Journal of Accessibility and Design for All

(CC) JACCES, 2012 - 2(1): 71-93. ISSN: 2013-7087

# USE OF ROBOTICS AS A LEARNING AID FOR DISABLED CHILDREN

Teodiano Freire Bastos[1], Carlos Valadão[1], Magdo Bôrtole[1]

(1) Electrical Engineering Department, Federal University of Espirito Santo (Vitoria, Brazil)

***Abstract:*** Severe disabled children have little chance of environmental and social exploration and discovery, and due to this lack of interaction and independency, it may lead to an idea that they are unable to do anything by themselves. Trying to help these children on this situation, educational robotics can offer and aid, once it can give them a certain degree of independency in exploration of environment. The system developed in this work allows the child to transmit the commands to a robot. Sensors placed on the child's body can obtain information from head movement or muscle signals to command the robot to carry out tasks. With the use of this system, the disabled children get a better cognitive development and social interaction, balancing in a certain way, the negative effects of their disabilities.

***Keywords:*** Learning support, disabled children, educational robotics.

## Introduction

Learning in childhood is done by exploration and discovery of the environment where the child lives. According to Piaget's definition, up to the second year of life the child is living the sensorial motor period (Thomas, 1992). During this step of development, interaction with the environment is done through physical sensation and body stimulus (Linder, 1990). This idea means that they learn how to interact with their own body as well as the environment by repeating experiences and exploring the world through their senses. At the end of this sensorial-motor period the children has the notion of space, position of objects inside the space and time, and some relation among them (Cook & Howery, 1998).

This spatial object manipulation and environmental interaction are fundamental for the child cognitive development and the ones with severe disabilities are blocked from experiencing the world as the other children do. With this situation they may become delayed in terms of learning through exploration by themselves.

Considering this lack of independency, exploration and spontaneity on discovery of the environmental area around the child, those ones can have a negative influence towards learning and social interaction. All this situation of lack of stimulus can produce a late childhood (Cook & Howery, 1998).

Due to these body-limitations, disabled children are, usually, very dependent on their parents or caretakers to interact with the world. Researches from Brinker and Lewis suggest that the child's behavior can, by itself, determine which experiences their parents and caretakers would allow them to have. These choices may restrict even more the cognitive and social development of the infant.

This entire situation can create a lack of interest of exploration and consequently also develop the idea of learned helplessness, which they see themselves as unable to do anything independently or without external help. With this idea the child usually adopts a passivity and lack of interest behavior towards the world he or she lives.

All these elements can compromise the behavior, as said before, once they become socially passives and dependents. To minimize this, it is necessary that the child has a way to explore the world, through alternative methods and according to what the child has to develop (Scherzer & Tscharnuter, 1990). Doing this is very likely that this child can have a better motivation and interest, giving them an opportunity to explore independently (or at least less-dependently) the world which they live. Finally, the idea of learned helplessness can be minimized and the self-esteem grows up (Todia, Irvin, Singer & Yovanoff, 1993). Figure 1 shows how the learned helplessness occurs.

Assistive Technologies have been providing to these severe disabled children a certain degree of environment control by themselves (Cook & Howery, 1998). This helps to take out the idea of learned helplessness, as shown in Figure 2.

According to Swinth, Anson & Deitz, children since their six-years old already have the ability to access and cause and effect computer software by pressing a key.

*Figure 1. Generation of learnied healpless idea in disabled children.*

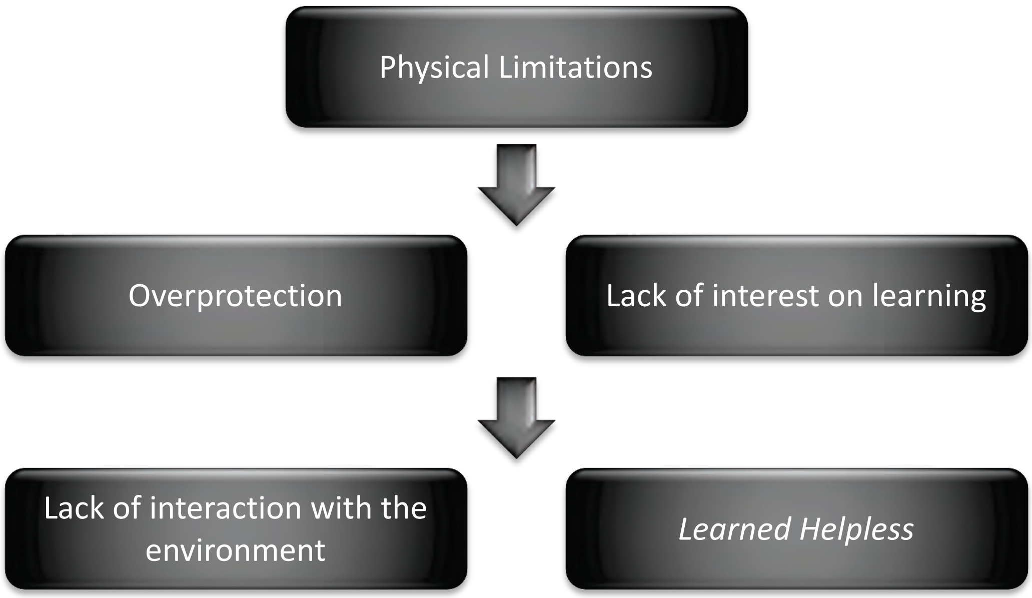
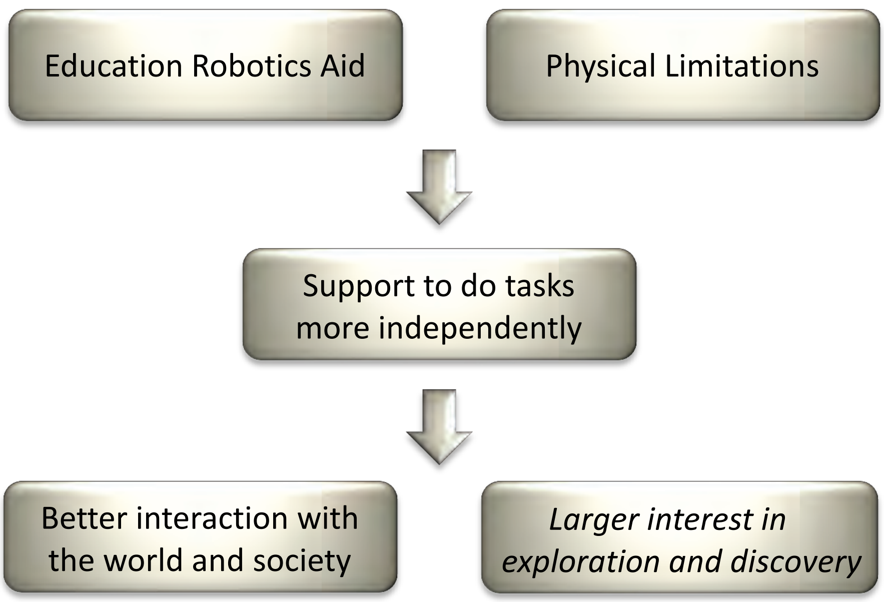



