AMSE JOURNALS-AMSE IFRATH Publication –2016- Modelling C; Vol. 77; N° 2; pp 51-59
Submitted Sept. 2016; Accepted Oct. 31, 2016

Evaluation and Optimization of a Communication Aid in Patients with Disabilities: Methodological Presentation

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Abstract

Assistive technology facilitate communication and promote mobility. Head-Pilot system allows control of a computer by movement of head using a webcam. It has advantages (i) to be used with tools already used by people with disabilities and (ii) it overcomes an infra-red source unlike many existing systems. The objective of this work was to verify by a study clinic multi-site system Head-Pilot performance did not differ according to different types of disabilities tested in comparison with control group. Thanks to the different tests created for this clinical validation study, we confirmed our initial hypothesis to know that custom Head Pilot system setting allow, the takers with disabilities, to get a performance equal to that of a subject control thanks to the adaptation of the scanning speed and therefore the sensitivity of Head-Pilot tracking system. The Head-Pilot system is efficient for types of disabilities tested and suggests that he may be offered to any type of disability. This work offers many opportunities, as there are currently few solutions of help for both

communication, follow-up and control of the automation that offers the Head Pilot/Pictocom system, which, in addition fits as deepens disability including for neurodegenerative diseases.

Key words

motor handicap, process to validate performances, Head-Pilot; webcam; assistive technology

1. Introduction

Thirty-five percent of people over 60 in situation of disability or not have resorts to technical aids [1]. In situations of severe disabilities, these technical aids can increase the level of independence of persons. Among the technical aids, those interfaced to a computer were studied in this paper.

Head-Pilot is a Head tracking software that allows to interact with an information system (Tablet, computer), without contact, thanks to the real-time analysis of the movements of the head of the user by a simple webcam. Unlike existing Eye Tracker systems, this device uses infrared source. The pointer moves on the screen controlled by movements of the head through the analysis of fixed points of the face-by-face recognition. This algorithmic technology is the result of the historic skills of the STARNAV society and derived from a very precise measurement system of the trajectory of satellites from "fixed" points (i.e. stars). "

After having shown that the functional limitations of the quadriplegic patient's neck muscles did not influenced the Head Pilot performances and that only a decrease of cognitive functions slowed learning [2], we have sought to test both the strength and speed of the Head Pilot control on a wider range of disabilities in different rehabilitation centers. To our knowledge this work is the first to test technical assistance in a clinical research protocol, with the final aim to improve the quality of life of people with disabilities.

Our working hypothesis was that the performance of the Head-Pilot system in individuals with limited autonomy, were similar between different types of disabilities and in comparison to those subjects without functional deficit controls.

2. State of the art

Many works were performed to develop technical aids, using various technologies. Kübler and al. (1999) [3] have developed an electronic sensor that used the brain's electric potentials. Subjects learned to fly a machine, which allowed the selection of letters. Miner, Mc Farland, and Wolpaw (1998) [4] have shown the feasibility to control the cursor on a computer screen through the control of electroencephalogram and Gelderblom (1999) [5] and De Witte (1999) [6] have developed a manipulator arm fixed to the wheelchair to catch objects in the environment. Finally Soukoref and Mackenzie (1995) [7] focused on the command of devices by hand while others have rated the pointing head-controlled devices.

The piloting of a computer or a Tablet is also possible through Eye trackers systems that are based on the analysis of the movement of the eyes with corneal reflection. These systems present the constraints of a specific facility (camera focused on the eyes) and an infra-red light. When the subject needs to be mobilized or moved from his bed or chair, when it modifies its position throughout the day, the cameras must be repositioned or no longer work. Moreover, the long-term effects of infra-red light on the retina are posed. The concept of device makes it sensitive to the environment (many objects can turn into infrared source), and imposes a strong limitation of the movements of the user and incurs a high cost, whether for the infrared source or the appropriate camera. There is also a system of tracking of reflective dots stuck on the patient's face or glasses (Tracker 2000) but these pellets require the help of a third party on the long term. Finally, free face tracking software offers summarily to fly a computer but this system is not very robust and has no interface dedicated to to the communication.

Our goal is to validate the functionality and to measure the actual performance of people with disabilities, which is different from the objectives of the technical aid previously presented where the developments were based on their feasibility.

