

## **POCUS PROJECT: ADAPTING THE CONTROL OF THE MANUS MANIPULATOR FOR PERSONS WITH CEREBRAL PALSY.**

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### **Abstract**

Under the POCUS Project, interactive studies are under way to adapt the control of the MANUS Manipulator for children and young adults with cerebral palsy. Various control approaches are implemented and tested with 6 test persons, ranging from 7 to 29 years, in an integrated clinical and special education environment. With the ADAPTICOM configuring method, initial control configurations were designed posing minimal demands on coordinated control input from the user. They only use 2 or 3 switches and timed responses, to control all gripper movements in space in a sequential way. For each user the controls and control procedures are then individually adapted, ranging from large push buttons on the lap board, a keypad, a joystick, head-controlled switches, or an individually-moulded hand-held grip with 3 integrated push buttons. Cognitive aspects are of major importance, and much effort is invested in guidance and training as an integral part of the study. In two cases, a PC labyrinth game with adapted interface facilitated initial training of basic concepts of movement control and mode switching. Experimental results halfway the project are

quite promising and two test persons have applied for provision of a personal MANUS manipulator. User spin-offs in related domains like wheelchair control and communication have also been obtained.

### **Introduction**

Case studies with adapted interfacing under the French Spartacus Project with a stand-alone workstation manipulator in a clinical setting have shown the potential use of a manipulator to enhance independence of persons with functional tetraplegias of different origins [1]. One case study concerned a 10-year old spastic-athetoid, non-communicating boy, who succeeded surprisingly well in using the system for all kinds of tasks once the appropriate interface and control procedures had been found. In this case, cognitive aspects did not appear to be a limiting factor, in spite of the fact that this boy had never been able to perform any "manual" tasks. The elements which finally allowed him to gain control were:

1. The use of *controls which could be released*, allowing him to use them when he could control his movements, while avoiding inadvertent inputs during

involuntary movements. In this case, they consisted of a potentiometric roller under his chin for proportional position control of gripper movements and a flexible-bar type switch controlled with gross arm movements for mode selection.

2. A scanning control procedure to give him successively access to only one degree of freedom ("DOF") at the time, thereby *selecting the direction* of the gripper movement to be made, and just control it back and forth, even with badly coordinated movements.

Since this boy had never been able to physically manipulate any objects, there was initially some doubt whether he would have the cognitive abilities to do so through a remotely controlled manipulator. In this case, this proved to be no problem at all and he was amongst the very best users of the system. Since the Spartacus system was never commercialised, he never obtained a system for his personal use, and no other case studies with persons with cp have been performed.

The MANUS wheelchair-mounted manipulator evolved from the experience obtained in the Spartacus Project and did result in a commercial product, supplied to some 40 persons in the Netherlands [2]. Amongst them, only one has cp, but he is controlling it very much like most of the other users with neuromuscular disorders, like muscular dystrophy, through a finger-controlled 16-key keypad and the standard procedures. The only specific adaptation con-

sists of a key guard on the keypad to facilitate selective pushing of different keys [3]. As such, he is not really comparable with the previous case as far as residual motor function is concerned. With the POCUS Project, researchers from iRv, medical and paramedical staff of SRL Franciscusoord rehabilitation centre for children, and its school for special education are developing and testing further adaptations of the control of MANUS to persons with cp, including cases where mild cognitive impairments may be a complicating factor.

### **Methods.**

In these studies, 6 test persons, ranging in age from 7 to 29 years, participate on a voluntary basis, and care has been taken to limit the burden imposed on them. Appropriate seating and correct posture are essential for them to diminish spasticity and improve their ability to control external devices. Therefore, they remain seated in their own wheelchair, with the manipulator mounted on a stand-alone support next to it (fig. 1). Although this meant sacrificing the two DOFs of wheelchair mobility, essential for real-life intervention in the environment, this arrangement is quite satisfactory for the supervised experiments of this project.

