Wireless Robotic Hand Using Flex Sensors

Malav Atul Doshi, Sagar Jignish Parekh, Dr.Mita Bhowmick

Abstract — Recent advancements in embedded systems have opened up a vast area of research and development of haptic technology. Surgeries with minimum invasiveness and high precision are becoming vital requisite. Surgical robots such as Da Vinci, Zeus and the Cardio-arm are able to perform various complex surgeries with ease, minimum invasion and high accuracy because of their precise controlled mechanism and technology. But these robots are extremely costly because of their sophisticated software and circuitries. This makes it unaffordable for various doctors and simple surgeries. This project deals with the design and development of a robotic hand with real time control, which is precise and cost-effective. This five fingered robotic arm mimics a small degree of dexterity and could be used for other applications such as prosthesis for leprosy patients. This will allow them to get a higher degree of freedom and will help in their day to day life.

Keywords: Robotic Hand, Flex sensors, Haptic technology

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1. Introduction

A robotic arm consists of several sections connected together by linkages that help the arm to travel specifically in a designed pattern, with sensors ensuring that all movements are exactly of the similar pattern [1]. They are endowed with several degrees-of-freedom, giving them the flexibility to move in many directions through multiple angles with utmost ease and agility.

Haptic technology [10] or haptics is a tactile feedback technology which makes use of a user's sense of touch for the enhancement of the remote control of machines and devices [2]. Devices that enable manual interactions with virtual environments or tele-operated remote systems are called haptic interfaces [12]. In general, they receive motor action commands from the human user. Tele-haptics is the science of transmitting computer generated tactile sensations over networks, between physically distant users. The movements of the robotic palm are controlled by moving the user's fingers using the Flex sensors and Wireless RF (Radio Frequency) modules. Wireless RF (Radio Frequency) module provides unprecedented range in a low-cost wireless data solution. RF modules are widely used in electronic design owing to the difficulty of designing radio circuitry. The current era of surgeries has evolved to bring forth astounding changes in the health-care system. However even the best traditional surgeries leave behind the huge scars and increased recovery time.

A boon still progressing, the Minimally Invasive Robotic Surgery (MIRS) surpasses this hitch too. This is a relatively new technique that allows surgeons to operate with specially designed surgical tools through access ports requiring incisions as small as 1 cm in size.[3] A Robot in lay man's terms is a mechanical device that has come into existence not only to make the human life simpler by replacing or replicating human activities, but to offer an excellent amount of precision and accuracy. It is defined as a programmable, multifunctional manipulator designed to move material, parts, tools or specialized devices through various programmed motions for the performance of a variety of tasks. The robot inspiring the project is a machine that senses the signals it is designed to recognize, processes the sensor information, and then uses it to carry out the assigned activity. A Robotic Arm consists of several sections connected together by linkages [4]. It involves motors coupled with joints that are resolved by computers. Multiple degrees of freedom in robots give them the flexibility to move in many directions through multiple angles with utmost ease and agility. They circumvent human errors. This offers great accuracy reduced production time and optimum output in regards to quality as well as quantity.

Some of the most advanced robotic arms have such amenities as a rotating base, pivoting shoulder, pivoting elbow, rotating wrist and gripper fingers. All of these amenities allow the robotic arm to replicate work closely resemble what a man can do only without the risk.

Medical robotics is a growing field and regulatory approval has been granted for the use of robots in minimally invasive procedures. Robots are being used in performing highly delicate, accurate surgery or to allow a surgeon who is located remotely from their patient to perform a procedure using a robot controlled remotely.

The project aims to design and implement a cost-effective and an affordable prototype model of robotic hand for telesurgery using haptic technology. The movements of the robotic palm are controlled by moving the user's fingers using the Flex sensors and Wireless ZigBee modules. The flex sensor system gives control signals to the arm wirelessly via ZigBee module and arm mimics the movement of the flex sensor system. Mini servo motors were used to move the fingers of the hand.

2. Literature Survey

Robots can be used to perform surgeries in a more accurate and precise manner where the surgeon can make decisions and operate the robot as and when needed at the spur of the moment. This ensures that no human error is involved, there is a reduced amount of blood loss, and the area of surgery is comparatively smaller.

