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PLEIA: A Reconfigurable Platform for Evaluation of HCI acting

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1. Introduction

For people with severe motor disabilities, it is difficult or sometimes impossible to use standard interface devices (mouse, keyboards, joysticks, trackballs, etc …). The evaluation of their capabilities, the education or re education of abilities and the compensation of their deficiencies is essential. Nowadays, the performance of a person is only determined by the observation of the trajectory followed by the cursor during the exercises and to facilitated people's accessibility to computer and electrical devices, few exist. Standard test and reliable indicators would bring a better evaluation of the use of peripheral interfaces for motor handicapped people. Two ways of research have been developed: some researchers have focused on defining new peripheral devices, others have focused their works on new rehabilitation process and algorithms to adapt commands. We assume that we are able to associate on the same study of pointing task: computer, wheelchair and environment control.

2. Problem

For the handicapped person, the use of interface controls could be a very complex task. The systems for aiding the person are controlled by an interface. It is founded on the relation between the Human Computer Interactions (HCI). The most important problem in the Human interaction is the adequacy between the user and the interface: computer, wheelchair, remote control… Moreover, the wide range of motor disabilities makes impossible the development of standard solutions. In most cases, a customized interface device is developed to fit to the deficiency of person. Some laboratories focused their researches on the design and the development of a personalized and adjustable Human-Computer Interface (HCI). However, for motor disabilities, few studies based on the interface tasks and quantitative evaluations were conduced. Nowadays, there are few works that present simple and reliable indicators (Buaud A.,2003)(Kadouche R, 2004) for evaluating the performance of impaired users. Usually this task is achieved by a qualitative evaluation led by the therapist (fig. 1). There are some methods for evaluating the dexterity. For example, the method used today by the occupational therapist is based

on the functional evaluation by a direct analysis of the other activity acting as operator (cinesiologic analysis):
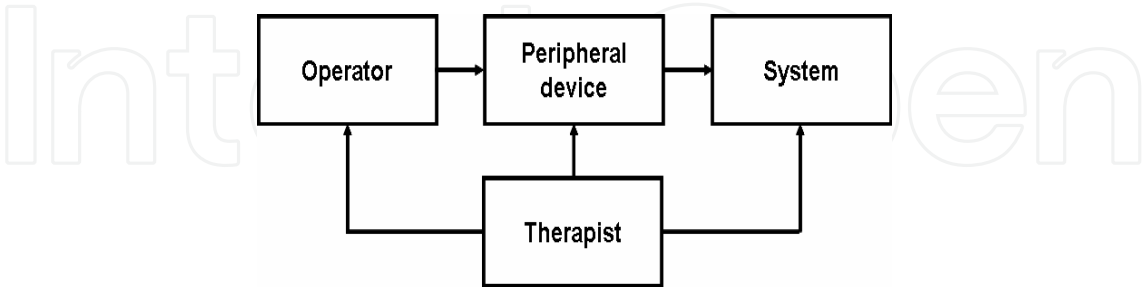

Fig. 1. Evaluation scheme for normal therapy session.

The therapist acts on the operator, the peripheral device and the system. This system can be a personal computer, an external system such as powered wheelchair or a toy. The feedback used by the therapist is qualitative. The therapist is able to adapt the device changing internal parameters (such as sensibility, position, as well as, the configuration of system). These corrected actions are done following the therapist expertise.

3. Objective

PLEIA (Peralta H., 2006) software can be integrated into the evaluation scheme (fig. 2) as assistive system for the therapist.
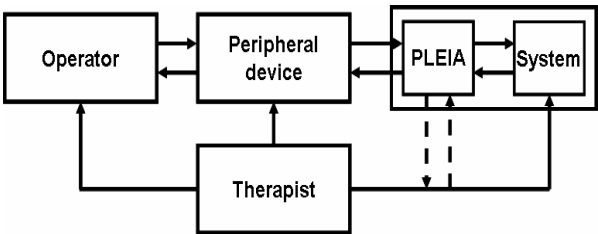

Fig. 2. Evaluation scheme with PLEIA Platform.

PLEIA gets information from the peripheral device. The therapist can access to these information. Then he can act on PLEIA, on the peripheral device or on the system. The evaluation of their capabilities by the interface capabilities is essential. Today in the scope of adaptation and quantitative measures of capacity, few evaluation standard methods exist. The evaluation are oriented to handicap, but the information measured just allow to determinate delay and trajectory by basic indicators. Therefore, it is necessary to find new methods to evaluate the peripheral devices by computers processing's mean. The monitoring of the user capability is useful for determining the diagnostic information. The plan for the rehabilitation could be also based on evaluation result (Dipietro, L. 2003). Thus, it is necessary to have a set of quantitative criteria, a therapy methodology and common tools to be applied by the occupational therapist.

The objective is then to define suitable exercises associated with quantitative criteria in order to evaluate the adaptation between the user and the peripheral (fig. 3). It includes performance but also handling evaluation at a time and on a period training.

4. Related Research

4.1 Evaluation studies

There are studies to determine analytical evaluation from the pointing devices with the user interaction. The first work about the hand movement is the Fitt's Law which is based on a model of human psychomotor behavior developed in 1954. It gets the measure of a Movement Time (MT) index. This is the result of the relationship between movement time, distance, and accuracy. Many works about the evaluation of movement and Human Computer Interaction (HCI) are based on this law.

Fig. 3. Examples of peripheral device.

