ROBOT ASSISTED PLAYING FOR SEVERE PHYSICALLY HANDICAPPED CHILDREN

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Abstract: The importance of playing for the cerebral development of children is well-known since many years. This paper addresses the central role of robotics and automation for making toys available to children with severe physical handicaps in order to provide this user group with comparable possibilities to share these experiences. A qualitative study has been carried out in order to find out how children with physical handicaps play in comparison with normal children. First results of this study are given in this paper. Based on the results of this study a dedicated robot system which supports children with the above mentioned handicaps for interaction with standard toys is being realized by ARC Seibersdorf research and is described in this article. First results from user trials are given and future development is outlined.

Keywords: Rehabilitation Robots, Robot Assistance, Human-Machine-Interface

1. INTRODUCTION

The relationship between play and spatial ability for children at a very early stage has been reported in literature (e.g. Brosnan, 1998).

This paper discusses the application of a prototype toy robot system for physical handicapped children in order to support autonomous playing. The main idea of the chosen setup – and this is also the difference to other known approaches in the field e.g. (Werry et al., 2001), (Michaud et al., 2002) - is to use the robot as an assistance system which allows interaction to standard toy and not as a toy itself. In order to make it available to a larger group of users one of the main criteria for the robot system was "low-cost" configuration. Special attention also was given to operation stability and especially to an appropriate human-machine interface. A first prototype of the robot is available since spring 2003 and could be evaluated in several user trials. Based on the results of these tests, a re-design of the system could be finalized in October 2004 and three robots have been installed at selected therapy institutions. Beside description of the general system setup and results from the first user trials, the paper outlines the new design as well as further research steps.

1.1. The role of playing

It is a well known fact in the field of developmental psychology that interacting is substantial for child development. Playing is an important part of daily life interactions (Piaget, 1951), (Vygotskij, 1967). Children with severe physical handicaps have limited possibilities for interaction with social and material environment. Starting in early 2002 the authors started working on a project about toy adaptations. Children with different kinds of physical handicaps should get access to common toys by using up to date (robotics) technology. In a first step, commercial available toy systems were equipped with dedicated interfaces in order to allow some kinds of interaction with the real world (Kronreif et al., 2003). Toys should be made accessible via sensors and interfaces used in the rehabilitation field (single switches etc.). Some other research was performed to combine these adapted toys with specially designed learning software (Prazak et al., 2002). The major goal for these applications was to establish the robot as mediator between the virtual and the real world. One other objective for the systems mentioned above was to train the children to get used to special input devices, like joysticks, sensors, and the like.

1.2. How do physically disabled children play?

A qualitative study has been carried out by the authors in order to find out how children with physical handicaps play in comparison with normal children. Another target of the study was to identify if and how the usage of up-to-date robot technology can provide enhanced possibilities to interact with the environment. The study was based on a formative evaluation - data was collected and analysed with qualitative methods. Interview partners were developmental psychologists, therapists who work with children with physical handicaps and parents. Each of the interviews took approximately 30 min to an hour and took place at their working places or their homes.

One result from the study was the observation that children with physical handicaps cannot make the same inter-action experiences which abled children can make. As a result of this lack of experiences handicapped children often suffer from a second handicap – in most cases a mental retardation. Children with physical handicaps have fewer possibilities to play and they are in most cases passive players. They need always a person who fulfils the role of an active player, so that playing alone is nearly never practicable for this user group. The role of the disabled child is to look and observe or order other persons what to do. Most of the therapists and parents are in complete agreement that PCs and special software (for playing and learning) offers enormous benefits for this target group. But children should play and learn – at least in early stages – also on real environments, because this is the basis for a good performance in the virtual world.

An eligible intention for therapists and parents is that this target group should get more chances for playing autonomously. Technical toys were seen as a reasonable solution for this user group. The first step in this direction is toy adaptation which enables children to play autonomously with "traditional" and commercially available toys. This gives them the experience to move something in their environment.

Finally, the results of this qualitative study set a cornerstone for a new project – the development of a toy robot system for children with physical handicaps. The autonomy and varied play for physically handicapped children should come to the fore. Additionally the special needs particularly in matters of input devices should be considered.

2. "ROBOT ASSISTED PLAYING"

A remote controlled robot system was selected to assist severe physically handicapped children when playing with toys. The robot should serve as an assistant – the way of playing is defined by the user in order to ensure a maximum on autonomy. Not the robot is the toy – but the robot helps to use the toy. Using the functionality of the robot system, the user is now in the position to manipulate real objects (toys) in the real world, despite of his/her handicap. In a first feasibility study, a dedicated robot system has been designed for manipulation of small LEGO™ bricks by ARC Seibersdorf research. In the following, system components are briefly described.