Head Pilot's technical assistance is based on the image processing, it is a software that can be installed on any type of machine as a webcam is available. The advantages of this system are the absence of emissive source, robustness to changes in light environment, the lack of physical contact between the user and the machine, the low power consumption. Head-Pilot software system has been recently coupled to computer interface Pictocom allowing it, apart from the control of a PC (use of the internet, word processing, etc.) to control the automation of the house, to carry out a follow-up of the patient's pain (type of pain by initial and follow-up questionnaire daily), to communicate with a range of predefined phrases and use his phone (phone, SMS) in a timely manner. This complete software system is very useful to control the environment and is decisive for the quality of social rehabilitation, family communications and working for people with disabilities [8]. In order to adapt the system to the capabilities of each patient, it is possible to achieve a complete personalization of the usage profile (set vertical and horizontal, sensitivities time to click) to optimize the comfort of the user, as well as set up the Pictocom computer interfaces according to the desired needs.

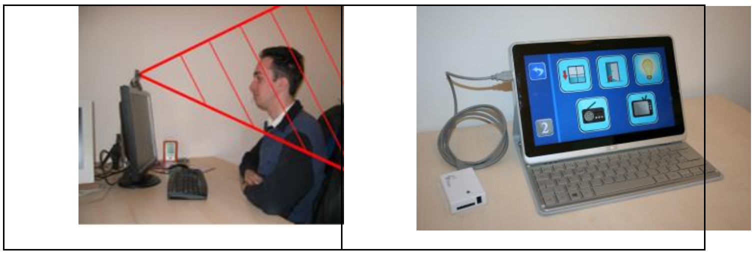

Fig 1: Installation of the Head Pilot on a desktop PC and field of action of the webcam for the analysis of the movements of the head (left), (right) coupling with Pictocom software to control home.

3. Design and development

3.1 Material

The material is composed of standard computers running windows 7. or windows 8 and equipped with a webcam either internal or external. It is worth noting that the Head Pilot software is suitable for windows 10 operating systems and android. The software needed for the study have been developed and installed on the machines (Head Pilot and T launcher).

3.2. The HEAD PILOT system design

The webcam of the tablet or the computer acquires images of the user using the PC or tablet. The head of the user is detected by an algorithm based on pattern recognition by neural networks. The nature of the image captured by a webcam means a sound position by a few pixels (electronic noise, brightness variation, movements). It is then necessary to implement a secondary tracking system using a sophisticated method of filtering. The behavior of the system is the same for both devices: in the field of navigation, inertial sensors operate at high frequency but are subject to temporal derivatives (Fig.2). During a long acquisition, the error of the measure increases in proportion to the square root of the time. Therefore, it is necessary to readjust the measures by another device not drifting in time. These readjustments allow to estimate previous errors and correct them. We use devices such as GPS or stellar aiming to perform these tasks. However, these devices are characterized by a measurement noise. Algorithms for errors and correction of these latest estimates are navigation filters.

To sum up, navigation systems use filters that allow to extract the optimal values of a system composed of inertial sensors characterized by a little noisy signal but drifting in time and devices of readjustments which provide an absolute measure (so not drifting), but the measurement noise is significant and insignificant bandwidth.

One very basic method is to regularly compare the signal drifting to the noisy signal and apply a constant correction at intervals of time. This method allows to get closer to the reference signal and limit the effects of drift. More advanced algorithms identify the characteristic parameters of the errors and correct them. Having a flawed sensor of an error is not important if it is possible to know this mistake and to correct the system. The choice of the retiming method is made based on the dynamics of the system. Fig.2 shows the result obtained by a simple filter of linear estimation by part. The best-known of the filters is the Kalman filter that allows to know the best estimated of the state vector characteristic of many systems.

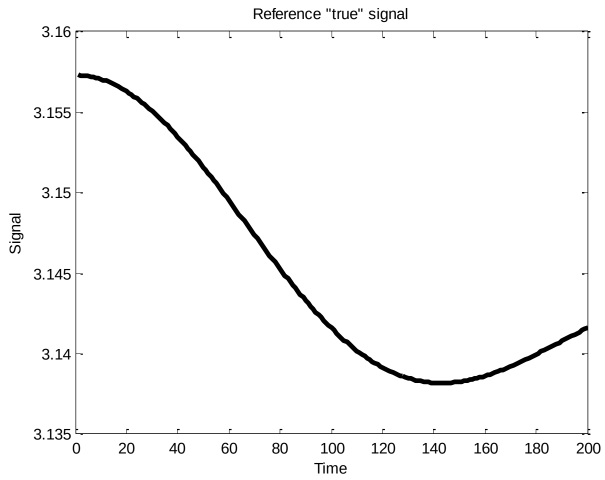

Fig 2: Reference signal

Application to the movement of a cursor:

With respect to the movement of a cursor on a screen, the parallel with the signal presented in the previous paragraph is straightforward: If the signal drift in time, the pointer does, after a certain time, to click on the items selected by the user. It is necessary to apply an important offset, which translates into large movements and very comfortable.

