A Serious Game with a Thermal Haptic Mouse

http://dx.doi.org/10.3991/ijoe.v9iS8.3399

A. Silva [1], M. T. Restivo [1] and J. Gabriel[1,2]
[1] University of Porto, Porto, Portugal
[2]LABIOMEP – Porto Biomechanics Laboratory, Porto, Portugal

***Abstract*—Human senses are responsible for providing feedback from the surrounding environment that enable the execution of any day life activity. But, has time passes by, the sensing ability tends to decline together with the capability to process information and control the members as well as the entire body.**

The present work reports an ongoing work on the development of a new haptic device, designed to be used mainly by elder person, stimulating and quantifying the nervous system response capability. This was achieved through a serious game, using a temperature controlled element. The user positions his/her hand/finger on the device in order to capture the temperature stimulus. Depending on the sensation perceived (hot or cold), a basic task is required to be execute. The time to execute the task can be used to get information on the user's global nervous system current condition.

***Keywords*—Haptic interface; Tactile sensors; Temperature control.**

I. INTRODUCTION

Haptic devices are used to bring enhanced feedback to the user (force, touch, temperature, 3D, smell…). In this way a more complete and realistic environment can be created. One field where these devices are used is in pilot training, like illustrated by Klaus Cappel [1]. In this case the pilots have a secure and controlled environment with realistic sensations to develop the piloting skills.

Haptic devices are also used in other situations, like video games and medical training [2] [3]. The usage of haptic devices in simulation exercises produces an even more realistic environment, reducing the cost and maintaining the trainee in a safe and controlled environment.

Despite some variations, tactile force feedback is the most common in haptic devices [4-6]. In these systems, a virtual environment is created where virtual forces and reactions interact. These forces are then recreated in the real world by a physical system.

Force feedback is one of the tactile sensations that can be reproduced by a mechanical system. Thermal perception is another sensation that can be used to supply a temperature sensation to the user. Especially in the hands, human beings have many thermal sensors connected to the peripheral nervous systems [7]. This important fact justifies the creation of a haptic device that uses the human ability of sensing temperature. This work suggests the concept and offers a technical implementation to create a thermal sensation related to a virtual reality and to demonstrate the device capabilities.

II. EXPERIMENTAL SETUP

A. Hardware Setup

The thermal actuator used in the device is a Peltier element from Melcor, model CP1.0-127-05L, with an active area of 10x10 mm^2. This Peltier element is a device of a solid state type that uses the Peltier effect of multiple N-P Bismuth Telluride paired junctions to create a temperature difference between the top and bottom surfaces; when one increases the temperature, the other decreases, according with the direction of the source electric current. By reversing the supply current direction, the temperature difference signal also reverses, i.e. the hot face becomes the colder one and the cold one becomes the hotter.

The Peltier element was controlled using the National Instruments NI-6008 data acquisition module with digital output lines, through a custom made power circuit based on field effect transistors. To control the temperature, a control loop system was implemented, being the temperature sensor a RTD (ref. PT100 SMD1206). A 1-slot USB NI-9219 module was used to acquire the temperature data together with a NI USB-9162 carrier to read the resistance of the temperature sensor. To remove the dissipated energy and improve the exchange with the environment, a CPU fan was introduced. This solution improved the response of the Peltier element and avoid condensation effects inside the element. A time delay of 1-2 seconds is normally necessary to achieve the desired temperature, depending on the available power supply. As the system is designed for elderly people use, this response time seems to be acceptable.

B. Software Setup

The software was developed in LabVIEW 2011, from National Instruments, and implements both the temperature controller and the game environment. The implementation followed a finite state machine topology. To begin with, the mouse position is verified and secondly the Peltier element temperature. The game algorithm is then executed to generate the temperature set-point reference. The reference is then passed to the PID controller that generates the adequate stimulation value to be delivered as a pulse with modulation (PWM) signal. The output of the NI6008 module is then connected to the power circuit.

In the *setting menu*, it is possible to change the PID controller parameters k_p, k_i or k_d to personalize the device according to the user personal requirements. Another possibility available in this menu is to save the system response to a transient stimulation and record the device response for evaluation. Finally, it is possible to set the temperature range correspondent to the coldest and hottest limits.

III. DESCRIPTION OF THE GAME

This game consists in a *drag and drop task* using the users' temperature perception.

In a first instance, the user is presented with a basic form, with a single color and a basic contour (as the black circle on the example of Fig. 1). With the progression of the game, new forms are generated, with different colors and different contours like triangles, rectangles, diamonds and others. The shape and color of the generated forms are randomized. Besides the shape, a temperature value is also randomized. The temperature is set to be between plus and minus 5 degrees compared with the ambient temperature, depending on the randomization.

Secondly, with one hand (typically the left) the user senses the randomized temperature on the Peltier element (Fig. 2) and, depending on the sensation, warm or cold, he/she should select the place where to drop the shape (the black circle in Fig. 1). This operation is conducted using the computer mouse. If the temperature generated by the Peltier element is above the ambient temperature (hot) the shape should be dropped in the "flames corner"; if the temperature is cold it should be dropped over the "ice corner". As usual, a correct action will increase the mark counter and the user is encouraged to continue.

