Actes du colloque
Tome I
HANDITEC décembre 1989
Les Technologies au service des personnes handicapées Moteurs

THE CURRENT STATE OF REHABILITATION ROBOTICS

R. D. JACKSON, R. G. GOSINE and W S. HARWIN
University of Cambridge,
Department of Engineering,
Trumpington Street,
Cambridge CB2 1 PZ
Telephone : Cambridge (223) 332690

ABSTRACT

The paper lists sixteen current projects in rehabilitation robotics which have been described in recent publications and classifies them under the three headings of workstation, wheelchair-mounted and autonomous mobile. The projects are further sub-divided into those mainly dependent on robot or on manipulator control methods. The problems associated with the user interface are noted. The current state of the robot hardware and software is discussed with reference to these projects and the inherent cost limitations. The main features required in a highlevel control language for programming an interactive robot workstation are identified.

RESUME

Cette communication passe en revue seize projets de recherches en cours dans la domaine des systèmes robotisés d'aide aux handicapés, selon la description- qu'on en fait dans trois publications récentes. Elle les regroupe selon trois catégories : station de travail, embarqué surfauteuil électrique, et mobile autonome. Ces catégories sont divisées à leur tour selon que les systèmes dépendent surtout de méthodes de contrôle robotique ou de manipulateur. On met en relief les problèmes qui découlent de l'interface avec l'utilisateur. Suit une discussion sur l'état actuel du hardware et du software relatif à ces projets, ainsi que les limitations inhérentes du prix. On identifie les caractéristiques du puissant langage de contrôle nécessaire à la programmation d'une station de travail robotique interactif.

KEY WORDS

Rehabilitation robotics, programming languages, control.

INTRODUCTION

A list of representative current projects in rehabilitation robotics, taken from some recent publications, is given in Table 1. The majority of these projects include clinical trials of some form. The publication sources are RESNA 1989 [1], the tnd International Workshop on Robots in Medicine and Healthcare [2] and the Cambridge Workshop on Rehabilitation Robotics in the UK [3]. The projects are classified in Table 1 under the broad headings of WORKSTATION, WHEELCHAIRMOUNTED and AUTONOMOUS MOBILE, and further sub-divided into those that rely predominantly on ROBOT or

MANIPULATOR control methods. Most of these projects use commercially available robots as their basis ; for example, the Puma or the UMI RTX. In some, notably Manus but including the work at BIME, the robot has been designed specifï cally for the project.

The tasks for which these systems have been designed can be divided into two categories, with some overlap. First, assistance within a general, mainly domestic, environment and second, assistance within an office, workshop or classroom environment. Environments in the second category are likely to be more structured and the tasks more clearly defined than those in the first. Two of the few systems now available commercially, the PRAB and Regenesis systems, are aimed at officebased tasks. For both categories a vital factor for succèss is the acceptability of the system to the user.

From the projects in Table 1 and earlier projects, a considerable body of data and expertise on design and use of robots in rehabilitation has been, and is being, assembled. Research is also being directed at the screening of potential candidates for robotic devices so that user and system are properly matched [4]. A person for whom a robotic aid is likely to be valuable will have some idea of what the robot should be able to do. Before the robot can become a useful aid to that person, he or she must build, adapt or change a cognitive model of robot behaviour so that he or she can make safe and usable predictions about the behaviour and capabilities of the robot. A learning process is essential and is likely to consist of observation and experiment on tie robot and its controls and the use of the results to update the behavioural model [5].

Two common limitations to work in the field of rehabilitation robotics have been noted [6]. First there is often little communication between research projects and second there are frequent problems of continuity in projects when equipment is upgraded or robots are changed. This paper discusses the current state of the hardware and software aspects of rehabilitation robotics with particular emphasis on the development of standards for software.

ROBOT HARDWARE

Six degrees of freedom at the end-effector is almost essential if a mechanical arm is to have sufficient flexibility to carry out a useful range of tasks in the Relatively unstructured environment of most rehabilitation activity. For some applications with a restricted range of tasks, though, five (or fewer) degrees of freedom may be sufficient, resulting in a simpler device. Mechanism size is limited by the need to achieve useful carrying capacity within the human scale. Similarly, joint speeds must be sufficiently high to prevent the user becoming frustrated, but not too high for safety.

