WORKING NOTE AC66

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ON DISABLED PEOPLE USING ROBOTS

BACKGROUND.

(I started writing this note in late 1987, in connection with a project which failed to materialise. I am finishing it now more to clear up unfinished business than from the access of any sudden new insight; but I hope it will prove useful again in the future.)

My intention in this note is to present an attempt at careful analysis of the requirements of robotic systems designed to be used by people with disabilities. I shall refer to the systems as *robots* in the interests of brevity, and it will become clear that the logic of the situation may well force the complexity of the system up to a point at which this description is appropriate; but I should remark that for the moment at least the term should be understood to include quite humble manipulators with little in the way of intelligent control.

There are two sorts of problem connected with this topic. First, the person controlling the device may have physical difficulties in exercising control. A number of physical conditions impair a person's motor skills, and may prevent the smooth and controlled hand movements universally assumed in designing manual control systems. Second, the person may have perceptual difficulties in observing where the device is, so that the normal feedback loop through the device's operator is broken. This may be a consequence of visual problems, or of total or partial immobility. The two sorts of problem may coexist, as in the case of someone confined to bed because of severe motor disability.

The problem is, then, that many people who could benefit from using a robot because of disability are hindered by that very disability from using a robot assistant in an ordinary way. In other words, if they were fully mobile and coordinated, they wouldn't need robots; but disabilities which hinder their mobility are equally likely to hinder their ability to control a robot. Is it possible to provide systems which will make it possible for people to benefit from robots while guarding against the obvious dangers attendant on powered, perhaps mobile, machines with an obvious destructive potential, and perhaps roving outside their operators' immediate field of perception ?

One other point should be made before continuing. The object of the exercise is not to automate everything within sight, nor is it to produce some commodity at the cheapest possible price. It is to help someone to realise the potential of abilities which might otherwise never be expressed. This is not just a philosphical point; it has direct practical application in the design of the system. We do not need a completely automatic system if its owner is able to control it; and, in general, the person using a system should at least have the choice of taking control at any point where it is possible. To automate functions which can be performed manually without permitting the person to intervene is not acceptable.

SOME DIFFICULTIES IN CONTROL.

Thinking in particular of control by hand-operated switches (though there are analogous comments to make in other cases), here are some possibilities :

- full mobility and dexterity - no problem.
- limited mobility : fine and coarse control must be distinguished.
- gross movements only : as above, but different scale - smooth out small-scale fluctuations.
- jerky movements : interpolate, smoothing.
- involuntary jerky movements : ignore short-term fluctuations.

As a crude approximation, I can sum up these observations by describing the control in terms of communication through a narrow and noisy channel. The problems are to extract the signal from a lot of noise, and to engineer the information content of the messages so that the limited bandwidth is used to maximum advantage.

USEFUL CONTROL FUNCTIONS.

What sort of control functions do we need to satisfy these requirements ? There are two parts to the answer, one related to the noisy signal and the other to the limited channel width, which reduces the maximum attainable rate of transmitting control information.

To cope with the noisy signal, we need trainable and effective pattern recognition procedures. They must be trainable, because every person using the system is likely to have different characteristics, so no universal set of patterns is likely to be acceptable. They must be effective to maximise the probability that a signal will be recognised on first transmission, reducing the need for retransmission.

To take best advantage of the limited speed of communications, we need to avoid unnecessary transmission of messages. For example, we may provide facilities to describe the robot's environment before normal use begins, so that instructions to move to some location need not always include details of how to avoid obstacles on the way. Similarly, we may provide means of saving and labelling points so that the robot can be directed to go there again with some comparatively brief instruction. (This is not directly related to the comon technique of teaching a robot to perform a task by leading it through; one would wish the device to go to the labelled position from wherever it happened to be before the instruction, for preference avoiding obstacles on the way.) An extension of the same idea is to save details of objects in the field of operation which may appear in different orientations, so that a couple of coordinates will identify the whole object.

