Virtual measurement technology in public education

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Abstract

Experiments have an important role in teaching physics and other sciences. New measurement methods based on digital signal processing and virtual instrumentation offer an alternative to traditional demonstration devices built for a specific purpose. When real physical, chemical, etc. phenomena are mediated by today's multimedia technologies, the scientific background of experiments is more likely to reach students familiar with the computer [1]s The basis of virtual measurement technology is to convert real signals (displacement, temperature, pressure, etc.) to electrical and – after that – digital signals. It permits the use of software for data processing, visualisation, and other instrumental functions.

The digital-analogue converter and the family of sensors developed by our group offer a much cheaper solution for teachers interested in virtual measurements than any other available computerised measuring system. Our virtual instruments were formerly made in a LabVIEW environment which is well suited for such tasks, but it is also expensive. New developments presented here have been developed in C#. This source code is freely distributable, and the free integrated development environments available provide a graphical editor almost as easy to use and learn as that of LabVIEW. Teachers – and also inquisitive students – can use ready-made programs (which are in the form of simple *.exe* files) or develop new experiments for themselves. It could also make a connection between scientific and technical skills of children.

Introduction

Measurement practices form the most high-standard class of school experiments in science education. Measurements in education are different from the ones carried out in scientific research. Their aim is to determine universal constants and to demonstrate natural laws effectively, making them clearer and more interesting. While doing measurements, students work alone or in small groups, register their results, make tables and graphs – so these activities also give room for self-dependent work, creativity and problem-solving ways of thinking.

Instruments play a very important role in the success of measurements. But new equipments are usually expensive, so schools have often no other option but using old and sometimes run-down devices. On the other hand, using modern instruments is very important in science education.

Teachers use computers more and more frequently to show simulations or animations. Digital technology also gives a chance to arrange experiments in a cheaper and easier way – by using virtual measurements. It provides facilities to make experiments for all parts of the science curriculum at a small expense. These are real experiments where measurements and data processing are done by computers. They have a lot of other advantages: using modern informatics devices is very motivating for students, who may also learn about sensors and get acquainted with a physicist's work.

Virtual measurement technology is based on real-world signal processing and generation. The interaction between the digital signal processor and real systems through signal conversions, sensors and actuators is sketched on Figure 1. Most parts of virtual instruments could be realised by software – the greater part made up by the software, the cheaper and more versatile the device will be.

To build virtual instruments teachers need only a few things. The necessary computers are achievable in most of schools, the sensors are cheap and accessible. The only special components are the measuring software and the intelligent general purpose data acquisition unit doing the analogue-digital conversion between the computer and the sensors. We can produce these two elements at a much lower cost than usual, and only a USB port is necessary to connect our device to computers. It is relatively easy to trace the working of virtual instruments – they are not absolute black boxes in spite of consisting of mainly electronic devices.

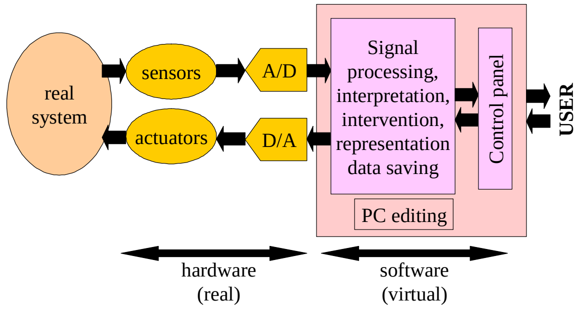

Figure 1 System of a virtual instrument

At first, we developed our virtual instruments exclusively in a LabVIEW environment [2], but some drawbacks of this software (high cost, limited compatibility and distributability) made us look for alternatives. Now, we also develop measurement programs in C#, which is freely accessible along with integrated development enviroments providing an easy-to-use graphical interface. Teachers experienced in informatics and electronics can customise ready-made programs or make new ones, which they also can share with each other. Additionally, the source code is compiled to a single *.exe* file, so users not so familiar with computer technology can also apply these virtual instruments in the classes.

