Lossless Multitasking: Using 3D Gestures Embedded in Mouse Devices

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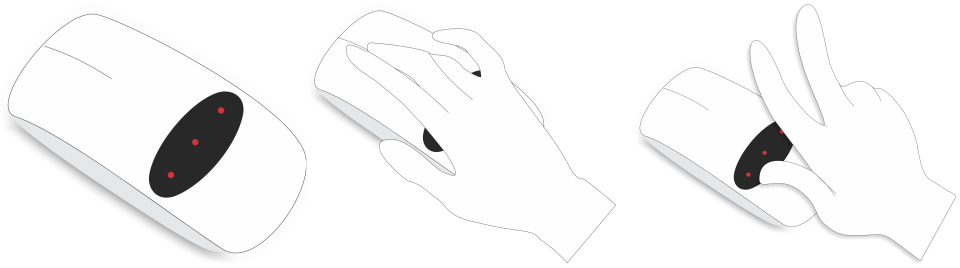

Figure 1: Conceptual model of the 3D Gesture Mouse. From left to right: a regular mouse with embedded cameras for gestures recognition; a user clicking the mouse for standard operation; and the mouse being used with in the air gestures.

***Abstract*—Desktop-based operating systems allow the use of many applications concurrently, but the frequent switching between two or more applications distracts the user, preventing him to keep focused in the main task. In this work we introduce an augmented mouse, which supports the regular 2D movements and clicks, as well as 3D gestures performed over it. While the keyboard and mouse conventional operation are used for the main task, with 3D gestures the user can control secondary tasks. As a proof of concept, we embedded a Leap Motion Controller device inside a regular mouse. User tests have been conducted firstly to help in the selection of the gestures supported, and then to evaluate the device effectiveness and usability. Results shown that the use of the augmented mouse as a strategy to keep the user focused reduces the task completion time.**

I. Introduction

Most of the 2D software interfaces such as text processing, Internet browsing and spreadsheets are developed to be used with mouse and keyboard as the only interaction method. Such devices have a limited range of possibilities, and when users need to perform different actions within a program, they need to use sub-menus and program specific shortcuts, usually matching keys to release explicit actions.

A typical computer user operates, most of the time, multiple software products simultaneously and, thus, various tasks. They, usually, have a central activity that requires more attention, and some secondary tasks that can be done quickly. To perform this secondary tasks, the users may need to switch between applications, focusing on different user interface elements and the use of special shortcuts forces the user to lost attention to the primary task. For example, when the user needs to change between applications using the alt-tab shortcut, s/he needs to stop what s/he is doing, search for the right application in the switcher, perform the secondary task and then repeat the switching process again to go back to the previous application.

In this article, we began to study the use of a new interaction method complementary to the mouse. We have created an augmented mouse with 3D gesture recognition capability that the user can customize to its needs. Some approaches already uses the gestures to interact with desktop applications for instance [8], [15] and [10]. These ideas intend to replace the traditional mouse, our proposal, however, is about create a third interaction technique which complements the mouse for using in everyday computing software *e.g.* media control and switch between applications to aid users to focus on their primary task.

Our proposal provides to the user the ability to adjust the gestures to his/her needs. Besides the tasks we implemented the prospect users suggested that the 3D Gesture Mouse could also be used to switch between applications, check social network notifications, create shortcuts to aid in text editing, change between browser tabs, scrolling, pass the slides in a presentation and others.

To validate the usability and feasibility of our proposal, we build a prototype using a regular mouse with a gesture device inside of it. Also, we conducted experiments with 28 participants, where they should do a determined activity and execute some fixed secondary tasks using the gestures or the mouse and keyboard only. Our findings showed that the use of our technique kept the user focused on its main task mostly when the task requires using the keyboard more than the mouse. The user can do his/her work with fewer distractions, thus s/he can finish the task more quickly and with lower errors than using the traditional method with the alt-tab shortcut.

