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DESIGN OF A TELE-OPERATED ROBOTIC HAND WITH IMITATIVE FEATURE

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Abstract- *This paper demonstrates a novel design approach for the development of a low cost multifingered anthropomorphic robotic hand which can mimic the movements of a human hand using glove data inputs. Moreover the paper offers an alternative solution to design a dexterous robot hand with very little cost and with much more simplicity. The approach consists of the integration of mechanical structure, the sensory & the electronic system and the control & the actuation system. The whole system is implemented using a glove equipped with flex sensors to receive the signal from the movement of human hand and transferring this signal to Arduino to operate the robotic hand. The approach to operate the robotic hand over a distance is carried out by using an XBee Module.*

Keywords: Low cost, Anthropomorphic, Flex Sensor, XBee Module, Imitating Robotic hand.

1. INTRODUCTION

Nowadays the design of advanced robotic systems is moving from the stiff and complex structures to that of simple and flexible ones which can perform even more sophisticated tasks with higher degree of accuracy, lower manufacturing cost and a better data input method. Also the design, development and analysis of dexterous robot hands remain an active research area worldwide as robotic hands and grippers (end effectors) play a vital role in the implementation of various tasks. There is a growing need of more accurate and simplified versions of robotic hands that can perform even more sophisticated tasks with better data input method.

Gestures can be used as command or interface to operate the machine with much more ease and comfort. Hence hand gesture based robotic hand control can be a better approach to overcome the complexity of the input system. An analysis indicates that data glove has a greater potential and a better precision for controlling the robotic hand in performing various dexterous tasks.

In modern days, there are a variety of robotic hands where the main concern is their precision, reliability and stability. An anthropomorphic multi-fingered robotic hand with stable grasping ability and with an imitative feature can play an important role in the growing fields of precise and dexterous applications. This paper demonstrates a simple design of an anthropomorphic, teleoperated robot hand, focusing mainly on the placement of all the actuation and sensing devices away from the main structure, in order to minimize the weight and complexity of the hand. Moreover the designed hand is made to mimic the movement of a human hand using flex sensor based glove data input.

2. PREVIOUS WORKS

In recent years robotic hand and grippers gained more and more attention due to their miscellaneous applications on the field of robotics. With the development in robotics technology since 70’s era until now robotic hands are rapidly changing in respect of design, architecture, complexity and effectiveness. An anthropomorphic hand is useful or even imperative when the robotic hand has to perform with human-like dexterity in hazardous environment.

M. A. Saliba and M. Axiak presented a new design for an anthropomorphic robot hand with joint position and grasping force sensing which is targeted to reproduce many of the capabilities of human hand [1]. All of the actuation and sensing devices of their robot hand are located remotely from the robot hand; therefore it facilitated the development of a compact and lightweight hand design.

Md. K. I. B. Ahmad developed an anthropomorphic dexterous robotic hand which approximates the versatility and sensitivity of the human hand by teleoperation method and communicates in a master-slave manner [2]. Glove operates as master part and multifingered robot hand as slave. The communication between the operator and multifingered robot hand is via KC-21 Bluetooth wireless modules.

A. Syed proposed a hardware and software co design of a robotic arm controller by the use of flex sensor based glove data input method [3]. The pick and place operation of the robotic arm is controlled using microcontroller programming.

Dr. S. K. Dixit proposed an idea about the implementation of flex Sensor and electronic compass for hand gesture based wireless automation of a material handling robot [4]. The idea is to design a robotic hand that copies the movement of a human hand to perform a specific task.

3. DEVELOPMENT OF A COMPLIANT FINGER ARCHITECTURE

An articulated finger structure approach is adopted in this paper. The main specifications of the proposed design are:

(a) The mechanical joints of the finger are restricted to one degree-of-freedom (DOF) which results in simpler control, mechanics and kinematics.

(b) The finger actuation is provided by remote rotary actuators (servo motors) with motion transmission obtained with inelastic elements (e.g. wires/threads) routed with low friction linear guides.

(c) Though for human fingers it is considered that four fingers of the hand have 4 degrees-of-freedom each and thumb has 5 DOF [5]; for the construction of the robot hand here some simplifications in the finger design are adopted. Hence instead of 4 DOF for each of the four fingers 3 DOF is assigned and for thumb it is 2 DOF.

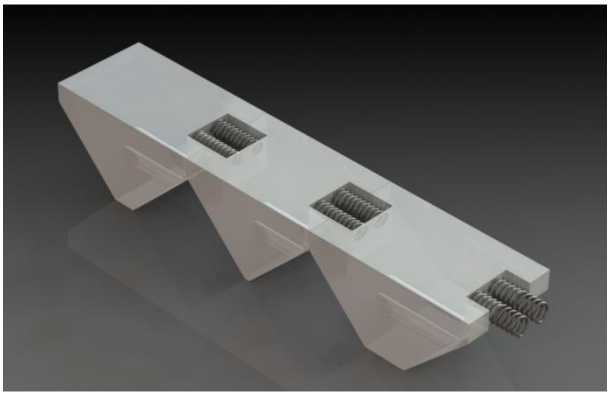

Fig.1: CAD representation of the finger under development.

