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ARDUINO-BASED SENSOR DEMONSTRATION TRAINER KIT FOR STEM EDUCATION

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Abstract
Sensors have made Automation scale greater heights which have led to improvements in technology. Undoubtedly sensors have become an important part of human life as they come across at least one sensor every day. With increasing trends in the 4th industrial revolution, it is necessary to create awareness and provide appropriate training in sensors to make the youth familiar with recent trends and prepare them for the industry thus, opening doors for Industry 5.0. In this paper, the methodologies for the development of the Sensor demonstration kit are presented and the outcomes will be displayed on a screen that gives information about the function of the sensor is demonstrated and shows its data (value) in real time. This paper aims to elucidate the concept of a sensor demonstration kit and create awareness of sensor training among the young generation thus supporting the discussions of sensor-based systems for the researchers and developers to elevate their work in the expanding topography of embedded systems, microelectronics and sensors.

Keywords: *Sensor, Display, Demonstration Kit, STEM.*

1. Introduction

The world has witnessed Industrial Revolution from Industry 3.0 to Industry 4.0 and currently, it is heading towards Industry 5.0. Sensors are one of the most important assets of this immense growth in Industry. They are devices that take physical (mechanical) input from the surroundings, process it and convert it into electrical signals. Sensors are responsible for the industrial shift from Mechanization to Automation. These devices provide important information about the input and exchange data with other devices in an automation control system. Any automation process is incomplete without sensors. They gather data process it and utilize it for controlling the system that is being operated. Sensors have made human life easy and smart as they are applied in almost every field of application like Industry, Medical, Offices, Education, etc., and devices like Mobile phones, Smart Vehicles, Washing machines, TVs, etc.

With the rise in recent trends of technology, the role of sensors and their utilization is getting significant day by day. It is very important to be aware of the type of sensor being used for a specific application. Lack of knowledge of Sensors has put the youth way behind in terms of understanding the technology and automation control systems. Hence, there is a need to have social awareness and appropriate training aids for sensor education which arises as a source of motivation to develop a system that gives basic knowledge of sensors and also demonstrates its working. The Government of India under the Leadership of Honorable Prime Minister, Shri. Narendra Modi has adopted STEM (Science, Technology, Engineering, and Mathematics) learning as a part of the Indian Education system which will help young minds to learn the tools and software that make them industry ready and stay updated with the recent trends in technology. Some of the primary education programs under STEM learning include Robotics, Java, Python, Sensors and Transducers, Sustainable Environment, Machine Learning, 3D Printing, 4D printing, Additive Manufacturing, etc. As an initiative towards supporting Sensor education and promoting STEM learning, the idea of a sensor demonstration kit became an important topic of research and development.

2. Methods and Materials

The system of the sensor demonstration kit works like an open loop control system where there is no feedback of output to the sensor. Fig. 1 below shows the system line diagram for the sensor kit:

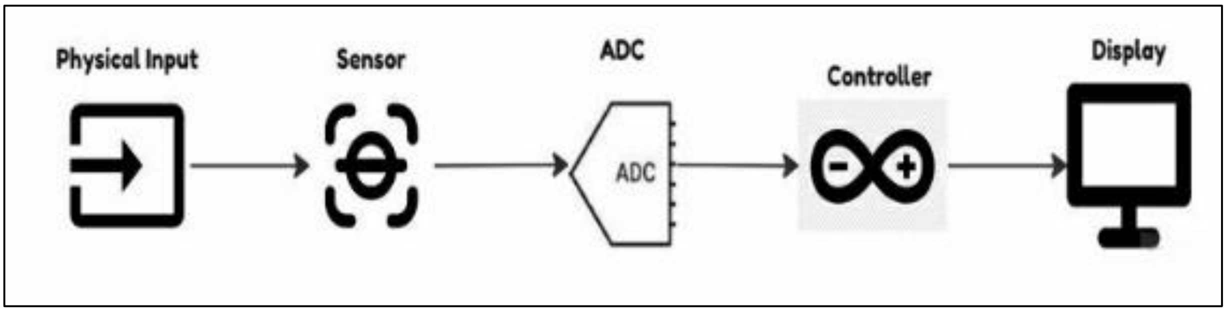


Fig.1 System Line Diagram

As shown in the figure, input is received from a physical surrounding which is detected by the sensor. The sensor processes this analog signal and sends it to ADC for conversion into digital which is further sent to the controller. The controller sends the received digital data from the ADC to the display screen which shows the digital value of the sensor and its function. Table No.1 below shows the list of sensors selected for the development of the sensor demonstration trainer kit. As shown in the table around 20 sensors are used in the sensor demonstration kit which is selected based on their type and application and the purpose of learning. The technical name of the sensors along of with the domain and type of sensors is mentioned in detail. The operating range of the sensor is also given in the table which tells us about the maximum value the sensor can give while detecting any physical input from the surroundings.

Table No. 1 List of Sensors and their specification

Name of Sensor	Domain	Type	Operating Range
HCSR-04	Ultrasonic Sensor	Analog	3-400 cm
IR Sensor	Proximity	Digital	2-10 cm
TTP223B	Capacitive Touch	Digital	Up to 3cm
LM393	Light Detecting Resistor	Both	0 – 1
Flame Sensor	Infrared	Digital	760-1100 nm
M35	Temperature	Analog	-55 – 110˚C
DHT11	Humidity	Analog	0 – 99%
FC-28	Soil Moisture	Both	0 - 1023 (ADC value)
FC-37	Rainfall Detection	Both	0 - 1023 (ADC value)
MQ3	Alcohol Detection	Analog	25 – 500 ppm
MQ2	Smoke Detection	Analog	200 - 10000 ppm
KY-038	Sound Detection	Both	3-6 kHz
360˚ Encoder	Rotary	Analog	0 - 360˚
SEN-18	Water Level Depth	Analog	640 mm^2 area
TCS3200	Color Detection	Digital	0.002 – 500 kHz
KY - 039	Heartbeat	Analog	3.3 – 5 V
LJ12A34Z/BX	Inductive Proximity	Digital	Up to 4cm
3-pin NTC	Temperature	Analog	0 – 150˚C
SW-420	Vibration - NO	Digital	0 – 1
MPU6500	Gyroscope Accelerometer	Analog	±250 - ±2000 dps

Table No. 2 shows selection of the controller used for developing sensor demonstration kit based on the comparison of Arduino and Node MCU controllers. From the table we can see that Arduino Mega 2560 has more digital and analog pins than Node MCU. The EEPROM and SRAM of Arduino is greater than that of Node MCU. Arduino provides a slot for the power supply whereas Node MCU does not. Hence, Arduino Mega 2560 controller is selected to interface maximum number of sensors for the sensor kit.

Table No. 2 Comparison of Arduino and Node MCU

Sr. No.	Parameter	Arduino	Node MCU
1.	Microcontroller	ATmega 2560	ESP8266
2.	Operating Voltage	3.3V – 5V	3.3V – 5V
3.	Digital I/O Pins	54 (15 PWM)	13 (All PWM)
4.	Analog Input Pins	16	1
5.	Flash Memory	256 KB	4 MB
6.	EEPROM	4096 bytes	512 bytes
7.	Clock Speed	16 MHz	52 MHz
8.	Static RAM	8 KB	Not Available
9.	USB connection	Available	Available
10.	Power Jack	Available	Not Available

Fig. 2 below shows the circuit diagram where all sensors are connected to the Arduino microcontroller using jumper wires. As shown in the figure, the sensors are connected to the Arduino Mega 2560 microcontroller. The sensors are connected to the digital pins and analog pins. The power supply and ground pins are connected in common to all the sensors. For individual display of output, most of the sensors were given digital input as they had the flexibility to give both digital as well as analog output. While some of the sensors which give only analog output are connected to the analog pins of the Arduino microcontroller.