The remainder of this work is organized as follows. Section II briefly presents other related works involving 3D gesture interaction with the computer. After, we introduce our proposed solution design and implementation. In Section III we talk about the steps of the development of our proposal. In Section IV we speak of the user study conducted to assess the effectiveness of the 3D Gesture Mouse and the results. To conclude in Section VI we discuss our results and speak about the future work on this study.

II. Related Work

The idea of extending a familiar device such as the mouse adding new functionalities is not new. Prior work have augmented the regular mouse with additional degrees of freedom. The Rockin'Mouse [3], for instance, is a 4 DOF input device that has the same shape of a regular mouse except that the bottom is rounded so that can be tilted, and that can be used to control two additional degrees of freedom, being suitable for manipulations in 3D environments. Hinckley, K., et al. [6] introduced the VideoMouse, which is a traditional mouse that uses a camera as its input sensor and a rounded base, like the Rockin'Mouse, thus it senses 6 DOF and is also suitable for 3D manipulation.

Other approaches use deformation to add degrees of freedom to the regular mouse, such as Kim et al. [7] who introduced the inflatable mouse, a deformable mouse that can be inflated up to the volume of a familiar mouse. The controls can be released by pressing the balloon inside the device, which add new funcionalities to the device that can be used for navigation or control of the scrool speed. Tang et al. [14] proposed a mouse with a circular shape that can be deformed by users to freely fit personal ergonomic needs. The adaptive mouse has sensors to receive input-events such as click and scroll. With a hemispherical base, the Roly-Poly Mouse [11] can be rolled, rotated and translated in any direction, detecting 6 DOF.

Using the touch approach, the PadMouse [4] consists of a 2 DOF touchpad mounted on a regular mouse base. The PadMouse can be used for spatial positioning tasks performed by moving the device on a planar surface, while the touchpad can be used to activate modifiers and commands. Villar et al. [16] introduced multi-touch mice (Mouse 2.0). Mouse 2.0 can be used as a regular mouse for pointer-based interactions and, in addition, allows the manipulation of graphical environments and the execution of commands via hand-gestures without the need to physically touch the display. The LensMouse [18] consists of a smartphone placed on a regular mouse, acting like a tangible and multi-purpose auxiliary window through which users can view and directly interact with additional information. The Apple Magic Mouse [1] can be also included in this category, since its multitouch surface supports simple gestures such as swiping between web pages and scrolling through documents

Three-dimensional gestures are widely used in human-computer interaction, mostly with 3D environments [2], [5], [13], [12]. However, gestures can be also used to interact with desktop applications. Ortega et al. [10] introduced the AirMouse which use fingers over the keyboard for interacting in 2D or 3D with the applications. The Mouseless [8] and the Virtual Mouse [15] introduce the idea of an invisible mouse, consisting of sensors embedded in a computer that detects the user's gestures on the table and map to commands like the traditional mouse features, as well as additional ones.

The conceptual model of our 3D Gesture Mouse considers a regular mouse augmented with sensors capable of detecting 3D gestures performed over it. Results shown that high precision is achieved, if compared to other interfaces.

III. 3D Gesture Mouse

When using multiple software programs simultaneously, the limitation of the standard mouse devices is accentuated. The users needs switch between the applications and that cause them to lose focus in their primary task. Our proposal consists in using air gestures as an additional resource to the regular mouse (see Figure 1). We believe that it will help the users stay more focused on their work and make it faster and with fewer errors. These gestures are meant to be used in everyday tasks, such as to interact with a media player controlling the volume and changing the music, to show pending e-mails, or to switch between applications, for instance.

The development of our augmented mouse was conducted based in prospect users opinion. To do this, we applied some questionnaires and conducted users trials to learn the preferences of the users about the tasks and gestures which would help them in their everyday work. We explained these procedures below.

