Advanced Educational Tools in Measurement and Sensors: from remote monitoring systems to magnetic fluids.

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***Abstract*—** In order to emphasize the large variety of situations and problems to manage in the didactic activity, two different tools have been implemented and are presented in the paper.

The first one has been realized for using during the teaching activity on informatics and training on computer for the visually impaired students. Indeed, they should be provided with useful kinds of assistance; moreover, the environmental conditions and their health conditions should be in real time monitored in order to discover any difficulties and to evaluate the development. Such requirements are fulfilled by the developed tool, based on advanced hardware and software technologies.

In the second tool an inertial sensor for vibration measurements based on the use of ferrofluids has been developed.

The device consists of a glass pipe housing a drop of ferrofluid in a water environment. Two membranes are used to seal the glass pipe at its extremities and to transfer the vibration to the ferrofluidic mass. An inductive readout strategy is used to sense imposed vibrations. Simulations of the device behavior and the real prototype are presented along with preliminary experimental results.

***Keywords*—**Bio-monitoring, Computer training, Educational tool, Multi-sensor system, Visually impaired.

I. Introduction

The didactic activity involves a large variety of situations, environments, problems, topics, students of different levels.

Particular attention has been devoted by the authors to the experimental training, taking into account the great importance of the technical aspects in the engineering area.

The realization of specific hardware and software tools can be very useful for the students: indeed, they can be acquainted with advanced technologies and can also make some private training, which is meaningful for testing their knowledge of the basic concepts. The students themselves, distributed in small groups, can carry out a complex project, at least a prototype, to be improved by other students. The theoretical importance, as well as the practical one, is evident.

In this paper a variety of didactic situations is focused. Indeed, two different tools are presented, which have been implemented in order to solve specific problems: they are directed to different typology of students, involved in different experimental training.

The first tool presented is related to educational aids for the Visually Impaired.

Researchers with the Department of Electric and Electronic Engineering of the Catania University are deeply involved in the development of both electronic aids and monitoring systems based on Advanced Sensing Strategies for the Visually Impaired. In particular, the performed activity concerns development of methodologies and systems for colour classification, light classification, path-assistance, obstacle detection, surroundings recognition, dangerous event recognition, landmark recognition and mobility [8-13].

The didactic activities oriented to visual impaired people have always played an important role, form a social point of view as well as a scientific one, on account of their complexity, but also for the difficult relations between such people and the tutors.

Qualified supporting teachers certainly can greatly improve the effectiveness of the didactic activities. A good relationship between the teacher and the student suffering from sensorial deficit can enable the student attaining results comparable to the ones attained by the other students.

During the teaching activity on informatics and training on computer use, the visually impaired student should be provided with useful kinds of assistance; moreover, the environmental condition and his health conditions should be continuously and in real time monitored in order to evaluate the development and the difficulties.

It should bear in mind that the continuous presence of either an assistant (social worker?) or a tutor can depress the student. Especially during the test in the classroom it is very important that the student doesn't feel the proximity of the tutor, sometimes embarrassing: indeed, he can be afraid of mistakes.

The system is intended as a PC based working station with

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auto-configuration features and the possibility to implement a remote monitoring of both some bio-parameters of the user and the PC status. In this sense it becomes an interesting way to perform experience in the field of sensors and remote measurement.

The second tool concerns the use of ferrofluids as the active mass in inertial sensors which offers the opportunity to develop reliable devices with tuneable specifications.

The use of ferrofluids as inertial mass offers advantages over traditional devices like robustness against inertial shocks and performances controllable via electrical signals; moreover, ferrofluids density and other physical features can be controlled by an external magnetic field.

Specifically, the device presented is intended to sense a physical movement of a medium connected to the sensor through a beam.

Inertial sensors with high performances can be achieved by using innovative materials and advanced topologies, that fix physical and mechanical parameters to specifications of reliability, robustness, high sensitivity and high resolution [1]. A deep review of the state of the art reveals the possibility to adopt ferrofluids for the development of inertial sensors with very promising performances.

Ferrofluids are synthetic compounds, in either aqueous or non aqueous solutions, composed by colloidal suspensions of ultra-fine (5-10 nm) single domain magnetic particles [2]. Magnetic fields applied to a ferrofluidic volume and the consequent magnetic forces cause the alignment of the ferrofluidic particles in the direction of the field. Moreover, under particular conditions, a ferrofluid volume subjected to magnetic force can behave like a mass connected to tunable equivalent spring whose properties can be controlled by modulating the driving magnetic field [3]. Therefore, in absence of an external magnetic field the ferrofluid acts as a liquid with respect to an external force; if the magnetization produced by an external magnetic field is strong enough, the ferrofluid can be rigid with respect to an external force, besides it can move to a more compliant position. The ferrofluidic nanoparticles are covered with a thin polymeric layer (surfactant) to prevent their agglomeration caused by Van der Waals forces.

Interesting examples of a ferrofluidic devices are given in [4]-[7].

The proposed device consists of a glass pipe containing water and a ferrofluidic mass whose position is monitored by a differential transformer wound around the glass pipe. The movement of an external medium is transferred to the device through a beam connected to the membrane sealing the glass pipe. The membrane movement causes the vibration of the ferrofluidic mass.

The main advantage of the proposed device is due to adoption of ferrofluid as seismic mass which assures a high reliability against high external stimulus; this gives high robustness against shock with respect to a device adopting lumped mass.

