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Multi-Fingered, Passive Adaptive Grasp Prosthetic Hand: Better Function and Cosmesis

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Abstract

The design and construction of a child sized prosthetic hand, capable of passive adaptive grasp is the primary goal of this research. Adaptive grasp is the ability of the fingers to conform to the shape of an object held within the hand. When the hand closes around an object, the four fingers and thumb flex inwards and independently conform to the shape of the object being grasped. The grasp of objects such as a cube, a ball, or a pyramid result in a different final grasp configuration for the fingers and thumb. This adaptability is passively achieved by the mechanisms within the hand. The resulting design is simple and effective, not requiring sensors or electronic processing. The purpose of this hand is to provide a more secure grasp of objects, as well as to improve the dynamic and static cosmesis of the hand, so that it looks as natural as possible.

1. INTRODUCTION

Conventional prosthetic hands such as the Otto Bock 61/2 [1] or the VASI 7-11 [2] are basically pinch type devices with two rigid fingers and a rigid thumb. These prostheses can only achieve a two or three point contact with objects that are grasped. As a result, they require a high pinch force to secure objects. In addition, there has been some criticism on the cosmetic appearance of these hands from users. Typical complaints are that the hands are 'too boxy' or that they look unnatural during a grasp, or after the grasp is formed.

A prototype hand was created that has a number of features that make it distinct from conventional prosthetic hands. It has four fingers that can flex/extend and a thumb that can flex/extend and also adduct/abduct. The fingers and thumb curl as they flex inwards and straighten out as they extend. All digits flex close in unison, but as individual fingers encounter an object, they come to a stop, while the remaining fingers continue to flex until they too encounter the object, or reach maximum flexion. All digits have a layer of silicone of 3-to-5 mm thick on the grasping side, to provide a compliant surface. The motor has been placed in the wrist to keep the palm flat, which is considered more cosmetic.

Two other experimental hands, created specifically for prosthetic use and also capable of adaptive grasp, have been

Southampton Hand [4]. The Southampton Hand uses four motors to drive the digits, and sensors and active computer control to create the adaptive grasp. The Montreal Hand is more similar to the prototype hand, but houses its motor within the palm and uses a different adaptive mechanism. Both of these hands are slightly larger than adult size. The weight of the Montreal Hand, which is less complex than the Southampton Hand, is almost twice that of the hand presented here.

2. DESIGN

The prototype hand was designed for use by children between the ages of 7-to-11 years. As such, the hand was sized to fit that age group. The fingers are 66 mm long, 9 mm wide and approximately 11 mm thick. The palm is 80 mm long, 64 mm wide and approximately 25 mm thick. Figure 1 shows a schematic diagram of the six links that comprise each finger. These fingers have only a single degree of freedom and will trace out a natural looking tip trajectory in space, as they flex.

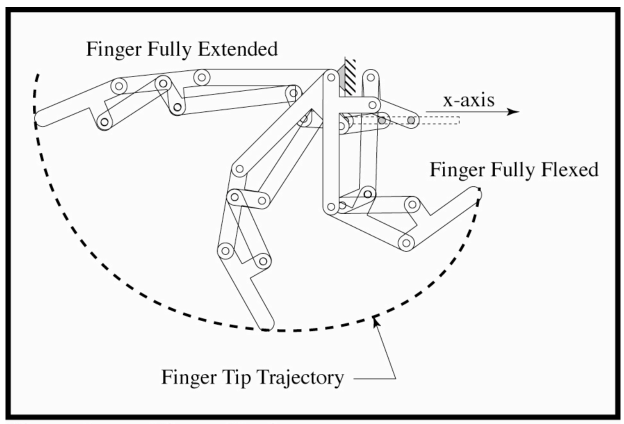

Figure 1 Finger Design

Figure 2 shows a schematic diagram of the whole hand. The digits are driven by the adaptive grasp mechanism, which is attached to the ball nut. This ball nut is able to translate forward and backward within the palm. The ball nut is coupled to the lead screw which is in turn driven by a double u-joint connected to the motor. The mechanism that creates the adaptive grasp uses compression springs that take up the translation of the ball nut, on any fingers that have encountered an object and cannot flex any further. This mechanism allows the remaining fingers to continue flexing.