In addition, the words corresponding to hot and cold objects, placed on the top of the figure, will be written and spoken loudly if the object is placed above the ice or cold areas for a certain amount of time (2-3 seconds), to increase the interactivity.

Thus, visual, auditory and tactile stimulation is achieved using this device. This is a very important aspect that may add a significant value, as an easy to use and friendly device is useful for elderly people to keep their brain activity as required to avoid dementia and other mental diseases.

Also, forcing the user to react and to move the mouse, the game is contributing to stimulate the agility in mouse motion which is a skill frequently absent in elderly people.

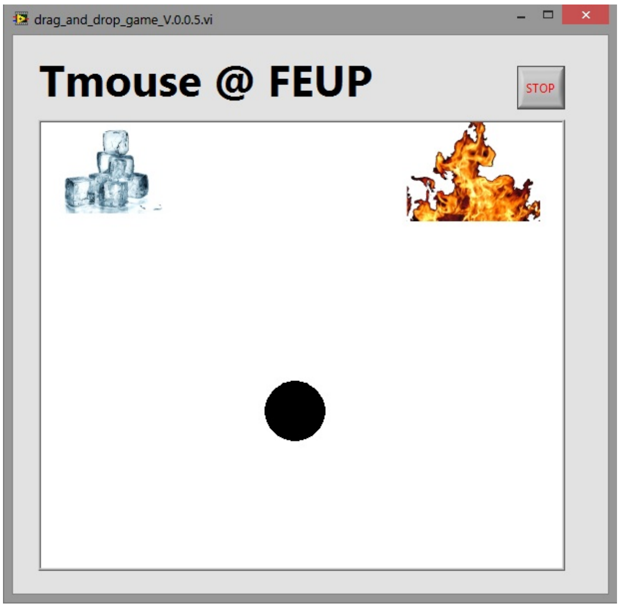

Figure 1. Graphical user interface.

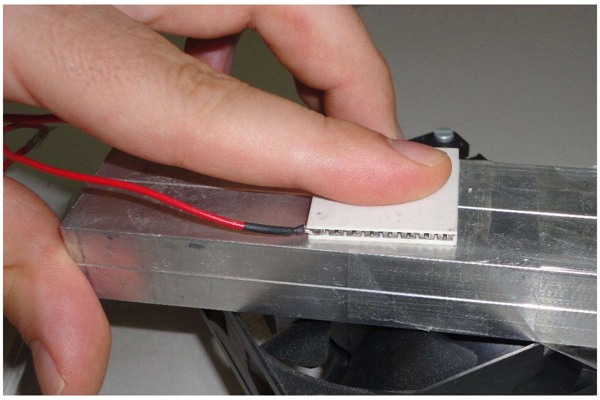

Figure 2. Peltier element providing temperature feedback.

IV. RESULTS

The validation of the device with the target public and goal was not yet fulfilled. But then, one of the most critical aspects of the device is the system responsiveness. Since the "actuator" produces temperature, the time response could be a problem. The executed test revealed that the system can respond to references with a frequency of approximately 0.7 Hz, as illustrated in Fig. 3. Like in all the data acquisition systems, here the temperature readings have a certain error. Therefore, the phase response was calculated including that same error (approximately 0.05 K). As a consequence of that error, in Figure 3, we calculated three curves: average response (black curve), fastest response expected (red curve) and slowest response (green curve).

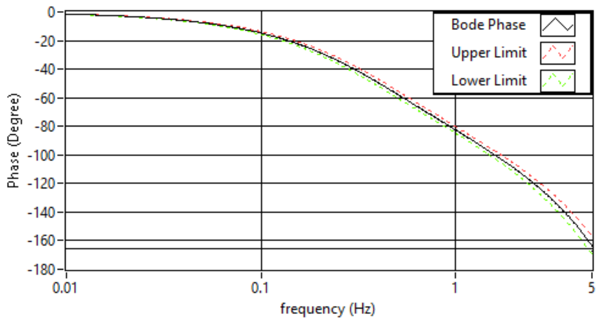

Figure 3. System phase response.

V. DISCUSSION

Nowadays life expectancy is relatively high and the number of years between the moment a person stops his professional activity (usually by retirement) until this same person dies, has been increasing. This long period with low physical and mental activity may contribute to and increase the possibility of mental and psychic problems, like dementia or other injuries [8].

After a certain age, especially in elderly people, it is observed a significant decay in the sensorial capabilities (vision, auditory, tactile, etc.). This usually comes accompanied with a reduction of the motion and movement control capabilities. Resulting in an increasing difficulty to execute daily activities like getting dressed, making the personal hygiene and even eating, until a state in which the person cannot execute the tasks without assistance.

This is an endless process, by reducing the physical and mental activities, elderly people tend to move to an even worse state, the brain is less stimulated and therefore its capacity may decrease in a process known as dementia. One serious problem is that as elderly people feel the decrease of their abilities, they tend to spend more time in passive tasks as a natural defense mechanism to prevent falls and other dangerous situations that they have afraid. As a consequence, they spend most of their time sleeping or watching TV which do not require any feedback or attention, but delivers a comfortable and effortless sensation.