We show some examples from our developments, illustrating the working and efficiency of this technology.

The propagation of thermal waves

Set a metal rod in a large-mass metal bulk (that will be the heat container) and some thermistors equidistantly along the rod. Heat the free end of the rod with an open flame burner (or a candle) for a short time, and measure how the temperature changes in time. Due to the short but intensive heating of the rod a thermal wave propagates through the whole length. The local increase of the temperature can be measured by small thermistors fixed in small holes in the material (Figure 2.). In our setup, the other end of the rod is turned into a larger metal piece (a buffer). The overlapping local temperature versus time curves make the propagation of thermal waves, the thermal equilibration, the effect of the buffer and the meaning of the thermal diffusion length clearly understandable. Different metals and geometries can be compared and the effect of thermal isolation can be emphasised. In our program the minimum and maximum values of local temperatures are also registered.

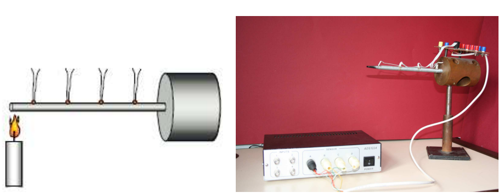

Figure 2 Set a metal rod in a high-mass metal bulk and some thermistors equidistantly along the rod

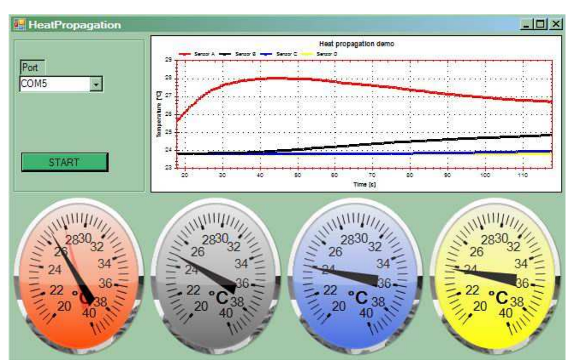

Figure 3 The four curves correspond to the temperatures at the four equidistant points

Thermocouple

A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference. If we connect the free ends of wires to a galvanometer or to a digital voltmeter, and heat the contact point of metals, the measuring device shows voltage. Sensitivity of our sensor is 10-40 μV/K, and it is usable in wide temperature ranges (from -100 to +1000 °C). Converting heat into electric power and to a digital signals we can track the changes of voltage and temperature in time.

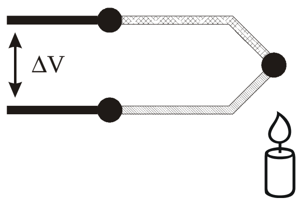

Figure 4 Construction of a typical thermocouple

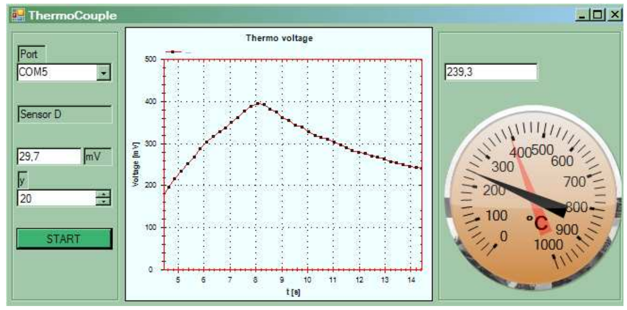

Figure 5 The curve shows the thermo voltage, the manometer shows the temperature (momentary and maximum)

Acceleration of a body on a spring

The principle of the accelerometer is to convert of the deflection of a movable (seismic) mass on a spring to electric signal. It is accomplished by capacitive sensing: there is a plane in front of the seismic mass and the plane and the bottom of the mass make up the armature of the capacitor.