As well as this approach, it may be worth exploring possibilities for increasing the bandwidth of the communications channel by providing addition sensors which the person can operate.

FEEDBACK.

It is clear from the discussion so far that the control signals given by the person using the robot will not be executed uncritically. They'll be interpreted somehow, and they may be interpreted wrongly - so to get adequate control we need some feedback to the person of what the computer has decided to do, so that the computer's interpretation can be checked. Ideally, we need the feedback *before* the robot performs the action; there is little point in telling the operator about the accident after the event.

In some cases, it may be sufficient simply to watch the robot. This is adequate provided that the robot is moving sufficiently slowly for the person controlling it to extrapolate its motion an adequate interval into the future, and provided also that the person can see what's happening and can respond quickly enough to cope with any trouble as it arises; but this may not always be the case.

If the robot's speed creates difficulties, it is presumably reasonably straightforward in most circumstances to impose an upper limit which will slow it down to a manageable level. It is possible to imagine cases where that would not be possible : a robot concerned with balancing some object, or tossing a pancake, cannot necessarily be slowed down without destroying its function; the examples may be frivolous, but they amount to an existence proof, and serious examples cannot be ruled out.

It is nevertheless perhaps more likely that the person controlling the device should be unable to see what it is doing, either because of immobility or limited vision. In the case of immobility, it may be sufficient to provide a television picture of the robot's areas of activity which are not directly accessible to the person, either by means of one or more stationary cameras, or from a camera mounted on the robot. Cases of total or partial blindness present much more severe problems for which even partial solutions are not easy to identify.

Limited speed of response may also give rise to difficulties. One "panic mode" answer to this problem is to provide a single fast interrupt which stops everything - probably such a facility should always be provided as a matter of course anyway. This is less than adequate for normal use, though, and the only other channel is to show the person what the robot is going to do well before it happens, thus allowing additional time for reaction. This could most easily be displayed on a diagram of the "world", showing the robot's current position and state and the plans for future change as far as they were known at the time. An intriguing, but much more difficult, possibility would be to display the future position of the robot on an actual television picture showing the current situation, though some practice would probably be needed to interpret such a display.

Simpler approaches may be possible : for example, it may be adequate to present in some way just the current position and speed of the robot, relying on the person's knowledge of the space to fill in the details. Information of this sort can be presented compatratively cheaply, and may even be presented audibly, thereby offering a potential solution to the blind person's problem. Experiment alone can answer questions like these.

SPEED.

It is clearly a good thing to have instructions to the robot obeyed as speedily as possible, but speed is not an entirely unmixed blessing. One question is how to decide in the degree of confidence with which one should follow instructions instantly. The instructions are noisy, and may be misinterpreted; how serious would it be to set out in the wrong direction ? It depends to some extent on the environment - if it isn't cluttered, then a bit of waving about doesn't matter a lot, but the control has to "sharpen" as we approach more critical areas.

Perhaps ideally the person using the system should be able to control the level of "sharpness" - but that means yet another thing to control, and more demands on the already limited information channel. Is it possible adequately to control this parameter automatically ? How can the robot tell when it is approaching a position which is in some sense tricky ? Part of the answer may be in terms of the closeness of other objects, which can be gauged by proximity sensors - but more senses means more expenses, and one would not wish to add undue complexity if it were unwarranted.

SAFETY.

This particular concern is closely related to the system's safety. Whatever the rest of the design turns out like, it is presumably a primary requirement that the system should be safe. This is a matter which should no more be left to the discretion of a disabled operator than it would be to an able-bodied person. It is therefore not impossible that we would wish to equip such a robot with something like proximity sensors anyway.

What sort of safety precautions are needed ? We must be assured that the robot, as well as anything connected with it (its burden, or any umbilical cords or power leads), does not collide with any other object; that it does not fall over; that it does not become immobile (perhaps by trying to negotiate a ditch where it can become "bridged"; that it avoids heat (fires, stoves, etc.); that it does not stray outside its permitted area; that its batteries, if any, don't run low; and so on.