The main interest in this law is that it can be applied to pointing and dragging using a mouse, trackball, joystick, and touch screen (Keates, S., 2002) (Soukoreff, R. 2004). Mackenzie (MacKenzie, I., 2001) proposed seven new accuracy measures to evaluate computer pointing devices. The measures are intended to elicit subtle differences among devices through an analysis of the cursor movement along the cursor path. The ISO standard to assist evaluation of pointing devices is ISO 9241: "Ergonomic design for office work with visual display terminals (VDTs)." The part 9 is "Requirements for non-keyboard input devices". In (ISO 9241-9) are included mouse, joysticks, track ball, tablets and overlays, touchpad, touch sensible screens. The standard specifies the quality of the input devices in terms of performance criterion: "it is considered useable, if users can achieve a satisfactory level of performance on a given task and maintain an acceptable level of effort and satisfaction".

4.2 Methods to improve the mobility with pointing systems

If the interface is correctly adapted to the abilities of user, there are many solutions to improve it. Some solutions have been developed for accessibility and mobility. These solutions are based on command sensor adaptation processing. For example, "smart wheelchair", "adaptive interfaces" and "adaptive commands" (Thieffry, R., 2005) develop assistive methodology in order to reduce the physical, perceptual, or cognitive skills necessary to operate with safety a powered wheelchair or another system (walker or computer pointing system). Other works on assistive robotic wheelchair system improve the

acting by the design of specific sensor interfaces like in the Wheelesley (Yanco, H., 2002). (Kang, S., 2004) shown one joystick for a system like an electric wheelchair. This system helps to drive easily and safety. Another system was experimented. (Jeong, H. 2004) proposed a new Human-Computer-Interaction (HCI) method for a quadriplegic, which is controlled by clenching teeth. Two clenching patterns, did seven instructions including rest, up, down, left and right as well as click and double click actions are made for the control of a pointing device. The control source is EMG[1]. An experimental system of voice interface is presented in (Tellex, S., 2005). It is an alternative controlled manner. The system "understands" natural language motion commands. The works show the possibility to compensate and improve the user mobility. The big parts of such systems use a pointing interface as command access. The questions are then: How could the users have the right peripheral device? It is convenient for his proper abilities? Can another interface improve his development on the control of his system? A step of evaluation with different interfaces is necessary.

4.3 Evaluation platforms

Platforms for improving the HCI acting based on exercises have been developed (Shimizu, H., 2006) for re-educational therapy. Today, the computer applications include graphical interfaces. Actions as "click", "displace", "drag and drop" are essential to handle a computer. There are many software, for handicapped persons that basically are centered on learning. For example, Judy Lynn Software, Inc. offers different categories of software for different patient (depending upon age and symptom), these work to improve certain activity as visual tracking, cause effect, hand - eye coordination, etc. We can find similar software of many companies as: Marblesoft, Simtech publication, Widget software. In conclusion, the exercises proposed by these softwares have an educational interest but they do not include a performance evaluation of user acting. Adeprio Diffusion proposes to save the results of patient acting. Efficasouris (Adameczek, A., 2005) is a software developed to evaluate the pointing capabilities of patient with the mouse, saving the performance. The designers have built four modules: 1) The game module, 2) The statistical module to save the performance data of patient, 3) Diagnostic or User identification and personal perception (this module is a questionnaire model, used to know qualitative the point of view on test and software) and the last one, 4) Virtual Keyboard, serves to design a virtual keyboard adapted to the patient from the analysis data. The last module is the objective of efficasouris. The medical team realizes subjective analysis (based on a questionnaire) and objective analysis which are made directly (observation of the interaction with the user during the test) and indirectly (using cameras and record data performance). The software has three indexes: task time, task error, and clicks number (accuracy). Another example is Catch Me™ by lifetool. It is evaluation software with interesting properties as creation of exercises, tuning of exercises and parameters configuration as mouse speed, colors, forms, wallpapers, volume. The analyzed results are: game time, right actions number, wrong actions number and average time by action. This does not include information on the user handling.

The following section explains the main idea for therapy methodology on PLEIA software.

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[1] Electromyogram (EMG)

5. PLEIA

5.1 Description of Software Platform for Interface & Interface Evaluation (PLEIA)

The PLEIA software platform (by French acronymic) is our specialized evaluation platform. The PLEIA proposes an open methodology (fig.4) to evaluate the user's dexterity with the pointing devices using different peripheral computer devices at the end of the process. It allows to adapt these devices to characteristic of user using different feedback modes (light, sound, haptic, etc...) dedicated to occupational therapist. PLEIA tools allow to elaborate specific exercises based on functional systems: from computer interface to wheelchair command.
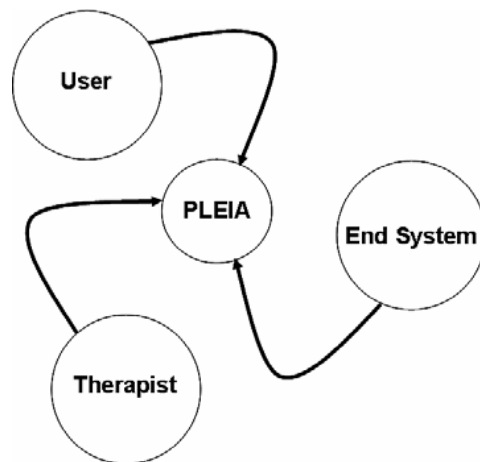

Fig.4. PLEIA as centre of the evaluation, assistance and compensation process.

The therapy session could be oriented on different goals: function learning (especially for the young children), evaluation of dexterity with different peripheral and generalization for other systems like wheelchair command. PLEIA is composed on three blocks with the same functionalities:

- **PLEIA evaluation**: This module was programmed to evaluate the dexterity through 5 main tests: 1) Reach Target, 2) Drag and drop, 3) Follow path, 4) Click Targets, 5) Exploration screen zones. This chapter is centered on this module.
- **PLEIA functional awaking**: This module allows user to act on real object (robots, toys, etc.). It is dedicated for the young children. The same evaluation could be done.
- **PLEIA functional**: This module is dedicated to evaluate handling of a powered wheelchair (often goal of the therapy).

