A New Type of Non-Contact 2D Multimodal Interface to Track and Acquire Hand Position and Tremor Signal

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Abstract: We present a new type of multimodal interface that is able to sense and track a 2D-hand movement and, simultaneously, to acquire a hand tremor signals. The main advantage of the 2D-sensing device is the possibility to track the position of the objects in the environment and to allow the controlling of various actions accordingly, without any physical contact with the hand. Moreover, the device interfaces with a personal computer (PC), like a standard joystick and, if we exclude the tremor acquires facility, it can replace a standard one. To use the tremor facility that this multimodal interface provides, we need additionally only one standard serial port to connect it with the PC.

1. Introduction

With the advance of speech, image, video technology and biomedical signal interpretation, virtual reality and human computer interaction (HCI) will reach a new phase. The final goal in HCI and virtual reality environments is that the communication between humans and machines will be similar to human-to-human communication. From these reasons, new types of multimodal input devices are necessary. These devices must be able to acquire biological signals related with the physical, psychological and emotive states of a person. Some times the interface rather than the machine or the application, constrains the interactivity, professional productivity, creativity, or the quantity of information exchanged in a work session.

The goal of this project is to develop a new type of non-contact 2D-sensor system, not cost prohibitive, simple to maintain. This multimodal transducer can be used starting with actual computer games (capable to act as a normally joystick [1] – in our case a virtual joystick) up to emotional communication [2] in virtual environment based on emotion space of features extracted from biological signals [3]. The term "virtual" is used because the joystick has the possibility to sense objects without any physical contact (hence the "virtual operation" capability).

2. Method

It is known that an element generating an external electromagnetic field changes its impedance due to the properties of the objects in its close vicinity. The change is due to the variation of the equivalent impedance (either reactive or resistive) viewed at the port of the measuring device. For the impedance change to be high enough, the oscillator should excite the transducer with a high frequency signal related to the sensor properties.

Accordingly to [4], [5], the sensor is composed of a planar winding. The winding has a relatively large conductor width and a relatively small spacing between successive turns in order to achieve a suitably high capacitance between the turns and a suitably large overall capacitance for this resonant sensor. The winding is shaped to provide a relatively uniform electric field in a sensing zone that is generally determined by the overall dimensions and shape of the resonant sensor. Such an electrical field is suitable for sensing dielectric (non-conductive and nonmagnetic) objects, as well as magnetic or conducting objects. Subsequently, we present the operation of the sensor accordingly to [4], [5].

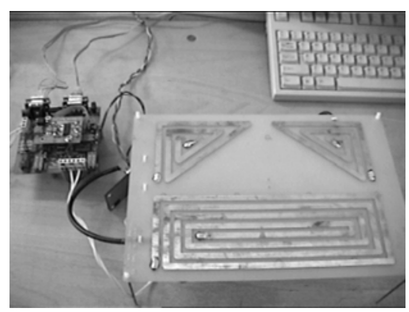

Figure 1. Sensor and electronic processing system

In contrast to conventional inductor/capacitor ("LC") circuits (that intentionally minimises "undesirable parasitic" capacitance and couplings to surrounding objects), the resonant sensor of the invention [4], [5] enhances the parasitic capacitance and the couplings and employs them as sensitive object-sensing elements.

The picture of the sensor is presented in **figure 1** and the general scheme of the circuitry used to drive this sensor is shown in **figure 2**. The sensing element is a distributed R_E, L_E, C_E circuit whose resonance frequency is turned close to the predetermined frequency of the driving oscillator. Resonant sensor and a resistor form together a voltage divider circuit that generates at their junction a signal that is directly representative for the position and/or movement of an object in proximity to resonant sensor. The proximity of the sensed object to the resonant sensor produces a change in the parallel resonant frequency of the resonant sensor. This change causes corresponding changes in its impedance and, also in, the magnitude of the signal across the resonant sensor. The driving circuits are used to command the sensors, with a class D amplifier. To obtain good high Q factors for the resonant sensors and a good sensitivity, the voltage follower circuits use the current feedback operational amplifiers LT 1229 that have 100MHz bandwidth and high input impedance of 25 MΩ, 3 pF. The detector extracts an average envelope voltage from the input signal. The new signal represents the movement signal. The filter is a low pas one with the function to stop high spectral components from the oscillator (in this system it works at 16.7 MHz).

