Teaching Physics: Utilization of Scratchboard in Laboratories' Activities

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Abstract. In this work we present two teaching modules, designed and realized using Scratchboard and Scratch. The two modules concern the measurement of the speed of sound in the air, by wave interference, and a consideration of oscillation's phenomena. Both of the modules have been implemented in the school laboratory, providing reliable measurements and getting the students engaged in a higher level than the usual one.

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INTRODUCTION

The progress of ICT provides tools for improving the quality and the ease of access to education and training. On science teaching, data acquisition systems are a powerful tool for real-time measuring and presenting various physical quantities in school science laboratories [1-3]. But these systems are in general quite expensive and sophisticated for average students' use [4]. In this work an alternative system is proposed: the combination of Scratchboard and Scratch. Both of them have been developed in MIT Media Labs; Scratch Board is a sensor board coming with several sensors embedded. On the other hand Scratch is a new freeware multilingual programming environment that can be easily used by kids to create their own animated stories, video games and interactive art and share their creations with one another across the Internet [5-8].

Both Scratch and Scratchboard have been developed to be used in a very wide field of activities. This system is not especially addressed to science lessons' activities. After all, there are available integrated data acquisition systems for such a use. One nice feature is that Scratchboard has embedded several sensors and comes to a very low price, less than fifty Euros. In addition, it communicates with Scratch, which is a LOGO-based education oriented software. This gives rise to the research question: can this system be used to perform science experiments in schools laboratories? Seeking the answer to this question, two teaching modules were designed and we are also in the process of preparing a new set of activities on subjects like optics, heat and electric circuits.

The two teaching modules being presented in this paper have been designed and realized using Scratchboard and Scratch. The modules concern the measurement of the speed of sound in the air by wave interference, and a consideration of oscillation's phenomena respectively. Both of the modules have been implemented in the school laboratory providing reliable measurements and getting the students engaged in a higher level than the usual one.

METHODOLOGY

Scratch has been developed by the Lifelong Kindergarten Group at the MIT Media Lab, with financial support from the National Science Foundation, Microsoft, Intel Foundation, Nokia, and the MIT Media Lab research consortia [9]. Scratch LOGO-based projects are made up of objects called sprites. One can change how a sprite looks by giving it a different costume, or he can make a sprite look like a person or a train or a butterfly or anything else. Any image can be used as a costume: it can be drawn an image in the Paint Editor, imported an image from a hard disk, or dragged in an image from a website. Instructions can be given to a sprite, telling it to move or play

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music or interact to other sprites. To program a sprite's actions, one has to snap together graphic blocks into stacks, called scripts. Double-clicking on a script, Scratch runs the blocks from the top of the script to the bottom [10-11].

Scratch is the software component of the system been in use. The hardware is Scratchboard, or Picoboard which is its new name. Picoboard is a sensor board (Figure 1) that comes with several sensors embedded and enables the Scratch projects to sense – and respond to – things going on in the real world outside your computer, by real time sensing and measurements. These sensors are:

- a light sensor
- a sound sensor
- a button
- a slider, and
- four sets of alligator clips that measure the electrical resistance in a circuit**.**

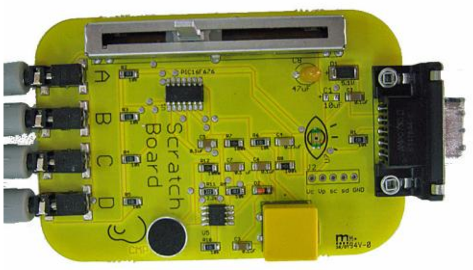


FIGURE 1. The sensor board.

Via the alligator clips, all kinds of custom sensors can be built. Picoboard is connected to computer through a serial-to-USB cable that comes together with the board. The communication protocol is the RS-232 and the transfer baud rate is 38.4k. The interconnection between scratch and Picoboard is realized using sensing blocks. Sensor value blocks give readings ranging from 0 to 100 or ranging from 0 to 1023 if user prefers to read raw 10-bit data [12]. These values can be used to control graphic effects or can be stored to a file.

A. Measuring the Speed of Sound in the Air

Creation of Sound Files

Using the software of Virtins Sound Card MultiInstrument [13], three sound files of specific frequencies (1000 Hz, 2000 Hz, 3000 Hz) and given duration (200 s) were created. These wav format files were transformed in mp3 format and then inserted in the script that was written in Scratch.