PLEIA is a program that allows therapist to create specific exercises with scenarios. It could be connected to different peripheral interfaces (joystick, trackball, mouse, keyboard, etc.) and act on devices as robot (khepera™), toys and electric wheelchair. All information and performance data (time, errors, coordinates, etc ...) are analyzed. The patient tests different peripheral devices. The therapist evaluates which is more adequate for pointing systems. Different analytic indexes have been developed (see section 6). The therapist could create suitable configurations of exercise (named scenarios) with different tuning parameters such as cursor speed, sound, cursor and objects dimensions and appearance. This platform can be

connected for remote experiment with other medical centers. Basically, PLEIA includes different exercises. The proposed test could include different elements, such as obstacles, objectives to reach, object to take, trajectories, cursor. These elements are shown in (fig. 5).
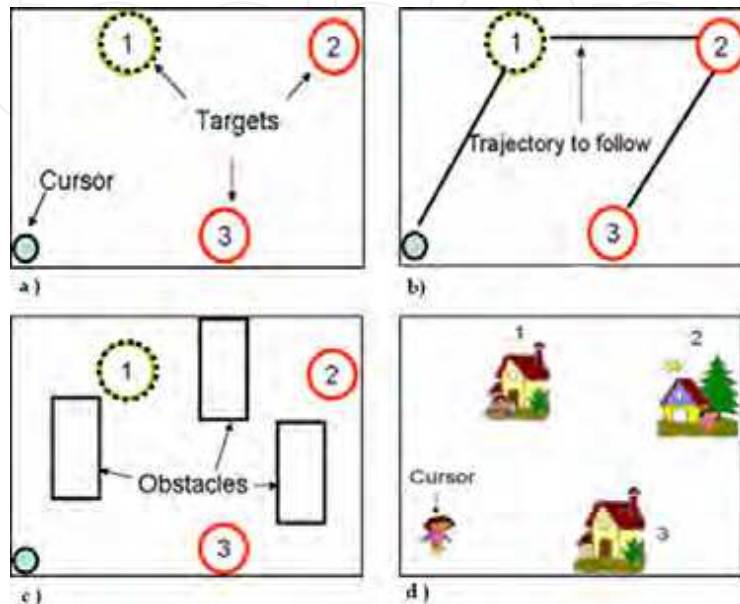

Fig. 5. Exercise models on PLEIA Software with the same scenario: a) Reach the targets, b) Follow path, c) Avoid the obstacles, d) Mode tuned.

Reach the targets (fig 5a), the aim of this test is to evaluate a displacement. The trajectory is shown by sequence of object. The dotted circle is the next objective to reach. The (fig. 5b) shows the same configuration of target, with path constraint. The next scenario (fig. 5c) is used when the patient present uncontrolled movements. The trajectory includes targets and obstacles to avoid. The (fig. 5d), shows the same test with different images. The therapist uses them to improve the attention of children. Fig. 9 present other example of PLEIA test.

5.2 PLEIA Functionalities

The functionalities that PLEIA offers are:
- Exercise configuration assistance:

The configuration of exercise is based on a wizard processing in order to be user friendly. The medical team is able to choose the suitable exercise for evaluating the patient performance. We suggest five main model exercises: (1) Reach target: reaching certain objects on the computer screen. (2) Drag and drop: It refers to the capacity to hold a button and at the same time do the displacement. (3) Follow path: It evaluates the capacity of following a track. (4) Click on the targets: this test has been thought to measure the user accuracy, with different target sizes. (5) Exploration screen zones: this exercise evaluates work reachable space. It is very important to mention that the objects designed by the therapist on the scenario (trajectories, obstacles, wallpapers, etc) can be simple or complex depending upon the type of exercise. The decision is taken by the therapist.

- Patient test information:

PLEIA memorizes user actions (see section 6).

- Performance indexes as trajectory length, errors, clicks used in the exercise, accuracy, time delay, and command analysis.
- Assistance Mode:

To compensate the patient disability, We used feedback such as visual, audio, or vibration associated to test conditions (ex. Impact with the obstacle) to inform the user. Specific assistance like sensitive attraction could be used in the execution.

6. Method evaluation

6.1 Participants.

We present in this section, two children evaluations, Claudia and Robert. Each participant was identified as "child with disability" by the medical team. They can not use mouse, basic joystick or trackball because of their limitation in the mobility and muscular weakness. The fatigability is another factor to take into account. The test must take a few minutes (1 to 2 min), and the session has a 45 min duration at the worst case fro the good results.

Claudia is four years old child. She suffers from myopathy. She uses minitrack stick. She handles it with the left index finger. Special technical adaptations are required (fig. 6).

Robert is seven years old child. He suffers from myopathy, uses a mini joystick HMC™ with InfraRed connection. Robert uses the left thumb finger to handle his medical aid.

We have then introduced new indicators that could help the therapists to evaluate the performance of each patient.

Fig. 6. Claudia with special adaptations for makes a test on PLEIA software.

Fig. 7. Robert in therapy session with PLEIA.

These indicators have been implemented in a software platform (PLEIA). It is developed in collaboration with the Raymond Poincare Hospital and Saint Maurice Hospital (Paris Hospital).
PLEIA include user information. It includes the data of test, date, disabilities of patient, and other information of patient.
The patient is placed in front of monitor (between 0.60 m to 0.80 m). The computer's devices are installed in the best condition of comfort and functionality for the patient. This last condition depends upon the deficiency and the position of the patient (fig. 8).

