Wireless Enabled Robotic Glove Controller

Gang Sun (Team Advisor and Sponsor)
Ben Ryan (Team Project Manager and Systems Engineer)
Darryl Wingate (Team Software Engineer)
Yousef Fatehallah (Team Hardware Engineer)

Electronics Engineering Technology, Northern Kentucky University, KY, USA

ABSTRACT

In order to protect human lives from harm and fatality in hazardous and harsh working environments, it is vital to develop new robotic control technologies that will allow people to operate robots and perform routine preventive maintenance or emergency repairs in a safe manner. The scope of this project is to design, implement and operate a wireless enabled robotic glove to control a robot. The movement of the robot would be controlled by bending each finger, simulating four directions (forward, backward, left and right). This is accomplished using four Flex sensors attached to index, middle, ring and thumb fingers and the fifth finger (pinky) would turn the communication on or off using a Hall-effect sensor. The measurements from the sensors are converted and interpreted by the TI-MSP430F5529 microcontroller into various task commands. These task commands are wirelessly transmitted via a Zigbee network using Xbee coordinator and router modules. The Xbee-router module that is connected to the Arduino and motor control board receives task commands from the Xbee - coordinator module on the MSP430 glove side to control a robotic car. The testing results showed that the proposed hand sensing glove can effectively control the robot via a Zigbee-based wireless network. Adding more controls and logic to other functions would also be possible by using suitable sensors to control the required tasks of the robot.

INTRODUCTION

Industrial robots are widely used for modern manufacturing applications, such as welding, painting, packaging, labeling, material handling, assembling, and product inspection, etc. Many of these robots are exposed to extreme conditions and harsh environments. In order to protect human lives from harm and fatality while working in such hazardous circumstances, it is vital to develop a new robotic control technology that will allow people to operate these robots and perform routine preventive maintenance or emergency repairs in a safe manner. Moreover, these industrial robots are usually controlled at a distance, but the length of the cable that connects the controller, which in most cases is a bulky and heavy box connected to the robot, limits the execution of such applications. Not to mention that as the environment or the task gets more hazardous, the chance that the cable breaks and loses control of the robot increases.

This project proposes a new method to remotely control the robot from a far distance via Zigbee wireless communications. Comparing this project with others [1, 2, 3], some similarities are present, with the major one being the concept of guiding the robot movement through a process of actions that can be learned and used by the robot to get past a workplace obstacle by itself.

Uniquely, this project does not involve creating a methodology for the robot to follow or create countermeasures in case of an issue arising in its environment. Also, we do not need this robot to learn a certain path to follow. Instead, our robot can learn how to move from a signal received after a finger movement. This would improve the reliability of our robot since it is not forced to operate on its own programming alone or learn any contingency procedures in case of failures in its programming. In addition, since the robot moves in conjunction with the user's hand movement, the robot can move from one task to the next without the need of additional programming.

MATERIALS AND METHOD

Figure 1 shows the conceptual block diagram of the wireless enabled robotic glove controller, which is divided into three sections: 1) Hand sensing glove; 2) Zigbee wireless communication for data transmission between the sensing glove and robot; and 3) Robotic car for system testing. Specifically, the sensing glove uses Flex sensors, a Texas Instruments MSP430 microcontroller, and a hall-effect sensor. The user wears the hand sensing glove to control the robot's direction and tasks through different fingers movements and Zigbee wireless communications.