If the signal is noisy without drift, the user is still in the area that interests him, but he lacks sufficient pointing accuracy to operate its software device. The issue is particularly sensitive for autoclic function, which is used to trigger a click by a temporary immobilization of the cursor.

STARNAV has thus implemented a filter allowing to optimally merge data from two distinct sources: the optical flow is a low noise signal, but which derives over time. The optical flow is initialized on the characteristic points of the face.

The image processing algorithms allow then to pursue these points from one image to the other, robust way, with great precision. Over time, the face turns, and some points can reach the 'edge' of the face. The algorithms are then forced to drift to keep the point on a part of the face.

These phenomena can also see the day when variations in brightness in which the contrasts are evolving.

To counter these abuses, we are implementing a powerful algorithm of face detection using an identifier of Haar. Requiring a higher computing time, this algorithm allows a regular updating of the position of the face and it is a step to reset the points followed by optical flow. Images acquired at 30 Hz are sensitive to the frequencies of light and prone to the space-time sounds of cameras at low cost we use. These phenomena induce noise detection to the center of the face of several pixels. By averaging multiple track points and adding a point of regular retiming, the moving of the cursor becomes faithful to the movements of the head and has a stability that makes it reliable, efficient and enjoyable to use.

3.3. Preliminary study

The first phase of development of this project was, initially, to study of the performance of 7 patients (cerebral palsy and tetraplegia) who conducted a series of physiological measures and computer testing at the Caen Hospital (France). The capabilities of head movement, visual acuity, psychomotor function were measured. The tests were carried out from software module (Tlauncher) developed for this clinical research. The analysis of this first series of experience has shown that physical disabilities were not limited to the use of the tool. The software settings adjusted to the possibilities of movement of each individual were essential to optimize their performance. Therefore, the first conclusions of this first group of testers have been only cognitive limitations (cerebral palsy) had an impact on the performance of the Head-Pilot [2].

4. Methods

The objective of the present study is to recruit twenty-four people to perform the tests using the Tlauncher to expand the sample of testers to other centers to test the system in other types of disability. This software Tlauncher is composed of 5 tests to assess performance (time of choice and speed of execution of fictitious commands that need to be validated) of the participants using the Head-Pilot system according to different requirements. A few minutes learning (about 3 minutes) before starting the test to adjust sensitivity control and adapt based on motor skills is needed. The comprehensive assessment consisted of 5 tests. The duration of the 5 tests is around 20 minutes

This project involves adults tested in various centers (Foundation Center Opal Jacques Calvé of Berck, Center of the Arche, at le Mans). The control subjects will come from the Caen University

Hospital. People with disabilities included will be traumatic brain injury or quadriplegia, multiple sclerosis, or neuro-muscle diseases (type Steinert dystrophy).

The first test assess overall dexterity and the ability to scan the entire screen. The subject must click on 8 targets in minimal time in the order he want. Time to go click on each target and the average time to perform the test are measured.

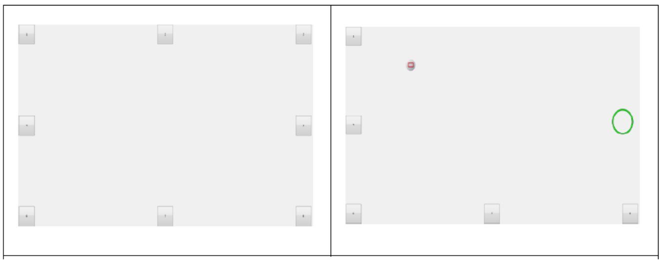

Fig 3. Test n°1: validation of settings

The second test measured the ability to scan according to the place of the screen. The screen was divided into four parts; the subject must click on targets appearing when they appeared in the half left, in the half right, in the upper half and in the half bass of the screen. The validation of each target time is measured.