Although the above discussed activities are quite different, the two subjects are strategic in the measurement and sensor context and they are extremely appealing for the dramatic interest of the research community on these topics.

Moreover, we want focus the reader attention on the strongly different target of the developed systems: the **first** one aims to improve the knowledge in the field of new materials while **the second tool** is strictly oriented to sensors for bio-applications and remote measurement systems.

II. A System to Enhance Educational Activities for the Visually Impaired

For this reason, there is a need of remotely monitoring the working condition of the student, in order to catch sight of possible difficulties happened to the user, with the purpose of arranging suitable assistance.

The operating conditions of the interaction between the student and the personal computer should be evaluated on the basis of both the status of the used PC and the values of some biophysical parameters of the student himself. Development of the ordinary activity requires concentration and attention: for some reasons, any difficult encountered can establish a condition of “stress”. Taking into account the inner connection with the status of the organism, in this condition an alteration of the values of some biophysical parameters can be observed (for instance, laboured breathing, irregular pulsation, perspiration, etc.).

A feasible way to solve the problem of carrying out a correct teaching assistance in a classroom of informatics can be based on:

- using solutions able to automatically adapt the working environment to the requirements of the visually impaired user;
- using distributed monitoring system: in particular, the realized system should be able to transfer to the monitoring PC-server the information concerning the state of the PC-client and also the values of some biophysical parameters of the students.

Such considerations stimulate to set up a research activity aimed to the design and the realization of a prototype of a working post with suitable features, like self-configuration and remote monitoring of the performances of the user.

The procedure adopted for the realization of the system for the teaching assistance includes the following points:

- developing a system for identifying the user;
- developing a system for the self-configuration of the PC on the base of the requirements of the user;
- implementing a multi-sensorial network for monitoring the biophysical conditions of the user;
- developing a distributed system for the remote monitoring.

A. *Sensing bioparameters*

The Biofeedback represents the information on the biological functions of the individual. Indeed, it appears as an external sign of the inner part of the body. Therefore, with the biofeedback a given bodily function can be monitored by using electrodes or transducers applied on the skin. The detected signals are amplified and converted in acoustic or visual signals.

These techniques are used to detect and measure the reactions of the Autonomous Nervous System, in order to adopt the suitable training to get better reactions. The electronic equipment can recorder signals related to various biological processes, among them the heart-beat, the intensity and the frequency of the electrical activity of the musculature, the variations of the bodily temperature, the characteristics of the cerebral waves, etc.

On the basis of this analysis the individual reactions to various difficult circumstances can be estimate, in order to train the person suitably controlling the reactions.

The purpose of this work is the design and the development of a system for recognizing any possible emotional upset of individuals during PC learning in an informatics room.

The system is planned to be used by Visual Impaired people.

The system should detect the variation of the biophysical parameters that strongly depend on the emotional status of the individual, mainly the heart-beat, the galvanic skin resistance and the body temperature. Monitoring the trend of these parameters the tutor will be able to notice if any of the students is subjected to a stress during his work, therefore he will intervene in time.

Taking into account the chosen parameters, two projects have been planned: the first one for measuring the heart-beat and the second one for measuring the temperature and the galvanic skin resistance. Subsequently, one instrument has been assembled for the complete procedure.

B. Heart-beat meter

This parameter can be easily measured by an instrument based on the use of an infra-red emitter diode and a suitable coupled phototransistor.

The ear lobe has been chosen to place the couple emitter-receiver: indeed, there is a large number of blood vessels, the blood afflux alters the transparency of the lobe, therefore the phototransistor, which receives a light intensity modulated according to the heart-beat, produces an analog trend on the electric current.

In order to assemble the cardio-frequency meter some blocks are needed for conditioning:

- a high pass filter to stop the dc current;
- an impedance decoupling and an amplifier;
- a low pass filter to eliminate the noise components;
- a threshold comparator.

In Fig. 1 the prototype designed for measuring the heart-beat is shown.

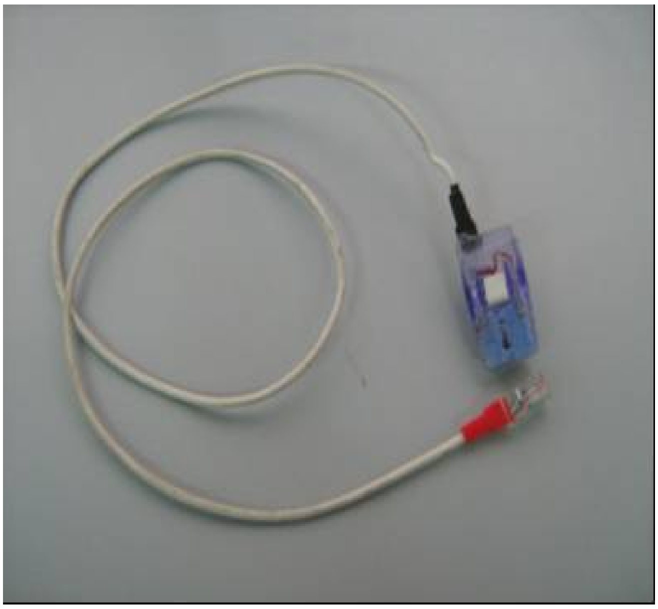

Fig. 1 The clip holding the diode and the phototransistor

C. Temperature meter and galvanic skin resistance meter.

Any emotional upset can cause perspiration and consequently the value of the electrical resistance decreases in some cutaneous regions, particularly in the palm, in the fingers, in the wrist, as it is shown in Fig. 2.