A. Characterization

To suitably choose the secondary tasks, we applied two questionnaires to learn some of the preferences of prospected users that utilize desktop computers in their everyday work on which shortcuts we could implement. In the first one, we asked participants to answer freely about which tasks they consider distracting to what they were mainly doing, which ones they think to be exhaustive, and which were repetitive. We received answers from 19 prospected users. They stated that media control, advertising in websites, switch between applications, and social media and e-mail notifications cause them to lose focus on their work. About the tasks they consider exhaustive, they mentioned doing replication of information, edition of spreadsheets, text format structure, and files organization. They thought to be repetitive interact with the mouse, organize files and folders, scrolling, and switch between apps and tabs.

The second questionnaire was applied to rank the answers of the first one. We ask participants on a 5-point Likert scale how much they consider those items to distract them, how much the items was exhaustive and how repetitive they were. We used this ranking in

the next step of the development, in which we asked participants for what tasks they would use the gestures we have implemented. From the answers of 19 prospect users, we have elected the following items: social media and e-mail notifications, scrolling, switch between tabs or apps, volume and music control, and global shortcuts.

B. User Trial

To add gestures to the mouse device, we used the Leap Motion Controller (LMC). It is a computer hardware sensor developed by Leap Motion [9]. Primarily, it was designed for hand gesture and finger position detection in interactive software applications. Weichert et al. [17] analyzed the LMC's abilities as a pointing device. In their experiment, the LMC was considered not precisely enough to replace the traditional mouse. Our approach, however, does not require that level of precision, but some of the reasons used to justified those results are that the users had no previous contact with the Leap Motion, and the higher number of degrees of freedom for LMC movements can introduce some noises.

We conducted a user experiment to ensure that the limitations pointed by Weichert et al. [17] wouldn't be a problem for our proposal. The objective was to check if the participants would be capable of accomplishing this gestures in a short period, and to verify if they can learn how to execute any gesture that they could no in a first try. The Leap Motion API provides some basic gestures, such as swipe, rotation, grab and pinch. The swipe and rotation gestures can be executed with several combination of amount of fingers. From all these gestures we have elected a set of eight gestures for the experiment, which we considered to be satisfactory for the proposed idea: 2-finger swipe (in 4 directions: up, down, left, right), grab, pinch, and full hand rotation (clockwise and counter clockwise).

Our hypotheses for this experiment were:

- The swipe gestures are the simplest gestures, so the participants will execute them faster
- The user inexperience with the LMC has been pointed before as a reason for the bad interaction with it. Each new attempt of performing the gestures, the user experience increase, so we believe that the user will execute the gestures faster on each new try

A simple program was used to conduct the experiments. We implemented the gestures above mentioned and asked users to follow the instructions and mimic the gestures presented. The independent variables were three pre-defined sequences with different orders of gestures. The dependent variables were the time to complete the gestures and the errors that participants did. Error, in this trial, was when the user executes a gesture, but the software did not recognize it correctly. Also, we applied a questionnaire to get the users' opinion about how easy was perform the gestures and for which tasks they would use them.

1) Participants: The evaluation involved a sample of 13 participants. They were volunteers recruited through personal contact and received no compensation for the participation. All participants were male working in computer science field with a mean age of 24.6 +/- 2.8 years. They had a little or no previous contact with gestures-based devices as the Leap Motion, for instance.

2) Procedure: We told participants that the experiment aimed to tested how fast they could execute the gestures. After the test explanation, they answered an initial questionnaire (age, gender, if they have any motor disturb in the wrist and about previous experience with Leap Motion).

An one minute video was used to demonstrate all gestures. There were three sequences of gestures organized at pre-defined orders, and executing each gesture three times. After watching the video, participants had to mimic the gestures following the sequences presented. All experimentation took about 10 minutes.

By the end of the test, we asked participants to agree or disagree, using a 5-point Likert scale, with the following affirmations: 'it was easy to complete each gesture' and for what tasks they would utilize the gestures for. We also asked them freely comment their thoughts about the trial.