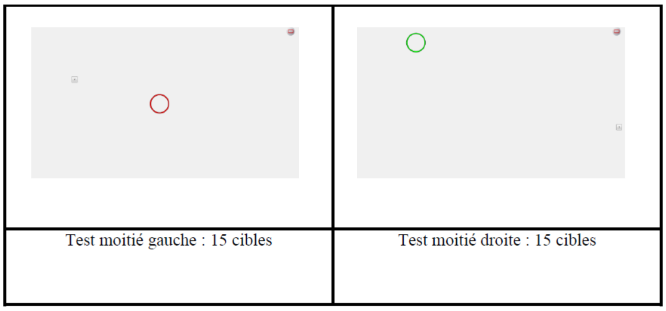

Fig. 4 Test n°2: Pointing accuracy

The third test assess the ability to maintain a target, or the stability of the control. At first the subject should stay on target 2 seconds then secondly they had to stay on target 3 seconds. The size of the target was reduced to reach the size of an icon of a computer window closing. Time to validate each target is measured with each subtest of 10 targets to validate.

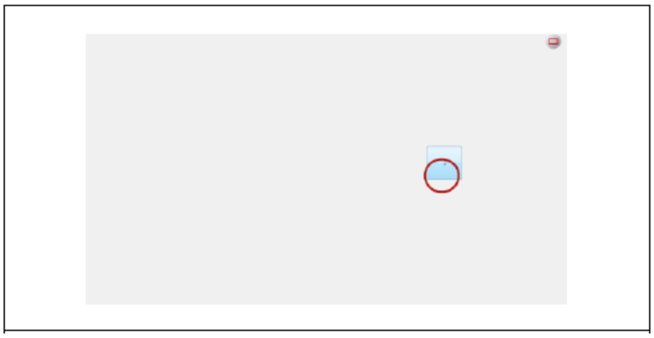

Fig. 5 Test n°3: Pointing stability

The fourth test measures the accuracy with which the target was the target. The subject has to click the more possible to the center of the target, and the size of the target decreases, and bombs appears. The goal is to be the most accurate possible without clicking on the bombs. The test is limited by the number of targets presented (8 in total).

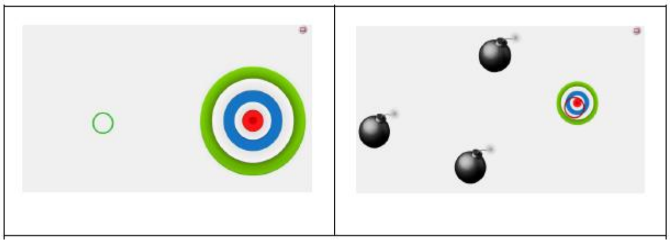

Fig. 6 Test n°4: Precision and speed

The fifth test (Fig. 5) is a test of writing with a virtual keyboard. The subject has to copy a sentence "*le petit chat miaule sous la gouttière, c'est insupportable*" and completion time was measured.

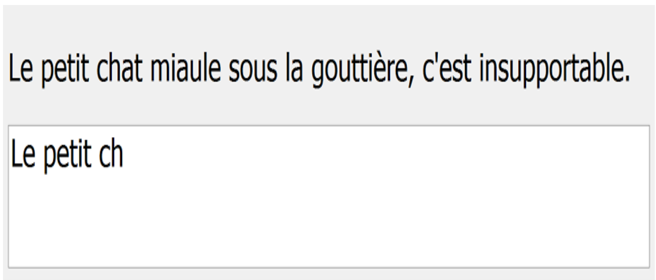

Fig. 7 Test n°5: Writing test

Conclusion

This work assesses the performance of control by movements of head of a computer interface, standardized and calibrated to people with reduced mobility. The procedure used is a comparison of the performances of the patients group to a control group. The objective of this clinical research is to reveal that the patients will have the same level of performances than control subjects, thanks to adequate adjustment of the scanning speed and the sensitivity of Head-Pilot tracking system. If this objective is demonstrated, thus the Head-Pilot system will be efficient for different types of disabilities tested and will suggest that he may be offered to any type of disability.

Acknowledgements

This first experiment was financially supported by the National Agency for research and the Directorate General for armament program reliability (ANR 09-TECS-007) and the complete experiment is currently supported by a Normandy FEDER-Region contract (DOME6 project)

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