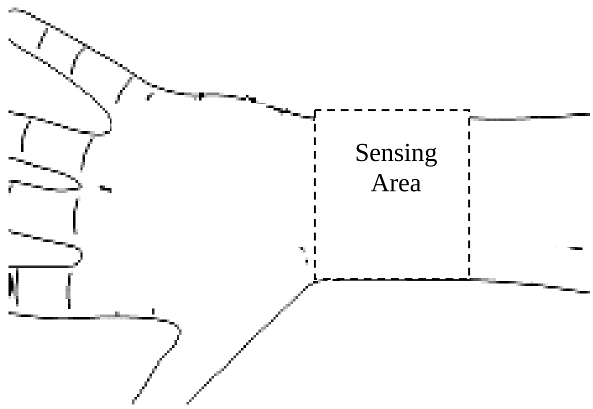

Fig. 2 Area chosen to detect perspiration

The realized device consists of an arm-band which contains the temperature sensor and two electrodes for measuring the resistance.

The signal supplied by the temperature sensor is suitably amplified (fig. 8b).

In order to measure the skin resistance the voltage difference between the electrodes is continuously measured, as the cutaneous potential changes according to the resistance.

Fig. 3 shows the prototype of the arm-band, which holds the temperature sensor and the electrodes for measuring the skin resistance.

Fig. 4 shows the hardware designed and developed for the purpose:

- a box that holds the electronic devices (the receiver),
- the arm-band with the sensor and the electrodes,
- the clip.

Through an additional connector, the receiver sends the signals, suitably conditioned, to a DAQ.

Fig. 3 Arm-band holding the temperature sensor and the electrodes.

D.The remote monitoring system

In order to implement the remote monitoring of both the user's status and the software running on the PC, a client-server architecture has been realized, therefore in the laboratory for training in informatics a server will be connected to a number of clients, as it is shown in Fig. 5.

The Java language has been used for this version of the software.

For this application it has been realized a properly structured database for storing the values of all parameters measured by using the bioprobe.

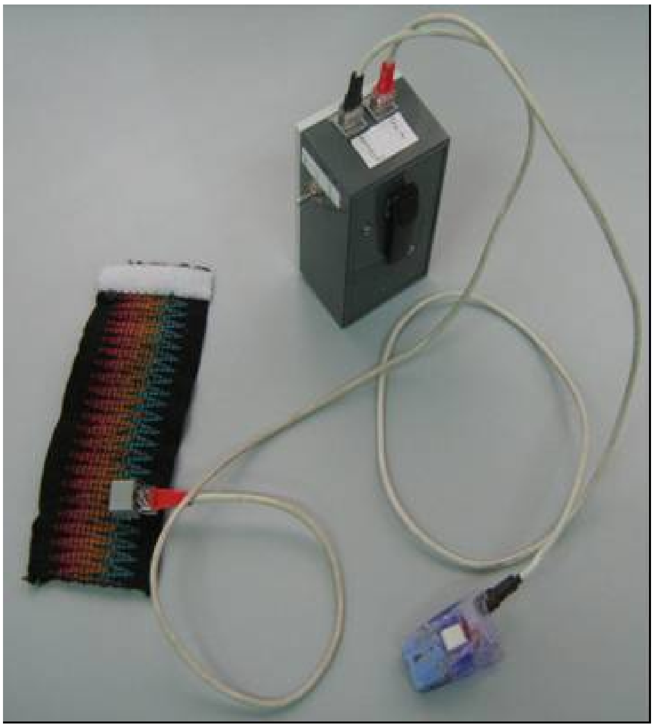

Fig. 4 The realized hardware.

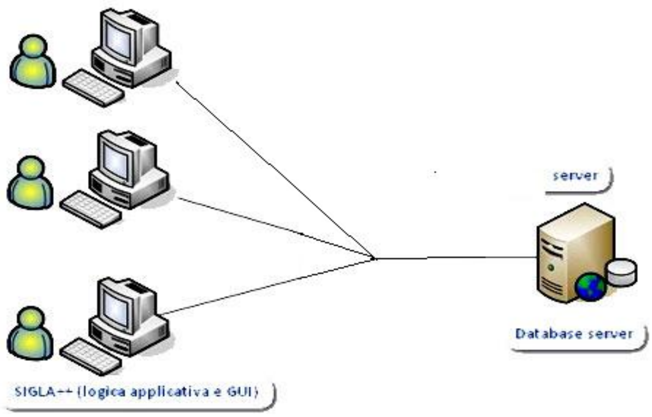

Fig. 5. The server-clients system in the lab.

Moreover it allows to carry out the acquisition of all pieces of information related to each user (the identification data and the programs to run on the PC for the planned training in the assigned post).

This allows to easily monitor and store bioparameters of each student, as shown in Fig. 6.

A software in LabVIEW has been implemented which is running on the server for performing the following operations: acquisition and analysis of the signals delivered by the DAQ and transfer data to the database in suitable form.

The front panel of the virtual instrument realized on purpose is shown in Fig. 7.