*Figure 2. Robotics support used to help blocking the learned helplessness idea.*



Thus, assistive technology and robotics can provide to these disabled children a unique opportunity to choose how they will interact with the environment and can also give a certain degree of control. So it is given to them the opportunity to choose what they will experiment, instead of experimenting only some tasks already designed for them (Cook & Howery, 1998). Furthermore, robotic system also provide control over three dimensional object manipulation, which is a more real situation compared with the two dimensional graphics provided by simulation with computer software, so the interaction can also be more realistic (Cook & Howery, 1998).

Several researches were done to determine if very young disabled children could interact with a robotic manipulator (Cook, Hoseit, Liu & Lee, 1988). Nine children took part of this research, being six with a disability and three without any. Everyone in this group of nine was less than 38 months of age. The system was, basically, a computer to control and acquire data connected with a small robotic manipulator (Cook et al, 1988). The manipulator was used by those children as a tool, once they can use that to bring to them objects (Gu, Cook, Meng & Dong, 1997).

In that study, fifty percent of the disabled children (all with cognitive age older than seven months) and all non-disabled children interacted with the robotic manipulator, using it as a tool, to catch an object that they could not reach. It was also observed that the cognitive and linguistic level of the children were higher than the motor level (Cook et al, 1988).

Later, this previous research was complemented, always focusing on exploration and discovery of the environment by the children. The new goals were (Cook & Howery, 1998): evaluate how severe disabled children could use the robotic manipulator for exploration and define the relationship between the keys pressed and the task complexity.

This research has shown the way three years up to six year-old children use the robotic manipulation for environmental exploration (Cook, Max, Gu & Howery, 2002). The same research was done analyzing how child behave when they could have access to a variety of movements through one or more keys, using the robotic in a discovery and exploratory way (Cook et al, 2002).

A complex progressive sequence task series was held and it was noticed an increase of cognitive development of those children. Consequently, as the task got more difficult, it was needed more pre-programmed keys to achieve the desired goal (Cook et al,1988; Gu et al,1997; Scherzer & Tscharnuter,1990). It was presented to the child how the manipulator moves using each key; showing the previous movement to them and encouraging them to use the system (press the keys) (Cook, Hoseit, Liu, Lee & Zeteno, 1998). To maximize the results of those experiences dry macaroni inside a box and a glass were used. The task goals were:

First, the robotic manipulator should let the dry macaroni falling from the glass (where the dry macaroni were at first moment) by pressing a key just once;

Next, the child controls the robotic manipulator in order to fill the glass with the dry macaroni. The child gets the macaroni; put it inside the glass by letting it falls from the robotic manipulator, which is located above the glass;

Finally, and the more complex task of these test, is the overall sequence. First the child should get the macaroni from the box, put inside the glass and let it falls inside the box again. This must be done by using three keys.

Each one of these experiences were videotaped for further revision (Cook et al,1988; Cook et al,1998; Cook et al, 2002). The research observations included the child's action and its behavior during task accomplishment. For such example, it was observed how and who or what the child was looking during the tests. Behavioral signals were also included such as fear, happiness, if the child is smiling or crying, boredom or joy. This was registered before and during the use of robotic manipulator, so they could evaluate psychological aspects towards the experiment. Fortunately it was detected great happiness using the robotic manipulator, instead of fear (Cook et al, 1988).

It was also observed that child can respond longer times using robots instead of 2D computer software (Cook & Howery, 1998). In those tests, it was also realized that the child could understand what each key can do by demonstrating its function previously. High interest about the tests was observed when child looked towards the robot or the keys, proving they were interested on doing that (Cook et al, 1988).