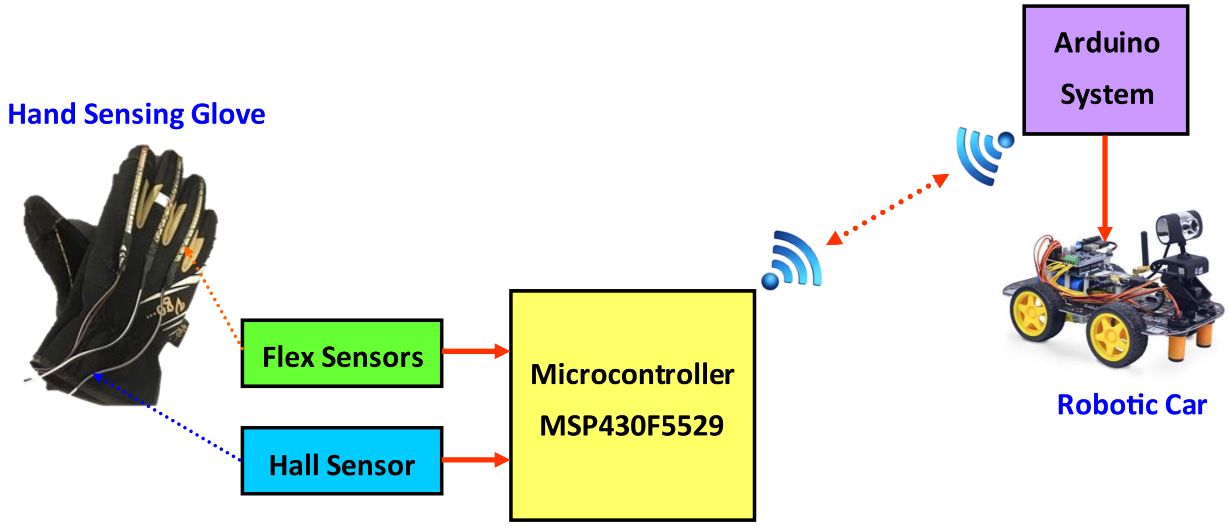

Figure 1: The conceptual block diagram of the wireless enabled robotic glove controller

The overall functional block diagram of the robotic glove controller was generated (Figure 2) to support simultaneous design and development of both hardware and software. The ability to have all parts and interfaces referenced within a single document allowed for the engineering team to have clearly defined specifications when completing their individual plan of action. As can be seen in Figure 2, the core of the entire system is the TI-MSP430 microcontroller (MSP430F5529) that can receive inputs from the multiple sensors, transmit the control commands to the robotic car, and provide power to the Zigbee modules (Xbee [4]), etc. Four Flex sensors are connected to the Analog to Digital Converters (ADCs) on the microcontroller. The microcontroller sends input signals to the Xbee-coordinator module that in turn sends information to the Xbee-router module and Arduino to control the robotic car. Another sensor, a hall effect sensor, is used as a digital on/ off switch, or a reset, and is hooked up to a general-purpose input/output pin of the MSP430. This project involved using two different mediums of coding, Code Composer Studio and Arduino IDE. The bridge between these two types of code is the master (coordinator) and slave (router) Xbee modules.

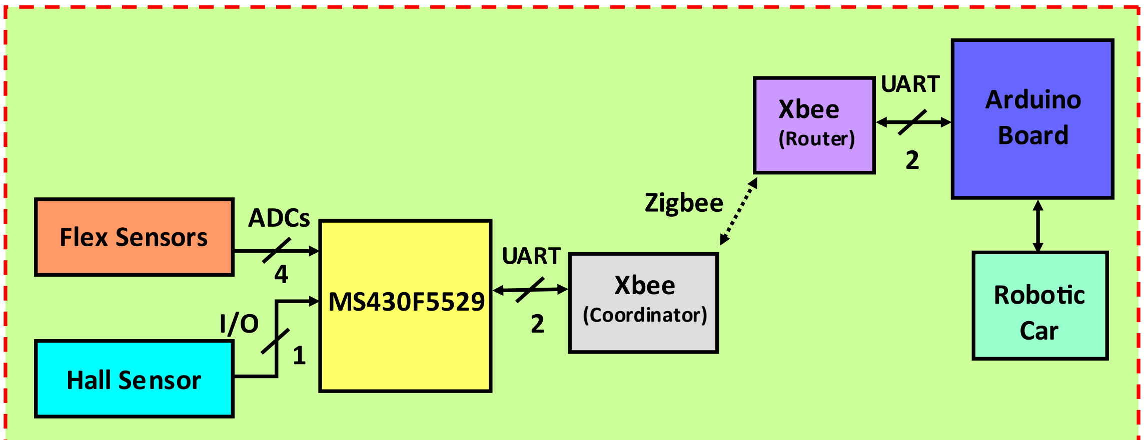

Figure 2: Overall functional block diagram of the robotic glove controller

1. Hand Sensing Glove

The hand sensing glove circuit shown in Figure 3 mainly consists of the TI-MSP430F5529 microcontroller [5], four Flex sensors, and a hall sensor.

