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Research Paper

Five Fingered Robot Hand Using Ultrasonic Motor

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ABSTRACT

A five-fingered robot hand having sixteen Degree of Freedom is developed. The robot hand is driven by a unique method using ultrasonic motors. All the components are placed inside the hand because the ultrasonic motors have characteristic of high torque at low speed and compact size. A five-fingered Robot hand is designed. However, it is not enough to reproduce the motion of human hand, because the conventional hand has problem in respect to degree of freedom and versatility. The fivefingered robot hand having size, shape and sixteen DOF is developed in this work. The main goal of the project is to make a model & analyze the five-fingered robot hand for industrial applications.

The robot hand is mathematically most complex to design.The CAD technology is used to design the robot hand. This study presents the processes undertaken in the modeling and analysis of five-fingered robot hand. The five-fingered robot hand provides wide trajectory coverage over the three-dimensional space around the base. Ultrasonic motors are very small and compact in size which is a great use nowadays to drivecomplicated structures easily in the field of robotics.Keywords: Robotics, Robot Finger, Finger joints,Driving mechanism, CAD.

I. INTRODUCTION

Robotics is the branch of technology that deals with thedesign, construction, operation, structural disposition,manufacture and application of robots. Robotics is related to thesciences of electronics, engineering, mechanics, and software.The word "robot" was introduced to the public by Czech writerKarelČapek in his play R.U.R. (Rossum's Universal Robots),published in 1920. Robots, or "robotics," are a segment of thebroader science of automation. Automation uses machines andcomputers which can learn or compensate for varying condition of operation. The term robot can be traced to the Czech word robota, which means compulsory labor. The first digitally operated and programmable robot, the Unimate, was installed in 1961 to lift hot pieces of metal from a die casting machine and stack them. Robots are also employed in jobs which are too dirty, dangerous, or dull to be suitable for humans. Robots are widely used in manufacturing, assembly, and packing; transport; earth and space exploration; surgery; weaponry; laboratory research; safety; and mass production of consumer and industrial goods. At first appearance of the industrial robots during the 1960s, the concepts for the usage of the robots wereonly as manipulator in which to perform pre-ordered commands. After 20years later during the 1980s, together with the appearance of microprocessor, it marked the beginning of the intense research of the field of robot. As the research progressed, robots were recognized not only as simple action performer but as a machine that have diverse and variety of purposes and usages.

IkuoYamano, [1]discussed about A five-fingered robot hand having almost an equal number of DOF to the human hand. The robot hand is driven by a unique method using ultrasonic motors. The method makes use of restoring force as driving power in grasping objects, which enables the hand to perform stable and compliant grasping motion. In addition, all the components are placed inside the hand.Dongwoon Choi and Dong-Wook Lee [2]developed the model of an android robot EveR 3 is an average human hand . When humanoid robots which use real human as model are designed, they use only size like height, length of the limb etc. in general. To make exact reference of model, the original hand was scanned by 3D scanner and the scanned data was handled by 3D MAX. From this process, the data which can be used in CAD program (Solid works) was obtained. This data contained all information of size of original model and this can measured exactly by CAD. Of course, it is hard to realize exact size of each factor of original model, but this process can help to make a robot hand which is the nearest to human hand than any other existing hands.

II. COMPUTER AIDED MODELING OF ROBOT HAND

For the functional structure, a virtual model was built introducing all the parts and components, linked to model the robotic system. In the robot kinematics, the gripper can be moved where ever is needed using rotation of links and joints. For this purpose, links and joints are accepted as a coordinate system individually. Components of the robot hand are [1]Palm
[2] Bottom link of finger
[3] Middle link of finger
[4] Finger tip

As combine features into parts, combine parts into assemblies. Assembly mode in Pro/E enables to place component parts and subassemblies together to form assemblies. Resulting assemblies can be modified, analyzed or reoriented.

CAD drawing and its modeling:

Before modeling of any part of any system, detailed drawing of the system is necessary. Here, detailed drawing of the robot finger and hand assembly is prepared and shown in figure. This drawing is helpful in CAD modeling of robot hand and its finger.