Two sound boxes are placed on a laboratory table in such a way as to be faced each other and to lie on a line segment AB with length 1m (Figure 2). Along this line a measure tape and a white paper were placed, so the students to be able to mark the pattern of constructive and destructive interference, if they have to.

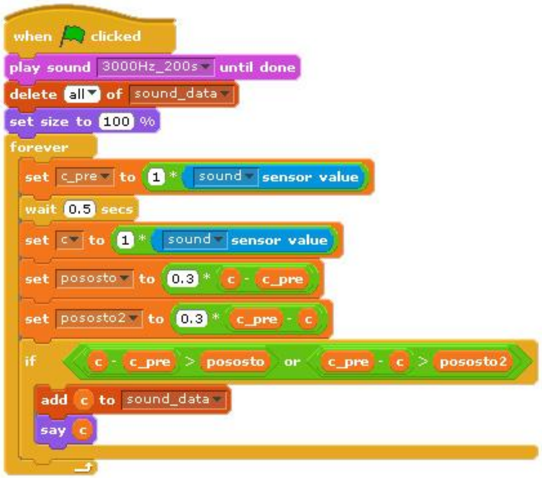
At first, the students use the measure tape to find out the midpoint M of the line segment AB. They put Scratchboard at point M and then activate the script Sound_Amplitude that have been written in Scratch (Figure 3).

The program measures the value of sound's intensity every 0.5s and if value's percentage change is over 30% then the value is recorded to a list. This amount of percentage change has been chosen after several tests in order to cancel the environmental influence to sound's intensity. For the same reason the sample rate was fixed at 2 Hz, instead of the default 10 Hz rate. The values of sound's intensity vary from 0 (no sound) to 100 (powerful sound), a scale that is not linear and it is not measure the sound's intensity in dB [12].

FIGURE 2. The experimental set up for measuring the speed of sound in the air.

The Experimental Set Up

The students start to move the Scratchboard keeping the board vertical to the line segment AB, at a height of 8-10 cm from the desk. At the same time they can watch at the computer's monitor or on a video wall the measurements of sound's intensity they take. As at the point M the sound waves of the two identical sound sources (the two sound boxes) are interference constructively the sound's intensity will takes a maximum value. Moving the sensor the sound's intensity is going down and takes, for the first time, a minimum (a zero value) at a point Λ, where the sound waves of the two identical sound sources are interfering deconstructively. It is known from the waves theory that the distance between these two successive points is equal to λ/4, where λ is the wavelength of sound been in use. As the students have calculated this distance they already know the wavelength λ. So they are asked to foresee the locations of next maximums and minimums of sound's intensity and to use Scratchboard to confirm their forecast/suggestion. Then they are told that the frequency of the sound wave was 3000 Hz and they use the fundamental equation of wave phenomena, $c=\lambda\cdot f$, to calculate sound's speed in the air.



```
when clicked
play sound 3000Hz_200s until done
delete all of sound_data
set size to 100 %
forever
    set c_pre to 1 * sound sensor value
    wait 0.5 secs
    set c to 1 * sound sensor value
    set pososto to 0.3 * c - c_pre
    set pososto2 to 0.3 * c_pre - c
    if c - c_pre > pososto or c_pre - c > pososto2
        add c to sound_data
        say c
```

FIGURE 3. The Script Written in Scratcht to record the values of sound's intensity.

The measurement is then repeated changing the frequency of sound to 2000Hz, through script's menu. The students calculate again the speed of sound in the air, following the above procedure, to realize that the speed of sound is not a function of the wave's frequency. To establish what was learned they follow the same procedure for third time but now they try to figure out the unknown frequency (1000 Hz) using the speed of sound in the air they have already calculated.

On Table (1) the values of the speed of sound in the air that have been calculated by students, following the method described are shown. To calculate the given uncertainty has been considered that the speed of sound in the air is 340 m/s and that the frequencies of the sounds used had concrete values. It looks that the accuracy of the measurements is higher as the frequency rises. This could happen due to better response of the sound sensor at higher frequencies or due to the greater directionality of the corresponding sound waves.

TABLE (1). Results of measurements.

