DEVELOPMENT OF A GYRO SENSOR BASED COMPUTER MOUSE WITH USB INTERFACE AS TECHNICAL AID FOR DISABLED PERSONS

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Abstract: This paper describes the development of an alternative computer mouse for disabled persons. The mouse is an advanced technical aid for a large group of disabled (handicapped) persons, and can be placed on variuos suitable body parts. The mouse is module based and have many functions that enable a disabled persons to control a computer. It also allows the person to work efficent on the computer. The functions have been developed togehter with disabled persons and are based on their wishes and needs. Therfor it is not only a «head-mouse», it is an alternative mouse! The device is a gyro sensor based computer mouse and it operates by sensing the rotation of a body part. The disabled users appreciated the high sensitivity of the mouse and that it is easy to install and use, thanks the USB «plug&play» functionality. The mouse is a small and comfortable computer mouse that suits a various groups of disabled persons with different types of movement handicaps.

Introduction

The technology of today gives more and more possibilities for all humans. But technical advanced products often are not userfriendly. Unfortunately not all products are easy to use or fitted to use for persons with a certain disability.

Today computers are an important part of our daily lifes. To be able to control them is in many cases necessary for working, communication or participation in our modern society of today.

Therefore are persons that can not use an ordinary computer mouse is in need of an alternative mouse. The reason of why an ordinary mouse can not be used is very different from person to person, depending on their abilities and needs. The need can also vary over time, not all persons are permanent handicapped, it can be a disability or bodily injury that can be healed.

Previous solutions for disabled people to control a computer mouse or similar input devices have often been technology focused [1] [2] [3]. Different technologies have been tried, but the technologies have not acctually been based on the disabled persons demands and needs.

From these aspects, a computer mouse that can be used by a wide range of people with different types of disabilties and that can be applied on different body parts has been developed and evaulated.

Materials and Methods

Before developing this alternative mouse, an investigation of which functionalities a mouse should have to best fullfill a user´s needs and demands was undertaken, and presented in an aspect list. The points in the aspect list are based on disabled users desires and the opinion from medical proffesionals, relatives or other persons from the daily enviroment of disabled persons. Also results and aspects from other alternative mouses for disabled have been considered [4] [5] [6] [7].

The disabled persons included in the interview study were mostly movement disabled persons without any mental retardation and thus they had no problems in expressing themselfs. For a disabled person also having a mental retardation, people in their daily environment represented their opinion. Totaly six disabled with different types of handicap was interviewed.

Also six proffesionals that are working daily with disabled persons and technical aids were interviewed. Everyone of them could speak for at least three to five disabled, (both mentaly and non-mentaly retarded), that they have personal contact with.

The summary of desired functions and other aspects on the mouse are described as follows:

1. It shall be simple to install.
2. It shall be easy (intiutive) to use.
3. If you need to wear it, it shall be easy to wear.
4. It shall have the same behavior in the same or similar situations.
5. It shall be realible and stable.
6. Specific mouse parameters shall be possibly to change and control for each individual user.
7. It shall have an ergonomic design that fits the individual user.
8. The click function shall be individual matched.
9. It shall work on different computers (home, work, school, MacOS, Windows, Linux etc).

These are functions that a «dream-mouse» shall have. These aspects were used to create a demand specification of the mouse.

(The parenthesis shows the valid function aspect/s.):

- It shall use the USB-standard interface. (1, 9).
- The system shall be module based. It shall be possible to change either the sensor or the click module for individual user adaption. (7, 8).
- The main module shall be the same for all module combinations (4, 6).
- The sensor module shall be gyro-based. (2, 3).
- It shall be based on open, stable standards (5).

The computer interface was very easy to determinate. The natural choise for a computer communication is the USB-interface. USB is an common, «plug&play» interface that all modern computers have. Another benifit is that no software drivers are needed to be installed on the computer because most operating systems have built-in support for USB-mouses.

Each user shall be able to have their own levels and functions designed after what suits them best and it shall also be possibly to calibrate and adjust the sensors for cursor movements and click-function. Thus some kind of programmable device was needed.

To get a movement sensor that responds to the demand specification in physical and technical aspects such as size, weight, sensibility and precision, and also in the aspects of how the user want to move the body part they control, the choise ended on a MEMS based component.

To allow different solutions for the click function a device interface was built-in that allows the most common click-devices to be connectet to the unit. This means that the user have the possibility to use his or her own private input device and not only devices that are obtained with the system. This gives more freedom and flexibility for the user.

Hardware overview

The system is connected to an regular computer and the block diagram represents the gyro sensor controlled computer mouse interface (Fig. 1).
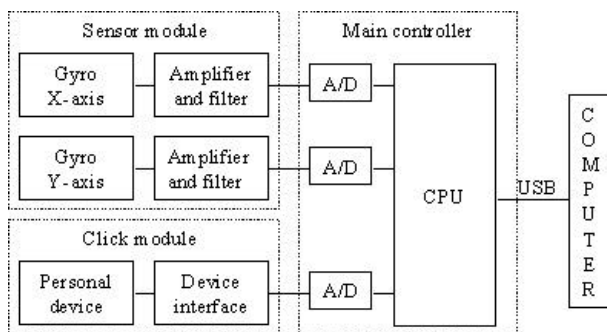

Figure 1: Block diagram showing the mouse system.