An overview of the developed hand is shown in fig1 and fig2. The hand has five fingers.the finger dimensions are as shownzzin figure 2. The ultrasonic motors are inbuilt in each joint of the finger. Each finger has 3 joints with 3 DOF. The movement of the base joint of the finger allows ante flexion movement of the finger. Motor is inbuilt in all three joints thus at all three joints to give three DOF to ecah finger. Table1 summarizes characteristics of robot hand.

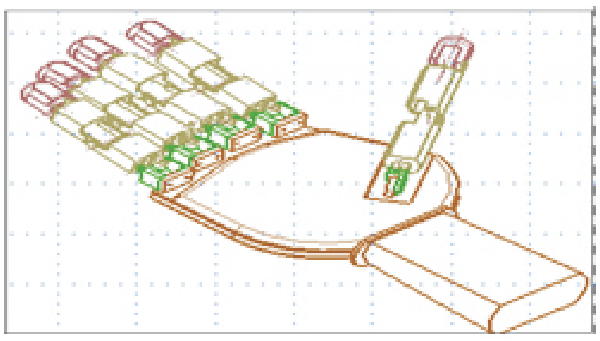


fig1: Robot hand Assembly

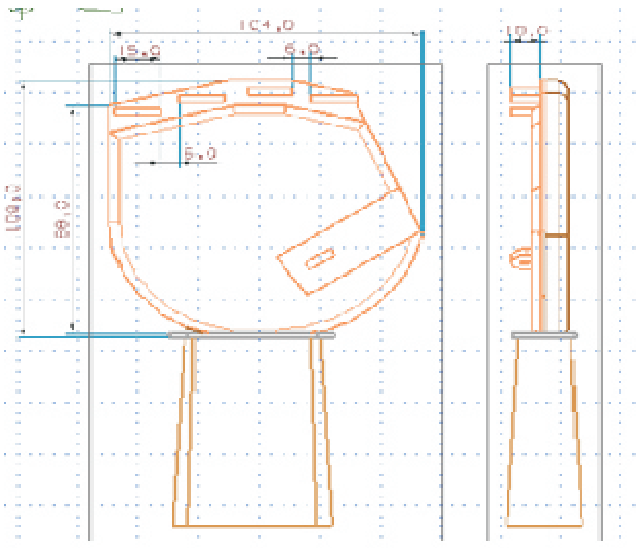


Fig2 Dimensions of robot palm

Table I : Characteristics

Finger Tip length	21.5mm
Length of middle link	37.5mm
Length of bottom link	34.5mm
Average thickness of finger	15mm
Total length of index finger	93.5mm
Total length of palm(from finger tip to wrist)	100mm
Total Width of palm	104mm

Finger Design: Most of robotic hands have their actuators like motors in palm or forearm and their finger is connected to palm, but the finger of this hand ha an actuator (ultrasonicmotor), sensor and gears as its own components. The combination of these components becomes independent finger module. The joint links are composed of three phalanges as a proximal joint, middle and distal like human finger. In case of a thumb finger, it is different to other fingers as a thumb finger has to match with other four fingers while gripping an object. Dimensions of different link of the finger are as shown in fig 3.Different link Dimensions: 37/23/ 21 mm (bottom, middle, tip) **[2]**

