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Study and Design of Dexterous Prosthetic Hand for Upper Limb Amputee

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Abstract

A new dexterous prosthesis hand design has planned that differs from that of conventional prostheses for upper limb amputees. With the objective of addressing amputees' requirements, functionality was increased and cosmetic appearance became more natural. By integrating servo and stepper motor different important grasping patterns of everyday life can be performed. Such as power grip, hook grip, precision grip, lateral pinch etc. As a result of image processing and better control objects can be grasped accurately according to the shape. For a more natural appearance and non-conductive, the hand is covered by a cosmetic silicone rubber glove. The hands are designed for performing everyday life activities.

Keywords: dexterous, prosthetic, grip

Introduction.

An autonomous robot can perform the coveted assignment in unstructured situations without or with ceaseless human direction. Numerous sorts of robots have some level of self-rule. Distinctive robots can be self-governing in various ways. Nowadays in Bangladesh, upper limb injuries are Transport Injury, Fall Injury, Machine Injury etc. Among them due to the high levels of trauma incurred, it was the fourth leading cause of permanent disability from injury, responsible for over 1,360 children being permanently disabled or almost four children each day. It was the eighth leading cause of morbid in children, causing over 110,000 child injuries, or over 300 per day. Besides, falls are the leading cause of non-fatal injury with over 770 children injured each day. Cut injuries are more severe, about 350 children are victims of cut injury and 5 of them becomes permanently disabled each day. Not only children, elder peoples are also the victim. Over 17000 are injured by machine each day, almost 50 per day [**Error! Reference source not found.**]. These people need to be helped with a dexterous hand that can help them with their amputation and get back to their daily life and works side by side with normal people.

The importance of designing robotic hand most likely originates from the expectation of using automated prosthetic hand to restore lost hands. There is still no consensus about the human hand dexterity. So all recommend that dexterity is a highly personal property that is not only shaped by individual's motor control ability but also the designing of all joints and biomechanical characteristics. That's why we cannot generalize without considering the biological difference of individuals. The staring work of this work is first to identify the important biomechanical information of the human hand and apply them in the prosthetics. This allows the hand a close replica that has the same kinematic and even dynamic properties. That means it will have nearly the same degree of freedom as the normal human hand has. In the following section, we first review related work and introduce the design motivation and then reinterpret the important biomechanics of the human hand from the engineering point of view.

1. Development of the biometric robotic hand.

In this section, we discussed the important biomechanical features that shape the movement of human hand from the following aspects: the bones, ligaments, joints, extensor hoods tendons, and tendon sheaths. We will explain the essential hand mechanics in engineering point of view:

The human hand has four fingers and one thumb and is composed of 27 bones containing 8 tightly packed wrist bones as shown in the figure. Each finger consists of three phalanges and one metacarpal bones. The thumb has two phalanges with the metacarpal bone. This thumb accounts for a big portion of the entire hand function. The trapezium bone connecting with the metacarpal bone form the carpometacarpal joint of the thumb. A joint is the connection between two adjacent bones whose shared contacting surfaces determine the possible motions of the joints facilitate a different set of finger motions called range of motion. The metacarpophalangeal joints are formed by the connection of phalanges to the metacarpals. Depending on the distance to the metacarpophalangeal joint, there exist two more types of joints, namely, the proximal interphalangeal joint and distal interphalangeal joint [2]. Based on this definition, the thumb only has one distal interphalangeal joint between the two thumb phalanges. During the bending motion, the three finger joints work as mechanical hinges. It is estimated that a tip pinch of 1 kg will generate12 kg of joint compression at the carpometacarpal joint. For a power grip, the load could become as high as 120 kg[0]. this shape will give the hand more flexibility.

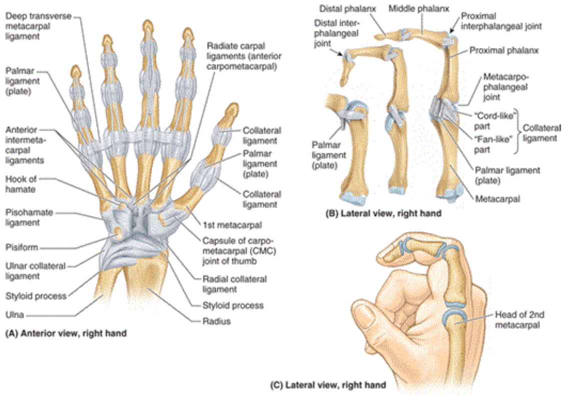

Figure 1: Different phalanges, joints, ligaments and tendons.

