Assistive technology: A multimodal interface to control PC mouse pointer and click

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***Abstract*—Although the use of technology, e.g., personal computers and smartphones, is essential in nowadays world, many users do not have enough motor skills to use them fluently. The commercially available assistive technology is expensive, compared to the conventional one, and many of these devices have limited configurability also limiting the number of users who can benefit from them. This paper addresses the design and prototype implementation of a plug & play mouse that can be used in four configurable modes in order to meet different users' requirements. The proposed mouse characteristics and prototype price is compared to various commercial devices proving the potential of the proposed solution.**

***Index Terms*—Accessibility, Assistive technology, Computer access**

I. INTRODUCTION

Nowadays, many electronic devices are used in our everyday life, such as personal computers (PC) and mobile phones, to access information, communicate, study, work, and recreation. The use of these technological devices has become so essential that technological illiteracy rises as a considerable problem, as those who are unable to use the technology are excluded from society. This exclusion has become even more considerable in the unprecedented pandemic situation due to COVID-19 as many activities migrated to virtual platforms.

Most electronic devices require considerable motor skills to be used. For example, many users face difficulties using a conventional keyboard or mouse. Therefore, a person with a motor disability suffers from technology access barriers, which further exclude them, especially in nowadays world.

To solve this problem some assistive technologies have been developed, such as keyboards with bigger keys, or alternative mouses. Regarding the commercially available mouses, which is the device addressed in this paper, the most typical are trackballs [1] (≈ USD 350) or joysticks [2] (≈USD 400), but there are other alternatives especially designed to be operated using a specific part of the body, e.g., the chin [3] (≈EUR 450), the mouth [4] (≈EUR 2000), the foot [5] (≈USD 100), or even the eyes [6] (≈USD 1000). A bit more versatile solutions are the switch-based mouses that can be used with various types of switches typically connected using a 3.5 mm jack connector [7] (≈USD 70 plus the switches) [8] (≈USD 100 plus the switches), and those based on an Inertial Measurement Unit (IMU) such as QuhaZono [9] (≈USD 400) and enPathia [10] (≈EUR 200) which can be used attached to different parts of the body.

Most of the commercially available devices are considerably expensive compared to a conventional mouse (≈USD 10) and its cost is not directly justified by the electronic devices used to build them. Additionally, some of them are designed for very specific uses, and present limited configurability options, also limiting the number of users who can benefit from them.

The academy has also addressed this problem, proposing accelerometer-based or gyroscope-based mouses [11]–[13], camera-based mouses [14], electromyography-based mouses [15], [16], and combining different technologies as gyroscope and electromyography [17], among many other recent studies [18] which proves it is an active research area.

In this paper, we present the design and prototype implementation of a low-cost multimodal configurable mouse, combining four operation modes in the same device: two switch-based modes (Sweep mode and Buttons mode) and two IMU-based modes (Tilt mode and Gesture mode) which are described in Section II. The proposed device is compatible with both capacitive and digital switches which can be connected using a 3.5 mm jack, and the movement thresholds and velocities can be adjusted to meet the user requirements. Therefore, more users can benefit from the same device which further reduces the potential commercial price. Additionally, the proposed device uses Bluetooth HID (Human interface device) avoiding extra software or drivers.

This paper is organized as follows. First, the operation modes of the proposed device are described in Section II. The prototype design and implementation is presented in Section III. Finally, the concluding remarks of this work including a comparison between the proposed device and various commercial alternatives is presented in Section IV.

II. Proposed operating modes

The proposed device aims to control the mouse pointer and clicks in a conventional personal computer (PC). The device has four modes of operation, meaning that the mouse pointer and click can be controled in four different ways. Two of them interact with the user through buttons and the other two through movements of the device. In this section, the different operating modes are detailed.

A. Sweep mode

In this mode, the user interacts with the PC through four buttons. Two of them correspond to the conventional right and left clicks. The remaining two buttons control the movement of the mouse pointer in a semiautomatic manner. This means that the mouse pointer will move at a constant speed in one of two axes of the display (vertical or horizontal). Each of the two remaining buttons starts (if the pointer was still) or stops (if the pointer was moving), one of these two axes. By doing this, any location in the display can be reached. The speed of the mouse pointer can be easily changed to the user needs.

B. Buttons mode

In this case, there are six buttons to control the mouse pointer and clicks. Two of them correspond to the conventional right and left clicks. The remaining, control the movement of the pointer mouse. Each button, while pressed, moves the mouse pointer in one of four semi axes (vertical up, vertical down, horizontal left and horizontal right). Here, the speed at which the pointer moves while pressing a button can be easily changed to satisfy the users needs.

