

# PREPROGRAMMED GESTURES FOR ROBOTIC MANIPULATORS: AN ALTERNATIVE TO SPEED UP TASK EXECUTION USING MANUS.

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## ABSTRACT

*In the rehabilitation robotic context, we are convinced that robotic assistive devices for severely disabled persons may compensate their impairments in grasping. However the use of telemanipulated robotic arms requires an excellent dexterity and cognitive efforts not often available among the concerned users population. Preprogrammed gestures and a control method that offers shared control between the human and the machine may improve the execution of complex tasks. In this paper we describe a new Assistive Control System (ACS) for the Manus robotic arm. This system supports several input devices and offers new features, such as a gesture library and new control modes. Results of the evaluations of this ACS are also presented. The aim of our approach is to make the robotic arm Manus easily controlled and accessible to a larger population of handicapped users.*

## 1 INTRODUCTION

Manus, a six Degrees Of Freedom (DOF) robotic arm mounted on a wheelchair, is presently commercialized by Exact Dynamics company in the Netherlands. The French Muscular Dystrophy Association (AFM) has introduced fifteen Manus in France to help disabled people to get acquainted in touch with such technology. The main advantage of the Manus is that it can perform tasks in non-structured environment which correspond, in general, to the real environment of the end-users.

To use the Manus arm in daily living with the actual command architecture, the user must perform repetitive actions in order to complete the different tasks. Our approach is to propose an assistance to the end-user in their daily life. We have developed a new control system called Assistive Control System (ACS) which relieves the handicapped user from executing the same sequence of commands for common tasks.

The ACS we are proposing will provide a semiautonomous controller for Manus that will lessen the number of mundane tasks (by preprogramming commonly used gestures) while still enabling the user full control on the robot.

Robotic workstations have shown their efficiency in providing fully automated tasks in a structured environment. However, the evaluations conducted in France in several rehabilitation centers with the Master-Raid workstation [3], demonstrated that users feel dependent of this type of restricted environment and excluded from the command loop such that they feel they become simply observers of the automated tasks. The users would appreciate a robotic system that could combine human with autonomous control such that they will feel active during the execution of tasks.

## 2 THE GESTURE LIBRARY

In human physiology, any complete natural gesture is describe as being two-phased: an initial phase that transports the limb quickly towards the target location and a second long phase of controlled adjustment that allows limb to reach the target accurately. Those two phases are defined respectively as a transport component and a grasp component [2], In our approach, we are interested in automating the first phase. The second

one continues to be controlled by the user.

The gesture library contains a set of generic global gestures that help disabled people in performing complex daily tasks. These gestures represent a portion of any particular task. Each gesture ( $G_i$ ) is characterized by an initial operational variable of the robot workspace ( $O_{ii}$ ) corresponding to the initial robot arm configuration and a final operational variable ( $O_{if}$ ) corresponding to the final robot arm configuration. Each variable ( $O_i$ ) is defined in the Cartesian space by the gripper position ( $x_i, y_i, z_i$ ) and orientation ( $yaw_i, pitch_i, roll_i$ ). The gestures generated by our system are linked only to the final operational variables. A path planner is able to generate, from any initial arm configuration, the appropriate trajectory to reach the final configurations. We have prerecorded twelve final operational variables as describe in [1] and allow the user to record two others.

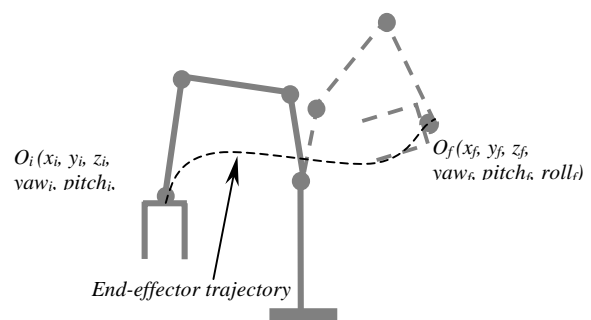


Figure 1: Representation of the two robot configurations that characterize any gesture.

### 3 ORGANIZATION OF THE NEW MODES

In addition to the Cartesian Control Mode (CCM) and the Joint Control Mode (JCM) (the first one allows the user to control manually the arm and gripper motion in Cartesian space whereas the second one allows a direct and separate control of the six arm joints) existing in the commercialized version of Manus, the ACS offers three other modes designated as: the Point-to-Point Control Mode (PPCM), the Record Mode (RM) and the Replay Control Mode (RCM). Fig.2 shows the ACS modes organization.

The gestures of the library described above are activated by the user in the PPCM. In this mode, each button of the keypad generates a gesture following the keypad mapping showed in fig.3.

