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TechFilter: Filtering undesired tremorous movements from PC mouse cursor

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Abstract. Informatics is becoming essential in our daily activities. The use of the human machine interface requires fine movements from the user. When human movements are distorted, for instance, by tremor, performance could be improved by digitally filtering the intermediate signal before it reaches the controlled interface. This paper presents a novel device able to filter out tremorous movements from the cursor of a mouse in the screen of the computer. This task requires real-time discrimination between voluntary and tremorous movement. To address this problem, a learning algorithm is introduced as well as the evaluation and validation with users of the prototype developed.

Keywords: Tremor, human-machine interface, techfilter, zero-phase estimation

1. Introduction

Tremor is a rhythmic, involuntary muscular contraction characterized by oscillations (to-and-from movements) of a part of the body [1]. Although the most common types of tremor were subject to numerous studies, their mechanisms and origins are still unknown. The most common of all involuntary movements, tremor can affect various body parts such as the hands, head, facial structures, tongue, trunk, and legs; most tremors, however, occur in the hands [2].

Even healthy people show tremor. Normal tremor, commonly known as Physiological tremor, shows very small amplitudes with an energy distribution located at frequencies higher than 8 Hz. Physiological tremor does not represent a serious problem for most daily activities in human life. On the other hand, pathological tremor can severely affect daily activities of individuals: It has been estimated that a significant number of people, around 54 million in the United States [3], shows some kind of pathological tremor. This large population includes people with cerebellar injuries, cerebral palsy, Parkinson's disease, multiple sclerosis, and ataxia. The power spectrum of the pathological tremor is significantly concentrated in lower frequencies, typically ranging from 2–6 Hz. In addition, pathological oscillation amplitudes are significantly stronger that those of physiological tremor, introducing uncomfortable distortion into purposeful movements. In many instances, the tremor amplitude can be so severe as to make purposeful movement totally impossible [2].

Tremor often accompanies neurological disorders associated with aging. Considering the increase in the life expectation of the world population, it is possible that in a near future this problem will affect more and more our society. Actually, just in United States, there are more than 1.5 million patients affected by Parkinson disease [2]. Although the disorder is not life-threatening, it can be responsible for functional disability and social embarrassment [4]. More than 65% of the population with upper limb tremor presents serious difficulties performing daily living activities [5].

There is no known cure for a number of tremor diseases. The overall management is direct toward keeping the patient functioning independently as long as possible while minimizing disability. In view of what is known at present, the treatment options available for

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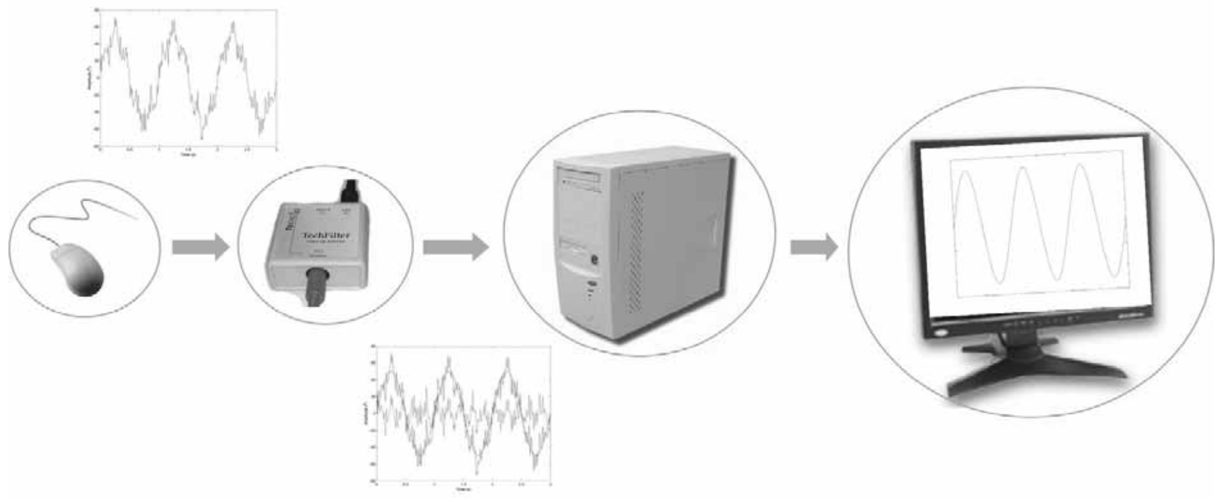