3) Results: In the post-test questionnaire, we asked the participants if they considered the gestures easy to execute. According to the participants (Figure 2(top)), the swipe gestures were judged easier to perform, followed by the rotations, and then pinch and grab.

Regarding the time to complete the gestures, the results show that the swipe gestures had the shortest times (Figure 3(top)) with a mean time of 3.22 seconds, following by the pinch, grab and then the rotations. The rotations had the sharpest learning curve (Figure 3(middle)), which showed an improvement in the time of almost 80%. Even the gestures that participants considered difficult to perform, pinch and grab, had a decrease in the time to complete (Figure 3(bottom)).

Concerning the number of errors performed by the participants, from the first attempt they reduced in 75%. The swipe down gesture had the bigger amount of errors with an average of 1.07 errors in the first try, and this number was reduced to zero until the end of the experiment. At every new attempt the time to complete each gesture, as well the number of errors, decreased, indicating that it is possible to quickly learn how to execute each gesture, proving our second hypothesis.

Once we had elected the tasks in the previous questionnaires, we asked the participants for what those tasks they would use gestures. In the Figure 2(bottom) we can observe that nearly 92% of the users preferred use gestures for music and volume control, followed by the global shortcuts. Almost 80% of the users also prefer to use the gestures for social media and e-mail notifications.

C. Conceptual Model

The 3D Gesture Mouse was developed based on the results of the previous questionnaires, the user trial, and the feasibility of implementing the selected tasks. The gestures' dictionary consists of 2-finger swipe (in four directions: right, left, up and down) for music control and check pending e-mails, respectively, and full hand rotation

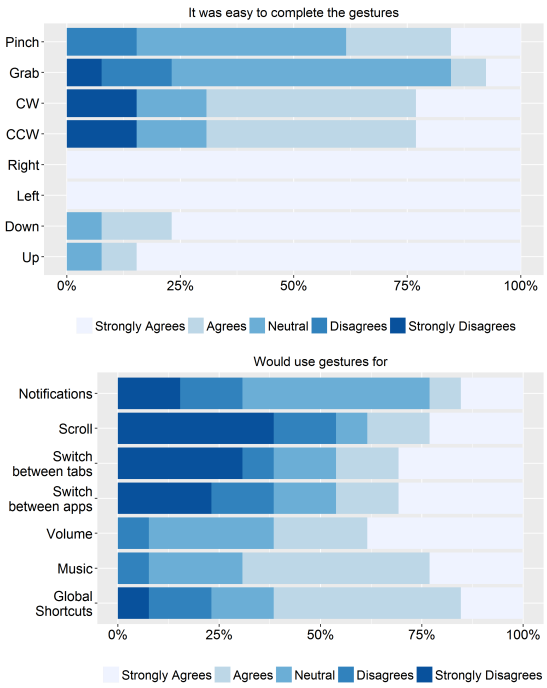

Figure 2: Post-test questionnaire. Strongly disagrees (darker color) to Strongly agrees (clearer color). (top) Affirmations about how easy was to perform the gestures. (bottom) Participants preferences about for which tasks the gestures should be used.

(in two directions: clockwise and counterclockwise) for the volume control. In the Figure 5 is shown three of them, and the execution of the remaining is in the reverse direction of these.

Our proposal allows the user execute everyday tasks with an easy and quick gesture, reducing the distractions caused by the need of switch between applications to perform secondary tasks. Our hypotheses are:

- H1. The user can be more focused on his/her primary task. So, it can be done more precisely, reducing the number of errors the user makes
- H2. The use of the 3D Gesture Mouse decreases the time spent to complete the user's principal task
- H3. We conducted experiments to suitably chose easy and quick gestures, so we believe that the use of 3D Gesture Mouse is easy and comfortable

D. Proof of Concept

We developed a prototype based on a regular mouse and a Leap Motion Controller to verify our hypotheses. The mouse was cut to fit the Leap Motion (see Figure 4). With the device underneath of the user's hand, the use of gestures is always easily available. The user only needs to lift his/her hand to perform them.