This study complemented the previous works of the same authors, once it focused on the child's understating about the system.

An important issue is the robot's design. Tests done with autistic child has shown that the robot should be seen as a toy and must be friendly and good-looking (Michaud, Clavet, 2001). As related in (Werry & Dautenhahn, 1999) those child must feel comfortable and safe with the robots, instead of felling fear of them. Some properties as the robot speed and robot's appearance should be carefully analysed (Werry & Dautenhahn, 1999).

Although those articles cited previously (12, 13) is about autistic children, the idea of the appearance of the robot can be applied to the disabled child, once the child must feel comfortable and safe with the robot. Other important thing is that tasks must be very joyful for those children, once boredom tasks often discourage them to use the system.

In autistic children the robots are used for better interaction, trying to take them out of their "own world" and bringing them to the "real world". In the case of the disabled children the idea is to amplify their experiences inside the "real world", increasing their contact with new and self-controlled experiences and consequently reducing the learned helplessness idea. So, some ideas can be used in both scenarios, although the two situations are completely different.

## Methodology

In our researches, we have used a mobile robot with tweezers for manipulation of objects. This robot is commanded by disabled children using some of their voluntary signals.

Several tasks were done by those children, always focusing on environmental interaction, taking objects and finally putting them off on another place, finding "hidden" objects (actually an object among others with some degree of complexity to find), and drawing on a paper located under the robot.

All sessions are videotaped for further revision (after the parents signing the Consentient Term, approved by Ethical Commission). With the video, child's actions (such as number and order of keys pressed necessary to complete, with success, the task), and behaviours during the experience are evaluated by a Pedagogue.

## Goal Attaintment Scale (GAS)

In order to measure the success of the trial executions, that includes emotional aspects, the Goal Attainment Scale (GAS) (Cook, Bentz, Hartbottle, Lynch & Miller, 2005) is used. GAS is a method that has a score which, in addition to evaluate statistically the data, takes into account aspects like fear and happiness when the child is carrying out the trial, putting a score if the trial was executed or not and how it was executed. On the other hand, the GAS method allows including results from interviews with parents, teachers and caretakers who are able to evaluate improvements in the cognitive aspects of the child when using the robot.

GAS is also known like "Goal Achievement Scale". This method uses different weights to the goals attained in addition to a grade to each goal. The total grade may vary between -2 to +2, where 0 is the expected result, positive grades are results better than expected and negative grades are results worse than expected.  It's worth to comment that this scale has high subjectivity level because it takes into account the disabled level of the child.

The global grade is calculated according the grades obtained for all goals accomplished. Equation (1) shows the overall score (Cook et al, 2005):

$$T = 50 + 10 \cdot \left( \frac{\sum_{i=1}^{n} g_i}{\sqrt{n\text{-}R \cdot n + R \cdot n^2}} \right) \qquad (1)$$

Where:

- gi – grade related to the goal i accomplished by the child.
- n – number of goals accomplished for each tasks (one task can have several goals. The partial accomplishment is also taken into account).

- R – constant used to estimate the correlation between the grade and the several goals in the tasks. A constant of 0.3 is used, in the same way of (Cook et al, 2005).

Equation (1) should be used in a comparative way, according to (Cook et al, 2005), i.e. it should be verified the improvement obtained in several trials after the execution of the first trial. This way, it is possible to evaluate the improvement in terms of learning and grades (which measure how many goals are accomplished), thus having a way to measure the cognitive improvement of the child.

## Hardware and Software

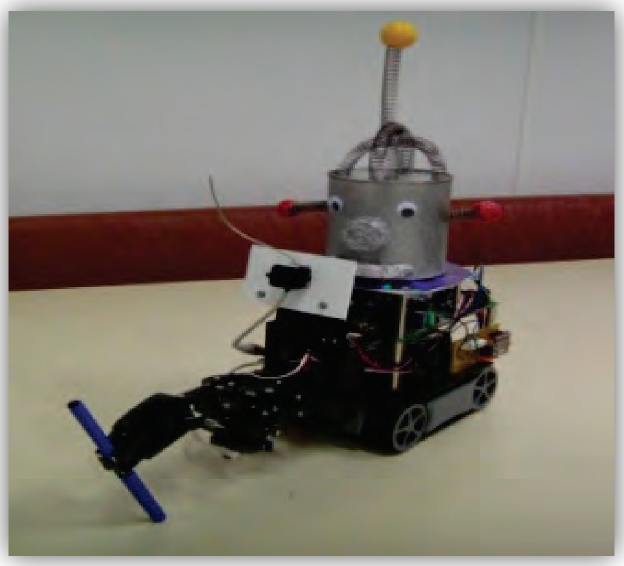
As part of the hardware used in this work, a sensor to capture both inclination of some part of the child body and his/her muscular effort (sEMG signal) was developed. Figure 3 shows the sensor developed, which has a battery and a Bluetooth transmitter included. The information of inclination is obtained from an accelerometer and the muscular effort is obtained from surface electrodes. Both data are transmitted to the robot which is used to execute movements and open or close its tweezers.

*Figure 3. Sensor developed to capture both inclination of some part of the child body and the muscular effort (sEMG signal).*

The mobile robot used in this research is the POB-EYE, manufactured by POB TECHNOLOGY. It is a mobile robot with tweezers which allow using the robot as a manipulator robotic as well.