The values of the already considered parameters are presented (the skin resistance, the temperature, the heart-beat and the ratio of the low frequency band to the high frequency band).

The diagrams are related to the cardiac activity, also the frequency spectrum has been carried out and is presented.

Fig. 8 shows the simplified schematic of the bioprobe and Fig. 9 shows the Java client-server interface.

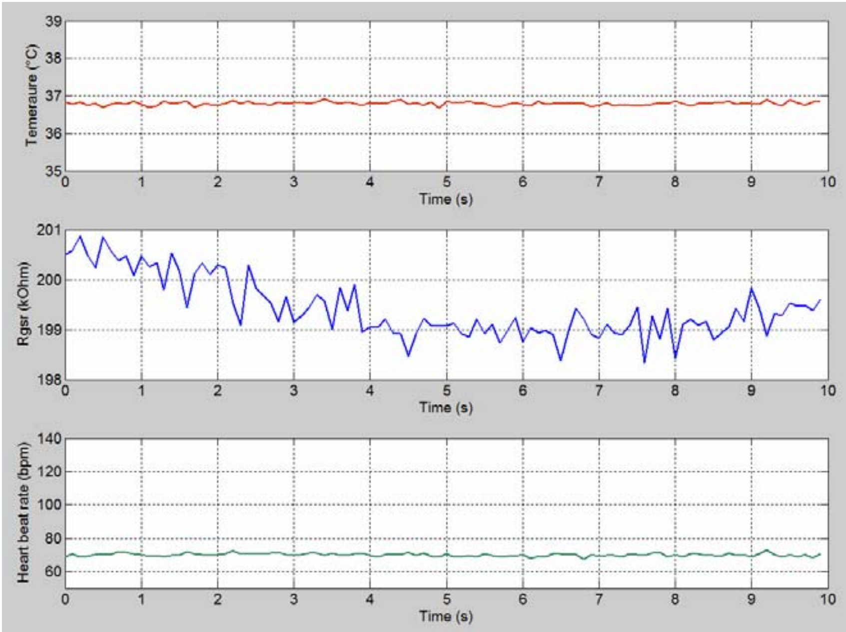

Fig. 6 Bioparameters server monitoring interface

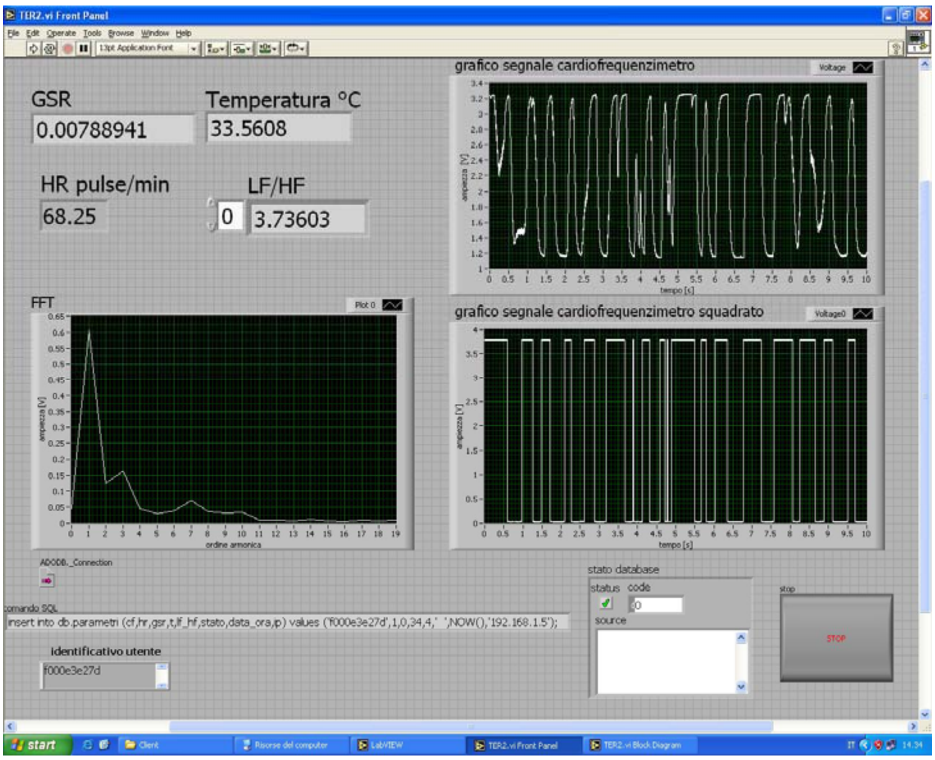

Fig. 7 The front panel of the implemented virtual instrument (in Italian language)