The software was implemented in C++ and runs in background on a MS Windows system. The Leap Motion API was used for gestures detection. When any of the supported gestures is detected, we mapped it to the

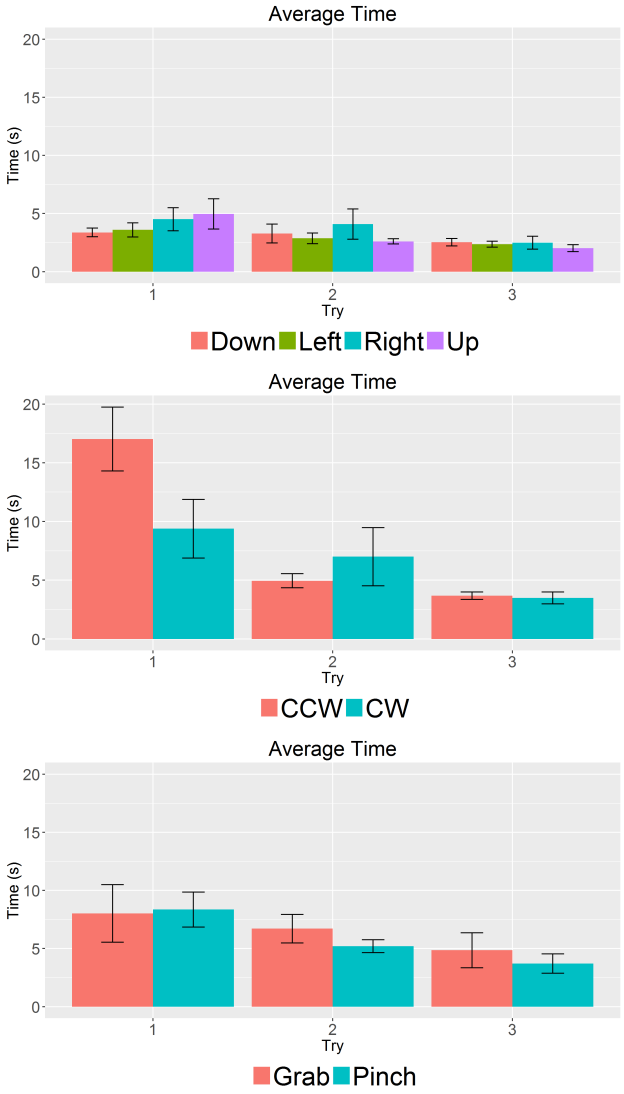

Figure 3: Average time to complete gestures at each try: (top) 2 fingers-swipe (four directions); (middle) rotate (two directions); (bottom) pinch and grab.

Figure 4: 3D Gesture Mouse prototype

corresponding action using the Windows API. Both Leap Motion and mouse events can be triggered concurrently.

IV. User Evaluation

In people's everyday work, some tasks are more frequent than others, such as typing text. Sometimes the workplace needs to be well organized, and for those people who use computers, that means to organize the files and folders. Both tasks require the user stay focused on making it right. The prospect users even pointed the second one in the previous questionnaires like been exhaustive and repetitive. We believe that the use of 3D Gesture Mouse allow the users perform tasks like those with more focus. To accurately evaluate our proposal, we conducted a user study using those two tasks to maintain the user concentrated on the main task.

For the organization of files and folders task, we gave the participants a folder with 120 files of 4 types (spreadsheet, text document, music and image) and 4 corresponding folders (see Figure 6 (bottom)). They should organize the files and folders placing each file into its appropriate folder, one file at the time. If the user placed the file in the wrong folder, s/he could not go back, and the we counted that as an error. We asked the users to complete the task as quickly as possible and with the least amount of errors as possible.