In order to change the appearance of the robot, a clown mask was adapted to the robot as shown in Figure 4.

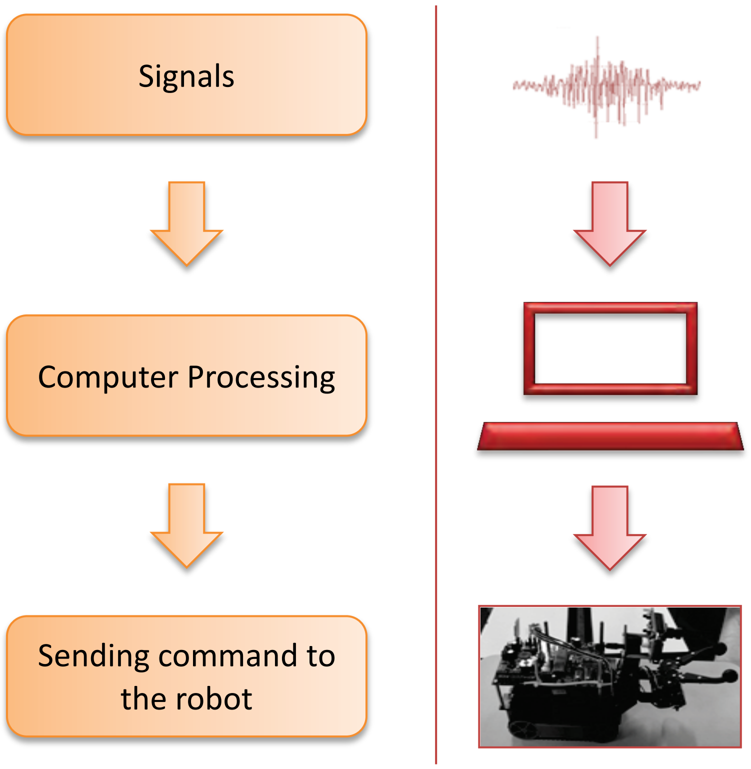
*Figure 4. Robot used in this research.*



Once the sensor acquires signal inclination of the body part and muscle effort from the child, that information is sent to a PC which processes the signal and makes an interpretation about which kind of action the child wishes the robot executes. So the movement order to move (or stop moving) or open or close the tweezers is sent to the robot. All the communication is done through Bluetooth devices.

While the computer is processing the signal to command the robot, the computer also makes a report recording each movement done, including time, picture of the child’s face in the moment of the movement and number of the movement. If there’s a correct sequence pre-programmed the report also shows if the movement is right or wrong. In this “correct sequence mode” the robot only executes action in correct movements. All this data is important for further evaluation by a Pedagogue. Figure 5 shows the scheme of the system.

*Figure 5. Scheme of the system used to capture the signals and to command the robot.*




According to the child's head movement the robot can drive ahead, backwards, to the left and to the right and other soft movements between those four main movements. To make the tweezers' movements it is necessary to use the EMG signal, so it is possible to switch the state of the tweezers.

On the other hand, the accelerometer's signal is received continuously and its value is converted to an angle which defines where the child wants the robot to go.

Limits values (maximum and minimum) are defined and are, actually, the highest and lowest inclination in each axis. It is done throughout two axes, so it is possible to calculate the angle between them.

Each value sent by the inclination sensor is a number that will be used by the software to understand where the child wants to move the robot. Firstly, it is analyzed the vertical axis (front and back) and later the horizontal axis (left and right), which means that the vertical axis is predominant. So if the

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inclination is diagonal being front and right the robot will drive ahead, not to the right. This allows the execution of soft movements with participation of the two axis, which means that the robot will go in the diagonal direction.

The signals sent to the robots are, actually, characters which indicate what movement it should do. Those characters are “w” for driving ahead, “d” for driving to the right, “a” for driving to the left and “s” for driving backwards. There is also the signal used to stop the robot that is represented by the character “t”.

The same idea is done with sEMG signal, which has a threshold trigger value to order the robot to switch the tweezers’ state.

Thus, when the robot is on a blank paper and has a pen hold by the tweezers, it is possible for the child, with some training, to draw something on the paper.

