ROBOTIC APPLICATIONS TO LIFE SUPPORT SYSTEMS

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Keywords: robot control, autonomous systems, navigation, visual servoing, agent oriented software design, programming by demonstration

Contents

Summary

This article presents the current state of research and development in the emerging field of robotic applications to life support systems, with a focus on rehabilitation robots. These kinds of service robots are designed for use by disabled people who until now depended on personal assistance throughout the day. The goal of the research and development in this area is to return to the disabled user some of the autonomy lost because of disabilities. This type of robot is under progressive research, and new and promising results can be expected in the near future. Transfer of these results into consumer products is a still open and important task requiring more attention and support by the research community as well as by institutions supporting the disabled.

1. Introduction

Rehabilitation robots are support and personal assistance tools for handicapped people. They support the user in daily life as well as in professional life, compensate for disabled capabilities, and allow the user a more independent life and a greater autonomy. The manner and level of seriousness of the handicap determine the equipment necessary for the rehabilitation system. Handicaps should be compensated, but the user should continue to use and train all available capabilities. In this article, technical systems for the support of people with paraplegy (the lower limbs are paralyzed) and tetraplegy (lower and upper limbs are paralyzed) are considered. These systems may also support people with other impairments but with a similar clinical picture like multiple sclerosis, spasticity, and cerebral palsy. Technical support systems for these people normally consist of:

- a wheelchair
- an additional manipulator coupled to the wheelchair in case of a user with tetraplegy
- a user and command interface.

All parts have to be adapted to the disability of the person who will use the rehabilitation robot. In the following sections we will give an introduction to the available user interfaces and then discuss hardware, software, and control solutions to build powerful, reliable, and affordable systems. A main criterion in research and development of assistive systems is the immediate usefulness for the user.

2. Basic Technologies

2.1. Wheelchairs

The mobile basis for assistance systems is normally an electrically powered wheelchair, which usually is equipped with a manual control unit to command direction and speed. The user needs a minimal agility in hands or fingers to control the wheelchair. Although the disabled become experts with very high capabilities to execute difficult tasks, it is often necessary to support them in navigation and obstacle avoidance, particularly if maneuvering in a cluttered or crowded environment. Several research projects worldwide are investigating methods for autonomous behavior of the wheelchair. Figure 1 shows a power wheelchair which is already equipped with additional control elements.

Figure 1. Autonomous wheelchair MAID with ultrasonic sensors and laser scan unit

2.2. Manipulators

People with upper limb impairments need, in addition to the wheelchair, a manipulator to support them in manipulation tasks. The manipulator is mounted either to the wheelchair or to an independent mobile platform. Presently only one manipulator especially designed for assembly on a wheelchair is commercially available. Several other systems are designed for research only.

Most of the systems use six revolution joints, a design which is also used in most industrial robots. In rehabilitation robots it is necessary to pay great attention to construction variables such as weight, energy consumption, and security, because they play a much more important role than in industrial design.

Figure 2. Rehabilitation robot FRIEND I consisting of the manipulator MANUS mounted at a wheelchair

Figure 2 shows the manipulator MANUS® sold by Exact Dynamics, the Netherlands, mounted on a wheelchair. Other systems that may be used in future are being developed at various institutions worldwide. For more information see the web pages in the Bibliography.

2.3. User Interfaces

There is a wide range of command systems and user interfaces available designed for people with different disabilities.