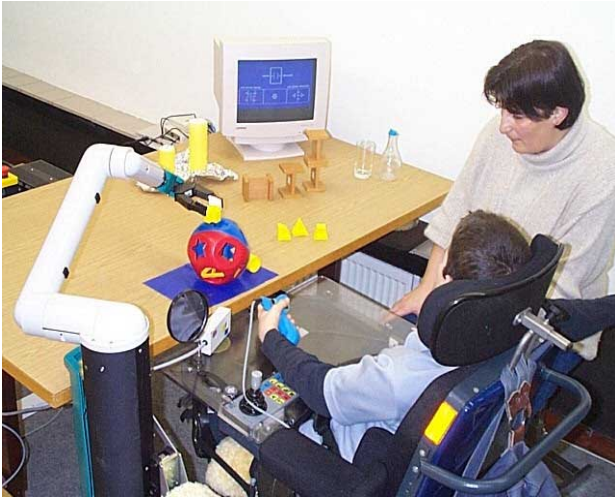


Fig.1. Drive-in experimental environment with a test person, seated in his own wheelchair next to a stand-alone MANUS manipulator, and an O.T. teaching its use.

The experiments are conducted as case studies in the Occupational Therapy Department by an O.T and one or two rehabilitation engineers. A short cycle of "interactive development" of implementing control environments, user training, testing and observation of effectiveness, analysis of problems encountered, and re-design of the environment is used with the different subjects. These items are not strictly separated, and sessions are conducted in a pragmatic game-like manner to keep the test persons motivated, essential in particular for the children. Besides the motor problems associated with spasticity, complicating factors to be dealt with consist of limited attention span, cognitive problems, lack of familiarity with mechanical interventions, communication problems, slow learning, and interaction with educational and rehabilita-

tion programmes. Therefore, collaboration between all medical, paramedical and teaching staff involved with the test persons is pursued and no attempt is made at this stage to collect objectively quantifiable data. Essential stages of the experiments are video-taped for off-line analysis, documentation, and presentation.

### **Control environment**

Building on the experience gained with both the Spartacus cp case study and the keypad type control used under MANUS [4,5], an elementary control environment has been implemented to start with. It uses only 3 push buttons: 2 to control one DOF at the time into opposite directions and a third one to scan through different modes, successively giving access to different DOFs. Controls and control procedures have then gradually been adapted and elaborated, guided by the performance and the problems encountered by the different test persons. The ADAPTICOM configuration method (previously "ADAPTICOL") was used for "rapid prototyping" of control configurations [4,5,6].

The design of the control environment requires finding a compromise between, often conflicting, criteria like:

- Design control for minimal demands on well-coordinated input signals;
- Use control procedures which pose minimal demands on cognitive abilities;
- Add protections and warnings for (presumed) control errors.
- Speed up control as much as possible

to avoid frustration from time-consuming execution of tasks;

- Give enhanced feedback to facilitate menu handling and error signalling.
- Design feedback to speed up mode selection by facilitating prediction (in scanning procedures).

### **Input controls**

The use of push buttons (AbleNet large Jelly Bean or small Specs Switches) on the lap board was an initial guess, successfully maintained in some cases, but changed in others. In the first cases, proper positioning of the switches is critical and has been optimised individually, taking into account any controls already used for other purposes like a communicator or a wheelchair.

In one case, the switches have later been replaced by the keypad with key-guard, used before by RTD [3] since enough finger function was still present.

In a second case, a switch joystick has been used, replacing the wheelchair joystick in the first 10 sessions. It only replaces the two movement control switches, while an associated push button is used for mode selection. At the 11th session, it has been replaced by a proportional joystick with flexible handle and a mode selection switch.

In a third case, where hitting any fixed button required a lot of effort, an individually-moulded hand-held grip was made with three thumb-activated keys (fig.1). This device provided a good

control, even with a hand moving about in a badly controlled way. Since, it is also used very effectively in the classroom with a text editor.

In a fourth, most difficult case, no effective control could be obtained from upper or lower limbs. In spite of poor head balance, head movements seemed to be the most promising source of control. The main problem consisted of avoiding simultaneous activation of signals, and many arrangements have been tried and rejected. Today, a promising arrangement has been found, providing two independently controllable switch signals by placing two push buttons on extended lateral supports of a headrest. In this case too, the search for control signals was pursued simultaneously with the control of a wheelchair and of an assistive communication device, and the head switch arrangement is also tried out for the latter.