We used a video game for the typing task, Mario Teaches Typing (see Figure 6 (top)), which aim teach people to type. The user have to type a text presented to him/her fast and with no much errors to pass the phase. We used two stages of this game in this experiment and asked users play it. We recorded the time to execute the task and the errors the user did.

While the participant was performing the above mentioned tasks, one of the conductors of the study instructed, at specific time checkpoints, s/he to complete five secondary tasks: move to the next or previous song in a media player, changes the music volume up or down, and check e-mail.

The experiment used 2 x 2 design. The independent variables were: two tasks (within subjects; the organization of files and folders and typing a text), two input methods (within subjects; 3D Gesture Mouse and mouse and keyboard only). The dependent variables were: time to complete each task using both input methods and the number of errors the user did.

A. Participants

The evaluation involved a sample of 28 participants, one of them was woman. They were volunteers recruited through personal contact which received a candy as thanks for the participation. All of them were right-handed computer scientists with an average age of 22.3 +/- 2.23 years. To suppress additional learning curves, all participants were MS Windows users. Only one of the participants had previous experience with the Leap Motion.

B. Procedure

We told participants that the experiment had the objective of compare two interaction techniques, 3D Gesture Mouse and the traditional method using mouse and keyboard only. After the explanation of the experiment, they filled a characterization questionnaire (age, gender, if they have any motor disturb in the wrist, and about previous experience with gestures and with Leap Motion). Then we explained the tasks they would perform, and we gave them some time to practice the two tasks for how much time they needed. Next, we presented to them our proposal, showed how to use the 3D Gesture Mouse and which were the gestures they have to execute using a short introductory video. We gave them how much time was demanded to practice the gestures.

The main tasks were executed two times. One time using gestures to complete the secondary tasks and another time using the alt+tab shortcut to switch between the applications and accomplish the task. There were two groups of verbal commands organized into pre-defined orders and according to the group the participant would start the experiment using gestures or mouse and keyboard only. At fixed time intervals the verbal commands were given: 10s after the beginning of the experiment; then 20s, 30s, 20s, and 10s after the previous verbal command. The mean time for the trial was 30 minutes.

At the ending of the test, they answered an opinion questionnaire in which they should agree or disagree, using a 5-point Likert scale, with the following affirmations:

- Believes that gestures would help in everyday work
- The gestures aided me to be more precise in the folder task
- The gestures aided me to complete the folder task faster
- The gestures aided me to be more accurate in the typing task
- The gestures aided me to finish the typing task faster
- Interacting with the Leap Motion did not make me tired
- It was easy to complete the gestures

We also ask them to comment their ideas about the experiment.

A chart illustrating the entire experiment procedure is shown in Figure 7.

V. Results

The data was analyzed using a paired sampled Student's t-Test with a two-tailed p-value. The significance level was set as p = .05. To assess which input method was the better to perform the secondary tasks, we compared the two primary tasks using both 3D Gesture Mouse and mouse and keyboard. In the pre-test questionnaire, we could observe that just a few of the participants had any previous contact with gestural interaction or the Leap Motion Controller.

To assess if the participants could execute the primary task faster using the 3D Gesture Mouse we verified the time to complete the tasks using both input methods.