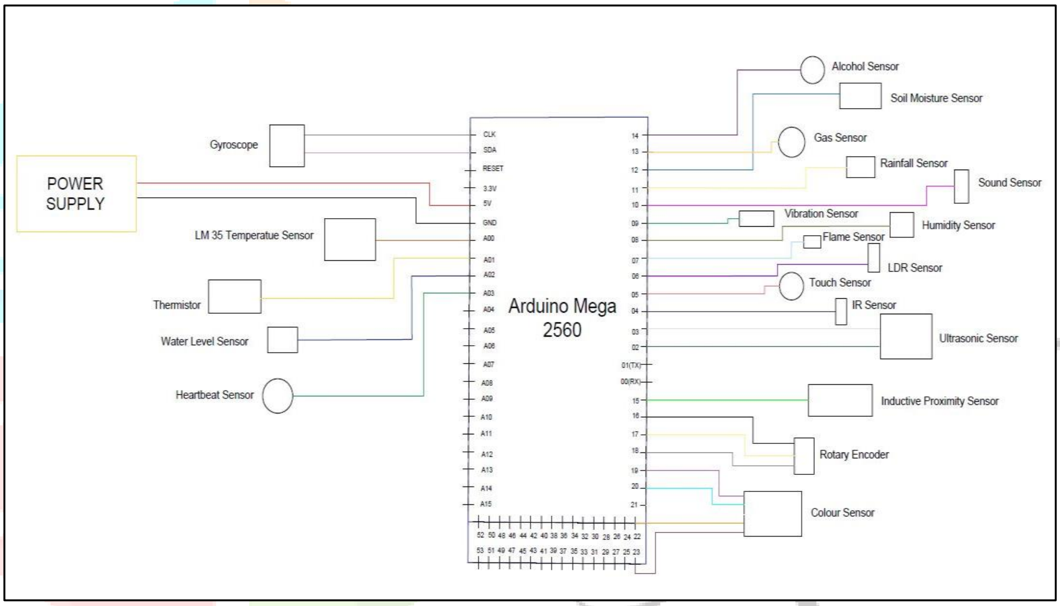


Fig. 2 Circuit Diagram

Fig. 3 below shows the 3D model of the sensor kit where all the sensors, display unit and switches are shown in detail:

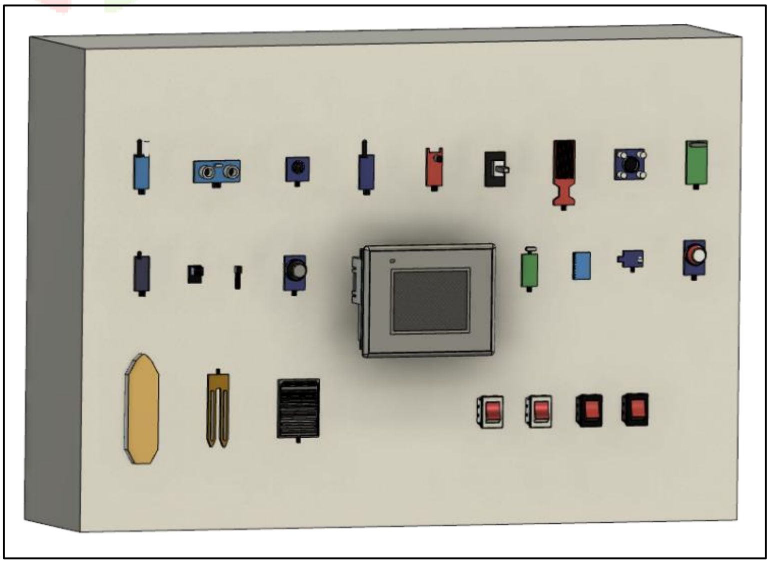


Fig. 3 3D Model of sensor kit

The sensors are mounted over the breadboard for the jumper wires to connect. A common line of power supply and ground connection is placed over the breadboard as Arduino Mega 2560 has only 1 slot for 5V power supply and 1 slot for ground. Hence, the last entire rung of the breadboard is made as a common power connection for the sensors to the microcontroller. The Arduino is powered using the USB B to A power cable which is then connected to the Arduino IDE software where the entire programming is done. The Arduino code is fed into the ATmega 320 microprocessor of the Arduino Mega 2560 which stores the code and processes the output to the serial monitor of Arduino IDE. The serial monitor shows the display of the output from the sensor. Fig. 4 below shows interfacing of sensors using the Arduino Mega 2560 microcontroller:

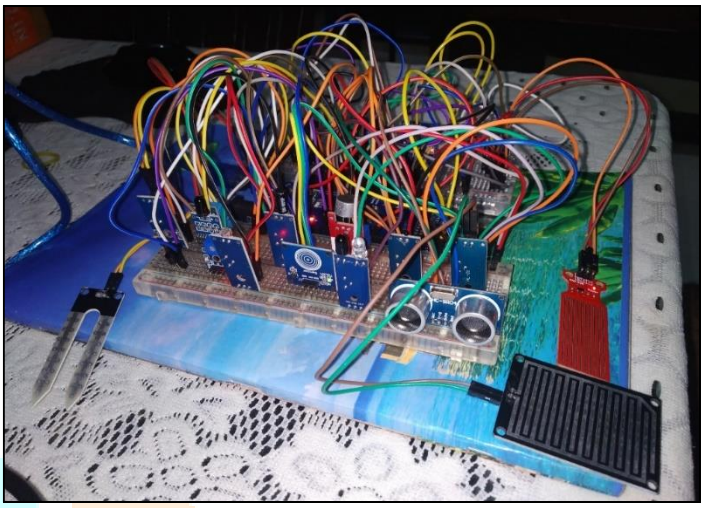


Fig. 4 Interfacing of Sensors

The screen used was Nextion 4.3” Intelligent NX4827P043-011R Resistive Touch HMI Display where the display of each sensor was shown and the dashboard was created consisting of 20 sensors. This is shown in Fig. 5 below. As shown in figure, status of each sensor is shown in detail in a matrix of 4x5.

Fig. 5 Dashboard Display Created on Nextion Screen

3. Results and Discussion

After the complete demonstration of the trainer kit the output of each sensor was shown on the display i.e., serial monitor of the Arduino IDE Platform. Fig. 6 below shows the detailed output from the sensor after demonstration:

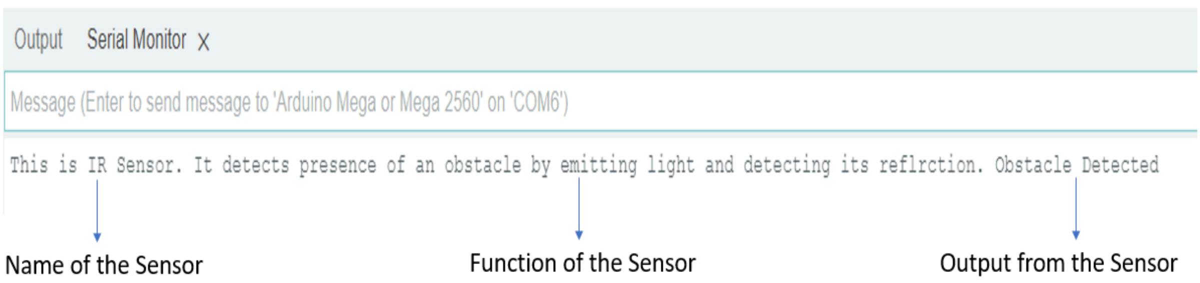
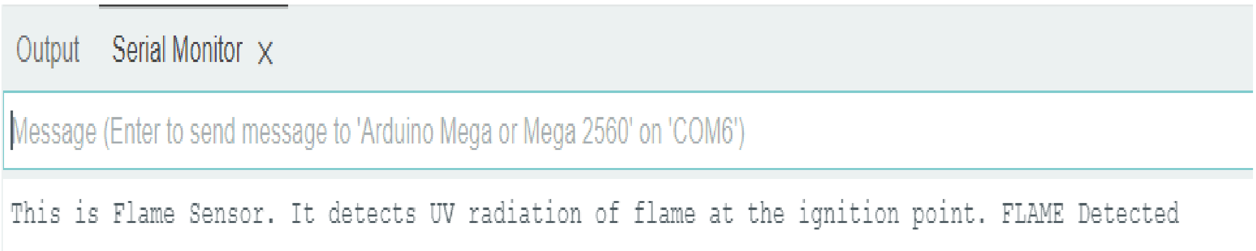