C. Tilt mode

The last two modes translate movements from the device into movements of the mouse pointer. To do this, an inertial measurement unit (IMU) is used. In this particular mode, the angle of the device with respect to an initial predefined position is used to determine the movement of the pointer in different directions. Usually, while considering angular movements, an aeronautic convention for naming the axes is used. This definition of the axes is relative to the aircraft and describes the relative rotations in these axes. The axes are called yaw, pitch and roll, where the yaw axis is usually defined co-linear with the gravity. For example, Fig. 1 shows the definition of these axes for head movements. When an angle is detected in the pitch axis that is greater than a predefined threshold, the mouse pointer starts to move in the vertical axis of the display at a constant speed. Actually, there are two thresholds, after the second threshold, the speed of the movement of the cursor is increased. The pointer stops when the angle is smaller than a third threshold. This small hysteresis between the start and stop of the movement was implemented to avoid false starts with undesired movements. The device has an analog behavior between the roll and the horizontal axes. Finally, fast movements in the yaw axis are translated into a left click in the PC.

In this mode, there are several parameters that can be easily configure, the two thresholds and the speed of the pointer after each threshold. Last but not least, the device can be used in any part of the body not only the head, it can be used in the foot, wrist or even attached to a handmade joystick.

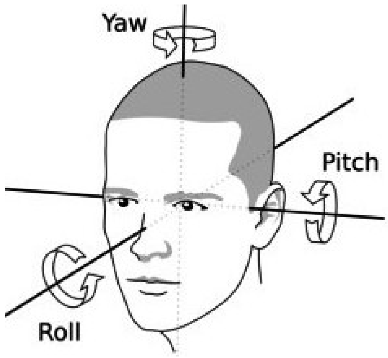

Fig. 1: Yaw, pitch and roll axes.

D. Gesture mode

The last operation mode implemented in the device is the gesture mode. This mode detects specific gestures, for example, a movement across one of the axes of the device. Fig. 2 shows an example on how to use this mode. Six gestures can be detected. Four of them correspond to positive and negative movements in the Y and X axes, then, these movements are translated in vertical and horizontal movements of the pointer in the display, respectively. When one of these gestures is detected, the mouse pointer starts to move to the corresponding direction at a constant speed.

Another gesture that can be detected is a positive movement in the Z axis. This gesture is translated to indicate the mouse pointer to stop moving. Finally, a shake of the device (this means a fast rotation in any direction), is translated into a left click of the mouse.

The gestures are detected by processing the signals obtained from the IMU. For example, Fig. 3 shows the acceleration obtained by the IMU when a movement in the X axis is performed. The device has an accelerometer,

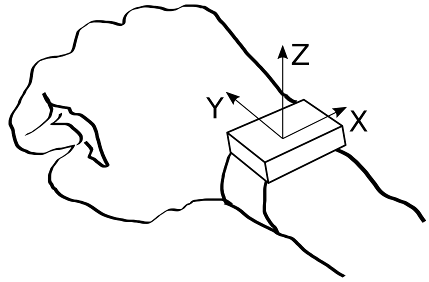

Fig. 2: Gesture example.

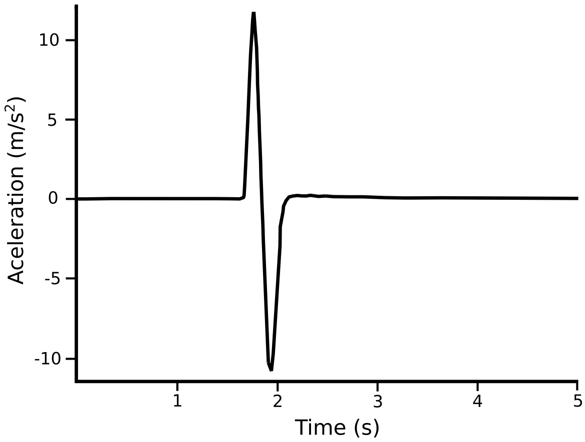

Fig. 3: Acceleration example during a gesture in the X axis.

a gyroscope and a magnetic sensor. These three sensors are used together in order to have the exact orientation of the device at every time. Additionally, there are several parameters that can be configure in order to adjust the speed and duration of the gestures that are detected.

E. General characteristics

The device communicates with the PC using Bluetooth. Bluetooth has additional protocols for specific applications, in this case we are using the human interface device profile (HID) which makes the communication easier, for example, between a Bluetooth mouse and a PC. Using this protocol allows us to build a device which automatically presents itself as a mouse avoiding the need of having a driver or software installed in the PC. This means the device is plug & play.

All the operation modes presented in this section are embedded in the same device and there is a simple way to switch between them. The device has an encoder and if the button of the encoder is pressed for 3 seconds, the devices enters the selection mode. To identify the different modes, the pointer does a specific pattern, for example, a small movement in the horizontal axis means that the sweep mode is about to be selected. Then by rolling the encoder the user can select the desired mode and start running it by pressing the button of the encoder again.

Another important characteristic, is that some parameters can be easily configured to adjust the device to the user needs. In order to keep the user interface simple, the same encoder that allows you to select the mode, is the one used to configure one parameter in each mode. This parameter depends on the mode and it can be the cursor speed or a movement threshold. To change the corresponding parameter, when the device is running a specific mode, the button of the encoder can be pressed for a short time, and by rolling the encoder, the parameter is changed. Finally, another press of the button confirms the value of the parameter.