Frequency (Hz)	λ(cm)	c (m/s)	(%)
1000	33	300	
2000	15.5	310	8.8
3000	9	330	2.9

B. Consideration of oscillations' phenomena

The Experimental Set Up

A bright light source is placed in front of a hooked on a spring cylinder. The cylinder is pulled downwards and then let free to move. The Scratchboard is laid on the laboratory table in such a way that the shadow of the oscillating cylinder just to cover the light sensor (Figure 4). In this way, the cylinder's shadow is also oscillating over the Scratcboard, resulting periodical changes to the amount of light that reaches the light sensor.

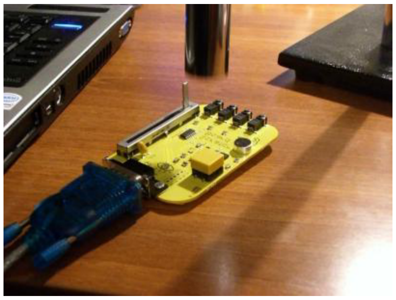


FIGURE 4. The experimental set up for measuring oscillations' characteristics.

A script written in Scratch is activated and the students can watch at computer's monitor the graphic representation of the recorded values that evolves in real time. The resulting curve is almost a sine curve, as it should be. The students are asked to calculate the period of oscillation by measuring the total time for a number N of oscillations and then divide with N.

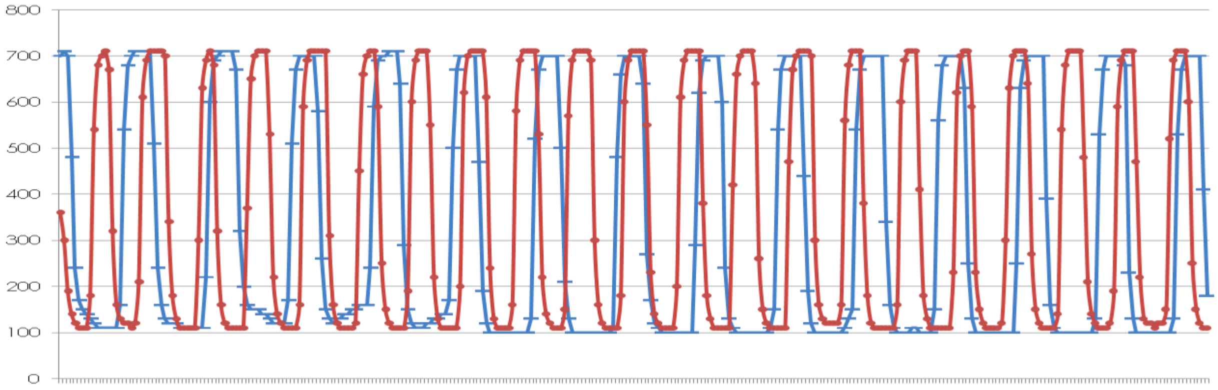


FIGURE 5. The experimental set up for measuring oscillations' characteristics.

This set up can be used to demonstrate the effect of mass and spring's constant in period of oscillation. The students are asked to find out what will happen if the mass of cylinder is going to be increased. Can they estimate the relation between mass and period? In addition, what will happen if the spring is replaced with a new one with a larger constant? On Figure 5 two curves that result when two springs with different constant were used are shown. In the same way the fact that of amplitude of the oscillation does not affect the period can be easily demonstrated.

It is quite obvious that this setup cannot provide an accurate measurement of the physical quantities involved. On the other hand the low cost apparatus offers the chance to all students in a science class to study a physics' law by participating in such a hands-on activity. At least in Greek schools, students usually just watch their teacher performing a high accuracy measurement using an expensive data acquisition system.

CONCLUSIONS

Data acquisition systems provide a powerful tool for measuring and presenting online various physical quantities in school science laboratories. As these systems are in general quite expensive and sophisticated, the use of Scratchboard and Scratch could provide an alternative solution for the most of schools' laboratories. According to our experience, the appropriate use of such a system amplifies the possibility for students to be engaged in learning process through inquiry based and hands-on activities. Technically speaking, the sensor board can measure several physical quantities simultaneously and the powerful user-friendly software makes the presentation of data as well as their processing easy. There is no doubt that the proposed system cannot totally replace the specialized data acquisition systems in upper secondary education where the students do have to take precise measurements. But it could be used in a very promising way in lower secondary and in primary education, where sophisticated data acquisition systems usually do not exist. This way would alter students' interest about science and laboratories' activities.

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