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Innovative approach towards understanding optics

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Abstract. Over the last few years, there has been a decline in the students' interest towards Science and Optics. Use of technology in the form of various types of sensors and data acquisition systems has come as a saviour. Till date, manual routine tools and techniques are used to perform various experimental procedures in most of the science/optics laboratories in our country. The manual tools are cumbersome whereas the automated ones are costly. It does not enthuse young researchers towards the science laboratories. There is a need to develop applications which can be easily integrated, tailored at school and undergraduate level laboratories and are economical at the same time. Equipments with advanced technologies are available but they are uneconomical and have complicated working principle with a black box approach. The present work describes development of portable tools and applications which are user-friendly. This is being implemented using open-source physical computing platform based on a simple low cost microcontroller board and a development environment for writing software. The present paper reports the development of an automated spectrometer, an instrument used in almost all optics experiments at undergraduate level, and students' response to this innovation. These tools will inspire young researchers towards science and facilitate development of advance low cost equipments making life easier for Indian as well as developing nations.

1. Introduction

Over the last few years there has been a substantial increase in use of sensors across the world in all spheres that has eased our life as well as research/education. However, being expensive there use is only limited to commercial and richly funded laboratories. This paper reports a low cost method of acquiring data using sensors and extending this system to perform diffraction studies using an automated spectrometer. Low cost, tailoring as per the need and easy deployment make this system suitable for schools and undergraduate laboratory. This provides not only a learning environment using sensors and advanced tools for data acquisition and analysis but also offers many opportunities to students to perform experiments in science and technology in real time to investigate physical phenomena. An automated science/optics laboratory will enhance interest as well as productivity of students in research by reducing time of collecting and analyzing data. New technology with increased accuracy will boost students to design new experiments as well as work in the depth of concepts.

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2. Experimental setup

Single-board microcontrollers like ARDUINO and RASPBERRY PI have made the application of interactive objects or environments more accessible. These prototype boards contain their own RAM, ROM and processors along with GPIO (General Purpose Input Output) pins for the Ease of Access which makes it a fun to interface with sensors.

The generic form of basic experimental setup is shown in figure1. As shown, the experiment is set up in its conventional form and the data from it is captured using different types of sensor like voltage sensor, rotary sensor, light sensor etc. These sensors are interfaced through the microcontroller Arduino board and then to the PC/ Android Device/ LCD/ any other display device. Various types of microcontroller board can be used; here we have used 'Arduino Mega ADK' as it also provides interface to most common mobile platform i.e. Android and windows. We discuss one experiment, performed using microcontrollers.

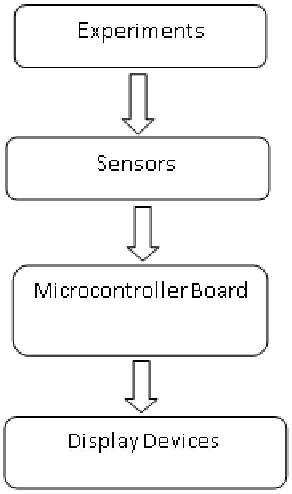

Figure1. Generic Experimental set up, using Microcontroller Board for performing various experiments.

2.1. *Calculating wavelength of light using diffraction grating and spectrometer*

For a complete understanding on how to calculate the wavelength of light using diffraction grating and spectrometer, the experimental setup is as shown in figure 2.

Spectrometer plays an important role in any optics related experiment in a Physics laboratory. Also, measuring angle using spectrometer is a source of error in the calculation of result. This problem can be solved by displacing conventional spectrometer with a set of light sensor and servo motor. [2]. The microcontroller has been programmed to calculate the wavelength and display the wavelength on LCD and Serial Monitor.

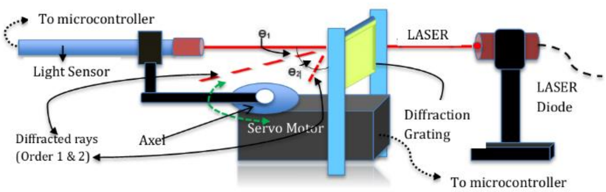

Figure 2. Schematic showing an automated experiment to calculate time period of simple pendulum.