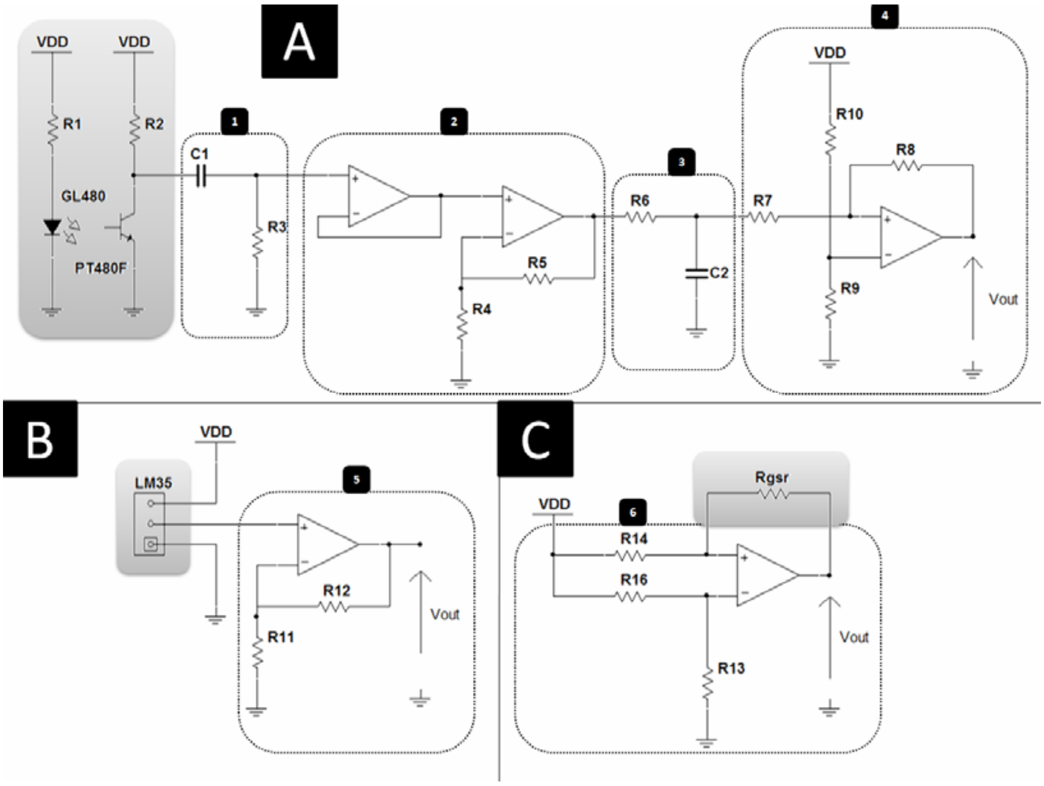

Fig. 8 Simplified schematic of the bioprobe.

(A) Cardio-frequency meter. We use an infra-red rays emitter diode (GL480) and a suitable coupled phototransistor (PT480F), we use an high pass filter to stop the DC current(1), an impedance decoupling and an amplifier(2), a low pass filter to eliminate the noise components(3) and finally a threshold comparator(4)

(B) Temperature Meter. We simply use a precise centigrade temperature sensor (LM35 by National Instruments) and an amplifier (5)

(C) Galvanic Skin Resistance Meter. The measure is obtained from a linearized resistance bridge circuit(6).

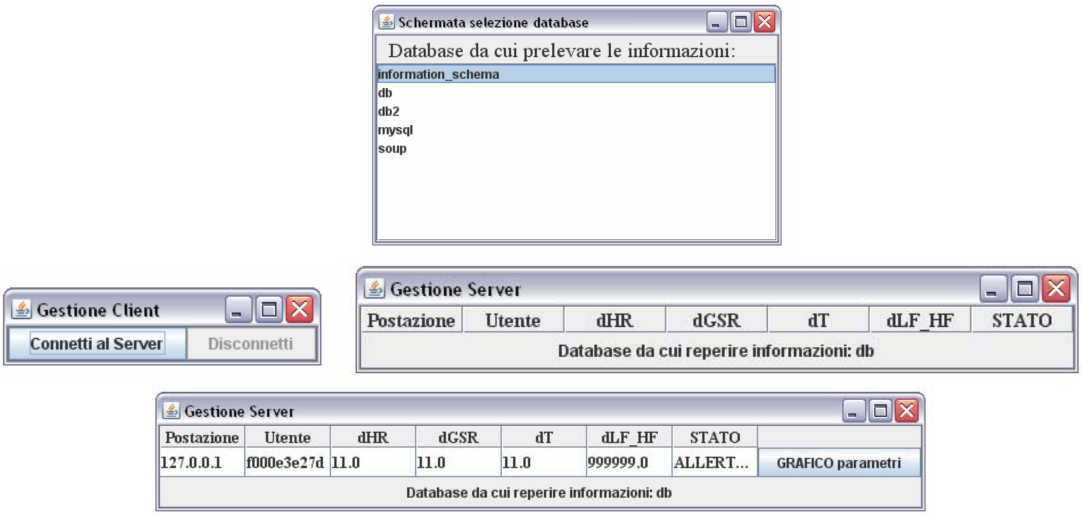

Fig. 9 The client-server Java interface (in Italian language)

III. Sensing a Physical Movement with a Ferrofluidic Device

In this section the sensor architecture, the readout strategy and the device implementation are reported.

The schematic of the architecture proposed is sketched in Fig. 10. As can be observed, the glass pipe, housing the ferrofluidic mass in water, exhibits two membranes at its extremities to propagate the external stimulus (vibration) to the ferrofluidic mass.

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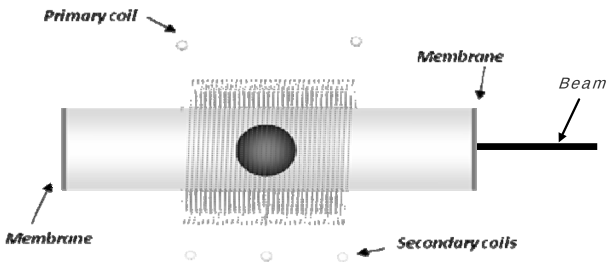


Fig. 10 Schematic of the ferrofluidic sensor

A 0.75 ml of EFH1 ferrofluid is adopted whose specifications are given in Table 1.