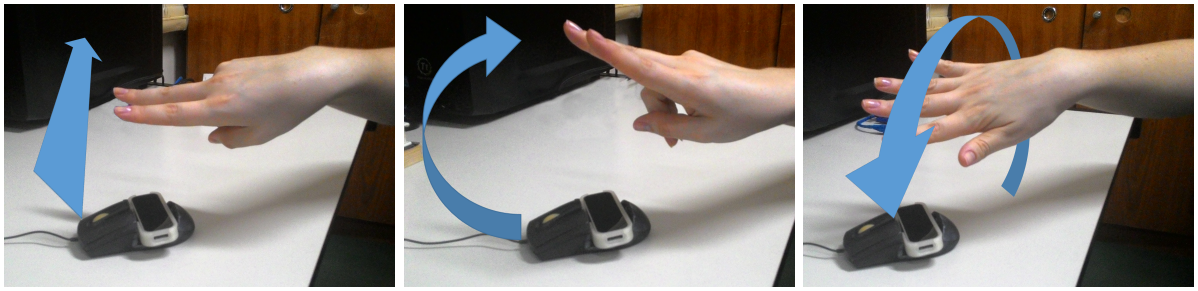

Figure 5: Gestures implemented. From left to right: swipe right; swipe up; rotate counter clockwise

Figure 6: Main tasks layout: Mario Teaches Typing (top) and Files and folders organization (bottom).

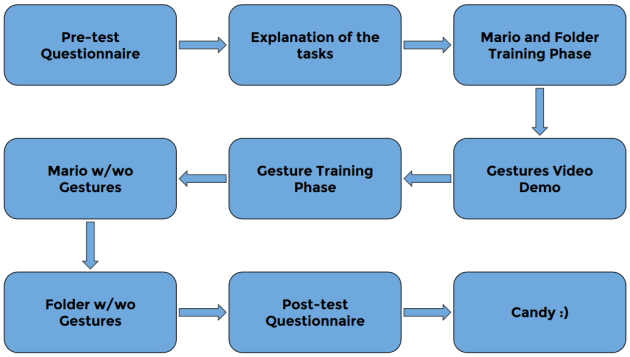

Figure 7: The procedure used during the trials of this study

This dependent variable reflects the time since the user started the task until s/he ended using each method. In the typing task, the mean time to finishing the task using 3D Gesture Mouse was 169.96s against 180s using the mouse and keyboard. We had a significant difference in the two methods ($p < 0.01$) indicating that the use of

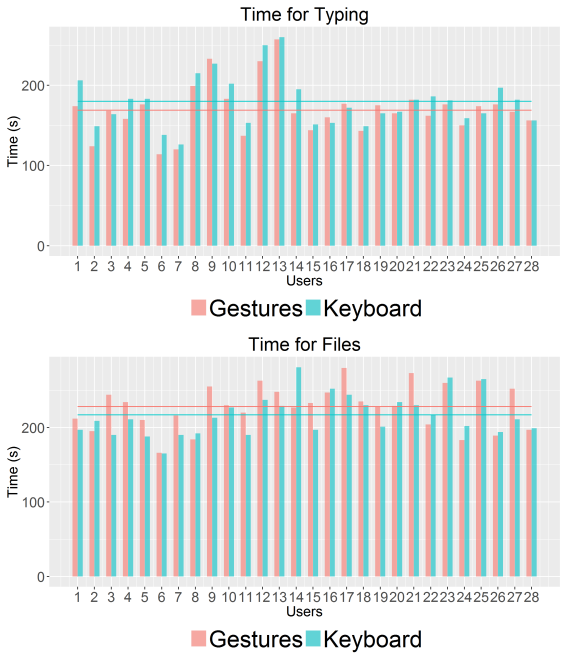

Figure 8: Time to complete the tasks with gestures (blue) and without gestures (orange). (top) Task 1: Mario Teaches Typing. (bottom) Task 2: Organize files and folders.

gestures aided the user execute this task faster, how we can observe in the Figure 8(top).

For the task of organization of files and folders, our results were quite different. The mean time was 228.88s to complete the task performing the secondary tasks with gestures. When using the mouse and keyboard, the mean time was 217.14s. The t-Test results in a significant difference with $p = 0.02$, indicating that the user couldn't execute the task faster using the 3D Gesture Mouse. This values can be observed in the Figure 8(bottom).