Fig. 1. Scheme of Techfilter.

tremor are medication, neurosurgical intervention, rehabilitation programs (psychotherapy), brain stimulation, and to assist the limb with compensatory technology [2,9]. The standard and most effective treatment of tremor is medication. One of the main drawbacks is that drugs are typically prescribed on a trial-and-error basis in order of decreasing expected effectiveness because the clinical phenomenological tremor classifications are not perfectly predictive of their success [6].

In an increasing number of situations, human machine control is becoming essential to fully participate in society. An example includes the computer mouse. The access to computer is becoming more and more important in our daily activities (both at work and leisure). Nowadays it is possible to have access to a big number of activities though the use of Internet, from buying a ticket to cinema to banking or shopping. As these interfaces become more widespread, accessibility of modern human-machine control to disable persons is a primary aim of rehabilitation technology [7]. Many people with pathological tremor are unable to use standard commercial interfaces due to the large tremor amplitude they exhibit [8].

This paper introduces a novel device developed by Technaid, in cooperation with IAI, that when connected between the mouse and the computer can remove tremorous movements from PC mouse cursor. In the next section, the main characteristics of Techfilter will be described. This will be followed by the description of the experiments performed to evaluate the device. In the last section, the results of the experiments as well as the advantages and applications of the device will be discussed.

2. Techfilter

Techfilter is an adapter connected between the mouse and the computer, see Fig. 1. Time delay in visual feedback degrades the performance and accuracy in the realization of tasks. An approach to tremor canceling requires a zero-phase filtering during computer input. The approach to suppress tremor is to filter in real-time the undesired tremorous movement from the overall movement described by the mouse. The device is based on a microcontroller that executes an error cancelling algorithm performing a real-time discrimination of the undesired component of motion. This estimation is removed from the overall movement and the assumption that the remaining movement is intentional is made. After this, the voluntary movement information is input to the computer and the movement described by cursor on the screen is free from the distortion originated by the tremor of the user.

The algorithm implemented presents a learning behavior that adapts to personal characteristics of each user. This algorithm does not require any special training stage by the user. Note that tremor is suppressed only in the hardware right before the access to the computer. The person and the mouse will still show tremor.

The algorithm implemented in the microcontroller is also responsible for the management of the communication between the mouse and the computer. Techfilter has an external input that allows the user to connect alternative devices to replace the click action of the mouse, for instance an external button. During the time that this external devices are connected to Tech-

