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TRENDS IN ASSISTIVE DEVICES FOR UPPER AND LOWER EXTREMITIES

R. Tomović

P. Rabishong

Abstract

Acceptance of advanced assistive devices in field conditions is still very low. Reasons for this unsatisfactory situation are analysed. Explanation is found in the complexity of man-machine inter-action, technological as well as socio-medical factors.

Introduction

It is interesting to look back at the period which elapsed between the First and the Fifth Conferences on External Control of Human Extremities with an attempt to determine the main lines of development of assistive devices. Although the period is not too long it is still large enough to give an insight in the past and future trends in this area.

First applications of electronics and control engineering to assistive devices, which started in sixties, have created a lot of enthusiasm and hopes for essential improvements of prostheses and orthoses. New hardware was produced all over the world followed frequently with great promises. Unfortunately, as we know it today, most of the great hopes for radical improvements of assistive devices by mere application of electronics and computers have failed. There were good reasons for this to happen and we shall try to point out to them.

It is easy to state that rehabilitation engineering is a multidisciplinary effort but it is not straightforward to apply advanced technology in an area which deals with handicapped persons. In our opinion following important problems must be first solved before advanced technology will be used to a larger extent in rehabilitation. Speaking broadly, the problems may be divided into following three categories: man-machine interface, modular design, socio-medical factors.

Man-machine interface

Active prosthesis and orthoses of human extremities present extremely difficult man-machine interface problems. The patient interacts with the assistive device in four different ways: energy exchange, transfer of mechanical forces, control system, sensory feedback. It is hard to say which way of interaction is more important to the patient but there is enough evidence now that advanced assistive devices are frequently rejected because they do not meet complex interface requirements. The more we offer to the patient, the more the man-machine interaction must be richer.

Energy supply affects the man-machine interaction in two basic ways. First of all, it sets a limit to patients autonomy from external sources. On the other hand, the choice of energy supply (hydraulic, pneumatic, electric) determines the nature of actuators. It must be pointed out that in any activity of considerable effort electrical actuators hardly meet the requirements of size and dynamics. One can expect that future advances in energy storage devices and actuators will meet the requirements needed for successful application of externally powered orthoses and prostheses.

Active assistive device implies transfer of forces to the body of the patient. Unique feature of this interface problem lies in the fact that the forces are transferred to the body at the contact surfaces where soft, shape varying, sensitive tissue meets rigid, geometric forms of engineering. Even if by suitable choice of materials the assistive device may be fitted to the patient, the problem of adaptation to changing living forms due to ageing, illness and weight changes still remains.

An interesting attempt to solve this interface problem in a new way, takes advantages of soft suits.The idea is based on dressing the patient's body into a soft suit which fits tightly man's anatomy. In this way external forces are distributed over large areas of the patients body. On the other hand, the rehabilitation device can be prepared in such a way as to fit man's anatomy with all the advantages of tailoring normal suits. The research along these lines in orthotics and prosthetics is only beginning and it remains to be seen if force transfer can be made thrrough contact-surfaces where biological and flexible artificial tissues meet.

Man-machine interaction at the control level is also very complex. Human control of motor activities is a multi-level system. Therefore, the external control must be also designed in the same way in order to fit fuman needs and optimization criteria. Another difficulty is due to the fact that the language of mathematics and computers is not suited for patient's control of artificial limbs.

The basic problem in external control of human extremities is now much better understood. Multilevel systems for assistive devices which take into account human control criteria, for instance sinergy, have been proposed and tested. The languages of logical control are also under development. Due to their nonnumerical nature they allow for a more natural coupling of external and internal control. Full advantages of these approaches should become evident with the use of new complex assistive devices.

Sensory feedback is an essential part of all our motor activities. Complex assistive devices without sensory feedback will be hardly accepted by the patient. In the past period the research in this area was not given full attention. In order to solve this problem the difficult interface problems must be solved. Completely new types of transducers must be developed which can generate information of the same kind as produced by proprioceptive and exteroceptive sensors in the man. Such bionic transducers are still lacking.

Even if the measuring signals are available, the problem of sensory feedback is still far from being solved. Visual or cutaneous channels are very inappropriate feedback paths for the propprioceptive and exteoceptive signals since they have their own tasks in the over-all functioning of the living system. The natural feedback path for sensory signals are corresponding spots in neural networks but practical difficulties in the application of this solution are enormous. First reports in this direction are available so that advances can be expected in the future.