The design of the mechanical linkages and joint drives and the construction of a limited number of robotic devices satisfying these constraints is feasible but expensive. So for projects in which the task definition can be largely satisfied by an existing device with a wider market, there is strong financial pressure to use it even though it may introduce further restrictions on available tasks. Hence the common use in rehabilitation projects of the relatively low-cost **UMI RTX** robot arm which also finds uses in testing, light assembly tasks and education.

There are also some commercially available mobile robot platforms which are likely to stimulate further developments in this field.

Hardware development costs may be offset by a link to a similar technology which already has a strong commercial base. The UK firm Inventaid, working in cooperation with the UK Royal National Orthopaedic Hospital, Stanmore, is developing a wheelchair-mounted manipulator arm using light-weight, low-cost pneumatic actuators. These patented air muscles also power the animated models developed by the firm Spitting Image Productions which is the parent company of Inventaid.

A number of researchers have proposed methods by which potential users can develop an internal model of the robot and its capabilities at the design stage and thus limit development costs. These methods range from the use of full-scale, but non-working, models, through small-scale models of the robot and its associated worktable to the use of animated views prepared using a computer-aided design package [7].

Perhaps the most important design criterion is that of achieving safe operation consistent with functionality. The problem of safety is becoming increasingly important for interactive robot operation both in workplace and domestic settings. The aesthetic aspects of the design are also very important, particularly for a robot which is to operate in a domestic setting.

SOFTWARE

Whereas the standardisation of the hardware of robotic arms may be possible with some form of modular approach, it is unlikely to be a feasible option in the near future. The standardisation of software, however, merits careful and wide consideration. While some of the comments in this section do apply at the joint servo-control software level, they are mainly addressed to the design of software which is to provide interactive control of a workstation robot and its end-effector. Computing hardware is rapidly changing, so the software should be computer-independent and it should be able to control a range of robots.

For these reasons standardisation is both possible and desirable.

Four main features of a rehabillitation robot language can be identified

(1) It must be easily applied to a wide range of rehabilitation applications.

As the current status of rehabilitation robotics is very concerned with the idencification and evaluation of potential tasks, it is very important to consider a language which can be applied to a wide range of tasks.

(2) It must support compact task specifications in a high-level language.

The level of the language chosen is critical. For example, an instruction of the form "make a drink" assumes that the language structure contains knowledge of the details of drink making. Since the system is intended to be always under the control of an intelligent user, instructions at a level as high as this are unnecessary. It is clear, though, that control of individual robot joints is too low a level for user satisfaction. Thus a balance must be found between the machine and human intelligence to make the user as independent as possible within the technological limitations of the robot system.

(3) It must facilitate an interactive approach to robot programming and control.

An interactive system is necessary for the programmer during the development and modification of programs. Similarly, an interactive system makes possible a dialogue between the user, who may also be the programmer, and the system.

(4) It must be capable of being extended and modified to incorporate subsequent developments.

This requirement also arises from the current state of rehabilitation robotics. The language must accommodate computing hardware changes and must link to a variety of robot systems.

The language CURL [8] represents an attempt to meet these requi**rements within an interpreted language.** The basic structure as shown in Figure 1 is divided into three levels. At the application level the programmer and user interact with the system through application programs, keyboard or voice commands, command menus and direct control of the robot.

At the interpreter level, the application level instructions are decomposed into a series of actions which achieve the desired result. A database containing a description of objects in the robots environment is created and updated as a result of the interpreters action.

The lowest level is the device level which accepts commands from the interpreter and carries out the necessary manipulation. The hierarchical structure makes it possible for the lânguage to incorporate a wide range Of input and output devices.

CONCLUSIONS

Despite efforts over many countries and many years, it seems that there is still some distance to go before robot systems become widely available to assist severely physically disabled users. It is encouraging, however, to note that surveys of users in clinical trials associated with a number of research projects [9, 10, 11] have indicated strong support for the use of robots in office, domestic and classroom environments.

Growing interest in thé development of domestic robots' will increase awareness of thé capabilities and limitations of robots on thé human scale, although human interaction is not intended to be a feature of many of thé applications proposed for domestic robots. Similarly, increasing interest in alternative technologies such thé smart house [12] and complex environmental controls will stimulate careful comparisons withrobotic assistance.

Wider awareness of common problems and possible solutions should increase thé rate at which thé work leading to a range of successful robotic systems is carried out.

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Figure 1 : Structure of the CURL programming language