By doing the whole mouse module based, it is possible to adjust both the sensor and click module to fit any person as good and optimal as possible. Every individual user can have their own personal input device without totaly rebuilding the mouse. Thus a person can test out what kind of input devices that suites him or her best. It is easy to test different devices and also change

between them. This is an important aspect because any person close the disabled should be able to assist in this, without any technical assistance.

Main controller

For the main controller some programmable components were needed. It should also handle the USB communication to the computer and the signals from the movement sensors and click sensors.

Most of the simpler (and cheaper) movement sensors give out an analog signal. Therefore the signal interface between the main controller and sensor module was chosen to be analog.

From the click sensors usually a digital signal comes out, but also an analog signal can be used like an digital two level signal (e.g «0» and «1»). Therefore an analog signal interface was chosen also for the click module. It gives the opportunity to modify the click module, but it is not necessary to do so to have the functionallity.

In order to construct such a simple solution as possible, the chose of main controller was a processor that had built-in communication for USB and A/D-converters. This gives both the smallest and simpliest construction for the main controller. Only some glue-component was needed for the processor.

The main controller uses the HID-profile for the USB-bus. This means that the mouse uses the standard mouse support that is built-in in the operative system (OS) on the computer. The assummtion that the OS on the computer has an USB-support was made, which all modern personal computers and OS of today have.

Therefor no drivers or other hardware specific software was needed. It is just «plug-and-play» on any computer. This makes the mouse very easy to install and bring if you want to use it on any other computer. Thus one mouse is enough even if you have different computers at home, at work or at school. It also make it easy to travel and use together with any foreign computers.

The motion sensor module

The motion module is the part that detects movements. It is placed on the user on any free choosen body part that the user can move.

Figure 2: The movement sensor module.

When the user move his head, arm, foot or any other chosen body part the sensor detects the movements and sends it to the main module.

The motion sensor module is designed to enable use on any free chosen body part (Fig. 2). Therefore all electronics is mounted in a separate small sized box that can be attached with arrangements.

The sensor module box is a black plastic box, approximately 40 x 25 x 15 mm, and provided with screwholes for attachement.

It can be attached to a headset or simular or be carried around the arm, hand, leg or foot. The box also capsules and protects the electronics.

To construct a movment detection unit usually MEMS based accelerometers or gyroscopes are used. The performance of these components is getting better and better and the size and price are going down.

It exists a large number of movement detection solutions for alternativ computer mouses [8] [9]. A lot of them are built on accelerometers [10] [11].

Accelerometers are cheaper than gyros and are very often used to detect tilt movements. The requirements on this mouse, however, was to detect an angular rotation velocity and also a high resolution was required. Therefor a MEMS-gyro was chosen.

The MEMS-gyros are not ideal components, thus filters are needed before the signal from the gyro sensor is fed to the CPU (Fig. 3). The MEMS-gyro is very sensitive for disturbations such as vibrations and temperature variations.

Gyro sensor	DC-cut / HPF	Amp. & LPF	ADC & CPU

Figure 3: Gyro sensor signal way into the CPU.

From the gyro sensor a motion signal containing a direct voltage offset is received. Therefor a highpass filter (HPF) is used to cut off the DC-offset. The HPF also reduces the effect of temperature drift. The drift affects the DC-offset so the sensor output must be connected to a HPF for elimination of the DC-component.

After that a regular amplifier is used to get the desired signal level. Also a lowpass filter (LPF) is used to get a noise reduction on the signal. All filters must be designed so that they do not affect the gyro signal. The filters must accept both short fast and long slow signals from the gyro. This can be a problem when designing the electronics for the gyro signal, because the user can do both very slow and very fast movements and the system must be able to recognise them as a user signal.

Click module

The most common input device for disabled for click-function are simple push-buttons. The buttons exist in a great numbers of different shapes, sizes and colours [12]. Their function is very easy, when you push the button you close or break an electrical circuit. They are rather cheap and easy to use and install, but requires movement of a bodypart to enable the click-function.

For disabled that can not or have great difficulties in moving their body, alternative solutions are required. It is possible to get a click function by installing specific software on the computer [13]. Then you do not need to have a hardware solution. Acctually you can use both software and hardware solutions together. The disadvantages of software solutions are the need of installations and possibly different functions or behavior on different computers, if the computer not have the software installed or different settings of the parameters.

The alternative click module that was chosen is a «sipp-and-puff» unit. The sipp-and-puff unit is an analog unit that can give the user the same numbers of click functions as a regular computer mouse. Theoretically it is possible to change the numbers of click-levels up to the maximum of what the A/D-converter admits. But this is of no practical use. Most users are not able to handle more than a few numbers of levels. The human breathing is also to raw for that. Therefore the sipp-and-puff unit have six click functions. They are left and right click and four personal programable functions.