Figure 3a. Breath expulsion

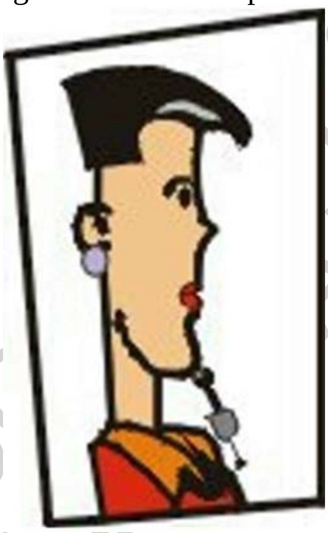

Figure 3b.Chin movement

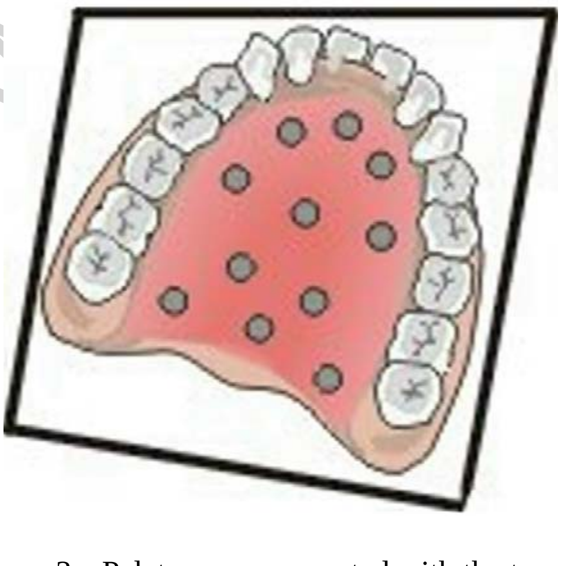

Figure 3c. Palate mouse operated with the tongue

The continuing development of new devices in the communication and electronic industry for several mass markets also influences the development of more specialized aids for the disabled. Environment controls via infrared or speech recognition are two typical examples.

Figure 3 shows three tactile command systems often used by tetraplegics to control their environment and the wheelchair. User interfaces are under continuous development, and even the measurement of electrical signals from the brain or the muscles may be used for the control of devices. Because it is very difficult to control a sophisticated aid like a rehabilitation robot with the usual commanding devices, it is necessary to support the user with an automation and control system that translates high-level user commands into specific control actions. This approach becomes especially important if we want to support the disabled in daily life situations such as eating, drinking, and so on.

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Tsafestas S.G. (ed.] (2001). Reinventing the wheelchair. *IEEE Robotics and Automation Magazine* **7**(1). [This special theme magazine gives an overview of the present state of rehabilitation robots.]

Weiss L.E et al. (1987). Dynamic sensor based control of robots via visual feedback. *IEEE Robotics and Automation* **3**(5), 404–417. [Basics on visual servoing.]

Web Links

Because of the rapid progress in this field some web addresses are given as a starting point for future search about the topics discussed above. The list is not complete but may be used as a reference.

Korean Advanced Institute of Science and Technology, Human friendly welfare robot system engineering research center, Prof. Dr. Bien. <http://hwrs.kaist.ac.kr/en/f_study.htm>

Vanderbilt University, Intelligent Robotics Lab, Prof. Dr. Kawamura. <http://eecs.vanderbilt.edu/CIS/IRL/>

Deutsche Forschungsgemeinschaft für Luft und Raumfahrt, Institute of Robotics and Mechatronics, Prof. Dr. Hirzinger. <http://www.robotic.dlr.de/>

Forschungszentrum Karlsruhe GmbH, Institut für Angewandte Informatik, Prof. Dr. Bretthauer. <http://www.iai.fzk.de/>

Universität Bremen, Institut für Automatisierungstechnik, Prof. Dr. Gräser <http://www.iat.uni-bremen.de/>

Technische Universität München, Lehrstuhl für Steuerungs- und Regelungstechnik, Prof. Dr. G. Schmidt. <http://www.lsr.e-technik.tu-muenchen.de/index.html>

Biographical Sketch

Prof. Dr. A. Gräser started his industrial career with Lippke Germany (now part of the Honeywell group), a leading manufacturer of process measurement and control systems for the pulp and paper industry. He was head of the control and software department and developed measurement and control algorithms especially for cross profile control.

From 1988 until 1994 he was Professor for Automation and Control with the University of Applied Sciences, Koblenz. Presently he is head of the Department of Plant Automation and Robotics at the Institute of Automation, University of Bremen.

The department consists of two research teams. One team works in the field of robotics and service robotics for the support of disabled and elderly people. The main research area is in vision feedback and algorithms for semi-autonomous control of mobile systems with robots. The other team does research work in several fields of plant automation. Important areas are also new sensor concepts in automation, such as micromechanical devices, vision systems for control of product quality, electric welding systems, augmented reality in welding, and the automation of logistic processes.

His interests are still connected with the pulp and paper industry. Since 1989 he has delivered courses about measurement and control for engineers in the pulp and paper industry as well as controller design for engineers in other industries.