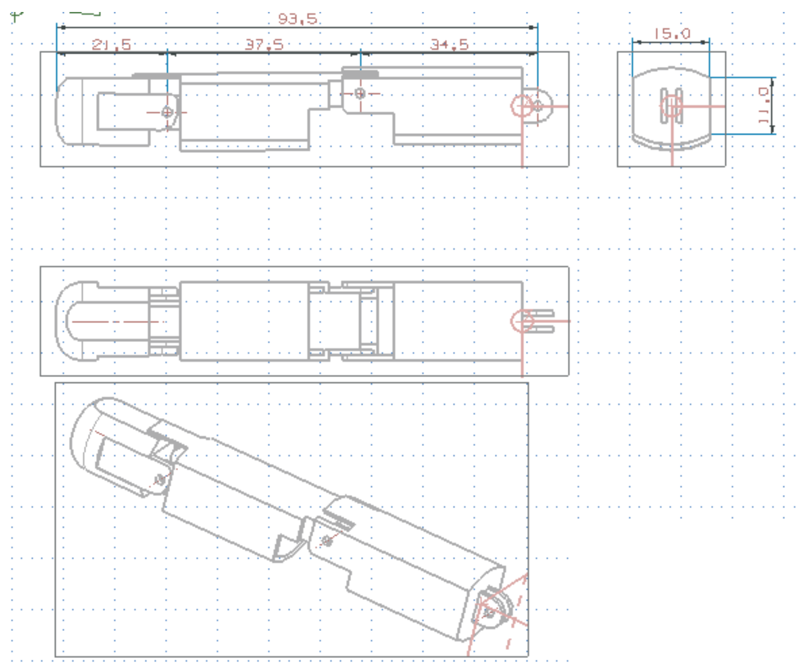


Fig 3: CAD Model indicating different links of robot indexFinger

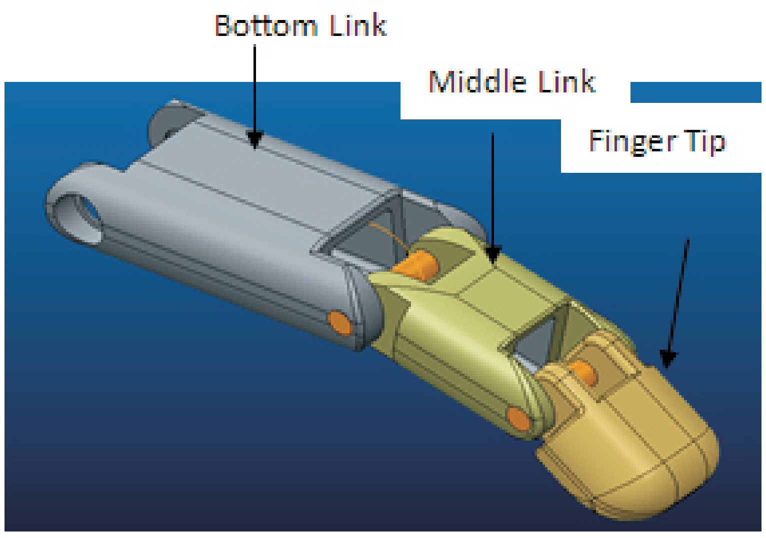
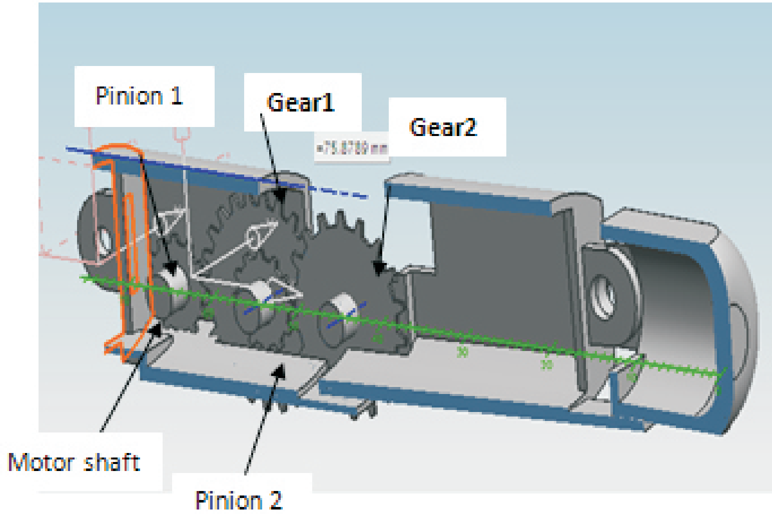