6.2 Measurement and performance indexes
The indicator based on a set of performance focus the peripheral adaptation problem. In other words, they allow quantifying the realization of pointing tests and to appreciate the choice and the configuration of the peripheral device. They carry out comparisons to appreciate the evolution of the results of one user or relative to different classes of users.
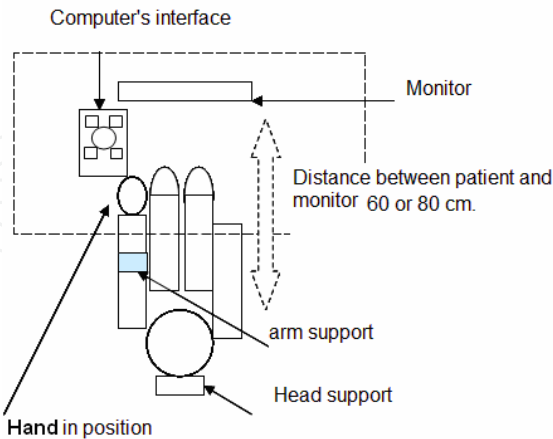

Fig. 8. Localization of patient.

We defined two groups of indicators: (a) task indicators which use direct results of the test execution, (b) comfort indicators which are centered on the behavior of the patient.

1) Task indicators: The indicators of tasks are the first order indicators which give a direct classification of the performances of the user. Based on tests, we retained three basic measurements:

o **Total time of exercise (TT)**: It is the time to finish the exercise.
o **The Covered Distance (CD):** It is the addition of all cursor displacement.
o **The collision (C) or Failure (F)** is a problem occurrence in the test: collision with obstacle, target unreachable.

2) Comfort indicators: The indicators of comfort have been introduced to evaluate user easiness in manipulating the device. The proposed indicators are:

o **Pause Rate (PR):** This indicator calculates the ratio of cursor stop delay in the exercise. This indicator expresses the "fatigue" of the user on a specification test with peripheral.

$$PR = \frac{PT}{TT} \qquad (1)$$

PT: Pause time
TT: Test time.

o **User Action (UA).** This indicator estimates the number of user action on the peripheral interface.

$$UA = \sum_{i=0}^{TT} \left[(K_1 \Delta I_1)_i^2 + (K_2 \Delta I_2)_i^2 \right] \qquad (2)$$

ΔI_1, ΔI_2: Peripheral inputs variation (between two sequential inputs).
TT : Test Time
i : Sample time in the test.
K_1, K_2: Normalization gains

o **Command Load (CL):** This indicator estimates the interface action number of the user versus a reference user.

$$CL_{user} = \frac{UA_{user}}{UA_{ref}} \qquad (3)$$

UV $_{ref}$: User action variation (Valid person).
UV $_{user}$: User action variation (User)

o **Efficient Coefficient (EC).** It estimates the efficiency of user commands. An inefficiency is defined as the user actions that tend not to optimize the result of the test

$$EC = \sum_{i=0}^{TT} \left[\left((K_1 I_1)_i^2 + (K_2 I_2)_i^2 \right) * K_3 \Delta G d_i \right] \qquad (4)$$

ΔGd_i : Goal distance variation on the sample i

ΔI₁, ΔI₂: Peripheral inputs variation.
TT : Test Time
i : Sample time in the test.
K₃,K₁,K₂: Normalization gains

o **Efficient Load** (**EL**). This ratio estimates the user efficiency between the Reference Efficient Coefficient (EC) getting of valid user and the User Efficient Coefficient, multiplied by the Rate Time. This Ratio Time is defined as reference total time (time to finish the test by the Reference User) and the user total time.

$$EL_{user} = \frac{EC_{ref}}{EC_{user}} * \left(\frac{TT_{ref}}{TT_{user}} \right) \tag{5}$$

ECref : Efficient Coefficient (Valid user).
ECuser : Efficient Coefficient (user).
TTref : Test Time reference (Valid user)
TTuser : Test Time reference (user)

7. Experimentation

The exercise designed for the children by the occupational therapist (fig. 9) is a sequence of 12 targets.
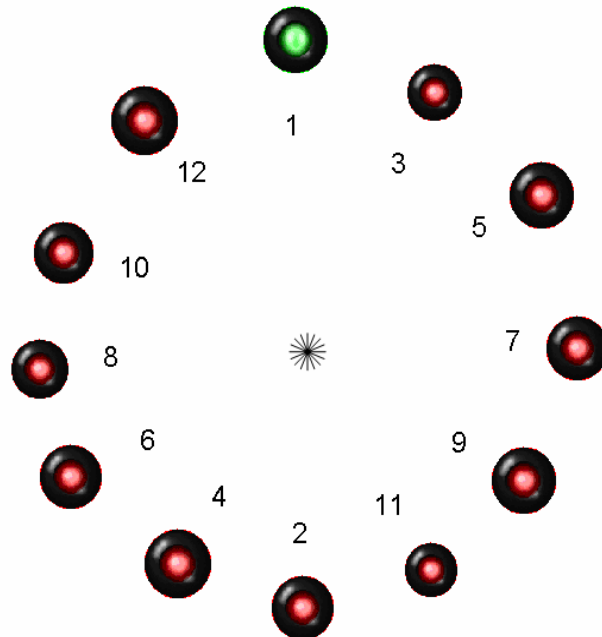
Fig. 9. Exercise designed for the Children

For a best understanding, PLEIA (configured by the therapist) displays sequentially only the next target, and hides the others. When the next target is reached, it is cleared and another

appears. One sound can be also associated (feedback configuration, target reaching). This exercise does not have obstacles avoidance and the aim is the evaluation of dexterity.

o   Experimentation with the abilities of Claudia.