An additional case was presented to us from another centre, concerning a 7-year old spastic-athetoid girl, very effectively controlling a wheelchair with "Adremo" interface, using minimal head and foot movements. The same interface also proved to be very effective for the control of the manipulator.

### **Control procedures**

To limit selection time and complexity, initially only 8 modes have been made accessible through a scanning procedure. They successively give access to gripper movements along the six elementary cartesian-euler coordinates (X,

Y, Z, yaw, pitch, roll), gripper opening and closing, and arm "swing" in cylindrical coordinates. In addition, folding the arm out and in can be selected only directly after switching on the system.

Feedback required for mode selection is obtained from the standard MANUS 5x7 LED matrix display. Icons representing a rotating arrow are used, favouring scanning prediction over explicit icon meaning, although it is not clear yet whether all subjects have the cognitive abilities to really exploit it to speed up selection. Signalling of mode transitions is further enhanced by short beeps, while longer ones are used in case of errors like wrong (e.g. simultaneous) key signals. A beep also signals activation of gripper opening to warn against dropping objects. During the initial training phase only, more elaborate feedback is given on a PC screen through the ADAPTICOM Monitor interactive teaching program (fig.1).

Scanning methods for mode selection have gradually evolved, both to enhance user performances and to facilitate teaching. Initially, two 3-key configurations were implemented, either scanning through a single-loop of 8 modes or a double-loop of 2 x 5 modes, sharing one mode to switch loops. Hitting the mode selection key resulted in an immediate step, and keeping it pushed continued with scanning at regular intervals. To facilitate training with a reduced number of modes, the second one was retained, grouping X, Y, Z and gripper open/close

in the basic loop.

The double approach of an immediate step followed by scanning gives a fast response, but also gave rise to frequent errors, at least in the initial phases. Therefore, three separate options have also been provided: "step-scanning" of one step at the time only; "active scanning" of successive steps while the selection key is pushed but starting after one delay time; and "auto-scanning", automatically scanning while no key is pushed, and thereby allowing control using 2 keys only. To further diminish the effect of accidental or multiple key strikes, key responses have been made history-dependent through "slow-key" processing (both requiring no key to be pressed for some time, and then keeping a key pressed for a minimal time before releasing it to obtain a response) or by increasing scan delay time, once only, after activation of any key. Furthermore, loop switching has been changed into a two-step operation: selection and confirmation, allowing correction of a wrong or accidental selection.

Some older procedures have since also been successfully adapted here for keypad control and for control with a proportional joystick with mode switch.

### **Training**

Cognitive aspects are of major importance for the successful use of a manipulator, and much effort has been invested in guidance and training as an integral part of the study. Several as-

pects to facilitate user training have already been mentioned above, like the use of the ADAPTICOM Monitor program during initial training. Since not all of the subjects are able to read, the help screens have been adapted to use a more graphical representation to clarify the different modes selected.

To teach control of basic gripper movements and mode switching, a tower building task with H-shaped elements has been used (fig.1). Starting from a simple arrangement, their initial orientations are successively changed to require more and more of the basic movements to be used [1,7,8].

All subjects have required more training time than average to integrate the remote control of a gripper to manipulate objects, partly due to the ongoing search for an appropriate control environment to which they had to adapt each time it was changed. Therefore, formal training has been alternated with more motivating "real-life" object manipulations, most of which being first-time achievements for the operators. Since most subjects had little or no experience with such type of mechanical tasks, guidance also included explaining object-environment interactions. This is particularly relevant in contact situations, where visual feedback alone is often not enough to accomplish the task without some comprehension of the mechanical constraints to be expected.

