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Comparison: 4 & 5 Finger Based Humanlike Robotic Hand

*Deepak Dhole **Chitradeep Khare ***Usha Soni

* S.V.C.E. Indore / R.G.P.V, Bhopal, India

** S.V.I.T. Indore / R.G.P.V, Bhopal, India

*** Swami Vivekanand University Sagar, India

ABSTRACT

In this paper basically we try to compare Four Fingered Robotic Hands (FFRH) with five-finger anthropomorphic robotic arm. The aim of this work was to find out a robot hand which is effectively used at workplaces for the ease or for immobile patients for their help keeping in mind that the robot hand should be cost efficient and have a good holding capability. The design of the FFRH system is simple and easy to control having 14 independent commands for all kind of movements of robot hand like pick and place. The robot hand is based on double revolute joint system mechanisms with a wireless feedback due to which it possess the ability to confirm to topology of objects. On the other side five fingered anthropomorphic robotic arm is a low cost robotic arm designed for object picking tasks for immobile patients with nine degrees of freedom. The robotic arm is made up of shoulder, elbow, wrist and five-finger gripper and it can perform various gripping actions. Here a high torque DC motor is used with gear assembly with five cables acting as tendons which lead to perform various gripping action. Finally, the results of the experimental work for pick and place applications for both of the robot hands are compared.

Keywords: DC motor, FFRH, finger, actuator, arm

1. Introduction

Robotics is basically a mixed application of many topics, including geometric transforms, circuit designing software, operating systems, DC and stepper motors, and digital signal processing, kinematics, signal analysis, and probability theory etc. Robots can be used to perform tasks that would have been very time consuming and boring for human beings to perform. They are capable of performing repetitive tasks more quickly, cheaply, and accurately than humans. Robots can be classified on the basis of their control (i.e. servo and non servo), path way (i.e. point to point or continuous) and finally based on level of sophistication i.e. low, medium or high tech. The basic idea has a robot leaving from a home base area, searching a limited area for a specific target, returning to the home base following the shortest path. It is dedicated for some particular task; in our case it is simply pick and place sort of work. A robotic hand is an electro - mechanical system which consists of two main parts i.e. electrical component and mechanical structure. Human hand is very complex organs of the human body after brain, thus, to understand the behaviour and structural detail of it is a difficult task.

In past decades during such research robot hands are developed on the basis of study of human hand. In many of these configurations, the robot hand has the same kinematic structure as a human hand, and can independently control the joints of each finger.

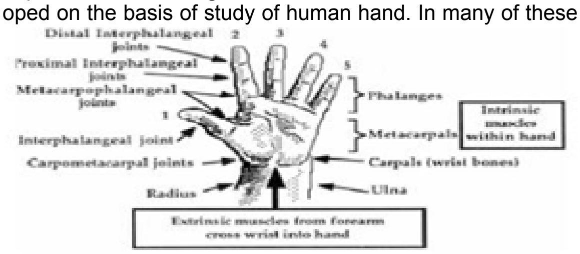

Figure1. Structure of human hand

The FFRH system [1] is only for pick and place kind of work, there is no need of having the complexity of construction similar to human hand. It has the sufficient grip and force to grasp any object but it does not used to manipulate them. FFRH that grasps a wide variety of objects with possibly complex shapes adjusts the grasp using a feedback and pick and place. It is capable of holding objects of different shapes and sizes as well as adjust grip in case of any sort of slip during picking of object. This purpose is achieved by 14 commands for hand .Examples of such four fingered robot hand is also built previously [3-7].

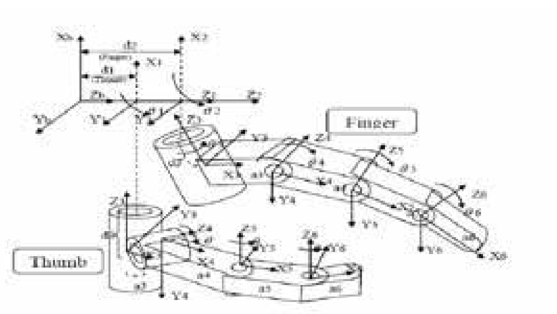

Figure2. Finger kinematics

In a robot hand for a good grasp of different shapes and sizes of objects, the gripper should be designed in efficient manner. In five fingered anthropomorphic robot hand [2] the roller chains are used to form fingers of arm and to give them movement like tendons cables and springs are used. For folding of fingers towards palm cables are used to pull the fingers while for unfolding of fingers away from palm, elastic force of spring is used. Previously, various attempts are made to form mimics of human hand [8-17] for same purpose but they are quite complex in design and expensive comparatively.

