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ANIMATRONIC HAND

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Abstract- Robotic hands are still a long way from matching the grasping and manipulation capability of their human counterparts. This paper presents an acquisition method that comprehensively looks for the mimic configurations of the human hand. The data obtained through this process is further analyzed, transformed, and then used to synthesize a reduced configuration space of a robot anthropomorphic hand. The method rely on a dimensionality reduction technique that provides a new basis of the full configuration space, from which one can select a subset of the vectors forming that basis, and finally obtaining a simpler configuration subspace. These vectors are called Principal Motion Directions, and represent the coordinated motions captured by a sensitized glove on a human hand and transferred to the robot hand. The characteristics and limitations of the animatronic hand are discussed in this paper.
Keywords- *Force sensor, hand, humanoid, multifinger, robot*.

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Introduction

Animatronics was developed by Walt Disney in the early sixties. Essentially, an animatronic puppet is a figure that is animated by means of electromechanical devices. Animatronics is the cross between the animation and the electronics. Basically, Animatronics is the mechanized puppet. It can be remotely controlled or preprogrammed. The abbreviated term originally coined by the Walt Disney as Audio. Animatronics is a subset of anthropomorphic robots which are designed drawing inspiration from nature. The humanoid robots will be equipped with anthropomorphic multifingered hands very much like the human hand. We call this a humanoid hand robot. Humanoid hand robots will eventually supplant human labor in the execution of intricate and dangerous tasks in areas such as manufacturing, space, the seabed, and so on. Further, the anthropomorphic hand will be provided as a prosthetic application for handicapped individuals. Many multifingered robot hands (e.g., the Stanford–JPL hand by Salisbury et al., the Utah/MIT hand by Jacobsen et al., the JPL four-fingered hand by Jau , and the Anthrobot hand by Kyriakopoulos et al., Robonaut hand by lovchik, Gifu hand by Jacobsen and Kawasaki) have been developed. These robot hands are driven by actuators that are located in a place remote from the robot hand frame and connected by tendon cables.. The elasticity of the tendon cable causes inaccurate joint angle control, and the long wiring of tendon cables may obstruct the robot motion when the hand is attached to the tip of the robot arm. Moreover, these hands have been problematic commercial products, particularly in terms of maintenance, due to their mechanical complexity. A mechanical arm is robotic, usually programmable, with similar functions to a human arm. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement. The links of the manipulator can be considered to form a kinematic chain. The business end of the kinematic chain of the manipulator is called the end effecter and it is analogous to the human hand. The end effecter can be designed to perform any desired task such as welding, gripping, spinning etc., depending on the application. However, these hands present a problem in that their movement is unlike that of the human hand because the number of fingers and the number of joints in the fingers are insufficient. The animatronics hand has a thumb and four fingers; the thumb has four joints with four-degrees-of-freedom (DOF) and the finger has four joints with 3-DOF; and the two joint axes of the thumb and the fingers near the palm are orthogonal.

Robotic Hand Design

UTAH/MIT Hand

The Utah/MIT hand shown in figure was developed by the Center for Engineering Design at the University of Utah and the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology (MIT) in 1985. It was intended to function as a general purpose research tool for the study of machine dexterity (Jacobsen, etc., 1986). The Utah/MIT hand has the same size as the human's hand. It has four fingers (three fingers and a thumb) in a very anthropomorphic configuration. Each finger has four degrees of freedom and can move at five times of human speed, including the grip of a firm handshake. There are totally 17 links (1 on the wrist, 4 on each of the 4 fingers) on the Utah/MIT hand. Among them, 16 joints on the fingers have degrees of freedom. Their bending and extension are controlled by cable driven by pneumatic pistons, which is integrated into the hand. By utilizing the finger tendon forces the grasp can react, to some degree, to the object being grasped. On the Utah/MIT hand, there are antagonistic tendons for each finger joint. The antagonistic tendons and the large amount of coupling between finger joints have complicated the work on the Utah/MIT hand (Jacobsen et al 1986). There are 4 kinds of sensors on the hand, motor position sensors, joint position sensors, tendon tension sensors and tactile array sensors. According to the signals detected, movement of the hand can be illustrated.