Table 1 Some properties of the EFH1 Ferrofluid adopted as inertial mass.

EFH1 Tecnical Specifications	
Medium	Light mineral oil
Saturation magnetization	400 gauss
Initial susceptibility	1.70
Flash point	92° C
Pour point	-94° C
Volatility (1 hr @ 50° C):	9%
Density	1.21 gm/mL
Viscosity	6 cp @ 27° C
Surface tension	29 dynes/cm

An inductive readout strategy is adopted to sense the ferrofluidic mass position inside the pipe, strictly correlated to the imposed stimulus.

A. The readout strategy

An inductive sensing system, consisting of a primary coil and two secondary coils, is wrapped around the pipette so to read the mass position. The primary coil is excited with a sinusoidal current that assures a suitable magnetic coupling between the primary coil and the secondary coils, function of ferrofluid position. When the system is in an equilibrium state – no vibration applied – the ferrofluidic mass is placed in the middle of primary coil and the output voltage is zero because of the differential configuration; if a vibration is applied the mass position changes and a variation of output voltage is obtained.
The conditioning electronics for the driving-sensing system is shown in Fig. 11. It consists of a voltage buffer and a non-inverting amplifier: the input is a sinusoidal signal of 2.5 kHz and amplitude of 100mVpp.
A real view of the sensing system located on the glass pipe is shown in Fig. 12.

B. The experimental set-up for the device characterization

In Fig. 12 the real view of experimental setup for the characterization is shown.

The driving system imposing the external stimulus to the device is made up of a loudspeaker, driven by an amplifier. A beam (diameter 10 mm) clamped to the loudspeaker is used to stimulate the sealing membrane with a known vibration which is then transferred to the ferrofluidic mass through the water propagation. Around the pipe there is the inductive transducer that read the mass position. A telescopic-like system is used to assure a reliable operation of the stimulating system.

Fig. 13 is a schematization of the experimental set-up adopted to perform a preliminary characterization of the developed inertial sensor.
The loudspeaker is driven by a OPA547 connected as a basic non-inverting amplifier; the input is a periodic signal. The schematic of the driving electronics is shown in Fig. 14.

The movement imposed at the ferrofluidic inertial sensor was measured independently by using an OADM-12U6430/S35A laser sensor device.

In order to characterize the device behaviour several tests have been performed aiming at evidencing the device response as a function of the stimulus characteristics. Fig. 15 shows the output voltage of the readout electronics for different amplitudes of the stimulus as a function of its frequency.

As can be observed the device exhibits a selective behaviour around 42 Hz and a useful band up to 50Hz. Nevertheless, it must be highlighted that the frequency behaviour of the device can be tuned on the requirements by modifying some structural parameters such as the mass of ferrofluid.
Fig. 16 shows the device response (the output voltage of the readout electronics) as a function of the imposed stimulus measured through the reference laser system. In particular, concerning the reference stimulus, the Laser output voltage, the estimated horizontal movement of the stimulating beam and the imposed acceleration are presented in Fig. 16a, 16b and 16c, respectively.