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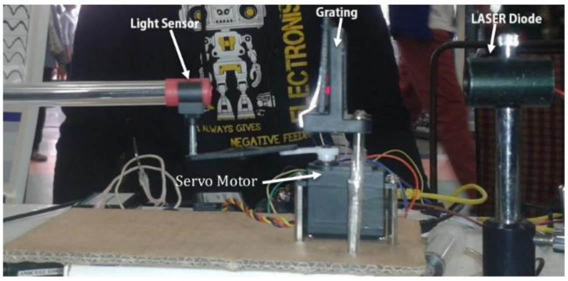

Figure 3. Actual Automated Spectrometer designed for measuring wavelength of LASER.

A diffraction grating is placed in between the light source and Light sensor. Light is diffracted at different angles for different orders. Light sensor keeps rotating with servo, the moment light sensor detects laser, servo provides the angle at which light is detected and is logged as ϴ1, i.e. first order diffraction. Since Microcontroller is connected to both light sensor and servo motor, the data collection from light sensor and servo is simultaneous.

Similarly, angle for second order is logged and further these values of ϴ1, ϴ2 is put in the equation (1).

$$n\lambda = (a+b)\ \mathrm{Sin}\Theta n \qquad (1)$$

Where λ is the wavelength of light, 'n' is the order of diffraction, '(a + b)' is the grating constant and 'ϴn' is the angle of diffraction of nth order. Thus the only unknown values are 'n' and 'ϴn' which is determined by the spectrometer. Thus the wavelength of light is calculated by the microcontroller. Figure 4 shows algorithm of the program for calculating wavelength of light by the microcontroller.

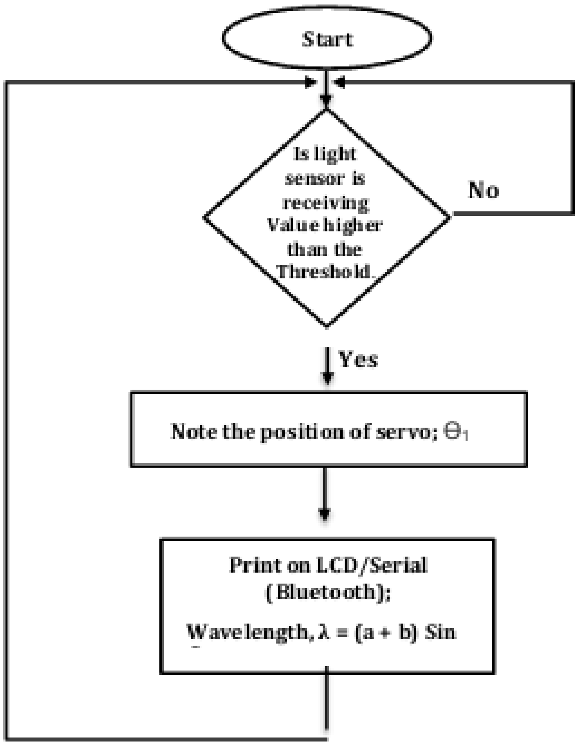

Figure 4. Flowchart depicting algorithm for programming microcontroller to find the wavelength of light.

Further, the result is displayed on various devices via various media using methodology stated. Figure 5 shows the results of the experiment on serial monitor of Arduino IDE on a PC.

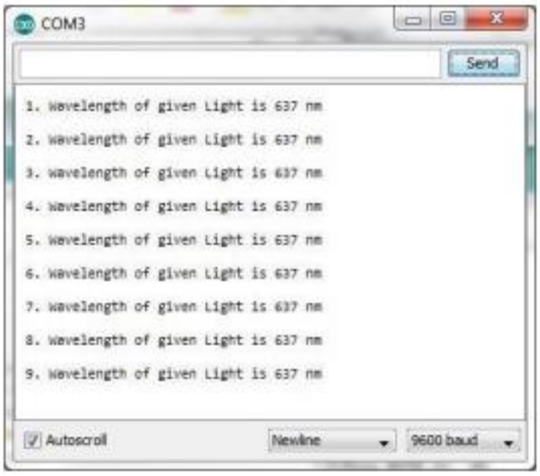

Figure 5. Wavelength of light is being displayed on a serial monitor.