Fig 4: Drawing of index finger indicating different links

Structure of typical drive mechanism

A terminal drive mechanism must have a particularly excellent control performance of small force. It requires, therefore, a high efficiency reduction gear with low frictional resistance and play. As type of reduction gear, a gear train will be adopted which uses only high efficiency spur gear, a gear train will be adopted which uses high efficiency spur gear capable of building a fine mechanism because of their simple shape.The length of the motor is restricted to the width of the finger joint because the motor must be incorporated in such a way that its axis of rotation is parallel to the axis of rotation of terminal joint [3]. Since the output of such a motor is very small, the reduction gear must have a high speed reducing ratio, to obtain an effective torque. However, realizing a high speed reduction ratio by increasing the number of stages of gear train should be avoided, because leads to deterioration of efficiency and increase in play instead. For this reason, build up a two stage gear of high speed reduction ratio.By reducing the size of gear module as much as possible and by combining gears and small gears while keeping in mind to maximize the speed reducing ration per stage. Fig5 indicate an example of concrete structure of terminal driving mechanism [3]. A pinion is fixed to the motor shaft and is turned. The spur gear1 engaged with the pinion 1 and the pinion 2 is mounted on the shaft of gear 1.Their axis of rotation exists on the middle joint. The spur gear 2 engaged with the pinion 2, connected to the terminal joint to turn together. Large spur gear 1, 2 are used for obtaining a large speed reduction ratio and by disposing them by the side portion of the finger mechanism; obtain a margin of space for housing sensor and electric fixtures etc in the finger mechanism.



SIMULATION

5.2 MOTIONS OF ROBOT FINGER

Axis 1

This axis, located at the robot finger base, allows the robot finger to rotate from up and down i.e. flexion motion only. This motion is carried out at the base of the each finger i.e. atmetacarpophalangeal (MCP) joint. In actual human hand MCP joint is having 2-DOF+/- 350 for adduction/abduction, -300 to 900 for extension/flexion [4]. While in the artificial joint is very complex to control all four motions adduction/abduction& extension/flexion. Thus for simplification of control system only joint is free for flexion .This sweeping motion extends the work area to include the area to either side and behind the arm. This axis allows the robot to bend the finger bottom to a 90 degree.

Axis 2

This axis is also located in between bottom and middle joint of the finger i.e. in between MCP and Proximalinterphalangeal(PIP) joint of the finger at the robot base, allows the robot to move in the upward and downward. As explained in the driving mechanism before the axis of finalgear is matched with the axis of the joint. Thus with the rotation of the gear mounted on the joint spindle, the finger moves to give the motion of bending. This joint gives the finger 1-DOF at middle joint.

Axis 3

This axis is located in between the PIP and Distalinterphalangeal (DIP) joint of the finger. This axis allows the finger tip to bend in one direction only. Same driving mechanism is mounted as that for middle joint motion. Thus with the rotation of gear 2, joint rotation is possible which gives the finger tip flexion motion.

5.3 Motion of thumb:

For the thumb, application of a human finger's mechanism was difficult. However, by setting DOF as shown in Fig6. , the thumb became capable for executing approximate human thumb motion. Motion of the TM1 jointenables thumb to face other fingers [1]. In addition, the torque required at the bottomjoint to produce force at the fingertip is small compared to the other finger of which the DOF placement is shown in Fig5. Therefore, the thumb can produce more force at the fingertip compare to other fingers. Bottom joint of the thumb has a additional DOF thus it has 2DOF. Total DOF for the thumb is four

Total Degree of freedom of robot fingers:

As explain above each finger is moved along three axes incorporated along three joints in between each joint. Each finger is having three DOF. Thus for four fingers we are having total twelve DOF. Additionally thumb is having four DOF thus artificial robot hand developed is having 16 DOF. In actual human hand each finger is having additional degree of freedom for adduction and abduction but in practical forartificial robot hand it become difficult task to have control on this kind of motion. Again more chances of collision of fingers are possible. For that need to mount more number of sensors and additional control system. To avoid this difficulty and for more simplification DOF is reduced.