Claudia knew PLEIA in November 2006. Her mobility and understanding were limited and difficult. This child had trouble with the test "follow path". This child could not avoid obstacles and the movements sometimes were without control. Then, the therapist proposed a test without obstacles and path. At first time it was only a simple test with one target. She practiced the test many times. After, the therapist proposed an exercise more complex. Test with 12 targets to reach. This article is based on two evaluations done in February 2007, November 2006 with the same 12 target test (fig.10 and 11) and the same technical aide and settings. Before , she practiced the model test proposed by the therapist without data saved. The therapist explained and practiced with her the activity and movements wanted. The therapist says when the patient has understood the activity, then, the data are saved.

The first session, Claudia made four practical test, the data were saved after (fifth test). The total test in the first session was eight. Trajectories at the beginning were sometimes uncontrolled.

The second session, the practical test number, was increased, because, the therapist saw that the patient did the test without difficulty, the test number in this session was nine. We can see that the movements in the second test are more optimized. The understanding about the aim of the exercise is better. She has a tactic to reach the target: when she goes to reach the next target, the displacement is very fast and exceeds the position of the target, then, she comes back to the target with circular and controlled slowly movement.
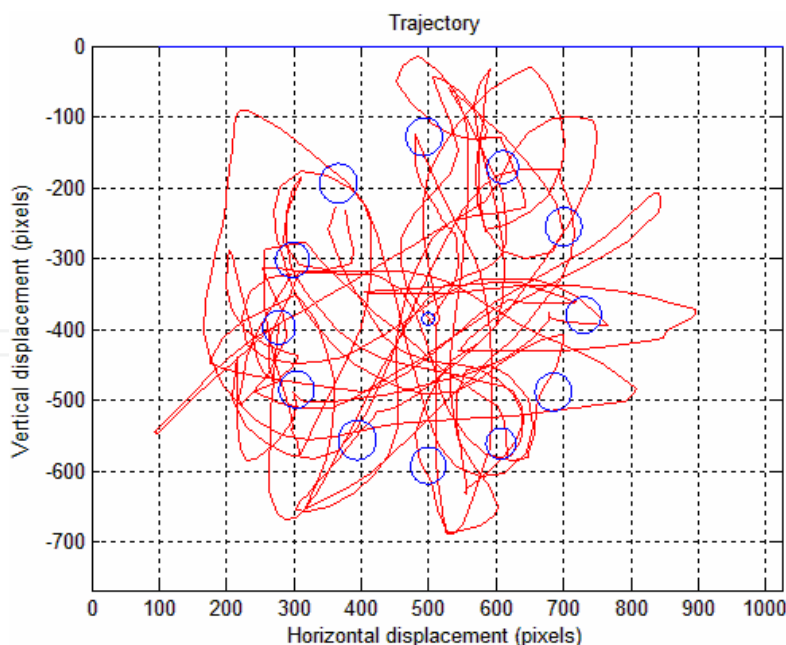

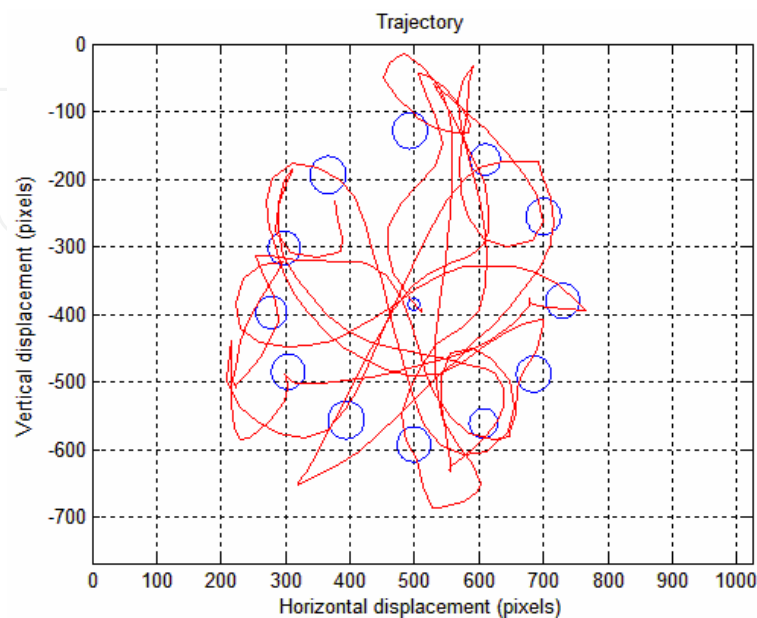Fig.10. Trajectory of Claudia in November 2006.

Fig.11. Trajectory of Claudia in February 2007.

