AUTOMATIC CONTROL OF WRIST ROTATION IN ARTIFICIAL ARM

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Nearly all artificial arms are supplied with a rotational wrist coupling between the forearm and the terminal device. This is most often a friction or ratchet unit which allows the user to pre-position the hand or hook for various tasks. While this is an adequate solution in many instances, observation of amputees at work and play indicates that it is far from ideal.

Most amputees, most of the time, use gross upper body motion to rotate the hand or hook into the plane of work. This is most striking in the case of the unilateral below elbow wearer who has the greatest capability to use the friction wrist and yet, does not. This does not appear to reflect a lack of awareness or a failure of training; it is simply faster, easier and, if you will, more natural to use compensatory motion of other joints than it is to interrupt an activity to reposition the terminal device.

Individuals using this technique are undeniably functional; what they lack is a quality that has been called "dynamic cosmesis". Statically their artificial arm looks like an arm; in use it looks like the sometimes awkward tool that it is. We live in a culture where people are judged by their physical appearance so this is not a trivial matter.

Electric wrist rotators which have been available for many years from Otto Bock Orthopaedic Industries, Inc., and more recently, Variety Ability Systems, Inc. (VASI) offer a potential solution to the problem of dynamic cosmesis. They certainly obviate the need for manually positioning the terminal device but they have not been well integrated into the artificial arm from a control systems standpoint. There are three general ways to control an electric wrist rotator: 1) Switches of various kinds to directly control the motor, 2) Mode switching schemes to transfer control temporarily from some other, default, device and 3) Multifunction control systems such as the Otto Bock 13E103 4-Channel Control.

Direct switch control of the wrist motor is the simplest but least integrated method. This clearly relegates the wrist motor rotator to "accessory" status. Mode switching is an improvement in integration but, depending on how it is implemented, may leave the wearer unsure of which mode is currently selected. The highest level of integration is achieved by the multifunction systems but they still require the wearer to do something "special" to engage the wrist motor. It would be surprising then if even wearers of these sophisticated systems did not, much of the time, use gross upper body motions to position the terminal device.

A more integrated approach to controlling the wrist motor would be to place a sensor in the forearm to detect forearm rotation and, past some threshold, engage the wrist motor in the desired direction. The hand or hook would then be rotated into the plane of work in response to minor, as opposed to, gross upper body motion. The sensor would also need to detect the angle of the forearm with respect to the horizontal. Wrist rotation is certainly not desired at full elbow extension (the spinning suitcase syndrome) and probably not at extreme flexion angles so the sensor must limit the action of the control system to a range of angles about the horizontal.

There are a number of ways such a sensor could be constructed. A metal ball rolling in a curved track with electrical contacts at either end could sense forearm rotation; the track could be shaped to capture the ball at extreme flexion/extension angles. A pendulum arrangement could also be used. Both of these approaches involve mechanical designs which, while simple in concept, could prove costly in execution.

A sensor based on precision tilt switches is the presently preferred approach. These switches operate on the same principle as the more familiar glass bulb mercury switches but are smaller and more rugged. Physically, the switch may be visualized as a shallow bowl with a pair of contacts in the center and a ball of mercury free to roll about in the bowl. When the bowl is vertical, the ball bridges the contacts and the switch is closed. If the bowl is rotated slightly (+/ -15 degrees) in the plane of the contacts, the ball will roll to one side and open the switch. The geometry of the device is such that it will tolerate more rotation transverse to the plane of the contacts (+/ -35 degrees) but, ultimately, the ball winds up against the rim of the bowl and no contact is possible.

Two of these switches arranged at an angle to the vertical can perform all of the functions required of the sensor, i.e. to tell the wrist motor when and in which direction to run and to prevent it from running at inappropriate flexion/extension angles. Only a modest amount of electronics is required to interface the switches to the motor.

Packaging would be similar to but simpler than the Otto Bock 4-Channel control; since, in this case, the hand and wrist control are independent and fewer interconnections are required. As with the 4-Channel, a manual on/off switch would be provided. Practical considerations dictate that the hardware should be installed and serviced through the wrist, no significant modification to the prosthetic art is envisioned. Adjustment to the wearer's "local vertical" would be made through a small hole or slot in the forearm.

The system described is certainly applicable up the above elbow level. Higher levels are more problematic but, to the extent that they use trunk motion to position the terminal device, it may be useful here as well. More generally, the control technique could be applied to other tasks. If the sensor were placed in the humeral section of an artificial arm, it would respond to the angular position of the humerus and could be used to directly control an electric elbow. Alternatively, it could provide the input to many of the mode switching schemes found in the more complex systems such as the Boston Elbow II.

One other potential application is worthy of mention. If the sensor were placed distal to the point of forearm rotation, the effect would be to stabilize the terminal device with respect to the external environment. Such a self levelling terminal device might be useful in a feeding arm.