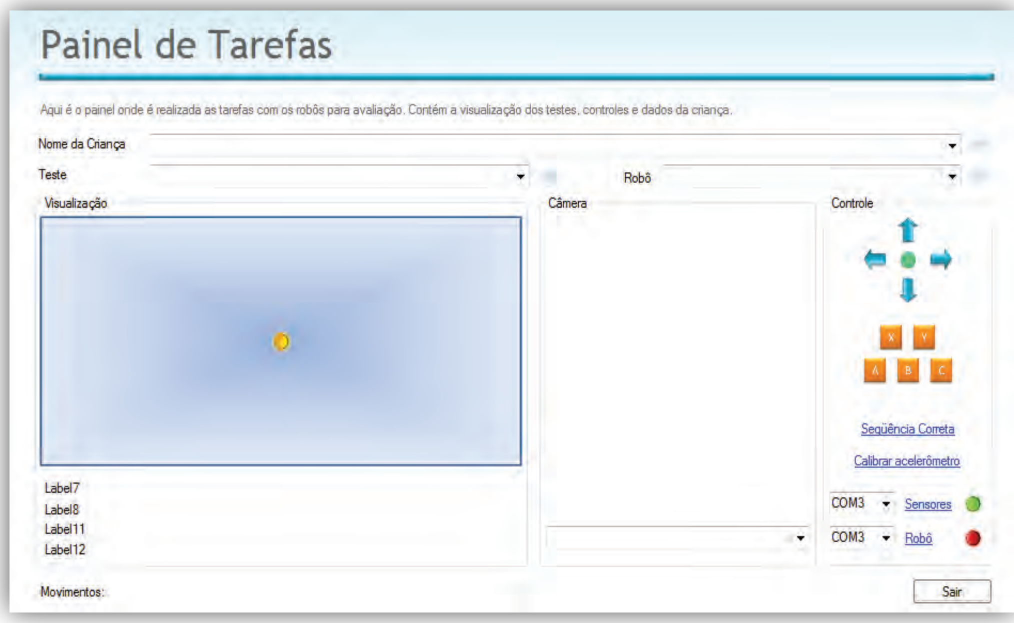
## Computer Interface

The computer interface was developed to help the evaluator and the child to achieve the goals. It resumes all the data of the tests and allows adding robots, tasks, children and auxiliary devices inside the database. It also allows searching for reports. The main screen of the program is used to better conduct the tests, once it shows all important data to the test achievement.

This computer interface can be divided, basically in six areas: main tasks, task registration, reports, children registration, robot registration, auxiliary devices registration.

The main screen is the task screen, which resume all the important data for the test achievement. It also allows the control and access of all the other parts of the program. It is necessary, before starting the test, to select a child’s name, a type of test, and a robot. It is also necessary to select a camera and the communication ports of the auxiliary device and robot. The screen is shown in the Figure 6.

*Figure 6. Main screen of the system.*




The child's name, robot and task is previously registered in the software database. Such information is very important once it is used to make the report.

Connection ports of sensors and robot are defined inside this part of the program. As said before, it is necessary to select a COMM port to allow communication for the robot and another one for the sensor. If the COMM port for the robot is left blank or it is not possible to communicate with, there is the option of executing the trial using the virtual robot, represented by a little yellow circle, showed on the screen. On the other hand, if there is no sensor the virtual joystick in this screen can be used as a virtual auxiliary device. The system scheme is showed in Figure 7.

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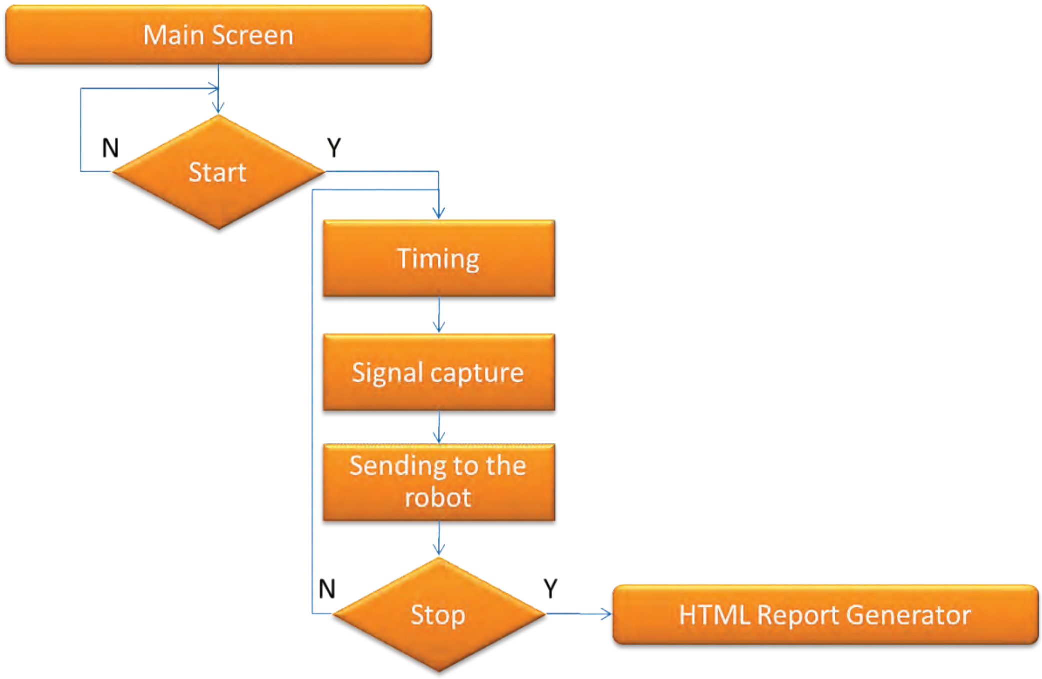
*Figure 7. Simplified flowchart of software operation.*




This scheme considers that a child, a test, a robot and a camera have been previously selected. If not, the system will show a dialogbox asking for choosing what is missing. Other important thing is that inside the block “send to the robot” there is a process that will be explained further. In the system “start” and “stop”, showed in the above diagram, are, actually, the green and red buttons of control’s groupbox.

Inside this screen there is a link to “right sequence”. This part of the software allows the evaluator to choose the correct movements and the robot only will do the movement when it is correct. Wrong movements will be registered and can be used to evaluate statistically if the child has adapted well or not to the system.