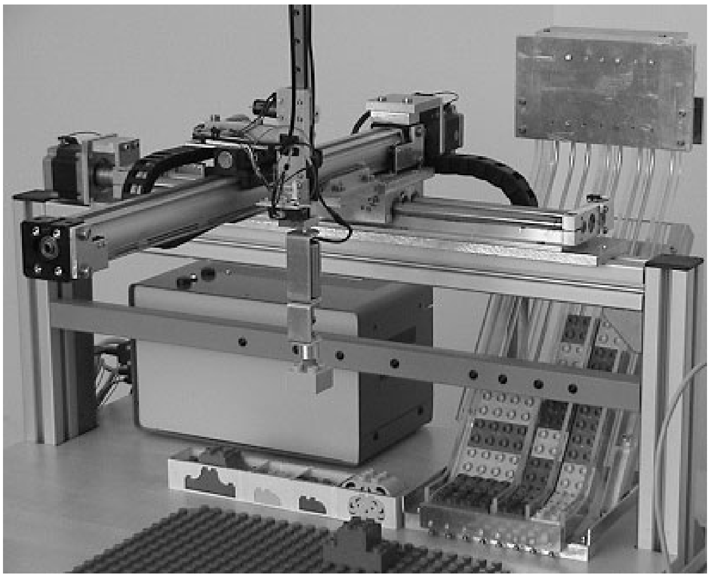

Fig. 1. Prototype of the robot system

2.1. Robot System

From the set of known kinematic concepts, a 3DOF (degrees-of-freedom) Cartesian configuration was chosen for the robot (fig. 1). First of all, this setup supports the required “low cost” approach by using standard components for the linear robot axes. In addition, the behaviour of the kinematic chain during movement is easy understandable (compared to other kinematic types) which may increase safety and acceptance of the robot system. In order to allow maximal accessibility, the robot system only has one portal for the main axis and to other cantilever axes for positioning of the LEGO™ bricks. Thus, the entire system can be accessed from three sides which also allow cooperative playing.

Assembling of LEGO™ bricks (i.e. joining of the bricks) also influence the kinematic structure of the robot. Positioning of the brick on the playground must be with very high precision – inserting of the particular brick requires appropriate force. Here, the concept of selective compliance is being used. The two axes in horizontal plane (for positioning) are allowing some self adaptation for the brick position during assembly process by having a reduced stiffness whereas the inserting axes supporting the inserting process by having high stiffness in vertical direction.

2.2. Storing system for different types of bricks

This system component indeed plays a decisive role as any disturbance during brick supply will stop playing immediately. On the other hand – again with respect to the desired “low-cost” approach, but also because of safety issues - the storing system should possibly do without any kind of actuators, switches and sensors. Thus, gravity is being used for actuation of the supply system by realisation of a simple but efficient stack.

Basically, the storing system consists of a set of supporting rails (made from aluminium) and center selvedge made from acrylic glass. The storing system is designed in a modular manner – setup of the system can be done quick and efficient by simply replacing particular stacker modules. For the current system setup there are two stacks for 2x2 bricks and one stack for 4x2 bricks (each stack has a capacity of 18 bricks). In addition, there is an additional magazine for four special bricks (fig. 1).

2.3. Gripper device

Also for the gripper device the two main criteria during design and realisation were “low cost” and robustness during operation. Another important requirement is that the footprint of the gripper system is smaller than the smallest brick used in order to allow unrestricted inserting of bricks at any required position on the playground– even if the desired position is already surrounded by some other bricks (fig. 2).

The chosen solution is based on frictional con-nection. Actuated by a solenoid a set of special designed yaws are spreading a PVC tube. Gripping force is resulting from the pressing between the tube and the nubs of the LEGO™ brick.

Fig. 2. Inserting of a new brick despite of the “crowded” surrounding

2.4. Control system

The control system mainly consists of a cascaded set of (in-house developed) controller boards for the used stepper motors interconnected by standard RS485 bus interface. Synchronisation between the motors as well as I/O control is accomplished by an additional micro-controller board. The control system stores pre-teached movements – e.g. for moving the gripper to the desired magazine, etc. – and also communicates with the connected input device. A set of dip switches allows easy setup of the system to the particular needs of the user (e.g. switching between different types of scanning mode, different types of magazine selection, etc.).

3. PLAYING SEQUENCE

After initialisation of the robot axes (“Homing procedure” in order to set each robot axis to a defined starting position) the system is ready for operation.