This application emerges as an idea to create a device that can produce different stimuli to the user (visual, auditory and tactile) and contribute to the elders' health. Since temperature sensation is provided to the brain through the peripheral nervous system to a set of specific neurons [9], this device can be used as a nervous system stimuli procedure. By performing simple tasks that can be easily handled by elderly people, but which require their attention and concentration, we expect a positive improvement in their lives. Additionally, the device can provide a combination of tactile, visual and auditory stimulation in a combined approach to achieve better results.

Since the device delivers a stimulation and requires the user to execute a specific task, it can evaluate the performance of the respective usage along a period of time. This way, it can work as an evaluation device to "measure" more objectively different recovery therapies.

A game for youngsters differs substantially from one targeting elderly people. The first want a good graphical 3D simulation, enriched with powerful sound experiences and high speed movements which requires usually fast, precise and well planned actions from the user. Conversely, elderly people present less dexterity, and therefore require slow actions, quiet environments and a far less complex user interface. Thus thermal feedback, due to the inherent time delay, is not suitable for the former, but may be used by the latter with good results. This may explain the reason why thermal haptic feedback is uncommon neither in the game industry nor on training devices.

Most games are nowadays developed using C++ or OpenGL, instead of specific software like LabVIEW, which does not provides physical motors neither 3D capability. Nevertheless, for a prototype application, LabVIEW presents an easier way to get a perfect integration with custom designed and built hardware and a fast programming environment with 2D basic functions.

This device was only tested by adults in a laboratorial environment, not yet by elderly people, due to the requirement of the ethical protocol approval. But the overall feedback at this point is that the temperature response is very fast (time response measured to be approximately 1.5 seconds). Regarding the game, due to its simplicity, the main goal is rapidly understood and pursued.

VI. FUTURE DEVELOPMENTS

Although the present solution is already working, it can be further improved. The data acquisition modules represent a high cost, and thus will be replaced by a micro controlled based data acquisition system. Also, the size of the Peltier and electronic switching board will be reduced to a small pack for easier use and transport. In certain cases, the palm of the hand is more sensitive than a fingertip due to thickness of the skin and the wrinkles, thus the device will be adapted to be usable in both circumstances. In any case this will represent a low cost "mouse" to be easily affordable. Also, the application will be freely available for online download.

Another target public to address in the future is children with autism and Down syndrome.

ACKNOWLEDGMENT

The authors would like to acknowledge the FCT – Fundação para a Ciência e a Tecnologia for the support of the project FCT-PTDC/CTM-NAN/112574/2009. It is also in line with the "emergent technologies developments" within PEst-OE/EME/LA0022/2013, co-financed by the European Community Fund through COMPETE - Programa Operacional Factores de Competitividade.

REFERENCES

[1] J. P. Merlet, Parallel Robots, Ilustrated. 2006, p. 394.

[2] J. Juul, A Casual Revolution: Reinventing Video Games and Their Players. The MIT Press, 2012.

[3] J. C. J. . G. J. Lynn, "Method and system for simulating medical procedures including virtual reality and control method and system for use therein," U.S. Patent: 57696401995.

[4] G. S. James Hemsley, V. Cappellini (ed.), "Digital Applications for Cultural and Heritage Institutions." pp. 273–284.

[5] S. D. Laycock and A. M. Day, "Recent Developments and Applications of Haptic Devices," Comput. Graph. Forum, vol. 22, no. 2, pp. 117–132, 2003. http://dx.doi.org/10.1111/1467-8659.00654

[6] H. L. Dee and a. L. Benton, "A Cross-Modal Investigation of Spatial Performances in Patients with Unilateral Cerebral Disease," Cortex, vol. 6, no. 3, pp. 261–272, Sep. 1970. http://dx.doi.org/10.1016/S0010-9452(70)80015-6

[7] R. Ângelo and R. Vardasca, "The Effect of Work Related Mechanical Stress on the Peripheral Temperature of the Hand Certificate of Research," University of Glamorgan, 2010.

[8] B. G. Truelsen T, Piechowski-Jóźwiak B, Bonita R, Mathers C, Bogousslavsky J, "Stroke incidence and prevalence in Europe: a review of available data," Eur. J. Neurol., vol. june, no. 13, pp. 581–598, 2006.

[9] Moran, M. M., Xu, H., & Clapham, D. E. (2004). {TRP} ion channels in the nervous system. Current Opinion in Neurobiology, 14(3), 362–369. http://dx.doi.org/10.1016/j.conb.2004.05.003

AUTHORS

A. Siva, is with Faculty of Engineering of University of Porto, Porto, Portugal (a.ramos@fe.up.pt).

M. T. Restivo and **J. Gabriel** are with the IDMEC-FEUP research center and with Faculty of Engineering of University of Porto, Porto, Portugal (trestivo@fe.up.pt, jgabriel@fe.up.pt).

This article is an extended and modified version of a paper presented at the International Conference exp.at'13, held 18-20 September 2013, in Coimbra, Portugal. Submitted 18 November 2013. Published as resubmitted by the authors 04 December 2013.