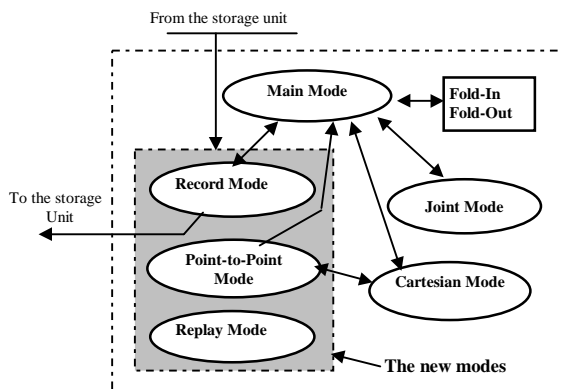


Figure 2: The ACS modes organization

The 3x3 matrix of pre-set buttons correspond to nine pre-set configurations of the robotic arm, following a vertical grid front of the user. For example, when the user wishes to reach a target in the left (left

side of the robot) and down position he/she may push the button “DL” that will bring the robot end-effector towards that position.

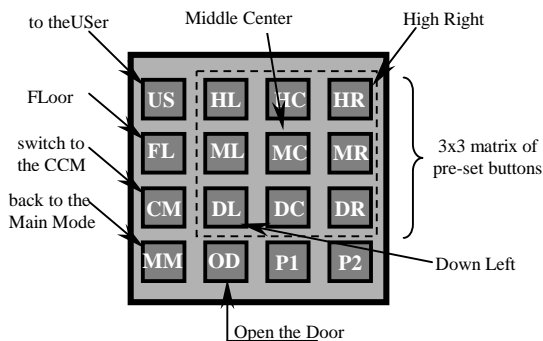


Figure 3: The keypad pre-set mapping in the PPCM

The button “OD” will generate a gesture towards an arm configuration allowing the user to open a door or grasp an object from the top, the button “FL”, will generate a gesture to grasp object from the floor, the button “US”, is a back gesture towards the user, and the buttons “P1” and “P2” will generate gestures towards two user pre-recorded robot configurations. These configurations are recorded in the RM. The RCM, which is not accessible from the user input device, will allow, for example, evaluators to replay off-line, a saved sequence of actions performed previously by the disabled patient.

### 4 EVALUATION

A pilot evaluation was conducted with six control subjects [6]. It was organized in two sessions during two

days. Subjects were asked to use Manus and execute 8 training tasks and one final task. The first 3 tasks were easy and consisted of moving a cubic object using only the CCM from a position to another with three different grasping strategies (from the front, side, and top). Tasks 4, 5 and 6 were the same but the subjects were now asked to use both the PPMC and the CCM. The 7<sup>th</sup> task involved pouring the content of a cup situated on a shelf and the 8<sup>th</sup> task asked the subjects to retrieve the cubic object from a shelf to read what was written on the back of this object. The final task consisted of a compilation of the strategies used in the 8 previous training tasks. It consisted of taking a bottle of water from a shelf, pouring the water from the bottle into a glass on a table, putting back the bottle on the shelf, bringing the glass close to the mouth and drinking the water. These last tasks were a little more complex and involved arm displacement with large amplitude, and additionally the subjects were also asked to use the two cited control modes. A quantitative analysis has allowed us to make the following observations:

1- We observed a decrease of the time execution of the task for the three simple tasks executed with the CCM only. Observations were made between the tasks and between sessions fig.4. This is probably due to the quick learning of the CCM.

2- We noticed that the use of the PPMC in tasks 4, 5 and 6 increased the duration of the execution of the tasks, particularly when the subjects discovered this mode for the first time. We emphasize that the PPMC may have seemed much more complex than the CCM and possibly the subjects needed more time to master this new mode.

3- The total latency time ( $\sum$  of latency time between two commands) varied linearly with the total task time and represented more than 50% of each task duration fig.5, time that the subjects spent looking for suited strategies to reach the target or for the correct button to execute the appropriate command.

4- We also noticed, when we separated the mode changes commands from the keypad mapping in order to have one exclusive keypad for the robot commands and one second keypad for mode changes, the command mapping in each mode seemed understandable for the subjects. They used the PPCM to a much greater extent. This suggests that this separation brings with it, an easier control of Manus

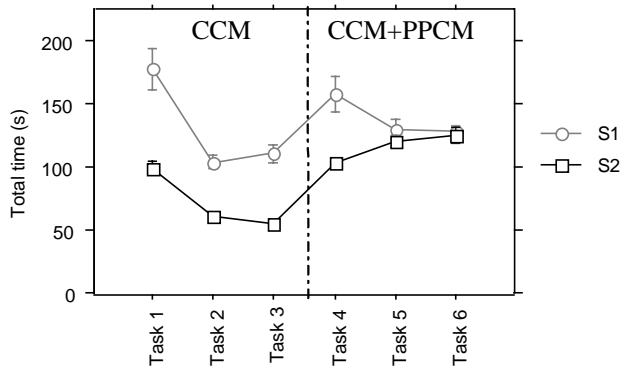


Figure 4: Total execution time of the 6 first tasks during the two sessions (S1 and S2), mean of the 6 control subject.