To determine if the users could execute the tasks with fewer errors when using the gestures to perform the secondary tasks, we compared the errors obtained in the two primary tasks using both input methods. For the typing task, the users had an average of 36.78 errors using gestures against 33.67 errors using mouse and keyboard. In the organization of files and folders, the users had an average of 1.71 errors when using our proposal against 2.21 errors using mouse and keyboard. The t-Test performed results at $p = .856$ and $p = .143$ for the typing task and

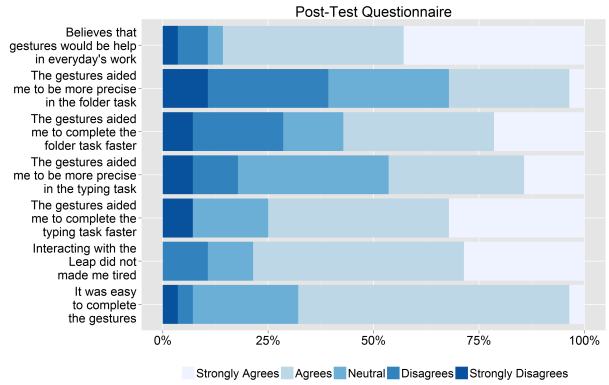

Figure 9: Post-test Questionnaire. A 5-point Likert scale.

the folder task, respectively. Thus, we did not observe any statistical difference between the two evaluated methods.

In Figure 9 is showed the user opinion about the technique. We can note that almost 85% of the participants believe that gestures can be used in everyday work. The gestures were considered easy to complete by almost 70% of the users and approximately 25% had a neutral opinion about this affirmation. Also, nearly 80% of the users did not feel that interacting with LMC make them tired. Approximately 30% of the users agree that the gestures help them execute the files and folders task more precisely, and almost 25% didn't note any difference. About the typing task, about 45% of the users believe that the gestures do aid type the text more accurately, but 40% of the them were neutral about this issue.

Regarding complete the tasks faster, the users agree that the gestures aided finish the typing task faster than the organization of files and folders task. For the first one, 75% of the users agree that gestures are helpful. For the folder task, a few more than 50% of the users felt that the gestures were useful to make the task faster. This result matches with the time to complete the tasks, which indicate that the 3D Gesture Mouse was more helpful to the typing task.

VI. Discussion and Conclusions

In this paper, we introduced a novel concept that makes use of 3D gesture interaction for helping users be more focused on their work when using standard 2D desktop applications. We developed our application based on the opinion of prospect users about their more distracting tasks and applying gestures to help them execute those tasks without losing the focus on their primary task. The gestures also were chosen based on users performance when running a particular set of gestures. Thus, we could develop an approach more appropriate to the users' needs.

The results obtained from our user study show that our proposal is very helpful for tasks heavily dependent of the keyboard, such as typing a text. For the tasks more dependent of the mouse, the time results indicate that the use of gestures to perform secondary tasks is not so effective. However, when analyzing the participants opinion, they believe that gestures had some positive influence helping them to execute both tasks faster. In the post-test questionnaire, we asked the users gave their feelings about their experience. Most of the users complain about how uncomfortable was to use the prototype we developed. That could be negatively influenced the precision and the time to complete the tasks.

Despite that the users found our prototype uncomfortable, they agreed that the use of the gestures are useful in everyday work, and are easy to execute. This indicate that a improvement in our prototype is needed, maybe changing the Leap Motion to a vertical position, but we can assume that there is room to embed extra functionality in mouse devices.

With our technique there is no need to swap between applications, that is probably the reason about why the participants well received it. Usually, they would lose too much time switching between windows because the application order in the alt-tab switches does not remain constant. Also, the users were able to stay focused on only one application interface instead of several.

In future work, would be interesting conducted some experiments comparing the 3D Gesture Mouse with some interfaces already based on gestures, such as the Padmouse, for instance, and evaluate a more comfortable prototype design.

The authors made fully available all the data and code from this study at: http://inf.ufrgs.br/~jmfranz/researchDemos/3DMouse.zip

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