III. Hardware: Block diagram

The block diagram of the proposed device is shown in Fig. 4a. The Mobile Device was designed to be as small as possible in order to be easily attached to different parts of the body while using the IMU-based modes. It is composed of the power management module (microUSB port, battery, charger, and the low-dropout regulator), the sensors (IMU and magnetic sensor), and the Bluetooth module (32-bit ARM Cortex® M4 CPU, 192KB flash memory, 24KB RAM, and a 2.4GHz Transceiver) which uses an external EEPROM. The encoder used to select the operation mode and configure them (speed or thresholds) is also included in this Mobile Device.

To use the two switch-based modes, the Switch Box is connected to the Mobile Device, using an RJ45 cable. Up to six buttons or sense electrodes can be connected to the switch box using a 3.5mm jack. Six switches allow selecting which type of button (digital button or a sense electrode) is connected to each 3.5mm jack. Additionally, in order to tolerate a wide variety of sense electrodes (different sizes and shapes) and to be able to configure its sensitivity, 3 jumpers were included to adjust the sense capacitance in each 3.5mm jack.

With the selected 300 mAh battery, the device can be continuously operated for at least 24 hours. The fabricated PCB for the Mobile Device and Switch Box are shown in figures 4b and 4c, respectively. A plastic case for each device (Mobile Device and Switch Box) was designed and 3D printed, and are shown in Fig. 5.

IV. Concluding Remarks

In this paper a multimodal interface to control the PC mouse pointer and click was designed and fabricated. Table I shows a comparison between the proposed approach and other commercial devices. This device outcomes previous solutions by including several operating modes in the same hardware, making this device much more versatile. The proposed mouse characteristics and prototype estimated price proves the potential of the proposed solution.

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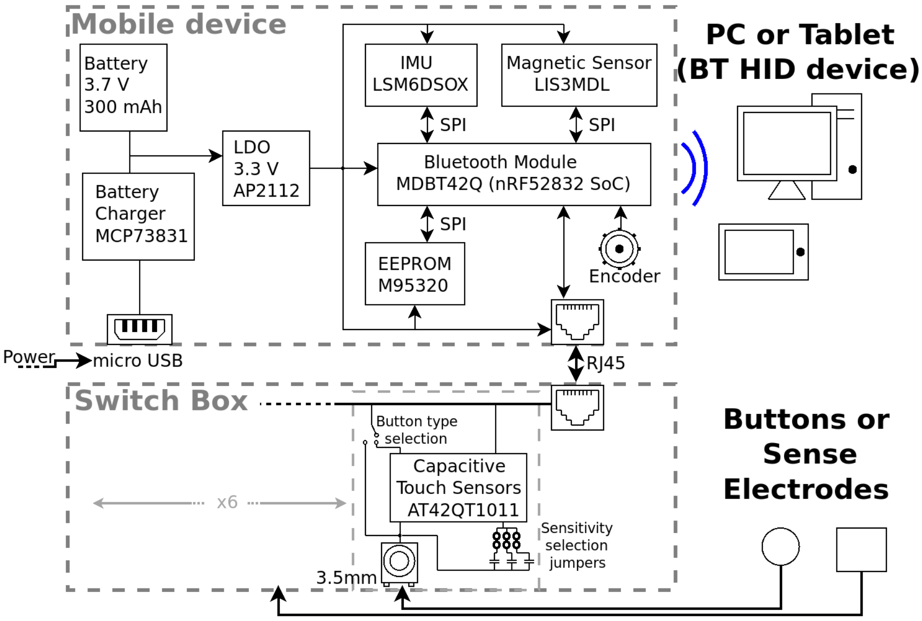
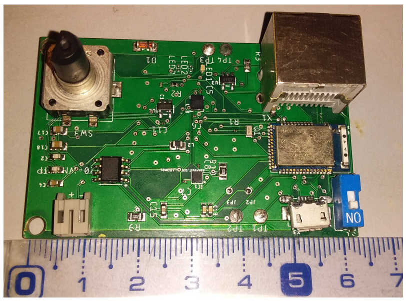
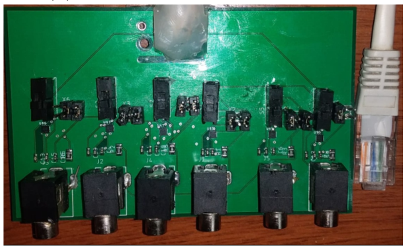


(a) Block Diagram of the proposed multimodal mouse.



(b) PCB for the Mobile Device.



(c) PCB for the Switch Box.

Fig. 4: Three simple graphs

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[9]	[10]	This work
Control Type	Hand	Hand	Chin	Mouth	Foot	Eye	Buttons	Tilt mode	Tilt mode	4 modes
Plug & Play	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes
Configurability	without software	without software	with software	without software	with software	with software	without software	with software	with software	without software
Estimated price	USD 350	USD 400	EUR 450	EUR 2000	USD 100	USD 1000	USD 70 + switches	USD 400	EUR 200	USD 110
Click & Drag	N/A	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes

TABLE I: Comparison between this device and commercial ones.

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Fig. 5: Picture of the implemented prototype.