But it is possible to change the number of buttons and also the levels for breathing that representants each button. Also disabled in wheelchairs often have a reduced lung capacity that gives a weaker breathing, so an adjustable gain is needed. This is achieved by changing the firmware for the CPU. Thus the same hardware can be used and optimised for different individuals.

The A/D-interface enables development of new modules for the clickfunction without changing the hardware. This gives extended opportunities to change or develop new click modules for the futures without developing a brand new mouse.

The complete system

To reduce the size of the whole system, the click module was integrated into the main controller module as far as possible. This gave a smaller, more compact solution and increased the user friendliness (easier to handle).

Figure 4: The complete system with a built-in sip-and-puff unit, five contacts for push-buttons, the motion sensor and one push-button in front.

Results

First-time users understood intuitive how to use the mouse, but had some problem before they had become familary with the behavior of the mouse and had made their own settings. The system works well and the users are able to control a computer even if they have a limited mobility.

Figure 5: A user with headset and a sip-and-puff unit.

The disabled users appreciated the high sensitivity of the mouse and that it gave the user a very high accuracy when moving the mouse cursor. In reality the user could get an accuracy of one pixel on the screen when using a moderate resolution (1024x768) on the screen. A more experienced user could get the same result on higher resolutions.

All users were able to connect the different modules to each other and install the mouse by themselves, without any help from technical personnel. The disabled user that needed human help for the installation, etc, was able to make it with help only from relatives or their personal assistant.

Discussion

For the acceptance from the users and there surroundings it is very important that the mouse works the first time it is used. Of course it shall keep working and have the same functionallity the whole time. Summary: *«It shall be realible and stable».* This is the aspect #5 in the aspect list. Actually this aspect has been the hardest to fulfil, so therefore, when developing a new technical aid, both short tests and longtime fieldtests by disabled users are needed.

It is also necessary that the users are involved in the development phase to ensure that their reliable aspects is followed the whole time.

Placement and assemble of the motion module and click module is the first thing a test person have opinions about therefor it is very important that the technical aid can be designed so it fits different users. In this case people with only head-, arms- or foot-movements have tried out the mouse.

The second thing they all have opinions about is the settings on the mouse sensitivity. Only having hardware were you can change parameters is not a good solution. It is acceptable by most users that a technician makes the changes and individual parameter settings and save it in the firmware. But it is a desire to have a software that can handle this, so the technical advanced user can handle it by him/herself, without external help. This means that software for different operating systems is needed and also that the mouse will not be so easy to move between different computers. But acctually most users only have one or two computers that they work on, so the installation problem is not to hard to handle.

But it still is beneficial that the mouse works on any computer with USB, without the need for any software installation and that it is rather small and easy to bring. Thus you only need one mouse even if you have different computers at home, work or school. It also facilitates the use on any foreign computer.

The parameters for mouse sensitivity and the mouse button functions are controlled and determined in the mouse settings, that each operative system have. No extra software is needed.

The advantages

The use of gyros gives the user a reference free mouse system. No external references are needed, that togheter with the USB-interface give a very easy mouse to travel with, install and use on any computer.

Except all other advantages the mouse gives, the main advantages are:

- Easy to adjust for each individual user.
- Very easy to install.
- High sensitivity.

If a technical aid shall be used daily over a long period of time it is important that it suites the user very good. Therefore it is very important that the user can optimise the technical aid for his or hers individual conditions. From fieldtests with disabled the most important property found, was that the sensor module must fit the user very well.

An easy installation is a prerequisite for getting an acceptance from disabled persons, relatives and medical personal. They are often sceptical to new things based on earlier experience from new hightech aids that have difficult installation (technicians often recuired) and that does not work properly.

High sensitivity gives disabled with limited movement possibilities also the oportunity to control a computer. High resolution also gives the limited user the possibility to move the cursor from side to side on a very large monitor. A high resolution is also possible to decrease.

The disadvantages

The mouse have also, as all other system, its disadvantages. Making a module based system means making compromises, in this case the whole systems size is traded against flexibility. But the biggest

disadvantages that disabled or medical (proffesionals) have expressed are:

- Not wireless.
- You need to have help to put the mouse on. (Wear the mouse.)
- An external click function is needed.

Making the mouse wireless is technicaliy possible. The natural next step in developing the mouse is to make it wireless. Due to the limited budget and time, the first version was wired.

Severely movement handicapped people need help to put the mouse on themself, and the wire makes them thighten to the computer.

The aspect that it is two different units for movement and click detection is both an advantage and a disadvantage. Due to the decision to make the system module based, this is a result of that.

Conclusions

This system is very easy to install and allow people with disabilities to use and control a computer. It shows that it is possibly to design a small and comfortable computer mouse for disabled persons.

The module system gives a very good flexibility and the main part of the hardware can be used by a large number of disabled with different handicap. That the same mouse concept can be used to many disabled and non-disabled persons gives a chance to larger product volymes and a better future safety for the mouse.

This gives a better chance to realize a mouse that can be produced and acctually help disabled and not only be another mouse prototype that never leaves the laboratory.

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