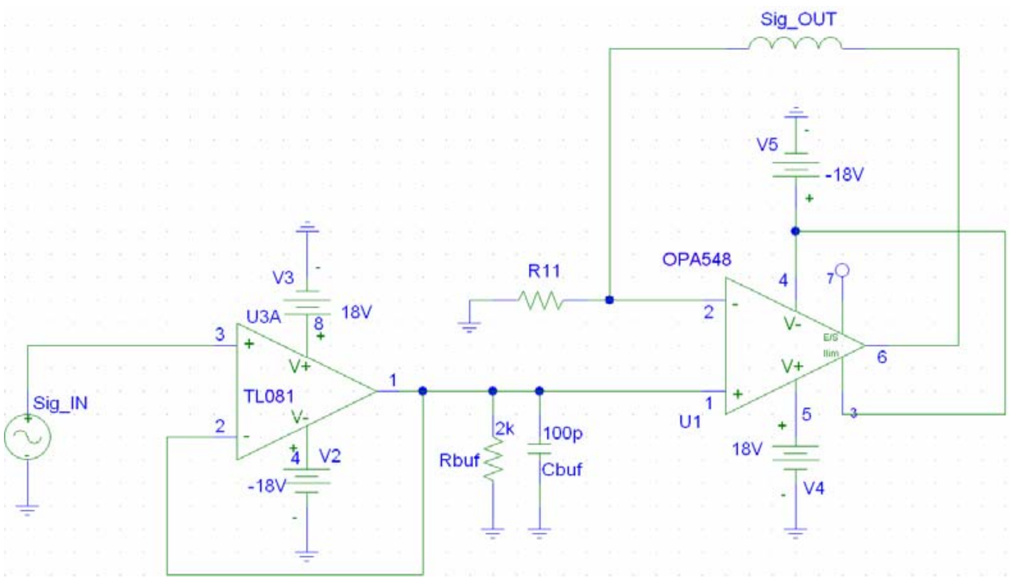


Fig. 11 Conditioning electronics for the driving-sensing system

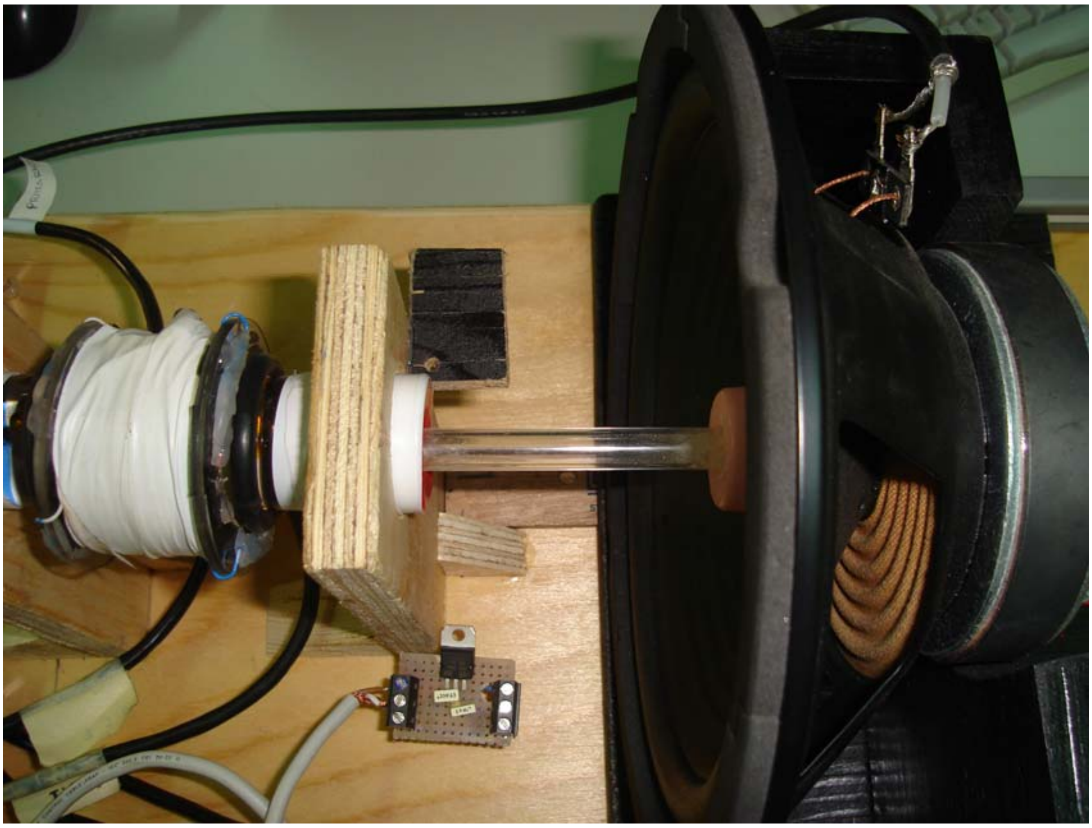


Fig. 12 Real view of the experimental setup

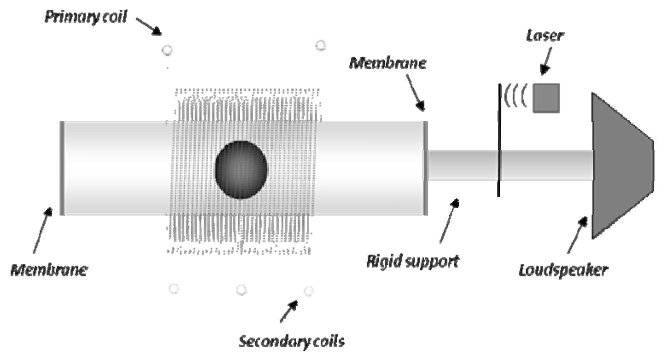


Fig. 13 The experimental set-up for the device characterization

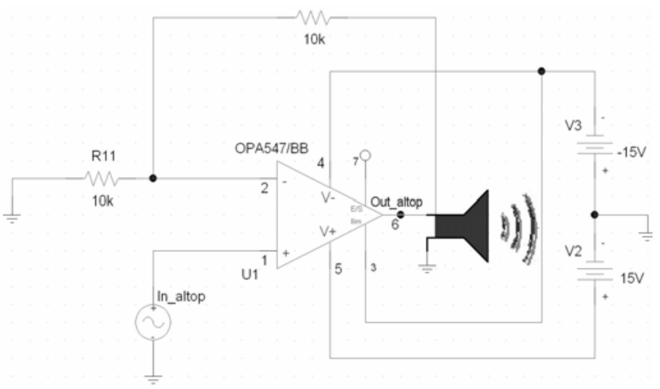


Fig. 14 Conditioning electronics for the driving system

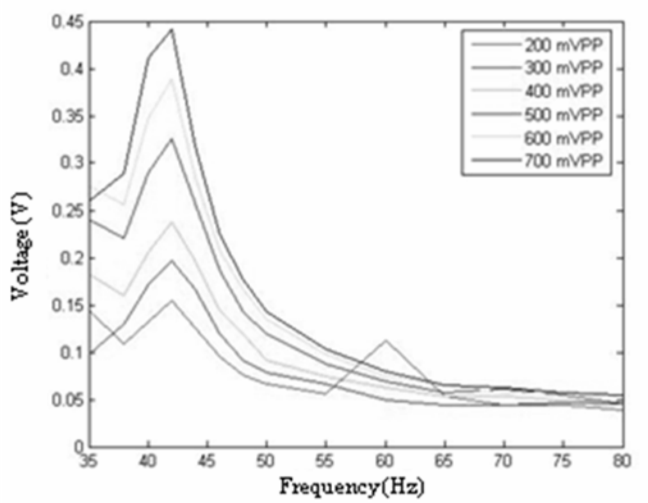
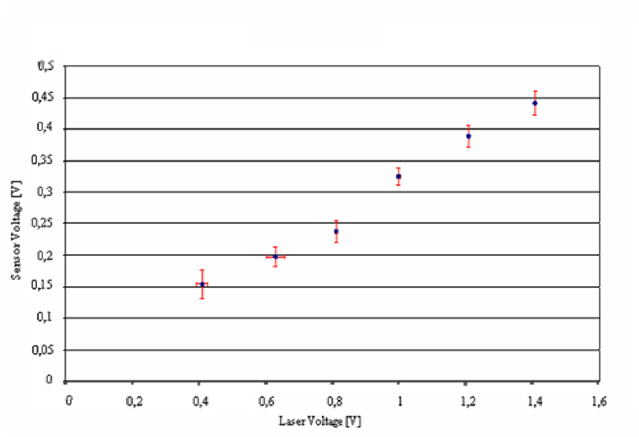
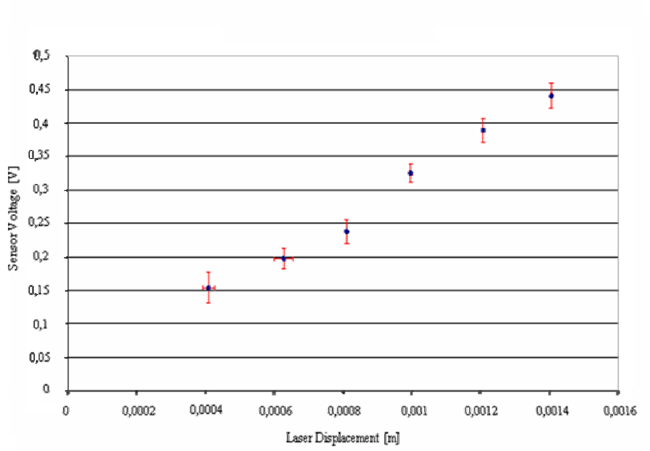


Fig. 15 Voltage sensor for a 0.75 ml of ferrofluid

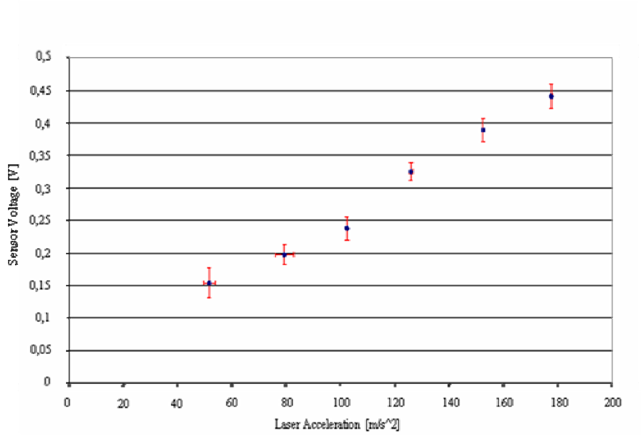
The obtained results demonstrate that a vibration sensor with ferrofluid as active mass is feasible. The main advantages of the proposed device are the robustness against inertial shocks, performances controllable via electrical signals and physical features controllable by an external magnetic field.



(a)



(b)



(c)

Fig. 16:
(a) Sensor voltage as a function of laser voltage with relative error bar for a 0.75ml of ferrofluid;
(b) Sensor voltage as a function of laser displacement with relative error bar for a 0.75ml of ferrofluid;
(c) Sensor voltage as a function of laser acceleration with relative error bar for a 0.75ml of ferrofluid

IV. Conclusion

Many purposes settled in the project have been achieved. Indeed, the first tool presented in the paper represents an effort to fulfill the requirement to provide visually impaired students with useful assistance, which involves continuously and in real time monitoring the environmental situation and the health conditions and also evaluating the difficulties encountered by each student in the room of informatics, in order to enable the student developing the training activity.

In particular, the bioparameters to be monitor have been defined, the related advanced hardware and software technologies developed have been presented. For the acquisition and the analysis of the signals delivered by the DAQ and the transmission of the data to the database in suitable form, a virtual instrument realized on purpose in LabVIEW, running on the server, has been implemented. The front panel of the has been presented. Preliminary tests show the effectiveness of the tool.

The second tool has been realized by groups of students in guided training sessions of Electronic Measurement Courses.

A vibration sensor with ferrofluid as active mass has been realized. The proposed device is characterized by robustness against inertial shocks, their performances are controllable via electrical signals and the physical features can be controlled by an external magnetic field.

To characterize the behaviour of the device several tests have been performed in order to evidence the response as a function of the stimulus characteristics.

Also the effect of modifying some structural parameters, such as the mass of ferrofluid, has been highlighted.

The device response as a function of the imposed stimulus has been measured through the reference laser system.

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