2. Methodology
Here the methodology used is simply an anthropomorphic hand with three fingers and a thumb for the former while four finger and a thumb for the later. In FFRH system, for each finger's joint movement double revolute joints are connecting three links whereas for thumb to links with two double revolute joints are taken. For the folding of fingers single opposing pair of tendons is used, one tendon folds the finger towards the palm and the other for unfolding it away from the palm. In five fingered robotic arm, for the movement of hand and wrist design based on mechanical structure having control circuitry, actuators and sensors without deviating arm's centre of mass with an electronic control system and trajectory planning algorithm.

In this paper we go through the structural design and implementation of both of the robot hand discussed. First the mechanical hardware and the electronics hardware is discussed.

3. Mechanical Architecture
The design of both the robot hand can be compared on the following aspects:

In the FFRH system the base can rotate whole 360˚ in both the direction. All the necessary control hardware including DC motors is equipped in arm of the FFRH. For controlling the movement of fingers limit sensors are used. The wrist of FFRH system can rotate in 180˚ in both directions while the palm can also be able to move up to 90˚ upward and downward. Geared DC motors are used to provide movement. To find out an object the IR sensor is placed in the middle of the palm. For folding and unfolding of fingers tendons are used. One end is attached to the tip of the finger and other is wound to spool connected to shaft of a geared DC motor. To find out an object the IR sensor is placed in the middle of the palm [Fig 3].

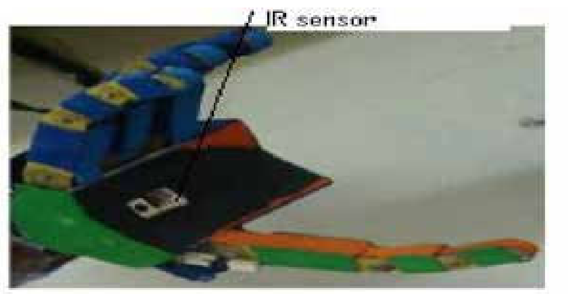

Figure3. IR sensor in the centre of palm

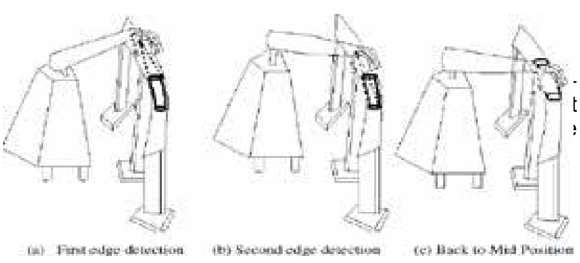

Figure4. The process of finding object

Mechanical specification of the FFRH system –

Distance between joints	Value(mm)
Palm to proximal joint – P0	19
Proximal to intermediate joint-P1	47
Intermediate to distal joint – P2	25
Distal joint to digit tip – P3	19
Joint to end of phalange – l	9
Phalange width – w	19
Finger to Finger - dff	44
Thumb & fingers - dft	75
Support thickness – t	3
Proximal joint pulley radius – R1	9
Intermediate joint pulley radius –R2	8
Distal joint pulley radius – R3	6

In five fingered robot hand, the platform is used to provide stability. It consists of 12V batteries, 300 rpm DC motors for arm alignment at any required position. Extra weight can be added to further increase stability. Base platform is connected to a rotating platform acting as a human shoulder but capable to rotate 180o only. The hand of robotic arm has 24 V DC motor and provide a rotation of 270o to the wrist which is also capable of moving 60 o up and down. The screw nut mechanism is used for movement of wrist and for its grip instead of tendons cables are used. For controlling the movement of wrist open loop control system and for restoration of the finger position springs are used.

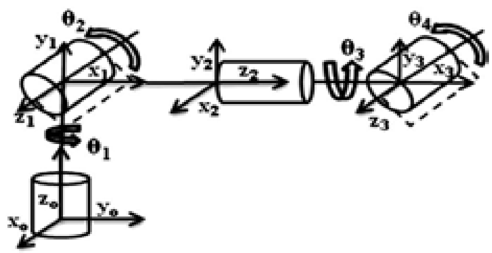

Figure5. Robotic arm with four degrees of freedom

In five fingered robotic arm, the object is find out and hold on the basis feedback generated error signal due to difference in element value and set point value.

Figure6. Prototype model of anthropomorphic robotic arm

Mechanical specifications of five fingered robotic arm –

Degrees of freedom	9 (1 for each finger)
Number of fingers	5
Position sensor	IR shaft encoder, 100 kΩ Potentiometers
Actuators	9 (12 V) +4 (24 V)=13 DC motors
Gear reduction ratio	1/80 for 24 V DC motors
Finger length	150 mm (from wrist)
Hand length	310 mm
Wrist length	70 mm
Cable length	680 mm (fingertip to motor)
Dimension of mobile platform	400x400 mm
Height of mobile platform	130 mm (from ground
Diameter of rotating disk	250 mm
Height of rotating disk	60 mm (from mobile platform)
Maximum load	4 N

4. Electronic Hardware Design

In the following section, we go through the electronic hardware of both the robotic hand.