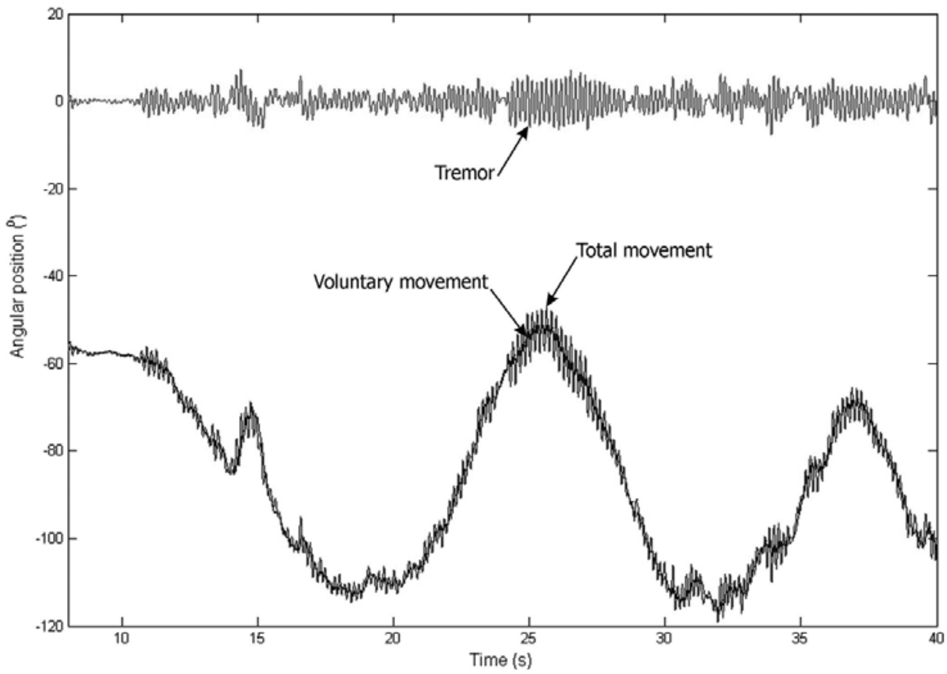

Fig. 2. Modelling of tremor as a sinusoid: movement performed by the patient, estimation of voluntary movement and estimation of tremor.

filter the buttons of the mouse are disabled. This characteristic is very important due to the fact that various patients have serious problems to control the buttons of the mouse due to undesired multiple clicking. The learning behaviour of the algorithm also makes possible that either people with or without tremor uses the device indifferently.

Techfilter was designed to operate with the majority of PC's and operating systems. It does not require previous computer knowledge since it offers Plug&Play characteristics. To start to enjoy the advantages the system could offer, the user just has to connect the mouse to Techfilter and the device to the computer. These characteristics make Techfilter attractive for home and office users, as well as for public places like libraries and universities.

3. Experiments and results

The performance of the system was evaluated in different experiments. In the first experiment we have evaluated the performance of the algorithm in the real time discrimination between voluntary and tremorous motion. As said before, the algorithm developed estimates both the amplitude and the time-varying frequency of the tremorous movement. In order to evaluate its performance, we have evaluated it with data obtained from 33 patients suffering from different tremor diseases. This data were obtained from gyroscopes attached to the upper limb of the patients. It was possible to measure the tremor activity in four movement of the upper limb: elbow flexo-extension, forearm prono-supination, wrist flexo-extension and abdu-abduction [10]. The results demonstrated that the algorithm has a convergence time lower than 2 s for all signals evaluated and the MSE between the estimated voluntary movement and the desired movement of the patient was smaller than 50, Fig. 2. This results show that the algorithm is able to estimate with a small delay the voluntary movement of the mouse with a high precision and a convergence time inferior to 2 s.

In the second experiment, the algorithm for tremor estimation was incorporated to the WOTAS active exoskeleton for tremor suppression [9]. In order to evaluate the performance of the device developed to suppress tremor we have planned an experimental phase involving 10 patients suffering from different tremor diseases. During the first clinical trials the algorithm was able to measure and estimate tremor parameters (Fig. 3). The capacity of applying dynamic internal forces to the upper limb for tremor suppression (based on the information provided by the tremor estimation algorithm) was also evaluated. Based on this parame-