The MSP430F5529 microcontroller was selected as a major system controller as it is a powerful advanced microcontroller, which features a 16-bit RISC CPU, 16-bit registers, four 16-bit timers, high-performance 12-bit analog-to-digital converters, two USCIs, a hardware multiplier, DMA, an RTC module, and up to 63 general purpose I/O (GPIO) pins. The MSP430F5529 Launchpad development kit [6] is used to connect the sensing circuitry of the glove, convert analog inputs from Flex sensors to digital signals, interpret finger movements of the user, and send their respective outputs (i.e., control demands) to a Zigbee unit for wireless communication.

The sensing circuitry combines two types of sensors: The Flex sensor (flex sensor 2.2” and 4.5”, Sparkfun), and the Hall Effect sensor (A3144, Allegro). Flex sensors are flexible sensors that are placed along the length of each finger on the glove. When it is bent, the sensor changes resistance to cause a noticeable change in output voltage. This output voltage change related to the degree of bend is measured by internal Analog-to-Digital converters (ADCs) inside the microcontroller. Each Flex sensors is set up with a 47K ohm resistor and the ADCs calculate the value of the voltage of the sensor coming in to properly read and use it. The Hall Effect sensor is a digital sensor that is placed next to a magnet to sense changes in a magnetic field. Once it senses the field change, it sends a signal to a GPIO pin of the MSP430 microcontroller. This signal can be coded to go either high or low. Also, this sensor can be brushed by a magnet, which sends a pulse level to the board to do a total reset of the program. Any routine or line that the code is currently executing will automatically stop and the entire process will restart. In the real working environment, this is like an emergency stop, in the event there is a malfunction in the machines or if human life is in danger.

