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# The importance of information feedback in prostheses for the upper limbs[1]

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In view of the progress achieved in the last few years in prostheses for the upper limbs, it has been found difficult to make further improvement without a system for information feedback. Research is being carried out to increase the speed of gripping of artificial hands in order to integrate better their movements within the functional capability of the amputee. The artificial hands in use at present have a gripping speed of between 8 and 12 cm/sec. These values constitute the limit that can be managed by digital controls. Higher gripping speeds require proportional control of speed. This, however, will not be sufficient by itself if one intends to use gripping speeds around 40 cm/sec. In this case it will be necessary to control the development of the gripping movement by means of information feedback. Because artificial hands will soon be made with high speeds of gripping, we have made studies in our Centre that have demonstrated that further progress in the work so far carried out is possible only with a thoroughly effective system of information feedback. We have therefore devoted a large part of our research effort to this aspect of the problem.

Before beginning the new development work, we carried out a survey among upper limb amputees. The enquiries were based on the following points:

(1) what type of information will be necessary in the future,

(2) what information methods are most suitable to the human organism as regards its capacity to receive information and as regards the tolerance of the body,

(3) what type of device can be manufactured with the least cost, bearing in mind especially its useful life, its reliability and energy?

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We have proceeded in our work following these points and have achieved experimentally the following possibilities of use:

(a) information feedback concerning the strength of gripping,

(b) information feedback concerning the position of the fingers,

(c) a tactile disconnecting device for switching off, on contact, for hands with fast movements.

In addition, a microdevice is being prepared for the location of close objects intended above all for sightless persons without hands.

We began our development work with control information on the gripping strength. In this case we fitted, in the elastic tips of the fingers, highly sensitive extensiometers which served as variable resistors, to receive and pass on the various gripping strengths. However, in practice this device was found to need repeated repairs and was, therefore, not suitable for a functional hand.

During the following phase of development a system was devised making use of a micropotentiometer (Fig. 1) connected to a specially

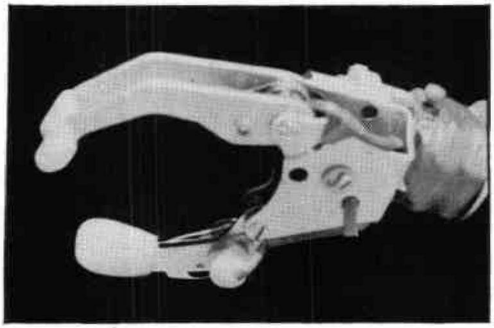

Fig. 1. Experimental hand using a micropotentiometer to detect amount of grip being induced at the fingers. The micropotentiometer is installed at the thumb joint.

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prepared electronic amplifier. This is a linear amplifier with analogue to digital convertor. The signal is then rectified so that in the rest position the amplifier output voltage is zero. When the case thumb encounters resistance, it varies the angular opening of the joint (Fig. 2)

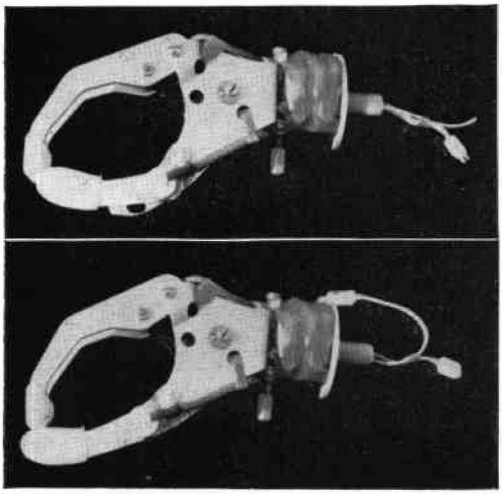

Fig. 2. Two views of the experimental hand shown in Figure 1. The force at the finger tips moves the thumb about the joint at which the micropotentiometer is installed.

in which the micropotentiometer is incorporated. This therefore changes the output voltage of the amplifier in proportion to the angular opening. In other words, as soon as the hand seizes an object, the output voltage increases in proportion to the pressure that the thumb exerts on the object. This voltage is then fed to the linear amplifier (Fig. 3) with analogue digital convertor. The input voltage is transduced in logical impulses of an approximate duration of 0.1 m/sec and at a frequency that varies, according to the pressure exerted, between 0 and 60 cycles/sec. Later these impulses are amplified and raised to 20–80 volts, which is varied according to the sensitivity of the individual. These are information impulses that stimulate the skin directly.