Fig. 6 IR Sensor Output

As shown in the figure the output displayed on the serial monitor is divided in 3 parts: 1. Name of the sensor, 2. Working/Function of the sensor and 3. The output data obtained from the sensor. When the user gives input to the particular sensor from the demonstration kit, the sensor detects it and processes the signal in order to display the output on the sensor kit. For e.g., in the above figure IR sensor is tested. Here, as the user places an obstacle into the vicinity of the IR sensor, the IR sensor detects the presence of an obstacle and gives the following output: “*This is IR Sensor. It detects presence of an obstacle by emitting light and* *detecting its reflection. Obstacle Detected*". If there is absence of an obstacle or if the IR sensor fails to detect the presence of an obstacle, the output won't be displayed on the serial monitor. This is done using the "If" condition in the Arduino program. Another example is of flame sensor which is shown in Fig. 7 below.

Fig. 7 Flame Sensor Output



Around 20 students from technical, non- technical and schooling background were given hands-on experience of using the sensor demonstration trainer kit. Based on their experiences, a survey was conducted in order to determine the overall performance of sensor kit (Table No. 3). As shown in the table, the survey consisted of 12 questions based on the overall functioning of sensor kit and the use of Arduino microcontroller.

Table No. 3 Student Survey

Questions based on the sensor kit's performance	No. of Students who Agree	No. of Students who Disagree	No. of Students who have a Neutral response
Satisfied with the working of sensor kit	15	2	3
Easy to use.	16	4	-
Easy to understand the sensor's output.	13	5	2
Easy to access the HMI display.	11	3	6
The sensor kit was self-explanatory.	12	6	2
The perception of sensor kit gave a strong introduction to Arduino.	15	-	5
Overall use of Arduino is satisfactory.	13	5	2
The pricing of kit is reasonable.	10	6	4
The sensor kit satisfies its purpose.	13	4	3
The sensor kit can be used in education institutes and industries.	20	-	-
Likely to use Arduino and sensor in future projects and lab assignments.	14	5	1
Satisfied with the overall experience of learning in terms of value addition to an individual's knowledge.	18	2	-

Fig. 8(a) and 8(b) below show Part-1 and Part-2 of the student survey. From the figure we can see that 75% of the students are satisfied with the working and functionality of sensor kit while there are 10% students who found it difficult to understand the functionality of sensor kit as they suggested to give clarification of the type of sensor. There were 15% students who had a mixed response for working of sensor kit. Almost 16 out of 20 students found the usability of the sensor kit to be easy while 20% students faced challenges while demonstrating the output of one sensor at a time. The output of sensor was divided in 3 parts: a) name of the sensor b) function of the sensor and c) value from the sensor. 65% of the students were able to understand the output given from the sensor while 35% found it difficult to understand out of which 10% students had mixed reviews on this question. They suggested to add a 4^{th} part to the output which is the type of sensor whether digital or analog. This will help to understand the sensor in detail. The HMI display was one of the most challenging aspects of the sensor kit but almost 55% of the students were able to access the HMI display while 15% found it difficult and 30% students had a neutral opinion. The sensor kit was developed with an intention of being self-explanatory to the students and 60% of the students found it to be the same as they got the required information of sensor and the output as well which was visible on the display screen. 30% students found the HMI to be less involved in being self-explanatory and hence suggested to add some audio modules as well. 10% students were bit confused regarding the Arduino programming and its relation with being self-explanatory. The perception of sensor gave foundation of Arduino to 75% of the students while 5 out of 20 students needed more insights on Arduino as most of them were from non-technical background.

The second half of the student survey primarily focuses on the commerciality of the sensor kit and its applications in industrial and education field from a product point of view. Around 13 users out of 20 found the use of Arduino to be satisfactory while 5 students needed more insights on applications of Arduino and 2 students shared a mixed review on the use of Arduino. The pricing of kit got balanced feedback from the students as 50% students found the pricing to be reasonable while 30% find the pricing to be costly. However, there were 20% students who were not able to determine the value for money. 65% of the students agreed to the satisfaction of purpose of sensor kit while 20% disagreed with this opinion as they required more clarity in output in terms of type of sensor and working. 15% of the students had a neutral response for this question. The biggest positive in this survey was that 100% of the students agreed that the sensor kit can be used in educational institutes and industries. When students were asked about using Arduino and sensors for future projects and lab assignments, 70% of them agreed while 20% of them disagreed as they had some different fields and areas to explore. 10% students had a mixed response as they were not able to decide. After the completion of demonstration of sensor kit and giving hands on application to the students, 90% of the students were satisfied with the overall learning process which helped them to add some new skills in their knowledge while 10% students found the experience to be average.