Using a dedicated input device (5-key switch, head switch, Integr@Mouse, etc.) the user firstly can chose a particular brick type by selecting a magazine position. Depending on the defined setup the current magazine is either marked by a LED or by direct movement of the robot. After confirmation of the storage tray the robot automatically moves to the particular loading position and grasps the brick.

After automatic positioning of the robot to a predefined starting point, the robot can now be freely positioned on the playground by means of the four direction functions of the connected input device. After reaching the desired position the brick is inserted to the playground and released by the gripper by activating the confirmation function of the input device. Optionally, a small marker is projected to the current position on the playground by means of a laser diode in order to have better guidance during positioning of the brick.

After releasing the brick the robot automatically returns to the position of the previously selected magazine and the next playing sequence can be started.

4. USER TRIALS

The user trials were composed of different steps. In a first series of expert tests the concept per se as well as the functionality and stability of the system could be evaluated. Some small adaptations to the system setup as well as a small redesign of the gripper system were the result from this evaluation phase and made the system ready for first user tests. It should be mentioned here that having the above mentioned expert tests and system refinement before starting the user tests turned out as very important in order to avoid frustration for the children if the system breaks down. From the series of user trials, the following paragraphs describe the experiences of 3 selected (because representative) handicapped children while testing of the system.

Child 1: At time of the user trial, child 1 was ten years old. He has multiple impairments and is wheel chair bound. He can use his arm for rough motor activities. At home he sometimes plays with bricks. For the toy robot system he used the five-key input device. Because of his severe mental retardation he did not understand the connection between using the key input device to control the toy robot system.

Child 2: Child 2 was eleven years old. He has a tetra paresis, is wheel chair bound too and cannot use his arms at all. A mental retardation comes along with his physical handicap. When playing with LEGO™ bricks at home, he orders his father what to do. For the robot trials, he controlled the robot with one single switch in scanning mode with his head. He is trained in using this kind of input device as he uses this setup also in school for writing. The first interesting finding at this test was that he has waited until his smaller sister comes when he started to play. One possible assumption is that he is accustomed to watch his sister playing. Maybe he preferred to observe his sister rather than to play for himself, because active playing is more exhausting for him. Choosing the bricks was a problem for him, what might result mainly from the double confirmation – first one to choose the storage tray and second one for final confirmation – required originally. Thus, the first test with this robot system was not associated with much fun for him. One other possible explanation might be that this child is not accustomed to strain himself while he is playing. There were waiting periods when he did not react at the desired time caused by an inappropriate setting of the scanning mode parameters.

Based on the experiences during test 1, the parameters for scanning mode as well as the magazine selection sequence were adapted. During test 2 – taking place 4 weeks later – playing with the system indeed was much more fun to him.

Child 3: Child 3 was nine year old. She has a transverse spinal cord syndrome and can only move her head. She uses the IntegraMouse® - a mouth operated input device also developed by ARC Seibersdorf research (fig. 3). Even tough she has a better cognitive development than the other test persons and her perception is good, she had problems to position the brick exactly during the first trial. It could be observed that she needed more than one time to position the brick before she put it onto the playground. One of the reasons for these difficulties might be that the laser pointer only marks the position of the centre of the brick. Another problem might be the colour contrast of the laser pointer which is poor for some brick colours. Another problem comes from the input device: normally the directions "up" and "down" are vertically from the floor to the ceiling. But for the robot these directions accord a movement of the LEGO™ brick in horizontal direction towards or from the child. Thus, a reorientation in her spatial perception as regards to the above mentioned direction was necessary at the very beginning of the play. Another interesting effect was that she only built a wall of bricks on the backside of the playground and concealed the storage trays with that wall.

During the second trial she performed the same way- she again only built a wall although she knew that she can use the whole playground. For both test sessions, she was very persistent playing more than one hour with the toy robot. Afterwards she mentioned that she enjoyed playing with this system, because this was the first time that she could play for herself and did not need another person.