## Automatic Reports

After executing the trials, a report is generated, including the child’s name, the test name, the robot name, the duration of the task, the number of movements and the pre-programmed sequence, if there is any.

The list of movements done is also presented in the report. This list contains the number of the movement, excluding the movements ordering the robot to stop. Together with the number of the movement there is a picture of the child that will be followed by an arrow showing which movement the child did.

If there is no right sequence, those arrows will appear blue. It there is a right sequence, those arrows will appear green when the movement is correct and red when the movement is wrong.

Following the arrows (any kind of them) there is a little text that says the direction of the movement and finally there is the movement time, compared with the first movement (the first movement is considered to be at moment zero).

When the system is in “right movement mode” it is possible to calculate statistically the system’s efficiency.

All this report is done to further be possible an evaluation by a Pedagogue. The pictures are very important to evaluate the emotional state of those children by looking their face expression, such as smiling or crying. Those elements are, certainly, very important, once it can make severe influence on the trials.

With some reports of those children it is possible to evaluate if they are or are not getting used to the system and if there is an improvement in behavioural-cognitive terms. A report example is shown in Figure 8.

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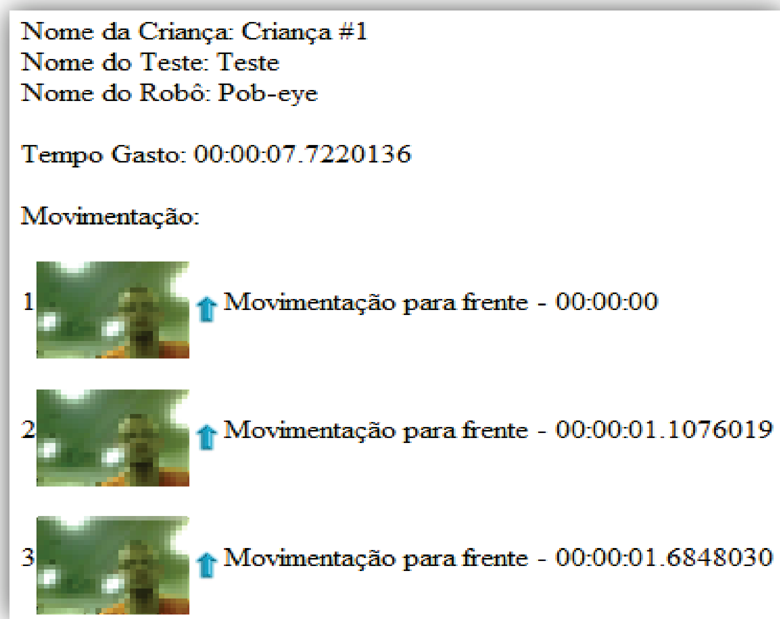
*Figure 8. Report generated with the software.*




Supporting the main part of the program there are the registration part (of people, robots and auxiliary devices) and the report screen.

Those registrations work similarly. They are connected to a Compact SQL Database included in Visual Studio Express Edition 2008 installation. Each registration screen has its own database.

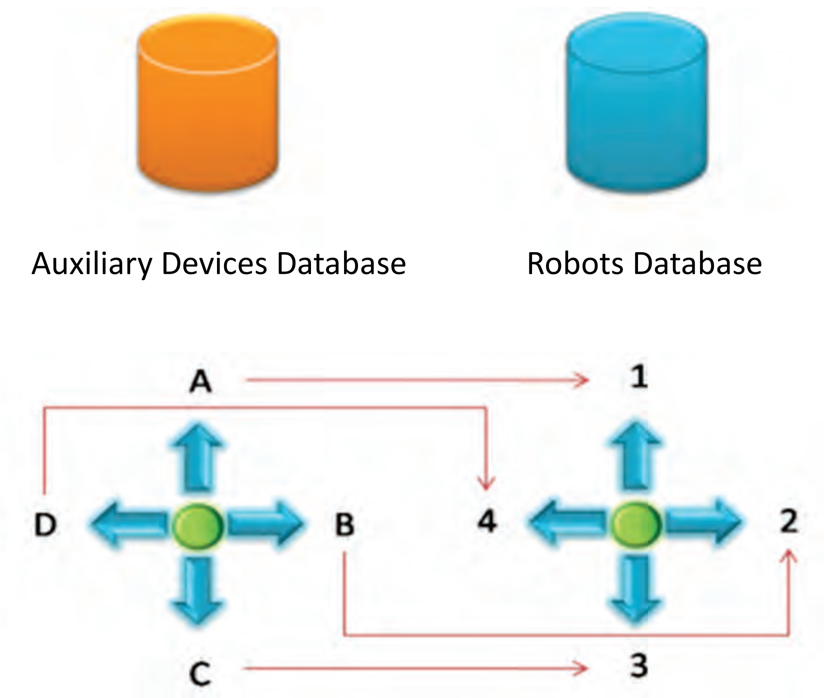
## Registration and data conversion

In the child register some questions are asked, such as child's name, birth date, which kind of disability the child has and the parent's name. In the tasks registration just the name of task and a brief description is asked. In each case there is a unique identifier to ease the organization and searching.

In the registration of robots and auxiliary robots some more information are asked, which are very important, due its use in the translation between the auxiliary device signal and the robot signal. In other words, in those parts of the programs it is asked which signal is received when it is wanted to drive ahead, backwards, left or right. So the database knows previously which signal represents each action.

