INTEGRATING CONTROL OF MANUS AND WHEELCHAIR

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Abstract

A review is given of recent developments around the control of MANUS with the ADAPTICOL configuring method in conjunction with wheelchair control under the M3S environment.

Introduction

The MANUS manipulator was designed to be mounted on an electric wheelchair, with the two degrees of freedom of its a mobile base taken into account in the over-all design of the manipulator. Mounting MANUS on various wheel-chairs, which were not designed to integrate such a mechanical arm, posed many constraints on its mechanical design. In particular, it must be possible to position the arm at a place which is available on most wheelchairs without adding excessive width to the total system. From a mechanical design point of view, a cylindrical structure for the base of MANUS offered many advantages for a compact integration of its mechatronic system. Taking into account many other considerations, such as functionality of arm geometry, respecting the space occupied by the user, visibility of both the gripper and the environment for the user, safety, and avoiding the arm to be higher than the user, a position for the arm in front of the arm rest, as close as possible to the leg supports, was finally chosen as a best compromise. Although from the wheelchair point of view it remains a bothersome add-on, the functionality offered made it a worthwhile trade-off in many cases, at least for the some 40 users in the Netherlands, most of whom have an advanced neuromuscular disorder and are using MANUS at home.

From the beginning, it was foreseen that besides mechanical integration with the wheelchair, an integrated control of wheelchair and manipulator would also be a highly desirable feature for the target group of persons with very limited residual control functions. Since the control of the arm requires significant data processing power anyway, an additional output in the form of an I2C bus was included on the MANUS controller for possible wheelchair control in the future. In this way, the various control procedures developed for the control of the eight degrees of freedom of the manipulator could also be used to control both the additional two degrees of freedom of wheelchair mobility and secondary wheelchair functions in an integral way.

M3S interfacing standard

One problem with this approach is that for every wheelchair controller a specific interface must be realised. Since then, we have initiated a more generic approach to standard interfacing within the european TIDE program, leading to the M3S standard serial interfacing concept for the electric wheelchair environment (or more generally: for the AT environment). Within a number of european projects, earlier initiatives under ISO to define a standard wheelchair bus were further developed, taking into account the requirements of integrating a wide variety of other devices (like environmental control systems and MANUS) and recent developments related to the automotive industry in the form of the CAN bus. These projects, financed by the CEC, have made it possible to develop the M3S concept into a new ISO draft standard and demonstrate its potential by integrating devices from different origins in demonstration platforms, tested both by rehabilitation professionals and by end users.

MANUS was one of the end effectors included in the M3S projects, leading to an acceleration in the efforts of integrating its control with control of the wheelchair. On the one hand, input controls used for MANUS were elaborated to autonomous control inputs to the M3S bus, on the other hand, new input devices became available through the bus for the control of MANUS. Although this created potentially many new control possibilities for all of effector devices like wheelchair and MANUS, it also created new problems since the control procedures available or required for different effector devices are not necessarily the same and, moreover, vary as a function of the characteristics of the control input device.

ADAPTICOL

In the development of MANUS a compromise was made between an open architecture and standard field programmability of human-machine interaction (HMI), open to - not only technical - rehabilitation professionals. The different approaches of HMI for control of MANUS could then be cumulated and shared in widely accessible libraries.

To this end, a special "ADAPTICOL" configuring method (or language) was developed. It functions as an interpreter, with functions specific for processing of control inputs, both to control (gripper) movements in space and to select different modes in a web-like menu structure. Editors running on a PC allow the configurer to define the corresponding strings of functions and associated parameters. After downloading into the MANUS controller, the functions are successively interpreted and executed.

The ADAPTICOL package also includes an enhanced interactive teaching (Monitor) program, running on the PC to facilitate initial training or to communicate new features to both users and professionals. For each mode (field-programmable) information files may be displayed on screen, selectively activated by MANUS through an RS232 link.

Since MANUS is used primarily in an unstructured human environment, interactive end-point control of gripper movements by the user in telemanipulation mode was implemented first. Extension with movement programming capabilities is still awaiting the necessary funds to optimise implementation, in particular at he robot layer.

Keypad control

User interfaces consist of two elements: the user input controls and the control procedures that define the way these controls affect the behaviour of the system. Functionally, two types of controls are used: "discrete" or "switch" type controls and "proportional" controls, giving a continuously variable control command like a joystick. For historical and technical reasons, with MANUS most experience was gained with the first type in the form of a 4x4 matrix keypad. Although this was initially thought to be inferior to proportional control, it proved to be much more effective than expected. Proportional controls, with their ability to give a smooth multi-directional control of movements, at the same time may require more dexterity to master the necessary simultaneous control of multiple degrees of freedom. The selective control of different keys of a keypad seems to make lower demands both on the user's dexterity and on his mental load required to avoid unwanted interactions between movements. A keypad can also give access to more degrees of freedom within the same mode than e.g. a joystick. Configurations designed for single-finger control with a 4x4 keypad of gripper velocities in space are used by just about all users in the field today, most of them with neuromuscular disorders, and have proved to be quite effective.

