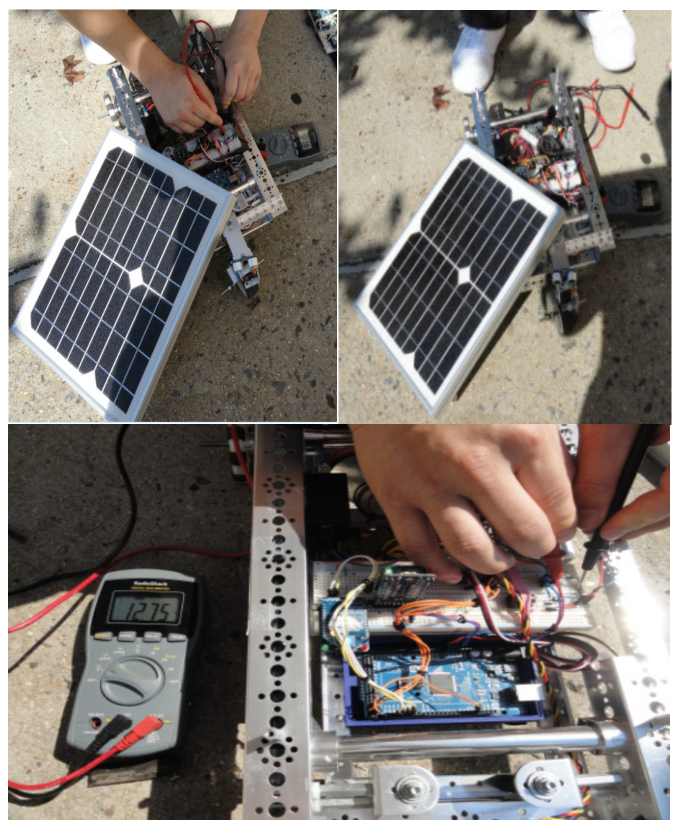

Figure 15. Solar-Power Data

Conclusion

The goal for this research project was to develop a custom -made finger controller capable of controlling (either in tele-operated or autonomous mode) different robotic applications. Three robotic applications have been discussed and have been integrated with the finger controller. The finger controller provides an enhancement of collaboration between human and robot interactions. Further, the finger controller provides the hands-on multidisciplinary activities in learning to work together as a team. For future research work, the authors plan to redesign the finger controller so that it is flexible and capable of controlling mechatronic devices such as mobile devices, appliances, TV, laptop, desktop and others. Currently, the finger controller is powered by two non-rechargeable 9-Volt batteries. Future plans include using solar power to recharge the finger controller.

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