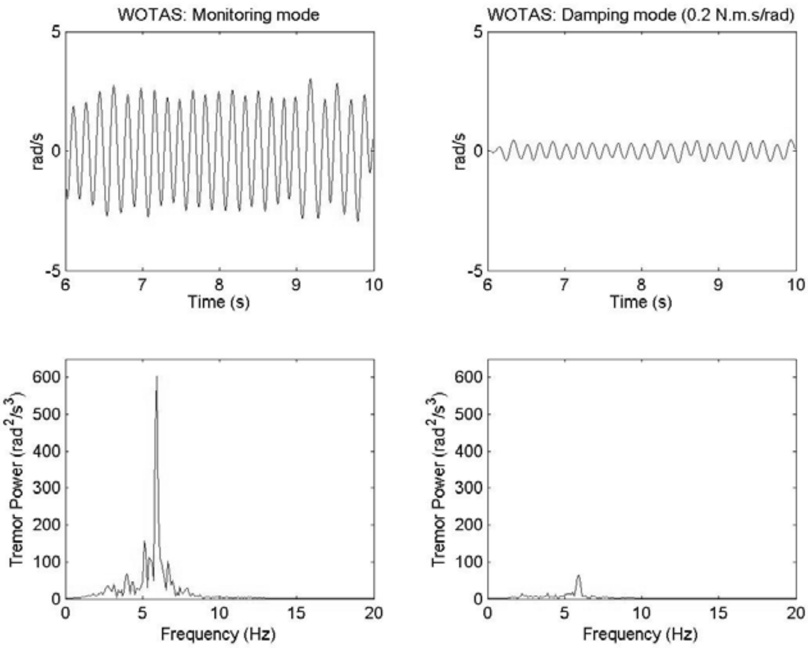

Fig. 3. The graphics illustrated the reduction in the tremor power when WOTAS is applying viscosity to the tremorous movement.

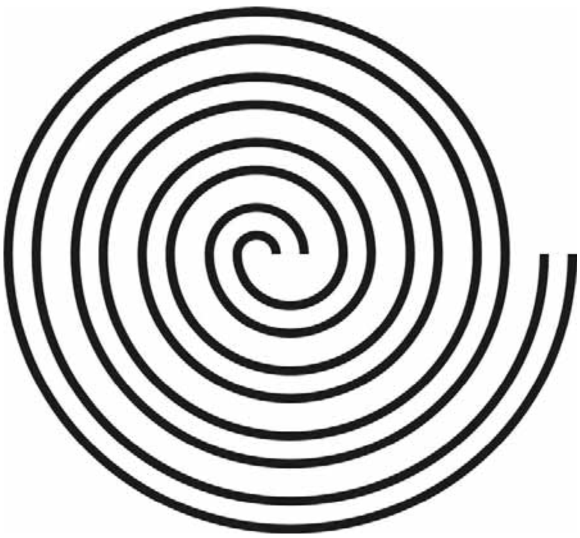

Fig. 4. Path in form of a spiral.

ter it was found that the device could achieve a consistent 30% tremor power reduction, with reduction peaks in the order of 80% in the tremor power for patients exhibiting severe tremor [11] (Fig. 3).

In the third set of experiments the clinical application of the prototype was validated. These experiments were carried out in cooperation with Spanish Foundation of Multiple Sclerosis. Previously to the realization of the experiment, the operation of the system was explained to the user. After, the patient was asked to achieve a comfortable position in the chair and to grab and use the mouse as natural as possible. After a time of adaptation and relaxation, roughly 10 minutes, the patient was asked to perform 2 typical movements when using a computer mouse:

1. *Draw a spiral* – The patient was asked to follow with the cursor of the mouse a path with the form of a spiral drawn on the screen of the computer (Fig. 4). The trajectory described by the user is not illustrated in the screen; with this approach it is possible to avoid the attempts of the user to correct the trajectory. The patient just has the reference of the model spiral on the screen. During this task the buttons are disabled and the trajectory described by the user was recorded by the software.
2. *Goal and click* – To move the cursor over 10 icons that appear in a random sequence on the screen of the computer.The patient was asked to click over the picture every time he/she reaches it. In this way, the next picture will appear just after the patient click on the actual one. The trajectories and the number of erroneous clicks were recorded.