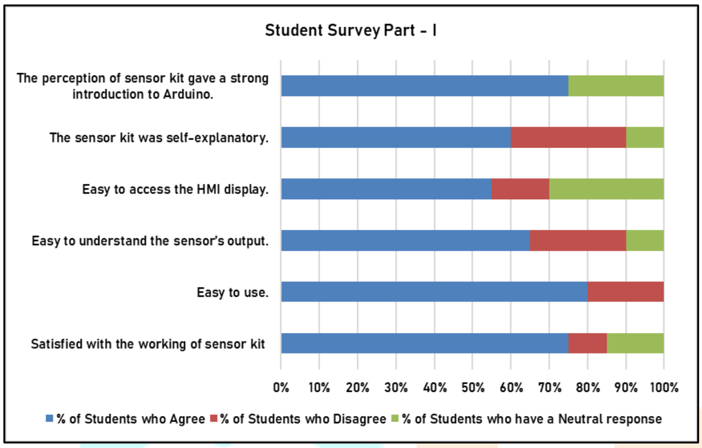


Fig. 8 (a) Student Survey Results Part-1

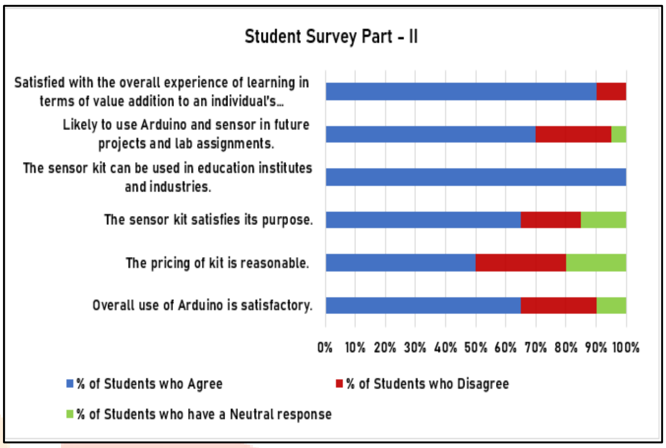


Fig. 8 (b) Student Survey Results Part – 2

Fig. 9 below shows the final development of sensor kit where all the sensors are mounted and the display screen is placed on the center of the front panel of the sensor kit:

Fig. 9 Final Development of Sensor Demonstration Kit

4. Conclusion

The purpose of sensor kit was to display the name of the sensor, it's function and the output value of the sensor which is being demonstrated. Overall, the sensor satisfies its purpose and gives us the detailed output. A total of 20 sensors were used consisting of digital and analog types which successful got interfaced with the Arduino Mega microcontroller. The integration of Nextion display unit was successfully completed and the display was clearly seen in both the serial monitor of Arduino IDE as well as the Nextion Display. The fabrication of sensor kit was completed taking the aesthetics into consideration. However, there were challenges faced during the development of sensor kit. As most of the sensors were analog, a difficulty was faced to convert the analog sensor into digital. Interfacing of sensors was a major challenge as every sensor had its own output conditions. Integrating the display unit and then importing the Arduino IDE program into the was another challenge faced.

The student survey proved to be an important asset in order to analyze and validate the development of sensor demonstration trainer kit for educational and industrial applications. Most of the students agreed to use sensor and Arduino for their future projects and lab assignments and also concluded that such systems are needed in the industrial society to create social awareness. There are a lot of future works which can be done in order to add value to the sensor kit which can help the researchers and developers to appraise their work in the field STEM education. As Arduino Mega 2560 provides 54 Digital and 16 Analog pins, a greater number of sensors can be added into the sensor kit to fill the remaining pins of the controller. As Arduino is flexible and compatible, it can be used in integration with Raspberry Pi and other controllers. Various modules like Voice system, Wi-fi, Real time Website can be integrated when used with multiple controllers.

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