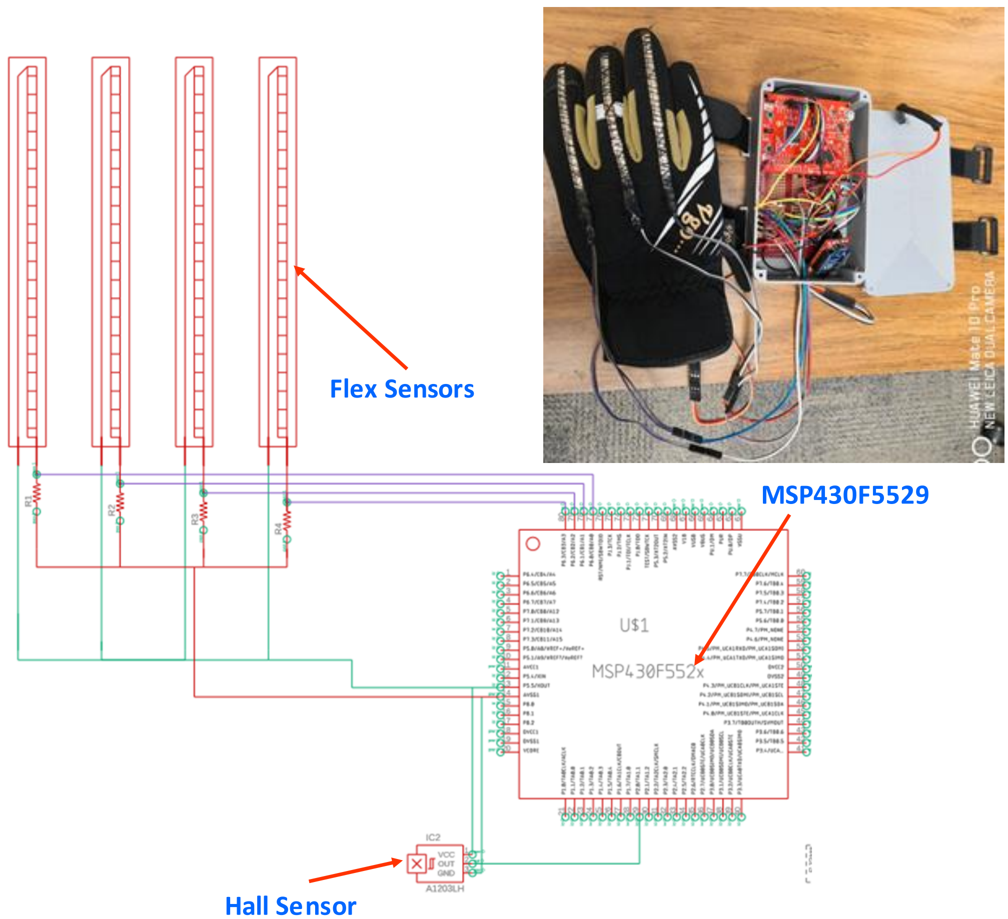

Figure 2: The hand sensing glove circuit

2. Zigbee Wireless Communication

The MSP430F5529 microcontroller collects all the finger movements, processes those gestures according to different commands, and sends the commands out to the robotic car via a new wireless networks (Zigbee) that is based upon the 2.4 GHz IEEE 802.15.4 radio protocol. Zigbee was chosen because of its features of reliability, extended communication ranges from 10 - 300 meters, low power consumption, the ability to communicate peer-to-peer point or peer-to multi-points, low cost and low latency [7]. All these features make it an ideal network for industrial level operations in which this project aimed to be considered.

Two Xbee modules (Xbee series 1, Digi International) are used to provide the wireless communication between the user controller glove and the robot via Zigbee communication protocol (Figure 3). The Xbee-coordinator module (transmitter) is mounted on the MSP430F5529 Launchpad via a shield board on the user glove side. It is powered by the same power source that powers the microcontroller rated at 3.3 volts. Additionally, the digital I/Os on the Xbee are used to send the desired commands through the wireless signal to the Xbee- router module (receiver) that is mounted on the robot controlled by the Arduino. Each input/output pin is dedicated to the movements of the robot in a certain direction (Forward, Backward, Right turn and Left turn), as well as one pin dedicated to turn the robot's status ON/OFF.

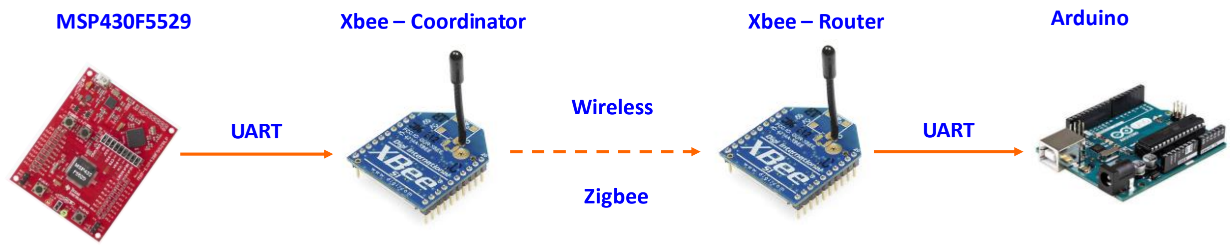

Figure 3: Zigbee communication networks

The Xbee interface software (XCTU) shown in Figure 4 is used to configure the Xbee devices. The Xbee coordinator and router modules are working on the same network and the same channel. Choosing designated channel and network names are essential to eliminate any interference that might come up from other working Xbee devices in the same area. For this project, the channel (B) and the network (ID) 2018 are used. The destination addresses low (DL) and the 16-bit source address (MY) need to be filled in on both Xbee devices, but in opposite order. In this project, the DL is (1234) and the MY is (5678) on the transmitter or coordinator side. Where on the receiver or router side, the DL is (5678) and the MY is (1234). After that, the I/O pins from (DIO0 – DIO4) are all configured on the transmitter side to have a digital input (DI) signal status. Alternatively, the pins from (DIO0 – DIO4) on the receiver side are all configured to have a digital output (DO) signal status (DO-Low).