(d) The finger structure can easily host both the tendon guides and springs with their wires.

4. IMPLEMENTATION

The project can be divided into two categories: Hand unit and Robotic unit. The hand unit consists of flex sensor. As shown in Figure 2, flex sensor are mounted on each fingers of a hand glove. Flex sensor is used to get appropriate signals from human hand movements [6]. Flex sensors changes in resistance depending on the amount of bend in the sensor. They convert this change in bend to electrical resistance. While mounting these flex sensors it should be made clear that it can bend as smoothly as possible during hand movements inside the glove. Hence creating pockets of specific sizes on the upper portion of every finger of the glove can be a simple solution to the problem. This small pocket holds the flex sensors in its desired position and also allows them to bend smoothly during hand movements.

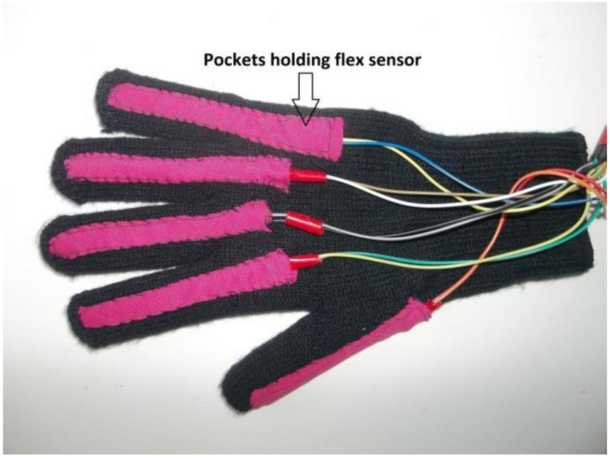

Fig.2: Hand Unit (Flex sensors mounted on a glove)

An idea about the dimensions of the robot hand can be adopted from the study of [7]. Robotic unit contains four fingers and an opposable thumb. In human finger separate bones (phalanges) are connected by ligaments which allow flexion and extension of the joints between the phalanges. Hence in the design concept of the robotic finger compliant mechanism is considered, i.e. the phalanges of the robotic finger are linked through elastic springs (see figure 1) allowing relative motion between them. The concept behind designing the robot finger is inspired from the human hand where each of the four fingers has three phalanges and the thumb has only two. Again phalanges are shaped as trapeziums where the angle (θ) between the consecutive phalanges is kept 90˚.

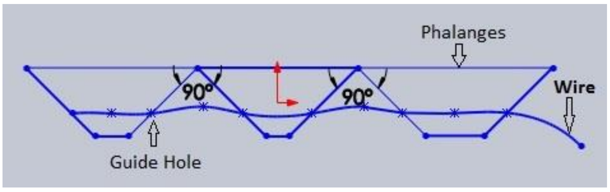

Fig.3: Drawing of the robot finger showing tendon based actuation.

The fingers are so designed that there is a hole at the middle section of a normal plane in every phalanges and a tendon medium (e.g. wire) can easily pass through that section. This allows the phalanges to bend to an angle(θ) of 90˚ when tendons attached to the actuators tightens which give rise to the folding motion of the fingers. As the joints of the phalanges are made of spring the finger gets back to its initial position whenever the tendon loosens. Tightening and loosening of the wire is achieved by the action of a servo motor where the wire is attached to the head of a servo motor by a clip.

Whenever the operator wearing the gloves equipped with flex sensor folds his/her fingers, flex sensors inside the pockets of the glove bends according to the finger movement and change in resistance. This change in resistance is then sent to analyze in Arduino Mega 2560. Arduino transfers the signal to a wireless transmitter module (e.g. XBee transmitter) where it gets transmitted to a receiver module (e.g. XBee receiver) set in distance. After receiving the signal XBee receiver transfer it to another Arduino board where it get analyzed and a pulse signal is send to the actuator/servo motor [8]. Then the servo motor changes its angular position according to the programming in the Arduino. As a wire is attached to the motor clip, whenever the motor changes its angular position the wire tightens and the robotic finger actuates. In this way an imitative movement of the robot hand is achieved.

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5. BLOCK DIAGRAM

Proposed system consists of two units: Hand unit and Robot unit. Hence there are two block diagrams.

5.1 Hand Unit

Hand unit contains flex sensors which are mounted on a hand glove i.e. hand unit is wearable and this unit is needed to be worn by the operator to control the robotic unit.