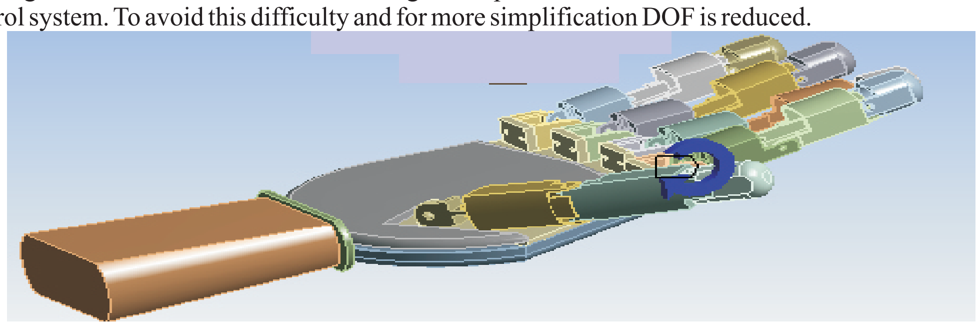


Fig 5: simulation indicating different axis of rotation

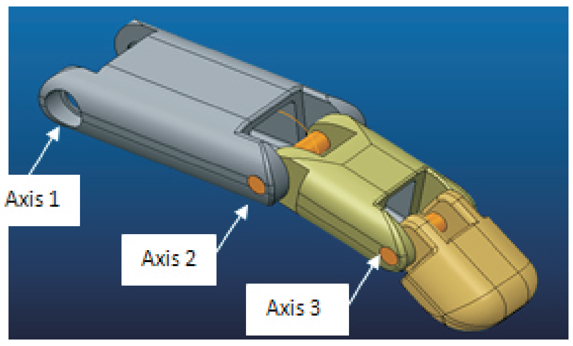


Fig 6: different axes of rotation

Weight of the motor	17 g
Weight of finger tip	10 g
Weight of middle and bottom link	12 g
Length of finger tip	18mm
Length of middle link	23mm
Length of bottom link	37mm

Torque calculation

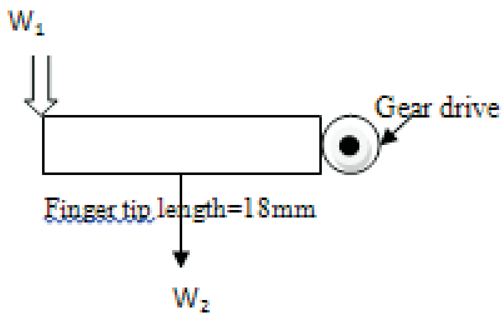


Fig 7: load conditions on finger

Now suppose robot is lifting a beer with a hand. A moment about the finger joint is being created by both the weight of the can, but also the weight of the robot hand link itself. Moment = (can weight × arm length) + (link weight ×½ × Link length) For the link length we only use half the value because weight is distributed throughout the entire link. Weight of the robot finger link is applied at the center of mass of the robot link. The center of mass is the exact point where an object canbe perfectly balanced. The center of mass is the midpoint (½ length) of the robot finger link as shown in the fig7.Moment is actually the torque being applied at the joint. So while the selection of motor for to power the shoulder of robot arm, this value is the minimum required torque. Total torque = (torque because of self weight) + (Torque because of motor weight) = (W1 × link length) + (W2 × total length/2) = (1kg×18mm) + (12gm×9mm) = 1.8 kg-cm + 0.0108 kg-cm Total torque at base joint of finger tip = 1.8108 kg-cm Above calculation gives the result of torque generated at the bottom of the finger tip joint. Even though the motor used (USR30) has 1kg-cm maximum torque capacity but under the effect of high speed reduction ratio and because of short distance of approximately 0mm between joints, motor is

capable of lifting 2.5 times more weight of its capacity. Considering factor of safety we can set up to 1.5 kg eight for the design of the finger Experimental results Analysis of the robot hand has been done to check the overall movement required to robot fingers to grip an object. Object is kept exactly over the robot palm at the center of hand. Object is spherical shape of 80mm diameter.(Fig 6).maximum movement takes place for thumb joint of 124.25mm while it very for remaining four fingers. Torque required at base joint of all fingers including thumb, is found different. Maximum torque is at thumb joint of 1.5 Nmm because of its self weight while torque at remaining fourfingers very form 0.45N-mm to 0.6N-mm as per its respective movement. (Fig 7)