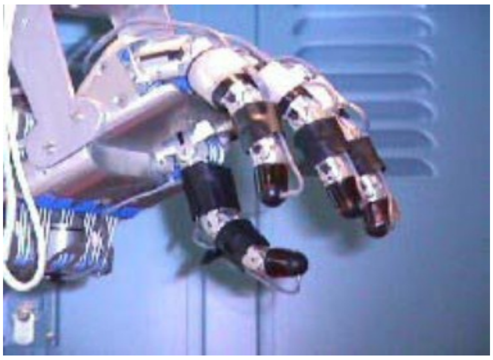

Fig. 1- Utah/MIT hand

NASA Hand (Robonaut Hand):

The NASA hand was designed in 1999 by C.S. Lovchik in Robotics Technology Branch of NASA Johnson Space Center and M.A. Diftler in Automation and Robotics Department of Lockheed Martin Corporation. It was developed for space extravehicular activity (EVA) use. It is close in size and capability to a suited astronaut's hand (Lovchik 1999). This five finger hand combined with its integrated wrist and forearm has fourteen independent degrees of freedom. It consists of a forearm which houses the motors and drive electronics, a two degree of freedom wrist, and a five finger, twelve degree of freedom hand. The forearm, measures four inches in diameter at its base and is approximately eight inches long. It houses all fourteen motors, 12 separate circuit boards, and all of the wiring for the hand. The dexterous finger set consists of two 3 degree of freedom fingers (pointer and index) and a 3 degree of freedom opposable thumb. The grasping set consists of two, 1 degree of freedom fingers (ring and pinkie) and a palm degree of freedom. All of the fingers are shock mounted into the palm. Overall the hand is equipped with forty-three sensors not including tactile sensing. Each joint is equipped with embedded absolute position sensors and each motor is equipped with incremental encoders (Lovchik 1999). The Utah/MIT hand has antagonistic tendons for each finger joint on the hand, but on NASA hand there is just one tendon sensor for each finger. This reduces the amount of coupling between finger joints which complicated the Utah/MIT hand. Figure 2 shows the working NASA hand.

Fig. 2- hand is working

GIFU Hand

The Gifu hand was designed in 2001 by Jacobsen and Kawasaki at Gifu University and is highly anthropomorphic with the total size of thumb, four modular fingers, and palm being only slightly larger than the human hand. Each of the fingers has four joints with the thumb providing four DOFs and each finger providing three DOFs. With a bandwidth greater than that of the human hand, the Gifu hand provides an excellent test bed for controls research.

Fig. 3- Gifu Hand

Operation

There is a control glove which has a flex sensors mounted on it. The flex sensors are the special sensors which calculate the change in resistance when they bend. When control glove is bending the flex sensor changes its value. This value is an analogue value which is given to microcontroller. The microcontroller converts the input analogue signal into digital signal. This digital value is transmitted wirelessly through RF transmitter. On the receiver side this digital signal is received by the RF receiver which is then given to microcontroller connected to servos on animatronic hand and the animatronic hand functions just as the movement of the control glove.

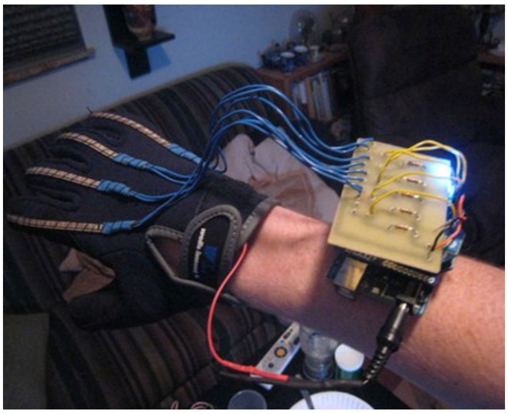

Fig. 4- Control glove with flex sensors, microcontroller and RF transmitter

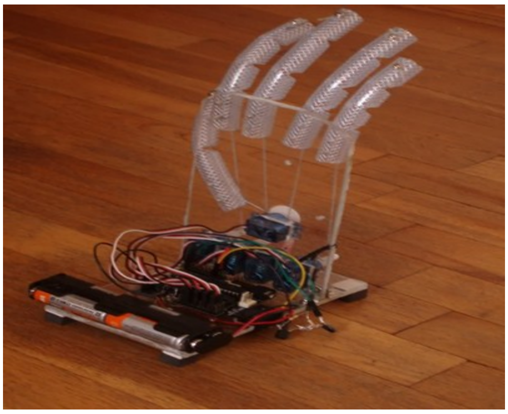

Fig. 5- Animatronic hand with microcontroller and RF receiver

Design Concept

Size- It is desirable for the robot hand to resemble the human hand in size and geometry for purposes of skillful manipulation. The robot hand was designed to be similar to a relatively large human hand, and has a thumb and four fingers.