2.Joint ligaments.

The range of motion at each finger joint is restricted by the length of ligaments. Ligaments are tough bands of fibrous tissues inserted on both sides of the two adjacent bones. Two important branches are called collateral ligaments. Similar structures can be found in all the finger joints with variations in length and thickness. Their function is to stabilize the joint, shape the range of motion, and prevent abnormal sideways bending of each joint. Like the collateral ligaments, the volar plate also has insertionson both sides of the bones. Its function is to prevent the occurrence of the finger deformity from hyper-extension.Together with other accessory ligaments and soft tissues, collateral ligaments and volar plate form important structureknown as the joint capsule. We will use a rivet to join the two phalanges which will save our time and give the hand more strength[5].

3.Tendons, muscles and extensor hood.

There are two types of tendons in the human hand. The on es straightening the fingers known as extensor and the ones bending the fingers are known as flexor tendons. The extension motions of the tendons originated from the corresponding muscle groups located in the forearm. The muscles give the contraction forces, the tendons of the hand serve as the transmission system that partition the forces and smoothly deliver torque to each finger joint. The extrinsic muscles originate from the elbow and have muscle bellies located in the forearm. One servo used for the contraction of the finger in the inner field and extensor part does this with spring, that makes the finger stay in the straight position.

4.Components used in the construction

Raspberry pi: the raspberry pi is a open hardware, which runs many of the main components of the board- CPU, graphics, memory, the USB controller etc. Used in the project to control several parts and take inputs.
Servo motor: we used here tower pro MG996R servo and some mini servos. The tower pro MG996R servo can give 130.54 oz-in and at speed .19 sec/60deg can lift 13kg of load.

Force sensitive resistor: this is a sensor which has .5inch of sensing area. When no pressure is being applied to the FSR its resistance will be larger than 1M-ohm. This FSR can sense applied force anywhere in the range of 100g to 10kg [3].
Camera: a VGA camera was used for the image processing process and to detect the object and its shape and distance.
Power source: 6V dc power supply was used to derive the servo and stepper motor and also to supply power to the raspberry pi.

5.Performance of the robotic hand gripper:

In practical constuction the ring and little fingers are coupled considering their collaborative relationship as the grasping fingers. Their flexion and extension motions are controlled by a pair of servos through a differential pulley transmission system. The benefit of using such a pulley structure is to provide an extra source of hand compliance in addition to the build-in compliance at each finger joint, since it allows the two grasping fingers to conform to the contour of an object by automatically adjusting the shared string length between the two insertion sites. But the drawback is that the underactuated mechanism could also become a source of uncertainty bringing the two fingers into certain unknown postures when they bend and straighten between the two extreme postures. So, it is important to first investigate the repeatability of our proposed mechanism, especially when the finger's range of motion is controlled in between full flexion and extension postures. Compared to the ring and little fingers, the index, middle, and thumb are each actuated single servo, therefore they can be better controlled in this case. With the help of camera this hand can sense where the object is and of which shape.

The area bounded by the two trajectories covers a big portion of the reachable workspace of the ring finger. The flexion trajectory closely resembles that of the logarithmic spiral curve observed from human finger's flexion motion. In order to further evaluate the overall performance of our robotic hand, we conducted grasping and manipulation experiments using 20 objects. This experiment can be seen as a series of cooperative grasping tasks in which the former could clearly monitor the status of the grasped object without the occlusion issue. During the object grasping task, we observed that different grasping postures can be done accurately. This is because our biomimetic robotic hand successfully preserves the important biomechanics of the human hand that essentially determines the hand kinematics. The resulting grasps cover most of the grasping types defined by human hand taxonomy, except for the ones that require independent control of the ring and little fingers. As we have used the force resistive sensor which gives:

$$V_{out} = \frac{R_u V}{(R_M + R_{FSR})}$$

Force	(FSR+R)ohm	Current through FRS+R mA	Voltage across R mA
none	infinite	0	0
.04	30	.13	1.3
.22	6	.31	3.1
2.2	1	.45	4.5
22	250	.49	4.9

This table shows the resistance variation of the sensor with the load lifted or force given on the sensor.

6.Conclusion

We have designed a highly biometric hand that can nearly do the daily work with the help of artificial joints and ligaments. In this work we used OpenCV with python and for the object detection process. This gives the hand clear view of the object. In the future we will try to update the programming part that does the brain work for the hand. As we have used the force resistive sensor for doing the touch and load lifting sensing process. We will try to use some updated technology that can do the sensing work more precisely.

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