The fig.12. Shows the evaluation phases distance in time (ms) for the two exercises. The scope of the first curves (noted (a)), is longer than the second (noted (b)). The displacement in the first exercise is slower than in the second test. The user action index (UA) represent user action on the peripheral device, this index is a function of the energy cost that the user must employ to realize the test. This index gives information to the adaptation between the user and his peripheral.
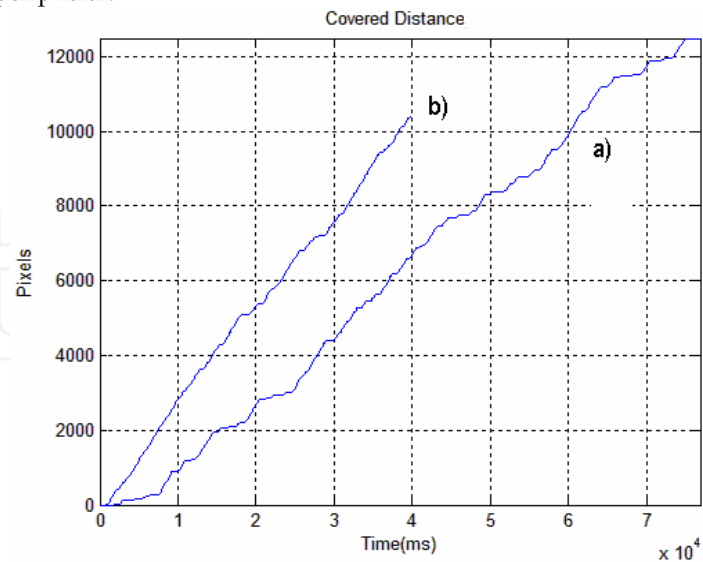
Fig. 12. Covered distance of two trajectories: a) November test, b) February test.
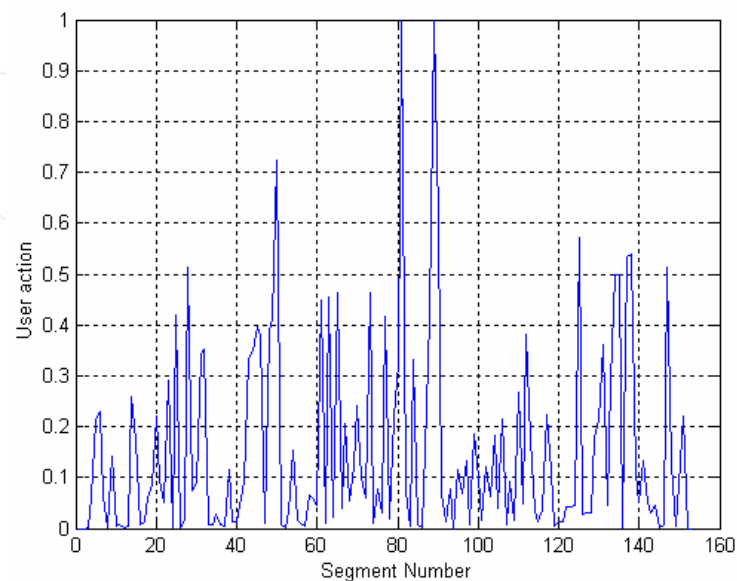
Fig. 13. User Action (UA) in November.

The Command Load (**CL**), shows the rate between the Action User versus a Reference User. Claudia acts more on the peripheral in the first test (2.43 on **CL**) . The efficiency Load (**EL**) is different (8 to 27 %). In fact Claudia had understood the test because the **RP** was lower (13.65 to 2.5). It is not an adaptation of peripheral but an adaptation of Claudia (a cause of training). She was more ready for the evaluation test (see table 1).
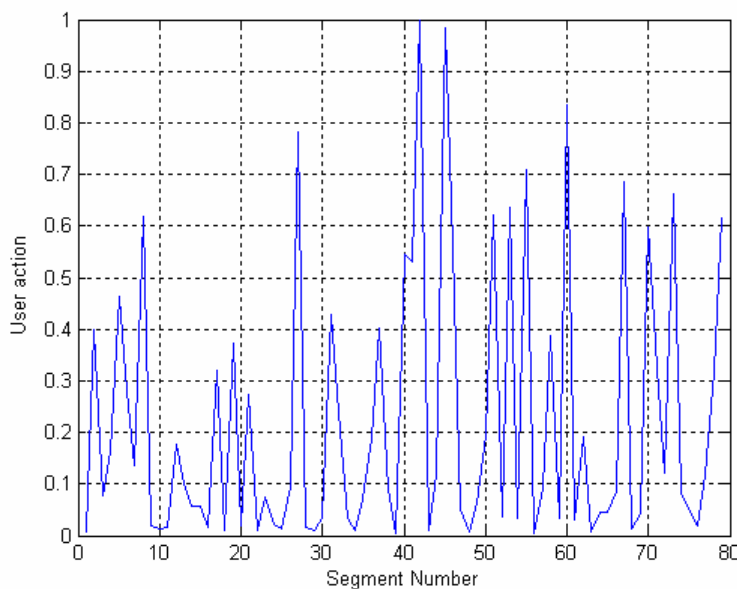

Fig. 14. User Action (UA) in February.

Sample	Test Time (TT) (ms)	Covered Distance (CD) (pixels)	Rate of Pause (RP) (%)	Command Load (CL)	Efficient Load (EL) (%)
Nov2006	76900	12500	13.65	2.43	8
Feb2007	39900	10500	2.5	0.89	27

Table 1. Claudia results.

o   Experimentation with Robert

The first contact of Robert with PLEIA was in May 2006. The test shows, were made in November 2006. He has a good control on the technical aid but he acts slowly. The same exercise was used, in similar conditions.