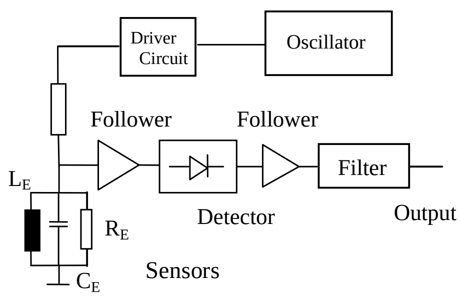

Figure 2. Block scheme of the sensor and circuitry used to drive it

Because the resonant sensor and the electronically system that drive it is employed in a mode of working (that implies object distance sensing) the resonant frequency of the resonant sensor should be either slightly lower or slightly higher than operating frequency given by the oscillator. Preferably, the oscillator should be tuned such as operating frequency be centred on a substantially linear portion of impedance versus frequency curve of resonant sensor.

When the hand is above one of the sensors, the output of the corresponding circuit has a high value. The sensors that sense left-right balance are placed symmetrically on the board and are paired, such that the signal from a couple of opposite sensors evidences the balance movements of the hand. The principle is similar when detecting the forward and backward movement. The distance between the proximity sensor and the hand is another factor that can influence the magnitude of the output signal on the corresponding channel. It is used for a supplementary control.

3. Schematics and Software

The multimodal system communicates with the PC through serial port in the case of transmitting the tremor signal and with the standard joystick port in case of movement signals.

In **figure 3**, we present practical implementation of the schematics shown in **figure 4**. The "heart" of the entire multimodal interface is the digital signal processor (DSP) TMS320F240 produced by Texas Instruments. Basically, it must acquire (in the same time but at different rates) movements and hand tremor signals, extract from the information supplied by the transducer the exact movement and, after that, command two digital potentiometers, drive three digital filters and, when the PC requires, transmit the tremor signal locally stored.

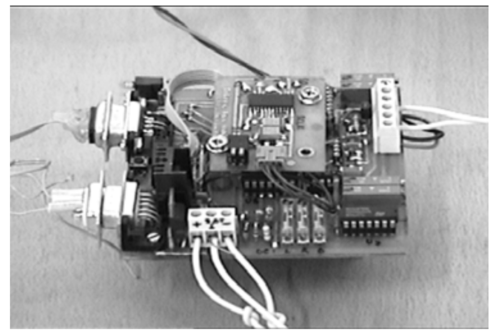

Figure 3. Part of the practical implementation of the multimodal sensor

Before acquiring the signal, we use on all three movement channels an ADC anti-aliasing filter realised with the *MAX 295* [6] circuit (**figure 5**) that is an 8^{th}-order, low-pass, switched-capacitors filter that can be set up with corner frequencies from 0.1 Hz to 50 kHz. The *Max 295* is a Butterworth filter that provides maximally flat pass-band response. The 8 poles provide 48 dB of attenuation per octave. For this kind of filter, the maximum recommended clock frequency is 2.5 MHz, producing a cut-off frequency of 50 kHz; the clock to corner-frequency ratio is 50:1. The TMS320F240 circuit symmetrically drives the CLK pin, on 50% duty cycle. The timer 1 in the DSP generates this clock signal with the help of associated compare register. To acquire the signal, we used one of the two 10-bit ADCs string/capacitors converters that are available on TMS320C240. Eight analogue inputs are provided for each ADC unit. For the three input channels, the ADCIN.2 and ADCIN.3, ADCIN.6 lines are connected and all sampled with a 3 Hz rate.