Modular design

The great disadvantage of the existing electronic artificial limbs from the engineering point of view is the way how they are designed and produced. As the situation stands now, each different active prosthetic and orthotic device is a piece of hardware produced almost independently of other equipment of similar kind. What this means in practice is not difficult to judge. Small production series, lack of adequate maintenance, expensive products are the general features of electronic artificial limbs.

As known, human extremities function in a "modular" way. The basic motor unit is the joint which is repeated in one way or the other in the over-all function of arms and legs. This basic fact could be the starting point for modular design of artificial limbs. The corresponding hardware should consist of modular motor units which, in the case of orthotics, could be attached to the joints out of function.

Modular approach, although simple in concept, is not easy to implement in the production of artificial limbs. The attachement of the external motor units to the body and the transfer of forces are very difficult problems due to the previously mentioned fact that engineering structures must be adjusted to biological tissues. However, with due engineering effort it is not unrealistic to imagine orthotic and prosthetic structures to which modular active units can be attached as needed. The principle of soft suit is perhaps one way of solving the problem of modular design, especially for lower extremities. Rigid structures serving the same purpose are also within the reality of modern technology.

Successful modular design implies modular control system as well. This is another challenging problem for the control theory. The problem in rehabilitation engineering is even more difficult because the man-machine interface is of hierarchical nature. Very different approaches may be conceived whose final value one can determine only by complex clinical evaluation. Let it be mentioned that in conjunction with the design of motorized soft suit a new artificial language is under development which is based on modular control concept. Starting point for this modular control system is found in the theory of logical control of locomotion. Final aim is to synthesise the control system for any type of motor deficiencies of lower extremities using the same special purpose computer language.

By concluding this section one can state that the modular approach to the design of artificial limbs is feasible as a new multidisciplinary research trend. If successful, it would bring with it all the advantages of mass production of which rehabilitation engineering has been so far deprived.

Socio-medical factors

These factors are adding new difficulties for succesful acceptance of assistive devices. There is more often than not a linguistic barrier between the medical world and the technological world, and it is essential to establish free and understandable communication between the engineer and the medical doctor.

Moreover, the social problem of the handicapped persons is not only a statistical problem. It is not sufficient to know the number of handicapped persons per category in the world,which is in itself difficult enough, to resolve the problem once and for all. Evidently, statistical knowledge constitutes the focal point for the agencies involved in health care who can then properly react. However, each handicapped man is a person with his particular psycological and social components which makes the acceptance of assistive devices extremely complex. To start with, the patient's needs must be exactly defined in order to apply technological research to the field of assistive devices. Technology must be adjusted to the patient's needs and not the patient to the possibilities of technology.

There are other difficult constraints that make the rejection of assistive devices quite understandable. Certain devices, such as the hand prosthesis, which is permanently observed by the patient and other people, must have sufficient esthetic qualities to lend it a normal aspect so that the defect can be forgotten. The noise of electrical motors in protheses is another example of the importance of technological and medical factors. From the point of view of engineering, the noise of motors is secondary, but for the patient it is a nuisance that he scarcely tolerates. Difficulties of control and inadequate integration of the apparatus in the nervous system increase the patient's fatigue and make the biological system slave of the artificial system. In such conditions there is high probability of rejecting the assistive device. This is the case of the upper limb amputees. Two situations are very different: the unilateral amputee can do almost everything with his normal hand and therefore the prosthesis brings him little help: the bilateral amputee has nothing and the prosthesis sould restore the maximum of functions.

It is evident that cost of health care, in a country where medecine services are free, is considerable. This brings about a choice in order to establish priorities in the way how the funds are spent. For this reason, close interaction between all interested groups must be established in order to develop useful devices. Laboratory prototype provide very often much help to the research workers but little to the patients.

We have mentioned main factors affecting successful acceptance of advanced assistive devices. As seen, the problem is very complex indeed. Although still many barriers must be overcome before handicapped persons will take full aavantage of advances in this area, the mere fact that the constraints are today much better understood than ten years ago must not be underestimated.

References

The AMOLL Project

P.Rabischong, J.P.Bel, J.Hill, E.Peruchon, M.Simeon, J.Screve, Unité de Recherches Biomécaniques de L'INSERM- Montpellier-France.
M.Pelegrin, A Benzaken, Ecole Nationale Supérieure de L'Aéronautique et de l'Espace - Toulouse.
R.Tomović, M.lazarević, S.Jauković, Laboratoire d'Electrotechnique, Faculté des Sciences, Belgrade, Yugoslavia.
A.Clot, Laboratoire d'Automatique et d'Analyse des Systemes, Toulouse, France.

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