During these tests we were able to establish that the main component of information feedback on the strength of grip can be utilized also for information feedback of the finger position. The only difference lies in the fact that for finger position information feedback we insert the micropotentiometer in the main phalange

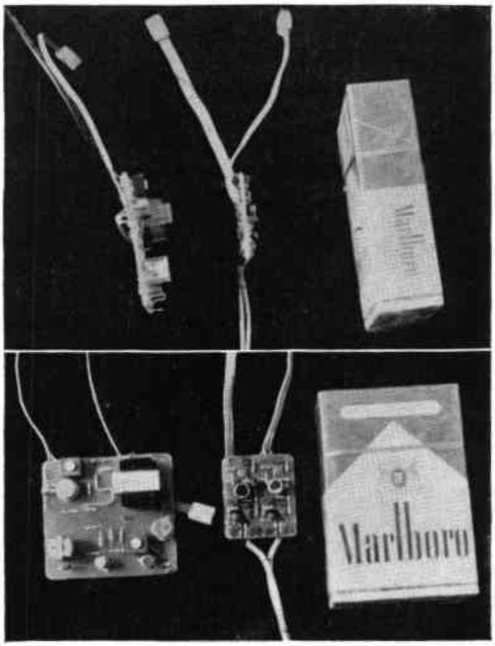


Fig. 3. Two views of the linear amplifier used in the experimental hand shown in Figures 1 and 2.

of the forefinger and middle finger (Fig. 1) in such a way that with the hand closed (that is, with the thumb, index and middle fingers closed), the potentiometer is in the "zero" position. According to the experiments we have made so far the finger position control information will be of practical use only to blind bilateral upper limb amputees.

For gripping strength control, a final thumb phalange was made which was passively mobile, in the joint of which a potentiometer was placed (Fig. 4). A return spring for the end phalange of the thumb was adjusted in such a

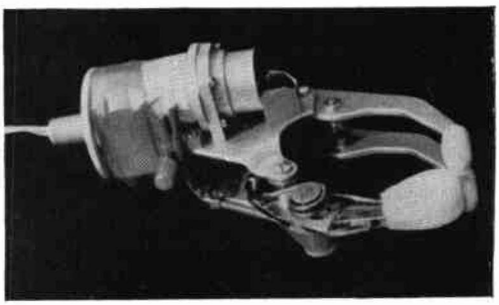

Fig. 4. View of experimental device showing the passively mobile thumb phalange and micropotentiometer for control of gripping strength.

way as to create a proportional relationship with the effective gripping strength of the hand. The receipt of control information was originally obtained by means of vibrators applied to the skin. It turned out, however, that after some time the amputees noted a diminution of the reception intensity. It is for this reason that we use two skin electrodes for the direct stimulation of the skin (Fig. 5) which, however, must be mounted outside the socket of myoelectrically-controlled prostheses. In applying the information electrodes, one must look for zones of the body that are especially sensitive. Particularly suitable are the medial parts of the arm and some central parts of the back. Practical research has demonstrated that in a relatively short time amputees on whom this system has been tried out experimentally, have perceived good lasting information feedback over a long period. At a gripping speed of about 40 cm/sec it is extremely difficult to exercise control of the grip even with proportional regulation. Nevertheless, in our enquiries we found some patients who were able to control an experimental hand at the above-mentioned speed. However, given the enormous concentration required, the effort, in the long run, was found to be too great for the patient.