At the same time, the robot registration asks which command the robot should receive to do certain action (such as driving ahead, backwards, left and right, changing of the tweezers mode). So the software catches the signal of the auxiliary device and "translate" it to the robot. Hence, using this system, virtually any auxiliary device compatible with any robot can be used to perform the tasks. This idea is shown in Figure 9.

*Figure 9. The correlation between the commands is done comparing equivalent items in different databases.*




To illustrate this, a child would be able to control the robot with any sensor. And on the other hand with one sensor he or she can control any robot (if it is compatible).

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## Tasks

In order to evaluate the system developed, three tasks were performed by 14 disabled children along three weeks. The duration of each task was about 30 min. The tasks were:

- Initial Task (Training) – Move the robot through a path with obstacles. This task allows the children have the first contact with the robot and it was necessary to command the robot in four directions. Figure 10 shows a picture of the initial task.

*Figure 10. Initial task (Training) with the robot.*

- **Task #1 - Drawing with the robot.** In this case, the robot has a pen hold by the tweezers and the child should command the robot to move on a paper in order to draw lines (Figure 11). In this work, the ability of making free drawing was also evaluated (Figure 12).

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*Figure 11. Drawing a path with the robot.*

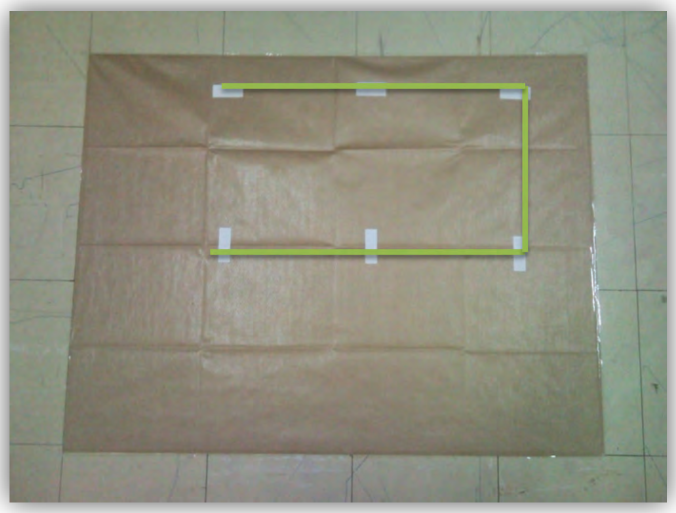
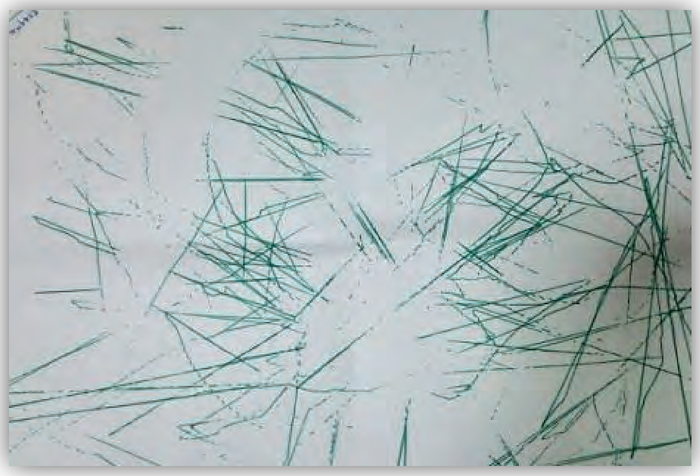


*Figure 12. Free drawing made by a disabled child.*



- **Task #2 - Command the robot through more complex paths.** In this case, the path contains some color blocks used as obstacles. The free space to move the robot is reduced which demand more precise movements. Figure 13 shows this task.

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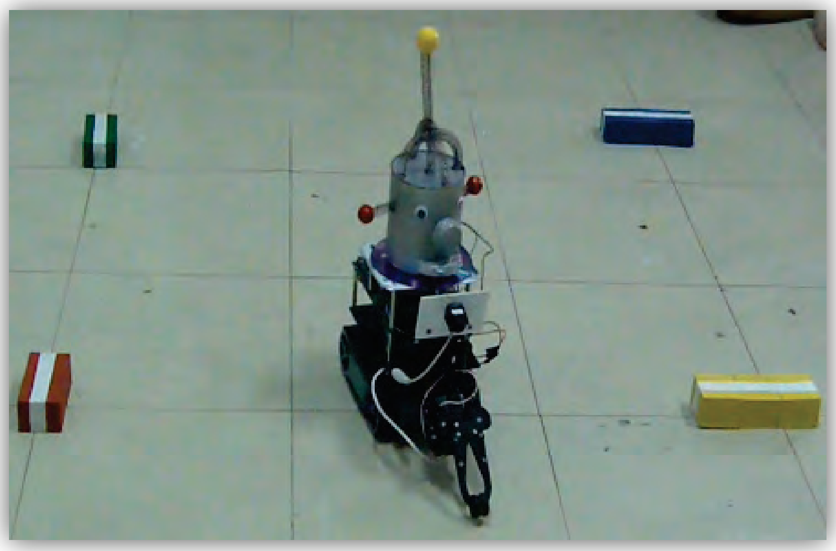
*Figure 13. More complex path.*