Fig. 15 and 16 show two trajectories. We can notice that he has a good control on his technical aid. The trajectories are "cleaner" and very specific, He has a little problem with the diagonal trajectory, but the straight lines are good.
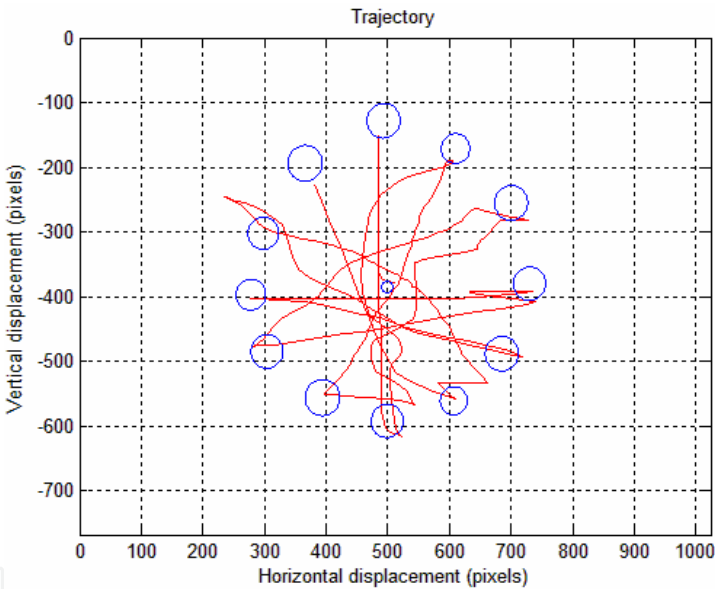

Fig. 15 Robert first trajectory

The occupational therapist observes that when Robert reaches the target, he makes a little pause. He is planning a few seconds the best trajectory to reach the next target. He has employed more time in the test 1 that the test 2 (10 %).

Between the two test, Robert has increase the number of actions (CL = 1.14 to 1.58 %) with some benefit (TT decrease of ~10%). However, he increases his efficiency (EL from 53 to 97%), see table 2.

In fact, in comparison with Claudia, the behavior is similar however he has a biggest pause rate (16.80). It means that Robert is more cerebral and he takes advantage from pause to stratify the next actions. Claudia is more reactive on peripheral. The result is that Robert acts more efficiently that Claudia.
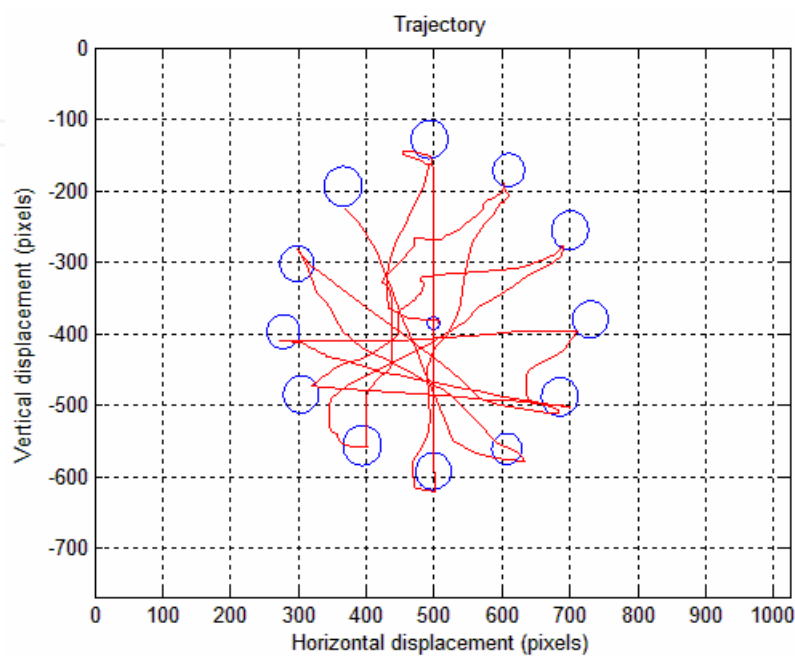
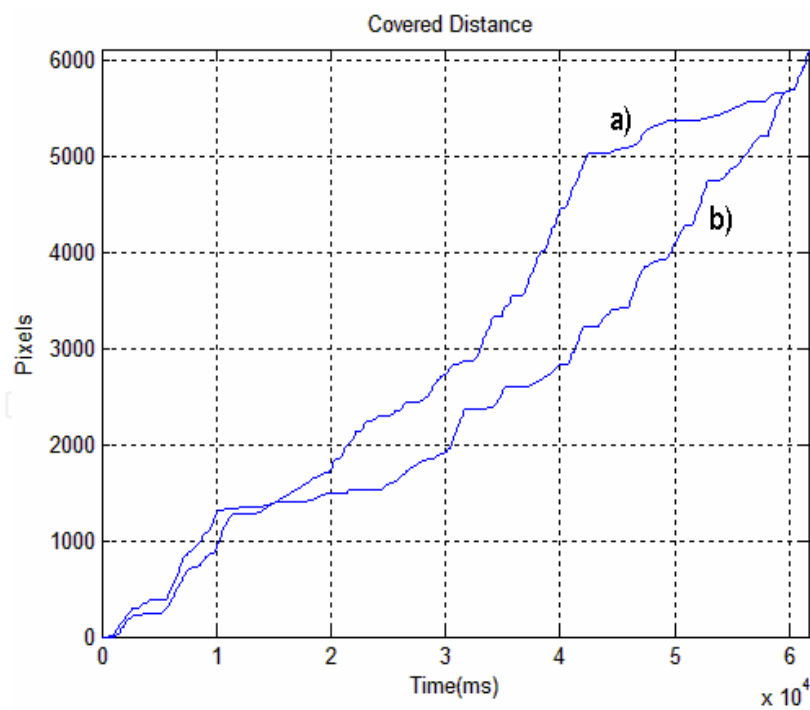Fig. 16. Robert second trajectory.

