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Development of Open Source Low Cost Wireless Data Acquisition Systems for Science Experiments

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Abstract

There have been substantial technological advancements over the last decade leading to development of precise measuring instruments which have increased the accuracy of experimental results and decreased the time taken during experiments. These measuring instruments are built on sensors and a robust data acquisition system. These data acquisition systems are often very costly, experiment specific and based on proprietary softwares leading to limited adoption in most of the Indian schools/colleges/Universities. Thus, there is a need to develop a robust system which addresses these issues. The present wok describes the methodology of development of such a system which can acquire data from sensors and send it to a directly connected or a remote display device. These have been developed using open source hardware and software tools which are often low cost and capable to support wireless acquisition of data. We are using Arduino microcontroller board, mainly 'Mega ADK', which provides interface between sensors and display devices. Further, wireless capability of acquiring/sending data through internet has been added to the system through an 'Ethernet shield', which has been integrated to Arduino Mega ADK. Some of the science experiments showing remote data acquisition on any device which has an access to internet have been discussed. The developed experiments show the versatility and robust nature of the system.

Keywords: Microcontroller, Arduino, Ethernet Shield, Sensors, Open Source

Introduction

In a science survey conducted by the NCAER (National Council of Applied Economic Research), India, 44.5% student do not opt for science subject because it is

not interesting whereas 20.4% think science as a difficult subject. Further 9.9% are not able to study science because it is costly. (refer with: Table 1) [1]. Thus, there is need to develop a system which should fascinate students. This paper reports a system which is not only low cost but also provides a student friendly methodology to perform experiments. The accuracy, low cost and student friendly nature of the proposed system will excite science students toward the experiments and will bring in opportunity and innovation in the field of science at school and undergraduate level. Additionally, higher accuracy and simpler mechanism can make the experiments cheaper at research level also.

Table 1: Reasons for not taking admission in Science

Reasons	**% non-Science students (Class 11^{th} -12^{th})**
Not interested in science subjects	44.5
Difficult subject	20.4
Higher studies are costly	9.9
Interested in commerce	5.4
Like art subjects	4.8
No future opportunities	2.1
No science college nearby	2
Others	8.9