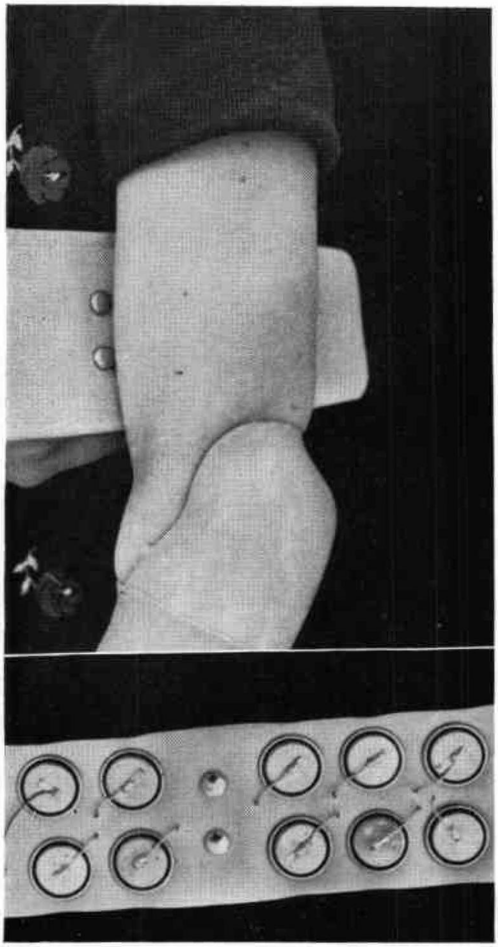

Fig. 5. Two surface electrodes are used over the arm to provide directly to the skin signals proportional to action of the prosthesis.

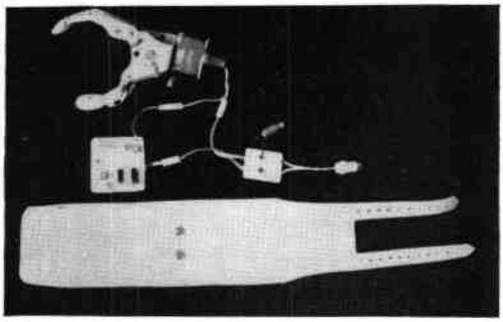

Fig. 6. The complete experimental system.

After various trials we arrived at the following system. At the tips of the fingers and on the inside of the index and middle fingers a disconnection system is inserted, which causes the breaking of contact when the finger touches an object. To prevent an amputee with a fast-moving artificial hand from being subjected, in spite of proportional control, to too great an effort due to the control itself, a tactile switching-off device has been made which, as its name indicates, automatically comes into operation when there is contact and therefore interrupts the movement of the hand. This mechanism ensures that the amputee shall not get into difficult situations especially when he has misjudged the movement. At the same time that the gripping movement is interrupted, information is relayed to the amputee giving him precise information on the pressure of the fingers. The interruption of the contact is for about 300 ms, a value that is in the range of reaction time. The combination of tactile switch-off, with simultaneous gripping strength information feedback, has given excellent results because there is no question of a pre-established programme. In fact, the amputee is allowed complete freedom in the entire control of the movement.

In releasing the object, that is, when contact with the fingers no longer exists, the tactile switching device is switched out without interrupting the finger movements. The information feedback system is connected to the regulating system and operates only as long as the hand moves. This results in a considerable saving in energy. The feedback system devised constitutes a logical process. The experiments clearly demonstrated that the amputee who took part in the tests immediately accommodated to the system. He showed greater assurance in gripping and above all clearly improved function.

To conclude, I should like to add that though this is an experimental project, the practical research has clearly shown that the functional possibilities in an artificial hand can be enormously increased with this system.

We are perfectly aware that this is only the beginning of the practical introduction of a system of information feedback, but it is certain that progress in the field of prostheses for the upper limb will depend upon the development of such a system.

## BIBLIOGRAPHY

BECKER, TH. W., DURING, J. and HERTOG, A. den (1967). Artificial touch in a hand prosthesis. *Med. and Biol. Engng.* **5**, 47–49.

HÄGG, G. and SPETS, K. (1973). Sven Project I electrically controlled hand prosthesis. FOA2 Report A 2575–H5.

KATO, I., YAMAKAWA, S., ICHIKAWA, K. and SANO, M. (1969). Multifunctional myoelectric hand prosthesis with pressure sensory feedback system —Waseda Hand 4P. 3rd International Symposium, Dubrovnik.

ROESLER, H. (1967). Ein Beispiel für bioelektrische Steuerung von Prothesen under Orthesen oberer Extremitäten durch Codierung. *Medizinische Technik*, **87**, 97–99.

SELL, G., SCHAUF, G., DZIEKAN, I. and GERLACH, CH. (1970). Neuroelektronische Ansteuerungsmöglichkeiten von Prothesen. *Medizinische Technik*, **90**, 211–214.

SOERJANTO, R. (1971). On the application of the myoelectric hand prosthesis in the Netherlands. Medisch-Fysisch Instituut, Utrecht.

SUEDA, O. and TAMURA, H. (1969). Sensory feedback device for the artificial arm. VIII, ICMBE, Chicago, U.S.A.