In minimally invasive robotic surgery (MIRS), the surgery is performed by the surgeon using tele-operated robotic tools instead of using manual instruments. In this scheme, robots do not replace the surgeon, but instead provide the surgeon with improved abilities to perform the intricate, precise surgical manipulations. The following are the examples of existing MIRS systems:
Da-Vinci Robot
This system has been approved by the FDA for laparoscopic, non-cardiac thoracoscopic, prostatectomy, cardiotomy, cardiac revascularization, urologic surgical, gynecologic surgical, pediatric surgical and trans-oral otolaryngology surgical procedures [5][9].
Zeus System
The Zeus system has the similar capabilities as the Da Vinci system. It has been approved by the FDA as well. It is composed of a master console and 3 table-mounted robotic arms. Two robotic arms mimic the surgeon's arms and hold the surgical tool and the third arm is a voice-controlled robotic endoscopic system [6].
The endoscopic instrument mounted on the slave manipulator provides five degrees of freedom to extend the dexterity inside the patient for the surgeon. Robotic systems thus have proven to play a very important role in the medicinal and surgical sector, be it in manufacturing medicines and drugs or carrying out simple tasks in specific surgeries. However, robots do not take over the whole procedure in a surgery, but certainly assist the surgeons to perform the task accurately and avoid large incisions, infections and blood loss.

3. System Design

The system basically consisted of three parts:
1. Master Section - This section includes the flex sensors connected to the transmitting Arduino board along with the ZigBee shield and the ZigBee module.

2. ZigBee Wireless Network - This is the section which physically doesn't exist. It consists of the wireless communication between the ZigBee modules attached to the Transmitter and Receiver Arduino board.

3. Slave Section - It includes the Receiver XBee module attached to the receiver Arduino board via the XBee shield. The output of the Arduino board is connected to the servo motors on the Robotic Arm enabling the corresponding motion of the arm.

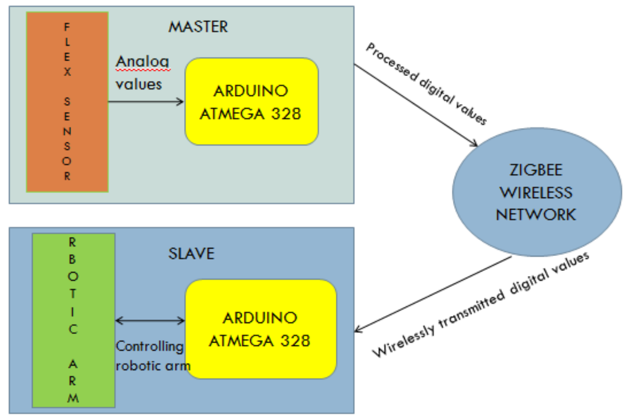


Figure 1: Block Diagram of a wireless robotic arm

The sub-sections of the fabricated robotic hand are as follows:
The Fingers- This is the most important part of our fabrication process. It provides the motion of our robotic hand.

The Palm- This was to provide support to fingers and give a realistic feel of a palm. And so it could also be worn by patients with no fingers like the leprosy patients]
The Motor System- These motors were screwed to the palm on the back side. Micro motors were used as they could be easily placed on the palm. Pulleys were attached to the motors which will pull the wires and bring about the motion in the fingers.

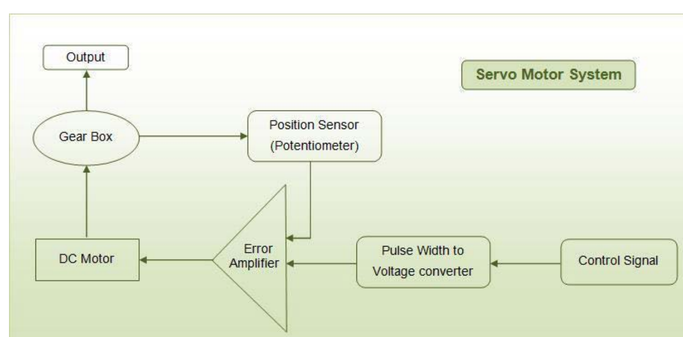


Figure 2: Block diagram of servomotor system

The Spring- The spring mechanism was placed inside the fingers. This mechanism was used to bring the fingers to the reset position.

The Arduino Board and Power Supply- The Arduino board and the power supply shown below were attached to another plate of aluminum which would be placed on the forearm of the patient.