Methodology

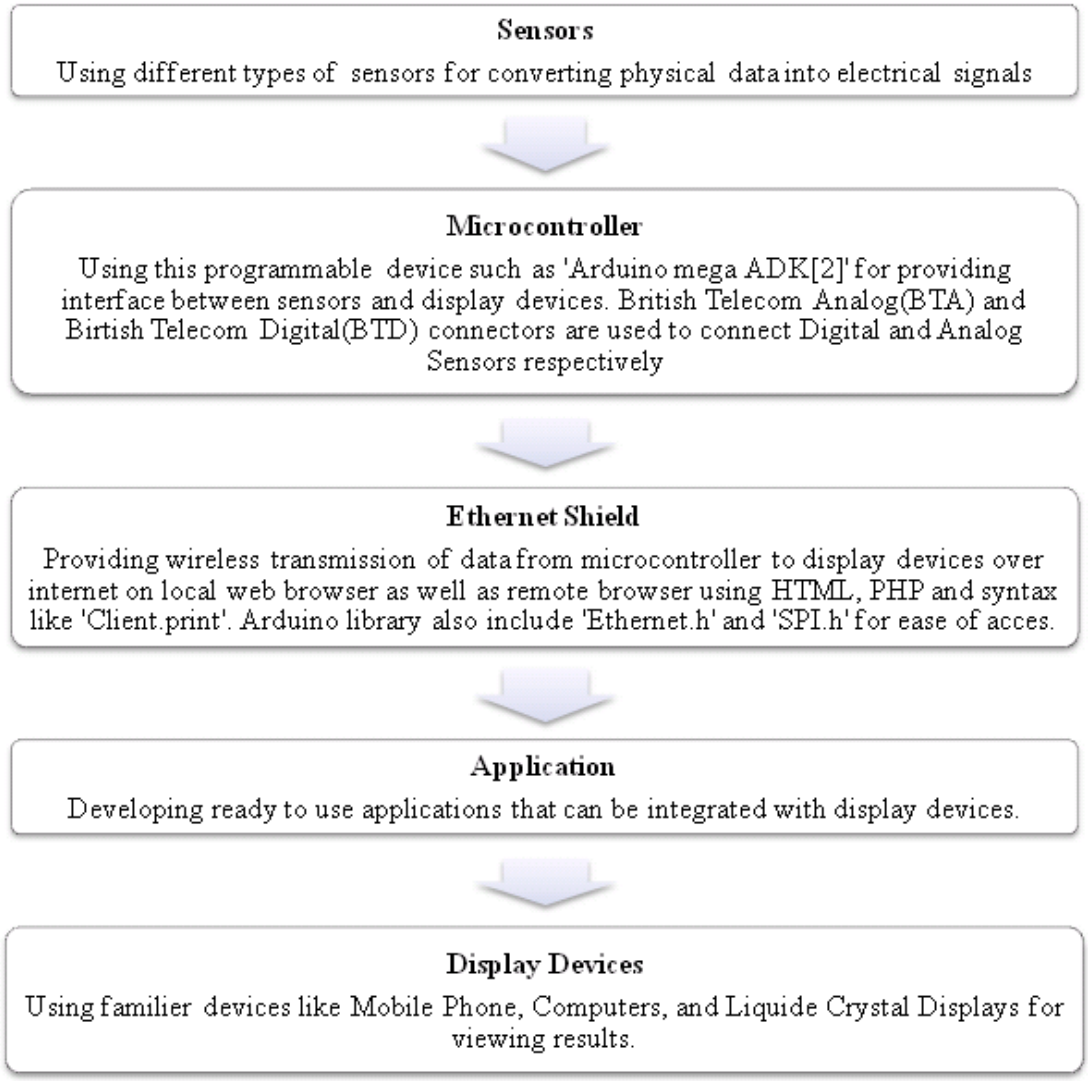

Fig. 1 Flowchart showing methodology of the wireless data acquisition system

Interfacing Sensors:

Fig. 1 shows the flowchart describing the working methodology of the proposed system. Available sensors from Vernier, USA are used to acquire data during experiments. Electrical data from these sensors are sent to microcontroller for processing according to the need of the experiment. A prototype microcontroller, Arduino Mega ADK [2] is being used which provide simple interface with different display devices including android based mobile phones.

These sensors are of two types i.e. Analog and Digital. Further, majority of the used sensors are of analog type and have linear calibrations. For these sensors, only

minor modification of the code to the VernierAnalogVoltage sketch [3] is required to get meaningful readings. Specifically, we need to convert from a raw voltage to the sensor reading, using Eq. 1

Sensor Reading = Intercept + Voltage * Slope (1)

For instance if we have to use a Vernier pH sensor, following sample code may be used:

```
*/
float Count;
float Voltage;
float SensorReading;
int TimeBetweenReadings = 500; // in ms
int ReadingNumber=0;
float Time;
//////////////////////////////////////
// This is the information on the sensor being used.
//See the www.vernier.com/products/sensors.
char Sensor[]="pH Sensor";
float Intercept = 13.720;
float Slope = -3.838;
//////////////////////////////////////
void setup()
{
  Serial.begin(9600); //initialize serial communication at 9600 baud
  Serial.println("Vernier Format 2");
  Serial.print(Sensor);
  Serial.print(" ");
  Serial.println("Readings taken using Ardunio");
  Serial.println("Data Set");
  Serial.print("Time");
  Serial.print("\t"); //tab character
  Serial.println ("Force"); //change to match sensor
  Serial.print("seconds");
  Serial.print("\t"); // tab character
  Serial.println ("newtons"); //change to match sensor
}
void loop()
{
  //the print below does the division first to avoid overflows
  Serial.print(ReadingNumber/1000.0*TimeBetweenReadings);
  Count = analogRead(A0);
  Voltage = Count / 1024 * 5.0;// convert from count to raw voltage
  SensorReading= Intercept + Voltage * Slope;
  Serial.print("\t"); // tab character
  Serial.println(SensorReading);
```

```
  delay(TimeBetweenReadings);// delay in between reads for stability
  ReadingNumber++;
}
```

We will get readings on Serial Monitor of Arduino IDE. For sensors having linear calibration, one can get the slope and intercept from the user manual of that sensor.

Deploying Ethernet Shield:

The Arduino Ethernet shield allows an Arduino board to connect to the internet using the Ethernet library [4]. The Arduino IDE is provided with Ethernet library. The example sketch for Ethernet can be used to acquire data, but IP address change is must according to the IP addresses of other surrounding device in order to provide an identical IP to the shield. Further MAC address also needs to be changed if we are using more than one shield. The Ethernet library uses clint.ptint(); syntax which allows us to send text or data back to the web page. This way we only use local browser i.e. when Ethernet shield and the display device is connected to same internet source (router).

If we require transmitting data more remotely then we need to assign static IP address to our system. If the service provider is not able to provide a static IP, then one can use Dynamic DNS provider. A Dynamic DNS provider *offers us our own static IP hostname (e.g. mojo.monkeynuts.com) instead of a number; keep track of your changing IP address and linking it to the new hostname [5]. Further, we will also need to do port forwarding*; this tells the router where to redirect incoming requests from the outside world. When the modem receives such a request, we want to send that request to the port number of our Ethernet shield [5].

Related Work

We have performed several experiments using proposed system and methodology. These include experiments of school and undergraduate level. Though we have automated a range of experiments, details of the following four experiments can be referred from our earlier work[6] :

- Measuring intensity of light
- Calculating time period of a simple pendulum
- Measuring pH of a solution
- Performing Acid Base titration

Conclusion

The present work shows how deployment of open source at school and undergraduate level help students to perform experiments precisely. The accurate results of the experiment not only attract students toward the experiments but also excite them towards research. Wireless data acquisition to mobile phones and PCs makes the experiments handy and student friendly.

Additionally, the present system can be used to analyse and log medical data of a patient e.g. the blood sugar/blood pressure data of patient can be wirelessly sent to a mobile phone for monitoring and action by the doctor. Similarly, remote and wireless data acquisition of data may be fruitful in performing experiments in a chemistry laboratory. It can reduce health hazards to the researchers/students ensuring their safety and security.

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