3. Stake holders response

The developed kit was demonstrated at the Mega multidimensional annual festival 'Antardhvani 2015' University of Delhi. We had an overwhelming response from all the stakeholders. The survey included 418 Students and 63 Teachers. The graph shows that this idea is acceptable to most of the Students and Teacher. Out of 418 students, 368 students (approx. 88%) agreed that this type of innovation is essential in laboratories across schools and colleges in India. Out of the 63 teachers, 51(approx. 81%). agreed for the same.

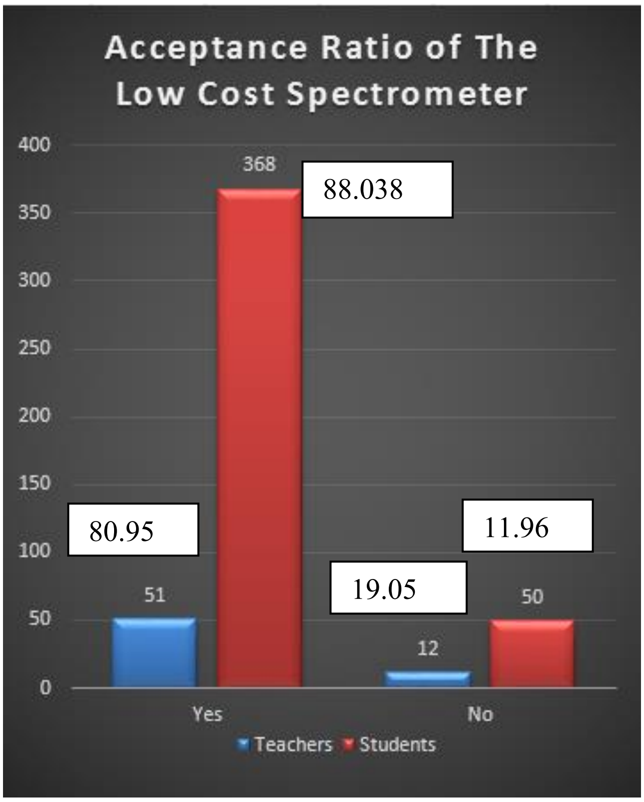

Figure 6. Acceptance ratio of low cost spectrometer.

4. Conclusion

The present development shows that how different low cost software and hardware resources can be deployed for acquiring data from sensors and further displaying these data on LCDs and other most common mobile platform i.e. Android. It helped undergraduate students integrate technology into a science laboratory, use same set of hardware components in different experiments, tailor the set up as per their learning need. At the same time, it helped in examining closely the underlying concept of experiment, minimizing the time of experiment, and reducing the error. Students have been able to complete error free experiment and go beyond the realm of the syllabus to develop innovative ideas.

Further, this beyond the classroom approach has made students work in an interdisciplinary team as well as approach preparing them as future Scientists/ Technologists pursuing healthy research.

In India majority of the experiments in Optics at the undergraduate level are based on Spectrometer. The development of the above mentioned Low Cost Spectrometer will enhance the capabilities of colleges as well as schools with inadequate facilities to perform the Optics Experiments with ease. Also the project eliminates certain restrictions and modalities related to the conventional Spectrometer. Some of the advantages are:

- The presence of dark room is eliminated as proper correction algorithms can be used to eliminate the error introduced due to the daylight.
- The developed Kit is easy to operate and eliminates the bulkiness of the Conventional Spectrometer.
- The program logic can be modified to meet the needs of any other experiment .e.g. Simple Pendulum using a laser diode and a Light Sensor.

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