The thumb is a self-contained unit capable of flexion and extension as well as abduction and adduction. It is mechanically powered by a Kevlar cable, which is connected to the ball nut via the adaptive grasp mechanism. The thumb has been designed to flex only the two most distal phalanges, unlike the fingers which can flex all three phalanges. The base phalange (the carpometacarpal phalange) of the thumb, is only able to rotate and provides the abduction and adduction action. Rotation of the thumb is performed by using the able hand(a majority of users are unilateral amputees[5]), or by pressing the thumb against a stable surface.

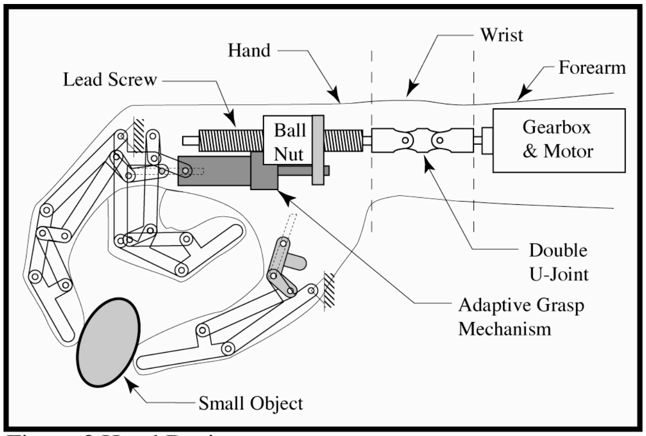

Figure 2 Hand Design

The digits of the hand were machined from aluminium and the palm was machined from Delrin plastic. A VASI 7-11 sized glove was heated and stretched over the prototype.

3. RESULTS

One prototype hand was built which was designed to function for 250,000 cycles. The weight of the hand is 217 grams and the total weight including the motor, gearbox and wrist is 280 grams. The motor used with the hand is a 6 Volt MicroMo 1724 with a 22:1 gearbox.

The static cosmesis of the hand is good. The curling and independently staggered fingers make the hand look natural after it has grasped an object. Figure 3 shows the hand with glove, grasping an object during a test. The dynamic cosmesis, as the hand is in motion, is also good.

Pull-out tests were done to determine the amount of force required to pull objects out of the hand's grasp and results were found to be similar to tests done with a modified, silicone compliant, VASI 7-11 hand. The grasp stability seems to be greater for small objects, as the fingers can form a 'cage' around these objects when they are adapting around them. This is not possible with a conventional prosthetic.

There are two areas of the hand design that are still deficient. The hand is able to achieve a maximum tri-digital pinch force of 14 N (3.2 lbf). This is approximately 1/3rd the pinch force of a conventional prosthesis, such as the VASI 7-11 or the Otto Bock 61/2. Although the adaptive grasp may secure some objects better, precision pinches of items such as a fork, still require a high pinch force. Therefore the pinch

Figure 3 Prototype Hand with glove grasping 1" ball

force must be improved upon. Also, the time to go from the fully open to the fully closed position is 4 to 5 seconds, which is much too slow. It should be in the range of 1 to 1.5 seconds. Both of these deficiencies are interrelated and can be overcome with the design of a two speed automatic transmission. A similar transmission is currently in use with the Otto Bock 71/4 prosthesis. It would serve to increase the pinch force while decreasing the closing and opening time.

4. CONCLUSION

Bench tests reveal that the hand greatly improves cosmesis. Further testing will be required to quantify the effects of adaptive grasp on stability. The next stage for the project will be to test the prototype hand on amputee subjects.

References

[1] Otto Bock Orthopaedic Industry GmbH: "MYOBOCK-Arm Components 1997/98", *Otto Bock*(1997).

[2] Variety Ability Systems Inc.: "Small and Lightweight Electric Hands for Children", *VASI*, Toronto(1996).

[3] Lozac'h, Y.; Madon, S.: "Clinical Evaluation of a Multifunctional Hand Prosthesis", *Proceedings of RESNA International 1992*, Toronto(1992).

[4] Kyberd, P.J.; Chappell, P.H.: "The Southampton Hand: An intelligent myoelectric prosthesis", *J. of Rehabilitation Research and Development*, 31(4), (1994)

[5] Atkins, D.J.; Heard, D.C.Y.; Donovan, W.H.: "Epidemiologic Overview of Individuals with Upper-Limb Loss and Their Reported Research Priorities", *J. of Prosthetics and Orthotics*, 8(1), 2-11(1996).