To detect the left-right, forward-backward and up-down movements, first we compare the difference between the output levels of all three transducers sensing the movements of the hand in the horizontal plane. In the next step, the actual values of all channels are compared with the last known result to sense the magnitude of the movements in vertical plane. Because one of our requirements was to interconnect the sensor using only standard PC ports for movements signal, we use joystick port. Usually, the joystick port is not integrated in the motherboard of a PC, being implemented in multi I/O- or soundboards. The connector of the port enables the control of two joysticks at the same time. Inside the standard joystick, the stick is attached to two 100 KΩ potentiometers, typically. One of the resistors changes its value according to the change in the position of the stick along the X-axis. The other potentiometer does the same for the Y-axis. Knowing this information, we change the value of the digitally controlled potentiometer X9250 [7] accordingly with the movements, generating controlling instruction conforming to the requirement of the communication SPI bus of this circuit.

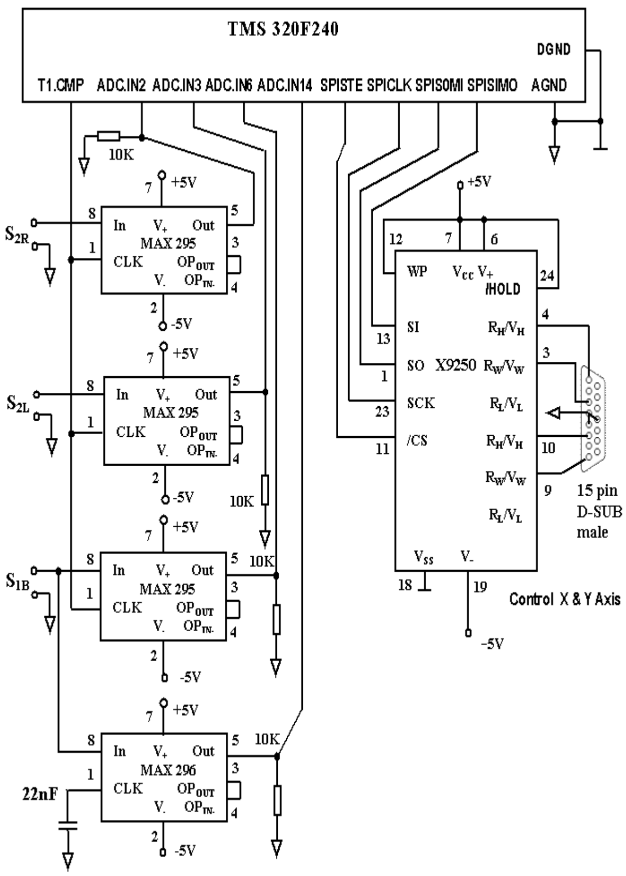

Figure 4. Schematics for anti-aliasing filter, DSP and digitally-controlled potentiometers

Because in case of the tremor signal the noise and non-linear characteristic of the pre-processing system can destroy the very noise sensitive non-linear information and can lead to unreliable results [8], special precautions must be taken. From these reasons, on the tremor signal acquisition path we use MAX 296 anti-alias filter. Since the *MAX 296* has a linear phase response in the pass-band (because is a Bessel switched-capacitor filter), all frequency components are equally delayed, preserving well the input signal information. The Bessel filter includes multiple filtering functions (other then ant-alias function). Because his cut off frequency is chosen to be 40 Hz, he removes, in the same time, the power supply hum (50/60 Hz and 100/120 Hz) and the noise frequencies, which, for example, in medical applications are greater than about 150-200 Hz. The tremor signal is acquired using the second ADC converter from the DSP. In this mode the movement and tremor acquisition can be done in the same time. Because the acquisition should be of the high precision, at least 12 bits (otherwise the sampling and quantization noise can destroy the results [8]) and because the both internal ADC converters are on 10 bits, we compensate this externally by the amplification of the electrical signal. The sampling frequency for tremor signal is chosen to be 120 Hz.

For PC software development we use Microsoft Visual C++ 6.0 programming language using for that Measurement Studio ComponentWorks++ library that extends Visual C++ and brings measurements and automation into Microsoft environment. The software package was developed to interrogate Joystick port through SDK function and to control the position of a point (**figure 5**). From five to five seconds a buffer with tremor signal is read from multimodal interface and displayed (see **figure 5)**.

4. Experimental results

Figure 5 shows a program snap shot of the software in time of one working session.