The two 8-year old children participat-

ing in the study have required more time and special attention for cognitive training to cope with the control tasks. Manipulation tasks appeared to introduce too many new elements at the time, and therefore a simpler approach was adopted to start with. A PC labyrinth game [9] was used here, with its interface adapted to a similar 3-switch control. Two push buttons move a puppet back and forth across the screen and a third one toggles modes, successively between X and Y directions. Once the basic operations had been mastered, it was also used to teach them to keep attention and use path planning strategy, looking ahead rather than engaging into dead-end paths. Since they were more motivated in using the manipulator than the labyrinth exercise, these sessions started with the latter and ended with manipulator "games". Although it took quite a few sessions, this method has given the results hoped for, and today sessions concentrate on manipulator use only.

Manipulator training starts with the use of the first loop only, scanning through X, Y, Z, gripper, and loop switch-over modes, while ignoring the latter one. In a second stage, the second loop is entered as well, training control of gripper orientation. Although loop switching has been acquired by most subjects today, it remains a relatively difficult operation which requires special attention during training.

## Results

With the exception of an 8-year old boy where basic interfacing did take much time, all test persons are or have been successfully using one of the double loop configurations, with feedback limited to the 5x7 matrix LED display and the beeps, as mentioned. Besides the results already mentioned before, among the other tasks performed in various variations figure:

- Moving about various objects and toys, bringing them within range and/or stabilising them for direct, manipulation, bringing them to the face, presenting them to others, dropping them;
- "Playing with water": pouring into a big container or a glass, drinking with a straw, drinking from a cup in one case, make a doll dive in a basin, etc.;
- "Playing with fire": lighting a candle from another one already lit, extinguishing it with an upside down glass or by bringing it to the face and blowing it;
- Eating a biscuit held in the gripper; eating using a spoon or a fork;
- Shaving with an electric razor;
- Using a soldering iron;
- Inserting differently shaped objects in corresponding holes of a Tupperware game box (fig.1): a rather difficult task requiring careful orienting, precise movements, and planning.
- Drawing with a felt pen.

As training progressed, the need did arise, as usual, for more speed and faster control, at the cost of fewer compensations. This also resulted in the changes of controls like the keypad and the pro-

portional joystick, which did indeed result in a more effective control once the basic principles had been acquired.

## Discussion

As reported under [4] and [5], it was observed that experiments involving persons with mild cognitive impairments are very revealing of any user-unfriendly aspects in the control which would remain unnoticed with users who can more easily adapt to them. They tend to get easily lost in menu structures and/or lacking sufficient feedback for guidance. This has been confirmed in this project, where mode switching, and especially loop switching, require significant training efforts.

Nevertheless, the results today are quite encouraging and several of the test persons appear to be good candidates to benefit of a manipulator for personal use. Today, two of them are indeed applying for provision of a personal manipulator, although it will be a long way yet to pass administrative barriers.

As mentioned, in two cases a spin-off to the control of other assistive devices in the classroom has been possible, thereby also mutually re-enforcing training of the user in different settings.

The Spartacus manipulator referred to in the introduction included a "pointing" or "piloting" mode, in which the gripper could be pointed into a given direction and then made to move into this direction, "flying it like an aeroplane" [7,1,5].

This was particularly important for the case discussed, and it would be in the ones reported here, since it allows the gripper to be moved into any direction, even when only one DOF is controlled at the time. Unfortunately, the MANUS manipulator does not include this feature yet, but it is expected to be included in a next generation.

Another feature of both Spartacus and the early version of MANUS was a display mounted on the arm, thereby moving with it and remaining within the user's field of view. This is lacking today, but is badly needed when head movements are used to control the arm, as in two of the cases presented.

### **Conclusion**

Although the study is still under way at the time of this writing, it is expected that the resulting control configurations can be used in practice by some of the persons from the complex cp target group. We have developed relatively basic control, configurations to start with, and more complex and faster ones to evolve to if possible.

As a spin-off, the basic configurations may also be useful again for other target groups, like progressive neuro-muscular diseases, when residual functions diminish. They are made available within the libraries of the ADAPTICOM package.

In this project, concept development, implementation, training and evaluation cannot really be separated. Much of it is

realised in the field with a major contribution from the users. We have called this approach "interactive development"

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