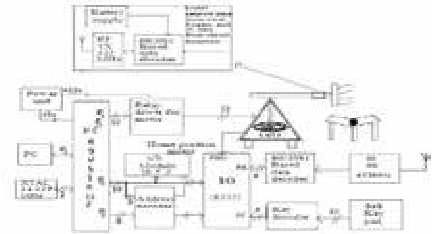

Figure7. Functional block diagram of FFRH

Above shown Fig 6 is the functional block diagram of control unit. Control unit has 5x5 key pad, decoder and 89v52 microcontroller, relay driver for geared DC motors, LCD displays and 433 MHZ receiver for feedback. The key pad is interfaced with microcontroller by using key decoder logic with parallel I/O interface8255. Keys are provided in the keypad for opening and closing of each digit, wrist up and down, pick and place and home position, Base clock wise and counter clockwise. As the keys are pressed corresponding base or digit or wrist is moved. This signal is fed to 8255 IC by key decoder. The decoder signal is fed to the microcontroller and corresponding relays are activated. Relay in turn energises the geared DC motors. The hand can moves up to 360 degree (free rotation) after getting a signal from keypad. The input from the palm is used to control the free rotation of the finger. The feedback unit is consisting of IR sensor placed on the palm, a microcontroller, 433 MHZ transmitter and 433 Receiver. IR sensor is used to sense the presence of the object. Assembly language program is written for the microcontroller with 14 individual commands for each finger and thumb open and close movement, wrist up and down, Base clock wise and counter clockwise, pick and place and home position.

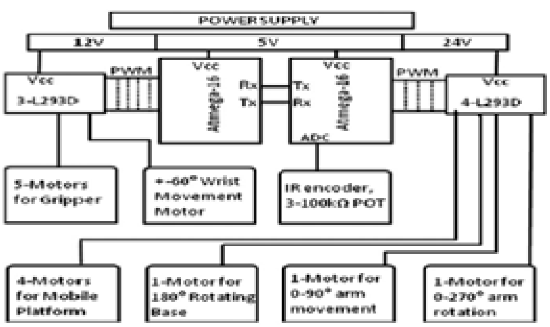

Figure8. Functional block diagram of electronic control system for five fingered robot hand

The electronic control system shown in fig.7 performs the open loop as well as the closed loop control using two Atmega-16 L microcontrollers and seven L293D motor drivers (H Bridge). Each L293D can control two DC motors in clockwise and anticlockwise directions using pulse-width modulation signals from the microcontroller. The Atmega-16 microcontrollers communicate with each other using the RS-232 serial protocol. A discrete-time PID controller was implemented in the Atmega-16 microcontroller using trapezoidal approximation and the Newton backward difference formula for the integral and derivative of the error signal, respectively. In a discrete-time system, an analog-to-digital (A/D) and a digital-to-analog (D/A) converter are employed to convert the error signal to digital form and the control signal to analog form, respectively, to drive the DC motor. The process variable is measured using a 100 kΩ potentiometer and the 10-bit A/D converter of the Atmega-16. In the case of the infrared encoder, interrupt signals are used to read changes in the voltage level [2].

5. Results

The main function of the robot hand is to pick and hold the object of different shapes and sizes efficiently. In case of cylindrical object as shown in fig 8 and 9, FFRH can pick and hold the object of 1 KG weight maximum. While five fingered robotic hand can pick and hold the object of 0.3 kg with ease and maximum up to 0.5 kg without any effect on restoring springs.

Figure9. FFRH holding a cylindrically shaped object

Figure10. Gripper holding a cylindrically shaped bottle

Now for the spherical object as shown in fig 10 and 11, FFRH can pick and hold the object of maximum diameter of 120 mm, and minimum diameter of 30 mm more efficiently than five fingered robotic hand which requires opposing force between thumb and middle finger to hold the same.

Figure11. FFRH holding a spherically shaped object

Figure12. Gripper holding a spherically shaped object

6. Conclusion

After comparing both the systems, conclusion can be view on different points. To build a robotic arm to perform simple tasks useful at work places and for immobile patients with having everything positive at every aspect as well as cost efficient is a tough task. In above discussion we find that FFRH system is having many advantages over five fingered anthropomorphic arm. In case of FFRH system, the robot design is easy to built, easy to control as well as inexpensive. The control algorithm used is also simple and provides the facility to first observe the shape of object and the pick. It also included the advantage of reliable grasping and easy mechanism using IR sensors. It is having a movement of full 360° and flexible finger joints. It can hold a weight up to 1 kg. While in case of five finger anthropomorphic robot hand, it is also be able to pick various objects and have a nine degree of freedom but it can move the arm to only 180°.It is also cost efficient, and the material used to built design is easily available but it does not have a smooth finger movement like previous one because the fingers are made up of roller chain and controlled by using cables and restoration springs. It is using DC motors and IR sensors for working of hand. It is capable of holding a weight up to 0.3 kg easily but can also hold maximum up to 0.5kg without effecting the restoring springs.

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