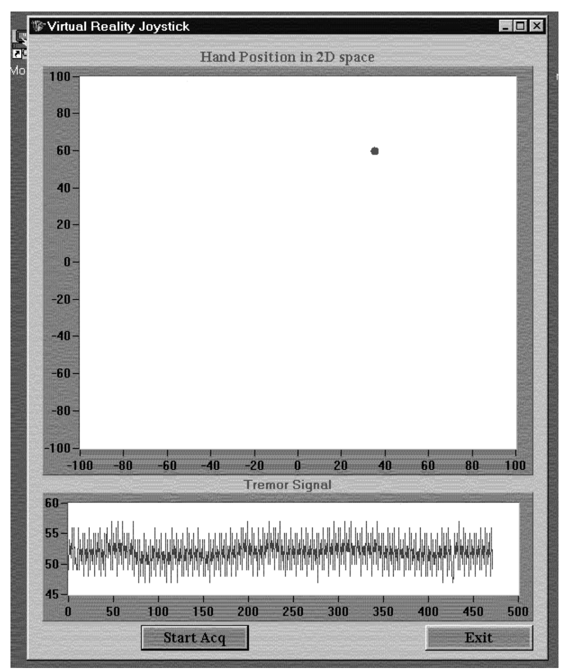

Figure 5. A view with the main window of the PC software program, with the dot representing the hand sensed by the virtual mouse

In the upper window is a representation of the active workspace where the position of the hand can be tracked. The active space has the dimension of 40 x 48 x 20.cm.

Some of the result tremor signals acquired with the bigger transducer, situated at the bottom part of the sensor system, are presented in **figure 6**. For the tremor measurements, the performance of the sensors is not critical as far as the sensor is low weight (if it is in contact with the hand) or has non-contact measurement capabilities, to avoid loading of the hand. Our sensing elements satisfy the last requirement.

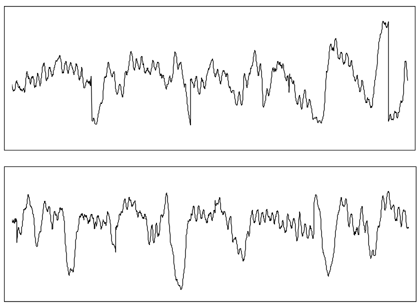

Figure 6. Two examples of tremor signals

5. Conclusions

The presented multimodal sensors are well suited for applications in both Virtual Reality and medicine. One of the main feature is that the presented multimodal interface can be connected to a computer without a special board to interface (the movement is transmitted through Joystick port and the tremor signal by serial port). Consequently, it is no need to develop special driver for this device; the standard function provided by Microsoft to work with joystick and serial port can be used. The only requirement for the use is a Sound Blaster card with a joystick port and a free serial port. The sensor is cheaper and definitely more reliable than a conventional (electro-mechanical joystick) one. Moreover, its capabilities are higher and the sensor does not require physical contact.

This new multimodal interface has several advantages. In the first place, there is the possibility to use it in a variety of applications as it has an excellent sensitivity and bandwidth appropriate for the acquisition of movements and tremor signals. The possibility of correlating the two kinds of information movement and tremor (taken in the same time) with the activity from virtual environment is another advantage. A final aim is to establish indicators of the subject attitude and to develop a “sensitive” computer, a computer capable to “understand” the state of a people using the information extracted from information supplied by this system. This will be a subject for future research.

Acknowledgements

The research related to the sensor design and manufacturing has been carried on during the stay of the second author at Swiss Federal Institute of Technology, Lausanne, Switzerland. The basic design of the monitoring (**figure 2**) system has been carried out at the same university and at the University of South Florida, Tampa, Fl., USA. Patents have been obtained with the support of Sensitive Technologies™ LLC, USA. Part of the information of this paper (from points **2. Method** and **3. Schematics and Software**) are taken, reprocessed and improved from the [1]. This multimodal sensor is a developed and enhanced one (ex. the facility to acquire the tremor signal relays only in this sensor) presented in [1]. The idea of using the sensor from patent [4] in direction of virtual joystick was suggested by Mlynek D. from Swiss Federal Institute of Technology, Lausanne, Switzerland.

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