If deflection of the body on the spring is vertical, its position changes sinusoidally in time; but if there are horizontal components in motion, you can observe the coupling between the oscillation and the pendulum-like motion component.

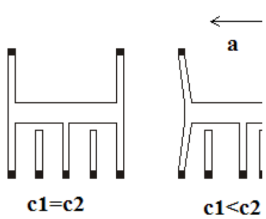

Figure 6 Operation of the acceleration sensor chip

Figure 7 Combination of an acceleration sensor chip and a body hanging on a spring

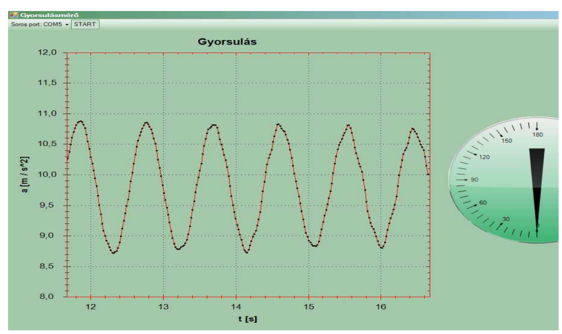

Figure 8 The curve shows the deflection-time history, the manometer shows the vertical deflection of the manometer (in degrees)

Pendulum

The swing of a pendulum can be followed by a fine rotary potentiometer: rotation results in changing voltage at the sliding contact. The number of 12-bit resolution data allows the precise calculation of the first and second derivates of the angular position, even at small amplitudes. The harmonic and anharmonic cases can be visualised.

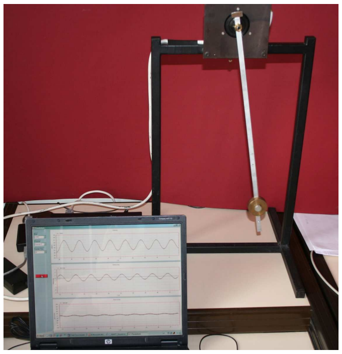

Figure 9 Combination of a pendulum with a coaxial rotary potentiometer.

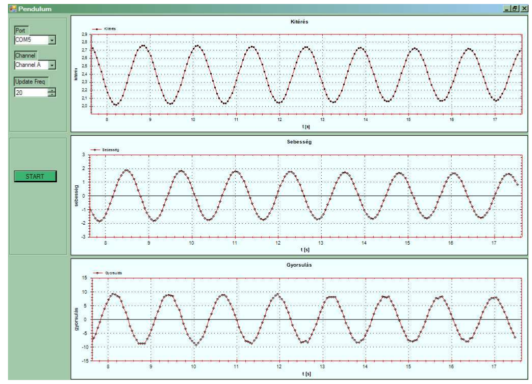

Figure 10 The curves show the angular position, velocity and acceleration (from top to bottom, respectively)

Summary

Our virtual instruments are usable as interesting and efficient experimental devices in measurements carried out by teachers or small groups of students – in classes as well as in tutorials. In spite of the decreasing amount of time allotted to physics lessons, we can make real experiments instead of simulations with the help of virtual technology. We can also involve prominent students in the development of experiments, giving them a higher motivation to learn physics and applying their knowledge.

Graduate students in teaching physics could be familiar with the virtual measurement technology in the labs of the University of Szeged – they learn to use and develop instruments and measuring methods. The interest of students inspires us to disseminate our results and develop new devices.

You can find additional information about virtual measurements and our work at this webpage: http://www.noise.physx.u-szeged.hu/VirtualM/default.htm

References

[1] Z. Gingl & Z. Kántor, „*Virtual Measurement Technology in the Education of Physicists and Communication Engineers*", PTEE2000, 14-17 June 2000, Budapest, Hungary

[2] Z. Kántor & Z. Gingl, „*Virtual instruments perform real experiments in the physics class*", PTEE2002, 5-7 June 2002, Leuven, Belgium