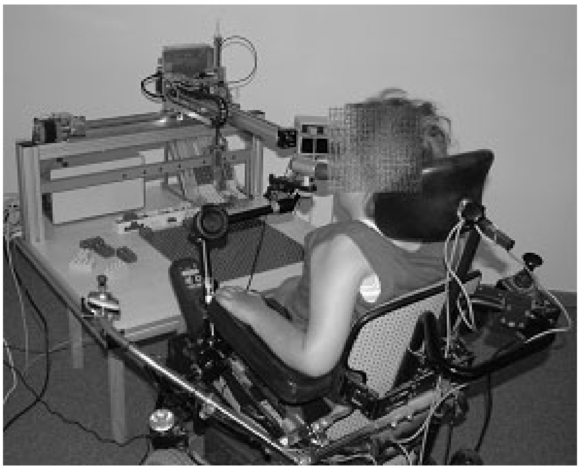

Fig. 3. Child 3 during user trials

4.1. Discussion of the user trials

The user tests revealed that robot systems can be attractive toys for children with physical handicaps. Most of the children enjoyed playing with that system and the goal to make autonomous play for children with physical handicaps possible has been achieved. The users all made new experiences – most of them were in an active player role for the first time. To have fun with the toy robot should be in the foreground - but it also can be assumed that playing with the toy robot system implicate some learning effects w.r.t. spatial sense and perception.

5. FUTURE WORK

A continuative research question now will be to investigate possible and estimated learning effects by means of a multi-centre study. One challenge will be how to quantify the learning effects by this target group mainly because of the difficulties to evaluate the starting level of development of the users and the progress they made after using this toy robot system.

Children with multiple impairments may have difficulties to understand this system as the first series of user-tests with the prototype system have showed. For this target group an easier handling of the robot has to be developed. For example they can freely choose bricks but put it onto default positions. Thus, the toy robot would get more automated and less autonomous play is possible. This of course raises the question: How much automating is useful and/or desired for this robot system? Finally the robustness and the fault tolerance will be continuously evaluated during the next test phases.

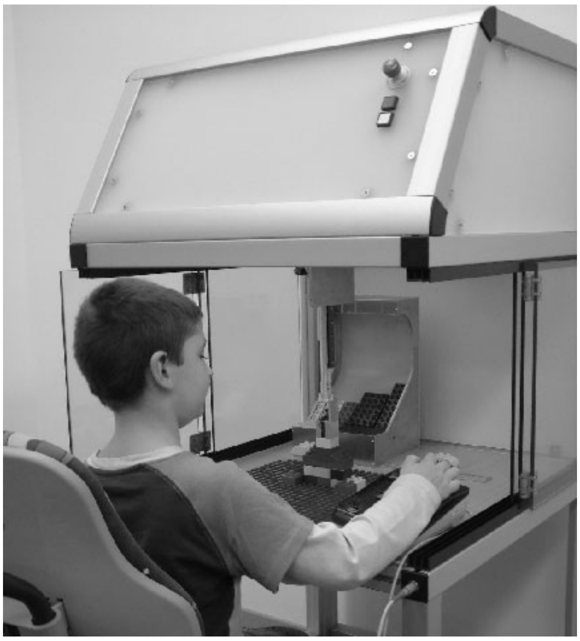

Fig. 4. New system design for long-term evaluation

In order to achieve the above mentioned results, a re-design of the robot system took place in mid 2004. Three systems of this advanced design (fig. 4) – called "PlayROB" - are currently being installed at selected schools and therapy institutions where playing with the robot is being included into the regular therapy plan.

For the desired evaluation of learning effects the following parameters are being recorded for every playing session:

- Duration of playing session
- Total number of used bricks and number of different brick types used
- Time required for brick placement (bricks per minute)
- Utilization of the playground area (%)

Results from the first evaluation period clearly show that a considerable improvement of these parameters can be observed for many children. This may lead to some further conclusions:

- Placement of bricks is being optimized in terms of time and accuracy
- Entire area of the playground is being used after some playing sessions
- "Distance" between selected and "optimal" brick placement is being reduced after some playing sessions
- With each playing session the number of different bricks used by the player increases
- The figures are getting more complex with each session

6. CONCLUSION

This paper reports on a new research topic dealing with "robot assisted playing" for severe physically handicapped children. The robot should assist in manipulation of standard toys and thus allow autonomous playing. A first prototype system for playing with LEGO™ bricks was developed by the authors and successfully evaluated during a couple of user trials. A small series of a re-designed robot system is now being installed at selected institutions in order to support long-term studies under realistic conditions.

Concluding this paper it should be accentuated that physical handicapped children should get improved access to toys to play with and – besides learning - to simply have great fun. Up-to-date technology can be a useful tool to realize adapted toys for severe physical handicapped children.

7. ACKNOWLEDGEMENTS

Re-design of the robot system as well as realisation of the long term study is partly financed by Austrian charity action “Licht ins Dunkel”. The authors like to thank Michael Meindl, Wolfgang Ptacek, Michael Salomon, Christian Synek, Alexander Vogler, and especially the entire testing group for their valuable contributions.

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