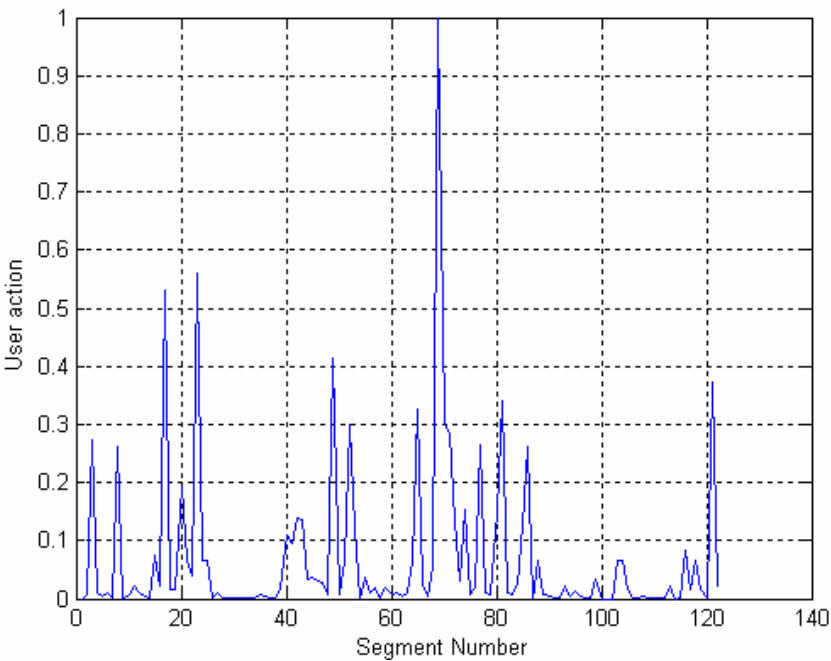Fig. 17. Robert Covered Distance (first test (a) and the second test (b)).
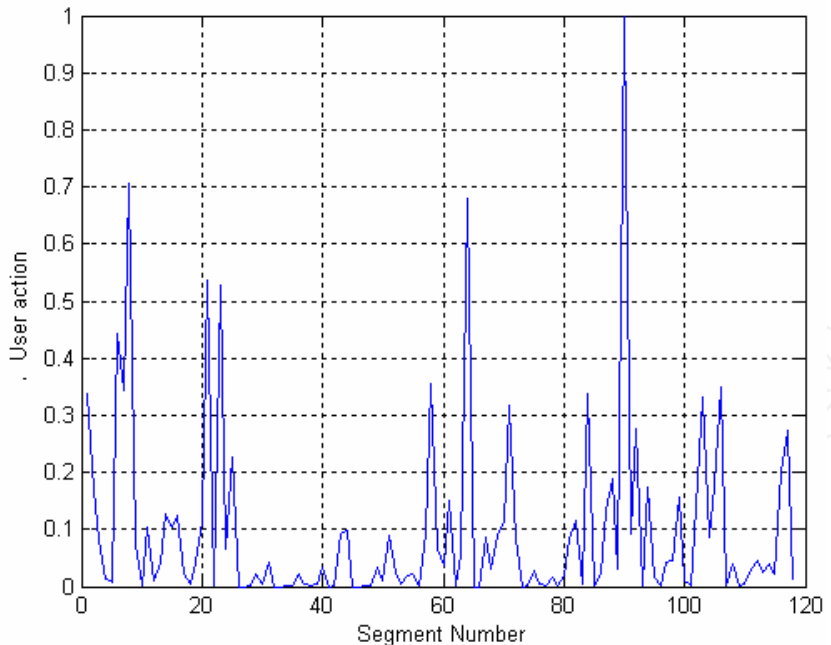
Fig. 18. User Action (UA) in the Robert first test.

Fig.19. User Action (UA) in the Robert second test.

Sample	Test Time (**TT**) (ms)	Covered Distance (**CD**) (pixels)	Rate of Pause (**PR**) (%)	Command Load (**CL**)	Efficient Load (**EL**) (%)
Test1	61800	6125	14.56	1.14	53
Test2	59500	5690	16.80	1.58	97

Table 2. Robert results.

8. Conclusion

Today the methods used by the medical team and occupational therapist are often qualitative. PLEIA software can be employed as a tool to evaluate the pointing user's capabilities.

We proposed the new indexes to improve the classical evaluations methods that use the common factors as distance, time, errors and trajectory.

The index command load shows the energy that the user employs to act on his technical aid. This energy could be not to be in direct relation with the efficiency, when the user realizes a task.

PLEIA's capacities can be expanded as rehabilitation platform, telerehabilitation and experimentation platform for HCI systems with different haptic devices.

The experiments are based on the real evaluation cases.

In two cases, we evaluated the initial capabilities. The occupational therapist conclusions were: interface difficulties, some uncontrolled movements and the technical aid needs a best adaptation. The trajectories and indicators showed clearly this behavior. Claudia has a good interest with the exercises of PLEIA. The therapist detects that she has the same behavior as she rides her electric wheelchair.

We start test PLEIA with the other modules in order to evaluate children with robots and wheelchair. In these modules, all indicators are included. We will compare evaluation tools.

9. Acknowledgments

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Rehabilitation Robotics

Edited by Sashi S Kommu

The coupling of several areas of the medical field with recent advances in robotic systems has seen a paradigm shift in our approach to selected sectors of medical care, especially over the last decade. Rehabilitation medicine is one such area. The development of advanced robotic systems has ushered with it an exponential number of trials and experiments aimed at optimising restoration of quality of life to those who are physically debilitated. Despite these developments, there remains a paucity in the presentation of these advances in the form of a comprehensive tool. This book was written to present the most recent advances in rehabilitation robotics known to date from the perspective of some of the leading experts in the field and presents an interesting array of developments put into 33 comprehensive chapters. The chapters are presented in a way that the reader will get a seamless impression of the current concepts of optimal modes of both experimental and ap- plicable roles of robotic devices.

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