While keypad control was originally implemented under ADAPTICOL, the manufacturer of MANUS unfortunately fitted the "standard" MANUS with a fixed "GMD" keypad configuration in PROM, thereby loosing all field adaptability. Although ADAPTICOL can still be installed as an option, it must be obtained directly from IRV.

GMD keypad control was optimised to give access to a maximum number of degrees of freedom without mode switching, but at the cost of limiting movement control into elementary directions only. IRV keypad configurations reserve a 3x3 key "joystick emulation" field on the keypad for multi-directional control and offer fast toggling between two privileged modes:

- Gripper displacements in cartesian coordinates (XYZ) plus cylindrical "swing" of the arm about its central column for long-range movements. Gripper orientation remains stabilized, either in cartesian space or with respect to the arm and the horizontal plane under swing.
- Control of gripper orientation in Euler coordinates (yaw, pitch, roll) centered at the wrist joint.

Other keys give in both modes access to vertical displacement of the gripper, gripper opening and closing, and mode switching.

Thus far, the keypad was used only for MANUS, added to the joystick for wheelchair control. With the integrated control of the M3S platforms, the same control input can be used for all devices. Although 8-directional keypad control of the wheelchair proved to be quite feasible, it does not give the smooth ride obtained with a proportional joystick, and therefore is not a first choice for this purpose.

Proportional control

ADAPTICOL supports proportional control inputs with functions for both velocity and position control. Two functional classes of proportional control devices can be distinguished: with or without a physical zero position (like a spring-centered joystick). For both categories, strategies have been developed for the control of MANUS. In conjunction with the M3S developments, some of the processing procedures have also been implemented in the interfaces associated with the experimental M3S input devices, which ultimately should be equipped with their own ADAPTICOL programmability. In view of the fact that the spring-centred joystick is the dominant control device in the wheelchair environment, all alternative controls must emulate corresponding signals if they are to be used for wheelchair control. Implementing such compatibility has been one of our priorities for the last years. Furthermore, since MANUS has also been interfaced to the M3S environment through ADAPTICOL programming, it became essential to provide the option of controlling it through the standard wheelchair joystick.

Spring-less joystick control

For the initial target group of people with weak residual finger movements, a spring-less or non-contact joystick could be particularly interesting. Such devices are especially suited for position control of movements, which can be quite effective for precise control over a limited range. In the few experiments on such control of MANUS carried out with end users thus far, keypad control was still preferred, and further development seems indicated. The spring joystick emulation strategies implemented with spring-less devices for wheelchair control have shown their feasibility, both with the devices mentioned above and with a headrest control device. They still do require more training and attention than a spring-centered joystick, however.

Spring-centered joystick control

For the control of MANUS with the wheelchair joystick only, a control strategy was developed in which both gripper movements and mode selections are controlled with the joystick. To this end, use is made of time-dependent functions, distinguishing between joystick excursions, both into different directions and of different durations, to activate different functions. Thus, eight modes can be selected with the joystick in a menu mode by pointing into one out of eight directions. The transition to the mode selected is made automatically after an adjustable time delay (0,6 second at present). In the active modes, a short excursion from the center, lasting less than this delay time, returns control to the menu mode. Otherwise, joystick velocity control of the two degrees of freedom of the mode selected is activated until the joystick is centered again.

Case studies

The spring joystick method has since been successfully implemented in an individual adaptation - for the time being without M3S - of integrated chin joystick control of a Scandinavian Mobility wheelchair and a MANUS manipulator for a 25 year old man with a C3/C4 spinal chord lesion. Thus far he has been living in a specialised residence for persons requiring frequent care. With MANUS, his care requirements have dropped from 32 to about 22 hours/week. As a consequence, he is now qualifying for a "FOCUS" independent living environment, where care requirements must not exceed 30 hours/week. This result is expected to be quite significant to help convincing paying parties of the potential impact of robotic assistive devices.

From the experience with the case studies under the M3S projects, one interesting observation was made with persons also having some mild cognitive impairments. This group is extremely useful to reveal any user-unfriendly aspects in the control, which would remain unnoticed with users who can more easily adapt to them. These users tended to get easily lost in menu structures requiring too many steps and/or lacking sufficient feedback for guidance. In particular when the control of many devices is integrated, mode selection may become a limiting factor, needing much more attention then it has been given thus far.

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