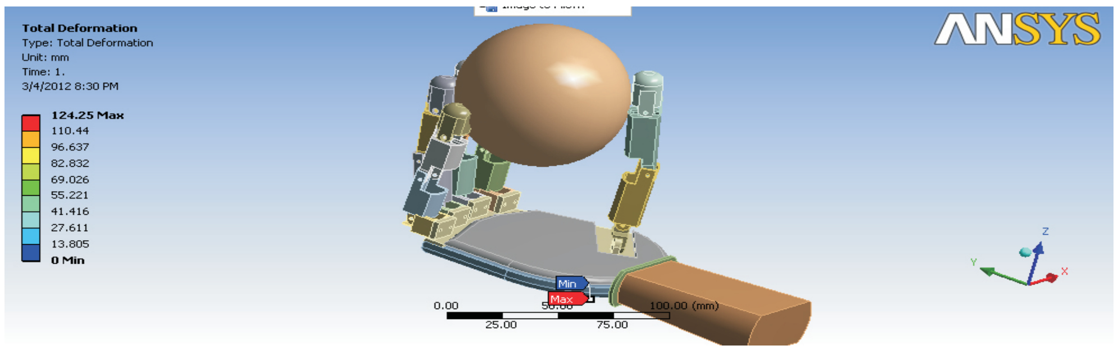


Fig 6: model showing movement of fingers

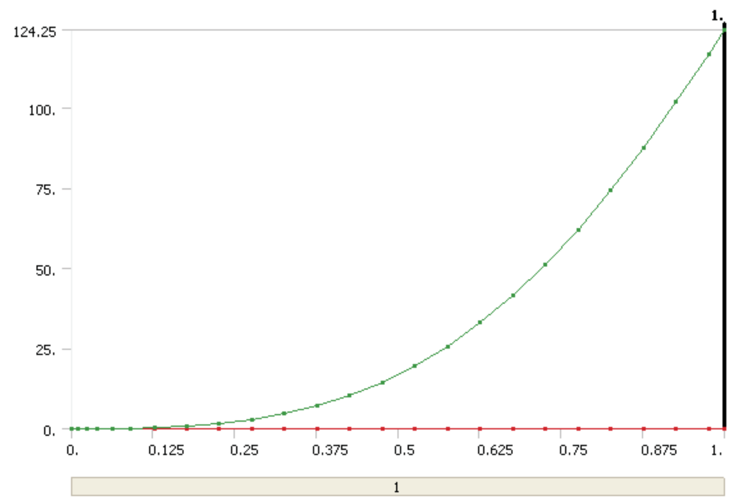


Fig 7: Graph showing varying deformation with respect to time

CONCLUSION

In this paper, design, implementation and controlExperiments of a five-fingered robot hand that hasMeasurement, shape and DOF equivalent to human hands ismentioned. Design of robot hand that has equivalent appearance as human being is modeled in CAD and simulation is done. All fingers are sufficiently flexible to grip an object of an average size. Maximum torque capacity of motor is calculated and found sufficient enough to bear the torque generated by weight to be lifted including the structural weight. Driving mechanism is designed and modeled which is required to give the finger movements. It is analyzed in ANSYS to know the displacement of each finger considering the torque.zzRobot hand is highly sophisticated as an end effecter forhuman operation. For future works, improvement ofreliability, mounting to a robot arm are considered. In addition, robot hand can be applied for a variety of uses including tale-operation in amaster-slave system

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