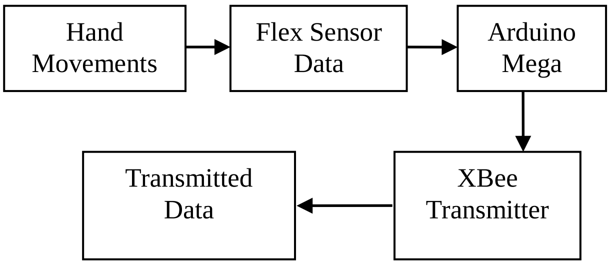

Fig.4: Block diagram of the hand unit

In hand unit the movements of the fingers of the hand is detected by the flex sensors inside the glove pockets. This flex sensor data is then transmitted to Arduino Mega to get analyzed and after analyzing the data is transmitted to air through an XBee transmitter.

5.2 Robot Unit

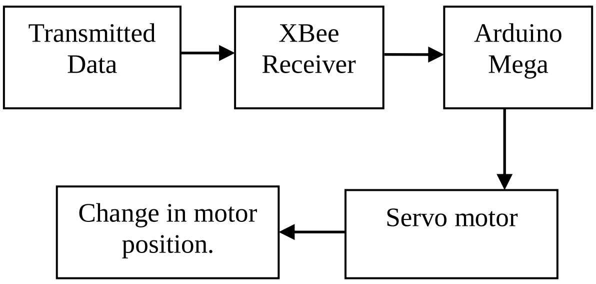

Fig.5: Block diagram of the robot unit

Robot unit receives the transmitted data from the air through XBee receiver and this data is then transferred to Arduino Mega to get analyzed and to create proper signals to change the angular position of the servo motor.

6. EXPERIMENTS AND RESULTS

In order to validate the design of finger and analyze the result some experimental tests have been practiced. Though there are some slight deflections from the desired output, the accuracy of the robotic hand is quite satisfactory. The experimental tests are performed to understand if there is some abnormality from the desired result. These two tests are: Imitating the hand movements and grasping an object. The results achieved by performing this test give an overview about the effectiveness of the whole system.

6.1 Imitating Hand Movements

Imitation of the human hand movements is tested by simply wearing the glove and moving the fingers to observe whether the robotic hand can imitate the movement of the human hand.

Fig.6: Imitating hand movements

6.2 Grasping an Object

To see whether the robotic hand can grab an object , a light weight box has been put in the palm of the robotic hand and by wearing the sensor glove fingers are folded to create a grasping movement in the robotic hand.

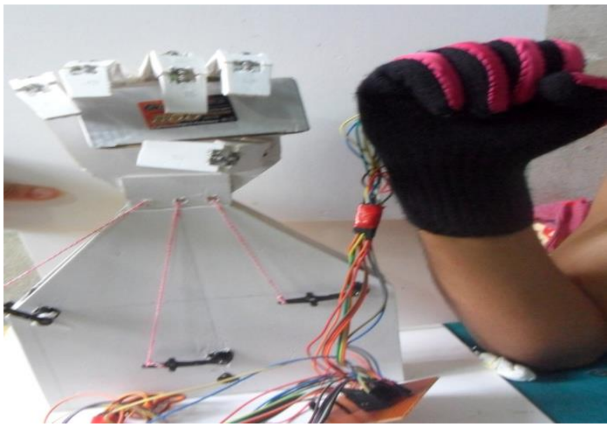

Fig.7: Grasping an object (box)

6.3 Results

The experiments conducted on the system showed the following results:

(a) The robotic hand responds accurately enough to the operator's hand movements.

(b) The movements of the robotic fingers are controlled in range and speed according to the programmed safety limitations.

(c) The imitative movement of the robot hand is quite smooth and is in a satisfactory level.

(d) The hand can grasp light weight objects precisely.

(e) The hand does not lose grip on the object and can function as an efficient gripper as long as human hand folds its finger accordingly.

(f) The robot hand can operate efficiently over a distance.

7. CONCLUSION

This paper reflects the development of a flex sensor based glove data input method to manipulate an anthropomorphic robotic hand. The robotic hand has 15 Degree of Freedom (DOF) and can be used to grasp light weight objects. The project also discusses a hardware and software co-design of the robotic hand using five servomotors employing Arduino Mega 2560. The structural design of the hand is simple but effective. This kind of robotic hand can be greatly useful to deal with the situations where human involvement is difficult and risky and also to the fields that require human input without human presence e.g. bomb disposal, working in dangerous chemical composition areas or radioactive environments. With necessary modifications it can serve the purpose of prosthesis for partial hand amputations and can also be used in surgical procedures.

8. REFERENCES

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9. NOMENCLATURE

Symbol	Meaning	Unit
θ	Angle	(˚)
DOF	Degrees of freedom	Dimensio-nless