Table 1- Desired sizing for finger design

PARAMETERS	FINGERS	THUMB
WIDTH	0.84	1.00
THICKNESS	1.14	1.00
PROXIMAL PHALANGE	1.37	2.00
MIDDLE PHALANGE	1.10	1.50
DISTAL PHALANGE	1.00	1.25

Number of Joints and Number of DOF- In a human hand, both the thumb and fingers have four joints . It is difficult for humans to control the outermost two joints of the fingers independently, because the fourth joint engages with the third joint. However, humans can control the joint angles of the thumb almost independently. The thumb is more dexterous and powerful than the fingers. The independent joint needs an independent actuator in the robot hand. This makes it hard to design a light weight hand. The finger can be modeled as a link mechanism with four joints and 3-DOF, and the thumb can be modeled as a link mechanism with four joints and 4-DOF. Controlling the finger made with coupled joints may be more difficult than controlling the finger made with all independent joints, in terms of grasping and manipulation. However, the finger made with coupled joints, which has more links than the finger made with independent joints, can grasp and manipulate more objects of various shapes than the finger made with fewer links. This is due to the fact that the area for grasping in the finger made with coupled joints is larger than that of the grasping area of the finger made with fewer links. Therefore, coupling will augment the dexterity of the hand. The number of joints and number of DOF of the robot hand were designed to mimic those of the human hand. The thumb is actuated by one servomotors and the fingers actuated by four servomotors. The fourth joint of the fingers are driven by the third servomotor through a planar four-bar linkage mechanism. The first joint and the second joint of human finger cross almost orthogonally at one point. Hence, the hand was designed such that the first joint and the second joint of each finger cross orthogonally at one point by means of an asymmetrical differential gear. Moreover, the asymmetrical differential gear enables the second joint axis to be placed near the surface of the palm, which make an effect to resemble a finger motion of the human.

Opposability of the Thumb- The thumb of the human hand can move in opposition to the fingers. Dexterity of the human hand in object manipulation is caused by this opposability. The robot hand was designed such that it has an opposable thumb.

Built-In Servomotor- For easy attachment to the robot arm, the robot hand was designed such that all joints are driven by built-in dc servomotors with a rotary encoder. To produce a high stiff hand, the transmission system was created by using high stiff gears such as a satellite gear and a face gear instead of low stiff gears such as a harmonic drive gear, and without using tendon cable.

Unit Design- Easy maintenance and easy manufacture of the robot hand are very important, so each joint was designed as a module and each finger was designed as a unit. Due to the unit design of the finger, hands having from two to five fingers are easily made.

Distributed Tactile Sensor- There are many sense organs in the human hand. These permit the human hand to manipulate an object dexterously. It is expected that more tactile sensors enable more dexterous manipulations. The robot hand was designed to be mounted with a developed distributed tactile sensor with 624 detecting points.

Wiring- Wiring is important in robotic mechanisms. All of the wires in the motor, force sensor, and tactile sensor should not prevent object manipulation by the robot hand. We designed all of the wires to be located along the back of each finger and palm. The hard wire used in the commercialized force sensor was changed to a soft wire, so as not to cause an external force to arise due to motion in the hard wire.

Microcontroller ATmega 328P is a low power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture.

Features
I/O and Packages:
– 23 Programmable I/O Lines.
– 28-pin PDIP.
2. Operating Voltage = 1.8 - 5.5V
3. Temperature Range = -40°C to 85°C
4. Speed Grade = 0 - 4MHz@1.8 - 5.5V, 0 - 10MHz@2.7 - 5.5.V, 0 - 20MHz @ 4.5 - 5.5V
5. Advanced RISC Architecture:
– 131 Powerful Instructions – Most Single Clock Cycle Execution.
– 32 x 8 General Purpose Working Registers.
– Fully Static Operation.
– Up to 20 MIPS Throughput at 20MHz.
– On-chip 2-cycle Multiplier.

Applications of Animatronic Hand
1. It can be used as a powerful aid for the physically challenged.
2. Can be used for diffusion of Bombs where there is a high risk of lives.
3. Can be used in space for repairs of space station.
4. It's a research project for the humanoid robotic.
5. Can also be used for household applications.

Future Scope
Digital camera can be placed on the robotic hand which will record the motions of a hand if a robotic hand is at a long distance.
Besides increasing the functions and stability of the hand rehabilitation device, a virtual environment could be developed to increase the interactivity of the stroke patient and the rehabilitation device. It can also crease fun for the patient and increase the rehabilitation efficiency potentially.

Results

Fig. 6- Transmitter hand

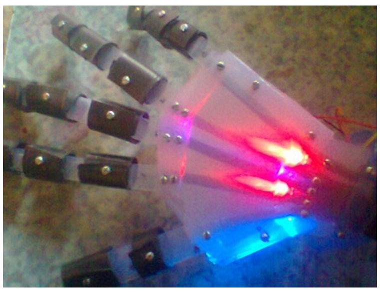

Fig. 7- Receiver hand

Conclusion
In this paper, we focused on the mechanical characteristics of hands, without treatment of sensing, controls, electronics, and power requirements and techniques. Since a hand, like any other tool, has many uses, sufficient performance for one application might not be appropriate for another. It is therefore difficult to establish exact mechanical and performance requirements. Ultimately the selection of hand characteristics and specification is a choice between tradeoffs in complexity, dexterity (achievable grasps), weight, and control methods.

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