EXTERNAL CONTROL OF UPPER EXTREMITIES

A GENERAL LOOK AT PREHENSION IN THE LIGHT OF EXTERNAL POWER

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It is always valuable to stop from time to time in the middle of any specialist activity and take a more general look at what one is doing. It is also useful to be able to place other people's work in relation to one's own. It seems that it might, therefore, be valuable at the beginning of a meeting of specialists if we considered the over-all pattern in which the various activities of members might be considered to lie.

There are many aspects of prehension, ranging from the clinical and biological right through to the control and engineering factors. The main points in any discussion of this field would seem to me to be the following:

1. The total arm-hand action can be divided into wrist positioning, which is brought by arm action, and prehension, which we believe in Britain also includes the attitude of the terminal device in space and its angle of incidence to the object to be grasped, and so includes wrist turning and angulation. Thus, arm movements and hand movements, so to speak, meet at the wrist; the arm is considered as a device for moving the wrist in space, the wrist and hand together control the plane through which the fingers or hook blades move as they come towards each other in grasping the object. This grasping cannot be considered apart from the attitude of the whole terminal device in relation to the object, since there is at the present moment very little likelihood of any terminal device being built and controlled which is capable of manipulating the object in its grasp.

2. The type of grip varies with the action desired. As a result of experiments using objects coated with ink, Napier (1956) concluded that there were two main types of grip, which he called the precision grip and the power grip. He found that when accuracy of positioning was called for, the object was held between some or all of the finger tips and the opposing thumb. When power requirements predominate, the object is held in a clamp powered by the partly flexed fingers and the palm, with the thumb exerting its pressure approximately in the

plane of the palm. At the same time the wrist is ulnar-flexed, so that the axis of the object tends more to lie in the long axis of the forearm.

3. There are though several other ways of looking at the problem of prehension from an engineering viewpoint, and with these considerations in mind, we look forward to discussions on:

a) finger or hook blade shape, finger or hook blade action, and hand action including the palm.

b) wrist rotation and the angle of inclination of the wrist to the long axis of the forearm.

There are, as members are aware, many different shapes of hook and several different artificial hands. Members are also aware that none of these is anywhere near as good as even the most inefficient human hand, and if this problem is to be resolved a great deal more work must be done on this important aspect of prehension.

4. These points are meaningless, however, unless we consider them in the light of the tasks desired. Here it is worth mentioning that a group based on the Centre for Muscle Substitutes at Hendon is preparing a list of daily tasks required of everyone, with a grading as to their importance in the activities of independent daily living. For if any scientific approach at all is to be made, there should at least be a preliminary attempt to list what the terminal device (the hand or hook) has to do, so that some form of specification can be worked out and the problem can be tackled in engineering terms.

5. The performance required of the grip for use with the chosen activities of daily living should be defined; at present the performance of the British myoelectric system which will be discussed by Dr. Bottomley is 0.8 second time from full opening to full closing with a force of 9 lbs. This is, of course, a proportional system and longer time and less grip can be employed at the will of the wearer. Note that we have not discussed the angular velocity of the finger or thumb action, and clearly the closing time depends on the degree of separation of the fingers and thumb at the start point. This is just one example of the numerous ways in which the variables interract procluding, at this stage, a total specification, something towards which steady painstaking work will have to be done.

6. The drive method chosen, gas or electricity, with mechanical or fluid transmission, is of considerable importance since it has an effect on many other factors. There are so many different ways in which these methods can be employed that a further discussion by me at this juncture would be somewhat pointless. Doubtless, those who are specialising in this field will have further things to say about it.

7. The control method, allied to the nature of what Hall calls the feedout, may comprise either a trigger or lever system (movement, or a muscle bulge) or a myoelectric system of which there are several types. We look forward to hearing from speakers from Russia, Holland and the United Kingdom in particular on these aspects.

8. Finally, we come to the control system itself with the possibility of open-loop velocity or force controls, or closed-loop velocity and/or force servosystems, with a position servosystem for the wrist. We

must not also forget that there may be sub-servosystems controlling the way the hand closes as shown so well in the Belgrade hand. From work by Ring at Cambridge and by Bates and Livingstone at Leicester and Southampton, hands may in time be provided with a sub-servo-system in which the object is automatically grasped just above the slip point. This idea of a sub-servo, so usefully introduced by Professor Tomović at the first IFAC Conference in Moscow and subsequently at Opatija, may well make much of what I have said somewhat obsolete, inasmuch as the analysis of hand action in this sort of way may well be a very much more realistic approach than the apparently straightforward method that I have used.

References

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