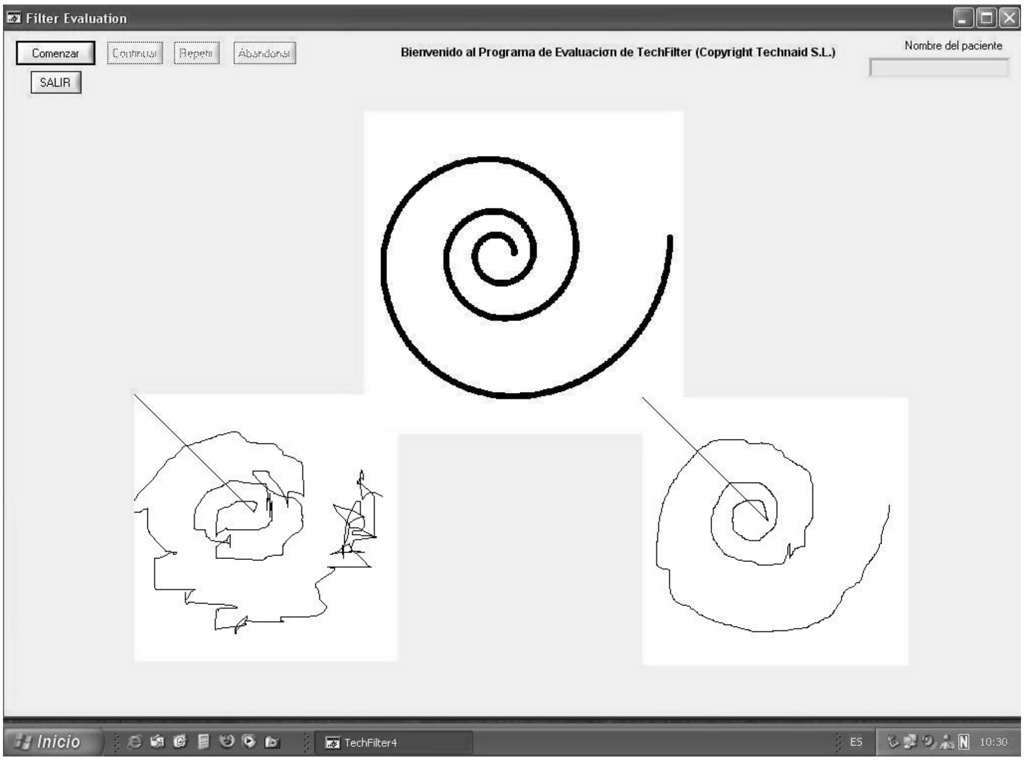

Fig. 5. Results of a patient performing the task of drawing a spiral.

Table 1
Results of the experiments

Patient	e_s	e_c
1	20%	44%
2	33%	100%
3	30%	28%
4	50%	33%

The total time of each experiment was 40 minutes and the main objective was to quantify the effectiveness of the device in tremor suppression. Each task was repeated 3 times, one with the filter disabled, another one with the filter activated and in the last trial, the filter is deactivated again. The order of trials was randomized. The figures of merit used to quantify the improvement in the ability of the patient in the realization of the tasks were:

1. The relation between the number of times the user leaves the boundaries of the path defined by the spiral, with and without the help of Techfilter, in the task draw a spiral, e_s.
2. The relation between the number of erroneous clicks, with and without the help of Techfilter, during the click and goal task, e_c.

Table 1 summarizes the results obtained in the data analysis. The results show that all patients improved their performance using Techfilter. In the case of the draw a spiral task, the mean reduction in the error during the realization of the task was in order of 33.3%. This is a sign of a improvement of the patient ability in tracking a shape in the screen. The patients also presented a mean reduction of 52% in the number of erroneous clicks during the execution of the goal and click task. These results indicates a consistent improvement in the ability of the patient in the execution of the tasks, see Fig. 5. During the trials it was noticed that feedback of a smooth movement has a positive impact. Two patients spontaneously related that they felt a decrease in the amplitude of their tremorous movement.

4. Discussion and conclusions

The use of computers is becoming essential to fully participate in society. The access to computer interfaces, such as computers? mice, is a clearly problem for people with pathological or enhanced physiological tremor. In addition, tremor often accompanies neurological disorders associated with aging. Taking

Fig. 6. Techfilter: filtering tremor.

into account the increase in the life expectation of the world population, it is possible that in a near future this problem will affect more and more our society.

In this paper we introduced a novel device able to filter tremorous movement from a mouse cursor before it reaches computer interface (Fig. 6). The device was successfully tested with patients. The results of the experiments showed an improvement of the patient ability in tracking a shape in the screen and a consistent improvement in the ability of the patient in the accomplishment of tasks, for instance, the number of erroneous clicks was reduced in 52%. This demonstrates that Techfilter can effectively reduce the impact of the tremorous movement on the ability of the patient in the use of the computers, then, helping the access of tremor patients to computers and all its benefits.

During the trials two patients spontaneously related that they felt a decrease in the amplitude of their tremorous movement. This indicates that that feedback of a smooth movement has a positive impact in the patient. This fact is very important and future research will be performed in order to evaluate this phenomenon with more patients of different pathologies.

Acknowledgments

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