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Upper limb prosthesis for developing countries

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Abstract

Today several kind of high technology prostheses are available; we propose a really cheap under-actuated prosthesis specially designed for developing countries users. Structure and actuation are integrated. The actuation is by tendons, trusted by the shoulder of the patient. These tendons are embedded in an elastomeric matrix providing hand body, compliance where required (finger joints) and grip; the palm is sustained by a wood plate suitably shaped. The project has been developed in collaboration with the ARTS lab of the S. Anna University (Pisa).

Keywords

Low cost prosthesis, developing countries prosthesis, artificial hand, compliant joints hand.

1 Description of the prosthesis

As a main constraint it is asked to produce the hand without special technical skills or machines. This is a must requirement for third world application.
By hypothesis, high dexterity is not demanded: this characteristic would make complex the design of the hand. In fact, this is acceptable since it is not supposed to provide the users with a prosthesis for fine manipulation but with a cheap tool helping in farming and some other raw tasks.
Under these hypotheses, the palm has been shaped with a wood plate, with borders and faces suitably rounded.
The fingers should be light, robust, simple and human like [1,2].
Two main classes of joints can be used: joints in which the relative motion between adjacent rigid links is obtained by means of kinematical pairs, and joints in which the relative motion is formed by compliant inserts permanently connecting the two rigid links and belonging to the structure of the hand [3]. The second class of solutions aims at simplify the design, obtaining articulated structures with a reduced number of parts, easy to be manufactured and assembled, cheap, yet fully efficient and compatible with the required functions. Figure 1 shows an overview of the designed prosthetic hand.

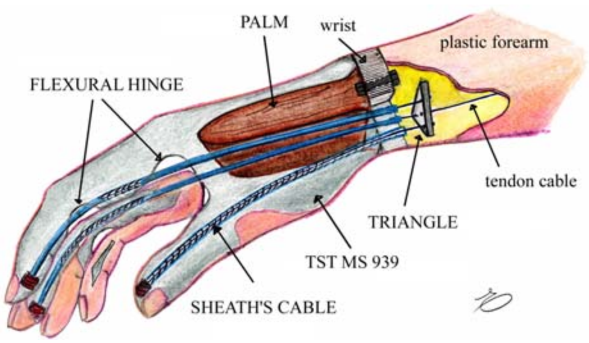

Figure 1. Sketch of the designed hand

The main attractive features of such compliant joints are that no ligaments are necessary and phalanges are

Figure 2. Construction of the prosthesis

structurally interconnected so that the finger skeleton is a one-piece structure and contact effects between surfaces are avoided.
Another advantage, coming also from the fact that the hand grasps by closing instead of by opening, is that one way tendons can be adopted. Such tendons bend the compliant joints and the undeformed configuration is regained once tendons are relaxed by the antagonistic elastic torques of the joints.
Figure 2 details the hand creation process. The prosthesis is shaped on a real human hand for a satisfactory external look. First, the operator wears a cotton glove (picture 1 in Fig. 2). Then the glove is immersed in a suspension of water and chalk plaster (picture 2). The undeformed configuration of the hand is shaped by holding a cylinder with a suitable diameter, such as a plastic bottle. The chalky glove is dried by hot air. The glove is then slipped off (picture 3) and cut in two halves (picture 4). Later it will be necessary to close the mould again; for this reason some references are created on the halves borders. The tendons (picture 5) are placed on the lower halve (picture 6); pieces of corks are disposed along each finger to create the flexural hinges. Then *TST MS 939* elastomeric polymer by *Locktite* is mould inside the halves (picture 7) to form the structural matrix of the hand. Once included the wood palm, the hand is closed between the two halves (picture 8). After two days it is possible to start breaking the chalk to let the hand dry faster.
The tip of each finger is connected to the triangular plate by a tendon. When the plate is pulled by the user shoulder, each tendon slides inside its sheath and closes the hand. The amount of movement of each tendon (respect to its sheath) depends on the shape of the grasped object. By pulling the triangle only (1 DoF) the whole hand is closed.
In the first prototype, the triangle collecting the extremities of the tendons is pulled by the shoulder of the patient. This makes the actuation very cheap and easy. Shape memory alloys tendons or artificial muscles can be adopted as well for actuation.
The realized hand is able to grasp objects having different sizes (Fig. 3).

Figure 3. Hand grasping and tests on the prototype

2 Conclusions

The elastomeric matrix makes it soft to the touch, with a consistence reminding the one of the natural hand. The grasp is effective: each finger, while bended, opposes a strong resistance to an opening force. The characteristics of the hand are summarised in table 1.

CHARACTERISTICS OF THE HAND	
DoF	1
Type of Grasp	Power and precision grasp
Force of power grasp	≈ 14 N
Speed (Time of closing hand)	Depends on the amputee
Range of flexion	Depends on geometry of flexural joint
Max. duration of grasp	Variable with energy
Number of sensors	0
Proprioceptive sensing	Force
Exteroceptive sensing	0
Proportional Control and Dexterity	Ability to regulate force and velocity according to the type of grasp, depends on the amputee
Stability	The grasp is stable against incipient slip or external load
Day-time of use	Body-Power, limited only by muscular fatigue
Life cycles	Not known
Total volume	50 cc
Weight (all included)	≈ 700 gr.
Protection against dust, dirt, humidity, etc.	Strong material, but a glove would still be useful

Table 1. Prototype datasheet

The main drawbacks are that the actuation force and the weight are too high. The concept works fairly well, thanks to the under-actuated mechanisms. The hand can fully adapt to every object shape, but it is not able to perform manipulation tasks.
Summing up, the main features of this hand are: *inexpensive to produce, purchase and maintain (materials and technical skills locally available); *easy to use (the hand control is intuitive and relies on a "natural" working principle); *effectiveness (the hand is designed in consultation with the users in order to satisfy diverse social and physical needs).
Further research will be addressed at reducing the actuation forces and bettering the accuracy.

References

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