## Results

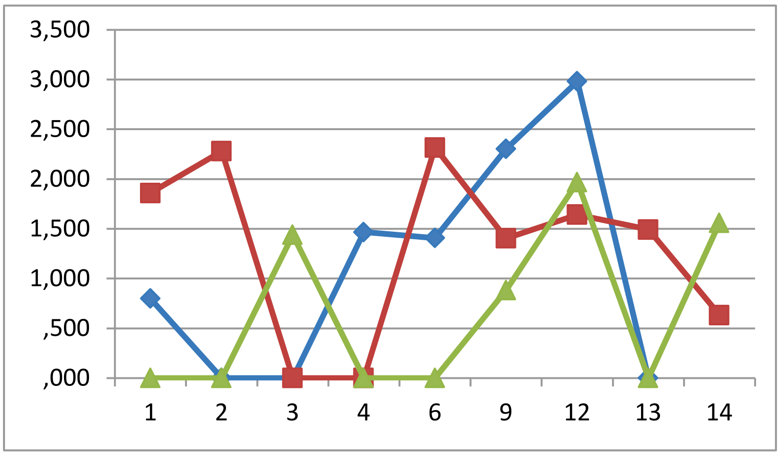
Several trials were carried out with 14 disabled children and it was possible to evaluate the results based on some aspects like time to finish the task, total number of movements executed by the child, number and percentage of movements that produce robot movements (valid movements), and movements by second. This evaluation was carried out after several weeks in order to find out the improvements obtained with the use of the robot to aid these disabled children.

From these aspects, movements by second and percentage of valid movements seem to represent the more important ones, because the number of movements by second trends to diminish according to the repetition of movements with the robot made by the child. In fact, according to Table 1 and Figure 14, the number of movements by second decreased from the first to the third week, although there was an increase of these movements in the second week because in that week there was a different draw carried out by the children, needing in that case higher number of movements by second.

*Table 4. Number of movements by second.*

| Child | Week 1 | Week 2 | Week 3 |
|---|---|---|---|
| 1 | 0,80 | 1,86 | - |
| 2 | - | 2,28 | - |
| 3 | - | - | 1,44 |
| 4 | 1,47 | - | - |
| 6 | 1,41 | 2,32 | - |
| 9 | 2,30 | 1,40 | 0,88 |
| 12 | 2,98 | 1,64 | 1,97 |
| 13 | - | 1,49 | - |
| 14 | 0,63 | 1,56 | - |
| **Average** | **1,60** | **1,79** | **1,43** |

*Figure 14.Movements by second during three weeks.*

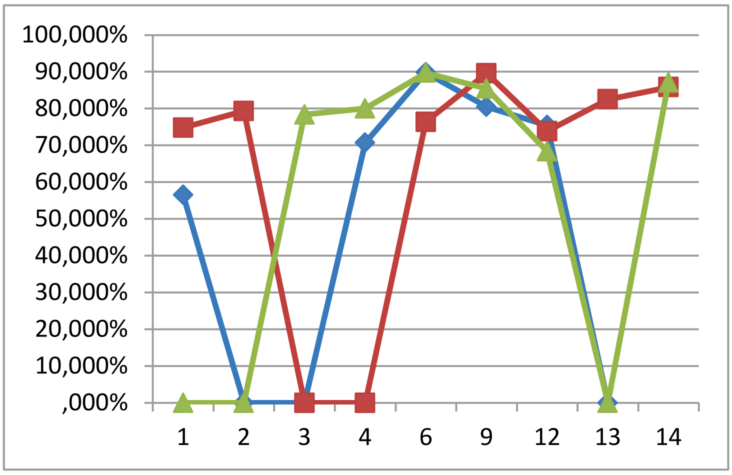



In relation to the percentage of valid movements, Table 2 and Figure 15 show the increase of this parameter along the weeks, which it is expected due to the confident of using the robot by the children.

*Table 5. Percentage of valid movements.*

| Child | Week 1 | Week 2 | Week 3 |
|---|---|---|---|
| 1 | 56,53% | 74,78% | - |
| 2 | - | 79,30% | - |
| 3 | - | - | 78,37% |
| 4 | 70,69% | - | - |
| 6 | 89,81% | 76,35% | - |
| 9 | 80,43% | 89,58% | 85,41% |
| 12 | 75,43% | 73,85% | 68,38% |
| 13 | - | 82,49% | - |
| 14 | 85,80% | 87,01% | - |
| **Average** | **76,45%** | **80,48%** | **77,93%** |

*Figure 15. Percentage of valid movements.*




## Conclusions

The main goal of this system was to increase the communication between the child and the external world. It consequently will bring a better learning and a better social interaction as well, which are important elements for human development.

All the system was evaluated successfully with 14 disabled children during a sequence of trials they performed.

From Table 1-2 and Figure 10-11, it is possible to find out that the children improved the learning of using the robot, which is verified comparing the number of movements by second executed along the week (decreasing of 10,6%). On the other hand, the number of valid movements also improved along the weeks (about 4%).

Using the results of the system's reports, it was possible to change and create new tasks in order to try to make those children interact even more with the environment, bringing them more independence and self- esteem.

Future works with this system include the use of this playful robot in different therapy with disabled children. This system helps also the execution of movements by these children in the field of Physiotherapy because children feel stimulated to move parts of their body when realize that their movements can command a robot.

## Acknowledgments

Authors would like to thank FACITEC (Vitoria City Hall Foundation) for the funding support.

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