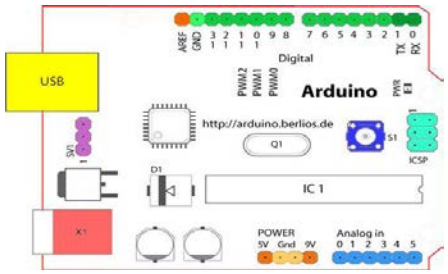


Figure 3: An Arduino Board

The Flex Sensors- Flex sensor is a unique component that changes resistance when bent or flexed. An unflexed sensor has a nominal resistance. As the flex sensor is bent in one direction the resistance gradually increases. The flex sensors provide with corresponding voltage change to the flex thereby providing us with an accurate replication of a natural movement.

Figure 4: Flex Sensor

4. Results

A prototype model of robotic hand for telesurgery using haptic technology was implemented. The arduino boards were configured to communicate which facilitated the data transfer wirelessly. The results shown below show changes in the flex sensor voltages, its analog values at the transmitting arduino board and its corresponding value at the receiving arduino board which can be mapped using 'Map" function[8].

The 'analogRead' on an arduino is basically a voltage meter. At 5V (its max) it would read 1023, and at 0V it reads 0. So the bend can be measured using the change in the voltage values using analogRead(). A voltage divider circuit is generated using a 22kOhm resistor with the flex sensor. The following are the voltage values for the five flex sensors.

Thumb:

	Flex Sensor Voltages	analogRead() values in Arduino	Mapped servo value in degrees
Upper Limit	1.67V	340	60
Lower Limit	1.41V	290	0

1st finger:

	Flex Sensor Voltages	analogRead() value in Arduino	Mapped servo value in degrees
Upper Limit	2.24V	460	60
Lower Limit	1.67V	340	0

2nd finger:

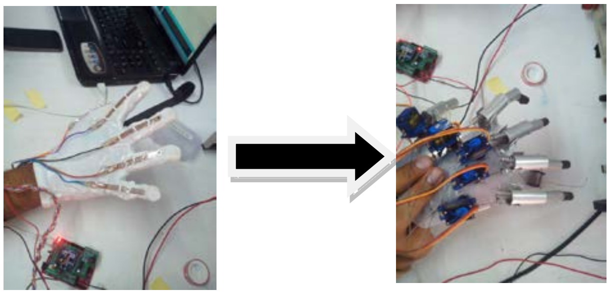
	Flex Sensor Voltages	analogRead() value in Arduino	Mapped servo value in degrees
Upper Limit	2.23V	470	60
Lower Limit	1.90V	390	0

3rd finger:

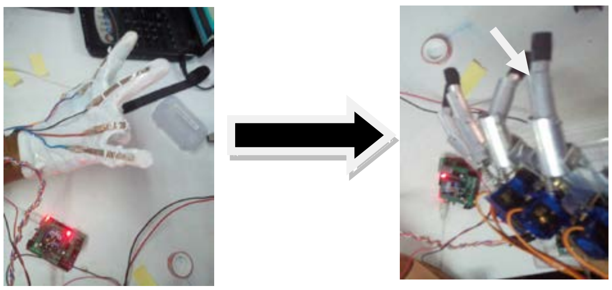
	Flex Sensor Voltages	analogRead() value in Arduino	Mapped servo value in degrees
Upper Limit	2.35V	490	60
Lower Limit	1.96V	400	0

4th finger:

	Flex Sensor Voltages	analogRead() value in Arduino	Mapped servo value in degrees
Upper Limit	2.2V	450	60
Lower Limit	1.71V	350	0



I. Non-flexed rest position II. Rest position of the arm



III. Ring finger is flexed IV. Ring finger movement

Figure 5: Hand movements with its replicated arm movement

Thus we can see the fingers in the robotic arm moving as we flex the various flex sensors in the glove. Hence, by mounting five flex sensors on the individual fingers of the glove, each finger of the robotic arm can be controlled separately providing greater degree of motion and more number of combinations with the fingers as seen above.

5. Conclusion

Our model could be used for small scale surgical procedures in case of an emergency but currently, the major limiting factor that was stunting the development of our model was “latency” which is the time delay between the instructions issued by the surgeon and the movement of the robot which responds to the instructions. With the current level of technology, the surgeon must be in close proximity.

Robot control refers to the way in which the sensing and action of a robot are coordinated. There are infinitely many possible robot programs, but they all fall along a well-defined spectrum of control.
No single approach is "the best" for control of robots; each has its strengths and weaknesses. The accuracy and efficiency of surgeries have improved greatly because of the application of robotics in the field. However there are still some problems that need to be addressed. Research is still being carried out to improve the wireless transmission of signal and reduce the delay and for the simultaneous movement of two servo.
Thus the control of a robotic arm was achieved wirelessly using flex sensor given by the user.

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