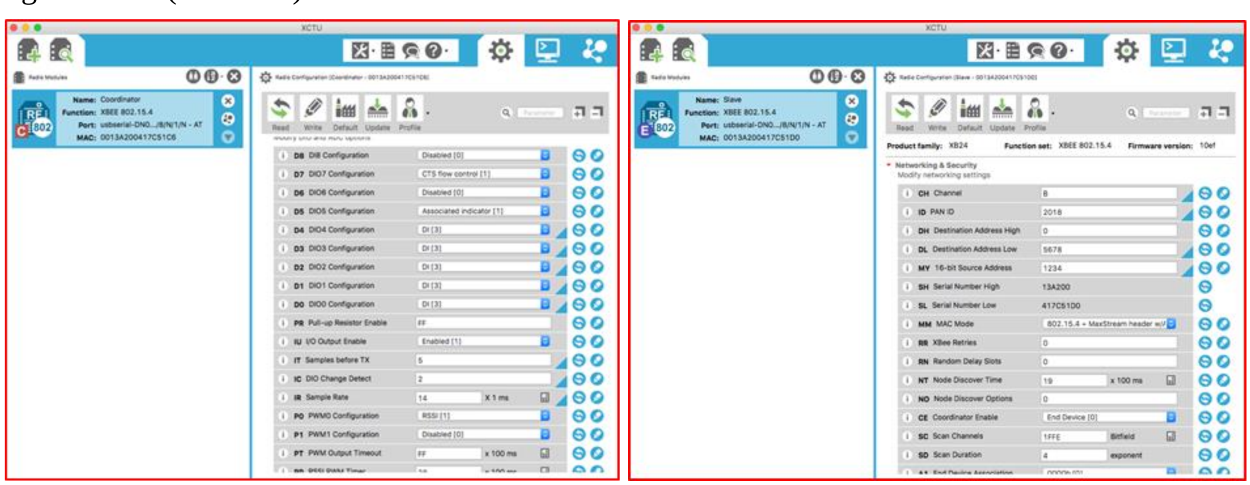

Figure 4: Configuring Xbee devices using XCTU software (Left: coordinator; Right: router)

3. Robotic car for system testing

A robotic car (XiaoR Geek) is used for testing the entire systems. This robotic car is equipped with a camera, accelerometer, Raspberry Pi wireless controller, and a motor control board attached to the top to control four motors. The motor control board is hooked to the Arduino that can receive the control commands from the glove controller. The motor control board has an H-Bridge setup. Figure 5 below gives a good display of this H-Bridge concept. To go forward, one must turn two outputs high and the two-opposing low. To go backwards, one must turn the two opposite outputs high and the two-opposing low. To go left or right, the outputs must only remain high on the left or right side, effectively turning the car in the desired direction.

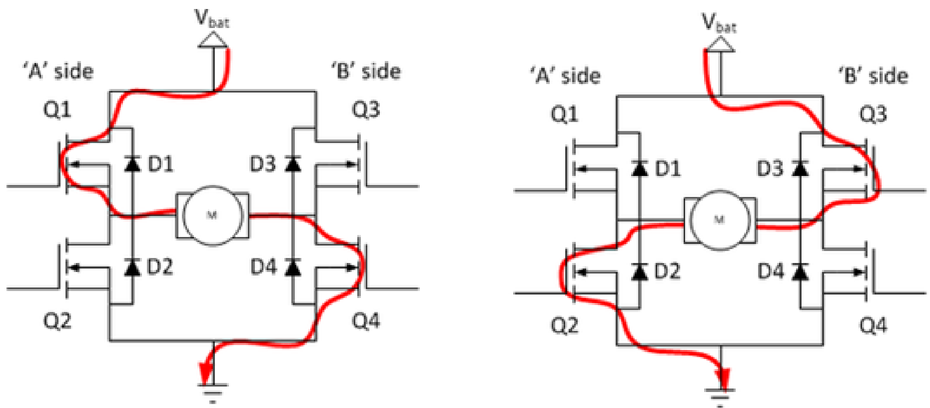

Figure 5: H-Bridge setup of the wheel motor control board

The different hand gestures output different analog signals that the software interprets to form various task commands. These tasks commands are wirelessly transmitted via a Zigbee network. The Xbee-router receives a signal from the Xbee-coordinator on the MSP430 glove side from its various sensors and turn them into signals on the Arduino and motor control board that control the robotic car with four different directions: forward, backward, left, and right.

CONCLUSION

This paper presents the overall design of a wireless enabled robotic glove controller, which is divided into three sections: Hand sensing glove; Zigbee wireless communication for data transmission; and Robotic car for system testing. The hand sensing glove mainly consists of the TI-MSP430F5529 microcontroller, four Flex sensors, and a hall sensor. The core of the entire system is the MSP430F5529 microcontroller, which is used to measure and interpret signals from multiple Flex and Hall sensors and convert them into various task commands (e.g., forward, backward, left and right movements). The tasks commands are wirelessly transmitted from the sensing glove to the robotic car via a Zigbee network using Xbee coordinator and router modules. The testing results showed that the proposed wireless sensing glove can effectively control the robot through a Zigbee-based wireless network. This wireless enabled robotic glove controller would provide a new way to operate and maintain robots within hazardous and harsh working environments in a safer manner.

Acknowledgement

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