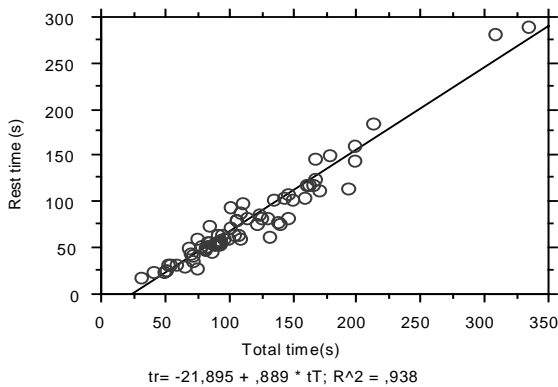


Figure 5: The regression curve between the task duration and the total latency time.

A second evaluation was made with the participation of four patients (two quadriplegic C6-C7 and two having muscular dystrophy) located at the hospital Raymond Poincare. Our evaluation has shown that, in spite of their handicap, their performance was not quantitatively different from control subject. For example, the final task was executed with an average time of  $485.6 \pm 61.5$  sec in the first session and  $449.4 \pm 36.6$  sec in the second session compared to  $476.9 \pm 31.2$  sec and  $425.75 \pm 26.4$  sec obtained with the control subjects. The latency time was

between 50 and 70% of the task duration. However, we failed to noticed a learning comparable to the one observed with the control subjects. and noted that the PPMC was used less in the final task. As mentioned earlier the assimilation of this mode is not as easy as the CCM.

The contribution of the PPMC appeared after another training session where two patients of the group cited above seemed familiar with the two main modes: the CCM and the PPMC. They were asked to collect, using Manus, five different objects located in different places and put them all in a box. This Evaluation was conducted into two sessions over two days. In the first session the patients were asked first to perform the task with the CCM only and then, to re-executed it using the PPMC. In the second session, they were asked to start with the PPMC and end with the CCM only.

The results (see Fig.6 and Fig.7 shows the contribution of the PPMC in the execution of the ask. It has allowed

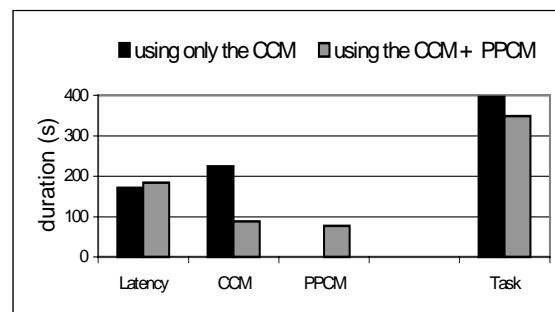


Figure 6: The contribution of the ACS in term of number of commands.

the patients to perform the task with, in mean, 13 commands less and to save approximately 50 seconds on the time task.

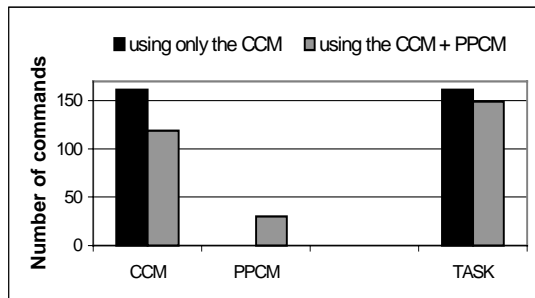


Figure 7: The contribution of the ACS in term of duration.

## 5 CONCLUSION

This paper has described a design approach of an assistive control system for the robotic arm Manus. The ACS is designed to meet the disabled user needs in term of manipulation of the assistive robot Manus. Its development is based on preliminary results obtained from quantitative and qualitative evaluation with the participation of disabled people [3,5].

This system is designed on the one hand, to reduce manipulation problems that disabled users meet during complex tasks, and on the other hand, to solve the problems linked to the user-interface. With its new functions, we plan to reduce the task time and the number of commands that are performed. For example, one command in the PPCM will be sufficient to perform the same results that will be

necessary with 10 commands of the CCM.

The evaluations of the first ACS version allowed us to bring some improvement to the system. The first trials with disabled patients showed their interest regarding the ACS. The results obtained, being preliminary, do not allow us to yet declare what real contributions of the new ACS modes will bring to the Manus end-users.

More evaluations in real life conditions with the help of disabled people are necessary to test all the new functions offered by the proposed new system.

The actual development produced during this project will lead to a new command architecture for Manus which will be integrated through the European Commanus project started in November 1998. The overall goal is to propose a new generation of Manus manipulators with the end-user needs taken into account.

## ACKNOWLEDGMENTS

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