Design and Analysis of a Localised Environment Monitoring Sensor System

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***Abstract*- This paper discusses the design of a localised environment monitoring system. The system consists of a temperature sensor, a humidity sensor, a global positioning system (GPS), a microcontroller and an LCD display. The temperature and humidity sensors measure the surrounding environment, while the GPS collects the current longitude, latitude and altitude position of the system. This paper highlights the verification method to ensure the accuracy of the system when performing the sensing operations. Each sensor is compared against the existing commercial device under various environmental conditions. The results show that the system can measure the temperature, humidity and location information, within an accuracy range of 96% to 99%, when it is benchmarked against the commercial devices.**

Keywords: environment sensor device, temperature, humidity, GPS, microcontroller.

I. INTRODUCTION

Environment monitoring devices are important in current and future monitoring applications, such as in precision agriculture [1], automobiles [2], machines, home automation [3] and buildings [4]. In animal tracking, for instance, the animal might travel from one place to another. In order to study the behaviour of the animal, it is important to collect information about the ambient condition and the animal's location. To collect these data, a reliable sensing device must be developed and attached to the animal. This device must be able to measure and store the data accurately so that the data can be used to study the subject's behaviour.

When designing the environment sensor devices, one of the main challenges is to obtain accurate measured data. In this work, we develop an environment sensor system that can collect temperature, humidity and location information. The objective of this work is to ensure that the device can accurately and reliably perform the required measurements.

The rest of the paper is arranged as follows. First, Section II will discuss the literature related to existing environment monitoring systems. Section II will discuss the method used to design our localised environment monitoring system. Section IV will highlight the results obtained from the experiments. Finally, Section V will conclude the paper.

II. LITERATURE REVIEW

In [5], information, such as temperature collection, tri-axial and GPS data, is collected to measure the comfort levels found in public transportation. The system consists of a microcontroller, an accelerometer, a temperature sensor and a GPS system. By collecting travelling pattern information, the driver's behaviour can be studied. Furthermore, the road conditions can also be assessed to ensure better comfort for the driver and to provide information that could be used to improve road maintenance.

Paper [6] discusses designing data acquisition for three-dimensional electromagnetic explorations for oil and gas detection. The design consists of data acquisition, a digital signal processing module (DSP), an embedded controller and a GPS system. While the embedded controller performs the main control operation of the system, the DSP module performs the FFT, decimation, filtering, correlation and custom data processing required by the electromagnetic exploration [6].

To improve the ability of drivers to deliver frozen products to the consumer market, paper [7] discusses developing a cold-chain temperature monitoring system. The system is equipped with RFID tags, a temperature sensor and a GPS system. The RFID tags provide a continuous record of temperature data, time and data storage. By implementing the system, various aspects of the services can be monitored and improved, such as product quality, management and logistics.

In [8], an animal tracking system is built to monitor the behaviour and migration patterns of swamp deer. The system collects important information, such as temperature, humidity, GPS, head orientation and ambient light. Once the data is collected, it is transmitted to the base station through wireless communication. The system is built using a microcontroller, temperature and humidity sensors, an accelerometer, a GPS receiver, a Li-Ion battery and a solar panel. The solar panel harvests the energy from ambient light and stores the energy in the rechargeable battery.

III. METHODOLOGY

This section discusses the design of the localised environment monitoring system in detail. This system consists of five main components: a temperature sensor, a humidity sensor, a GPS receiver, an LCD display and a controller, as shown in Figure 1. In this design, the microcontroller is the main component. Its main function is to receive input data from various sensors, process the measured data and output it to the LCD display. In this work, a PIC16F887 microcontroller from a microchip was selected. It is a low-power CMOS 8-bit MCU based on high performance RISC architecture [9]. The device has a built-in analog-to-digital converter (ADC) that converts analog

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signals from the sensor to a 10-bit binary. This eliminates the need for an external ADC in the system.

An SN-HMD sensor is used to measure the temperature and humidity [10]. That sensor is selected since it has good accuracy and a wide measuring range that is suitable for the targeted application. The device produces a linear output voltage as the temperature and humidity change. For the temperature, each change of 1^{o}C will result in a change of 0.1V at the output, whereas for the humidity sensor, a 10% change in the air humidity results in a 0.35 V change in the output voltage. All output pins from the sensor are connected to the PIC microcontroller's I/O through pin RA0 and RA1.

In this system, the location data is collected using the GPS receiver model EB-85A [11]. The GPS receiver will receive signals from satellites, calculate the current location information and output the longitude, latitude and altitude information. These data are outputted in NMEA format and are transfer to the microcontroller's universal asynchronous receiver transmitter (UART) port at a rate of 38400 bits per second [11]. The overall schematic diagram of the system is shown in Figure 2.

In order to ensure that the device can operate properly, the microcontroller has to be programmed to read data from multiple sources of sensors. In this work, the microcontroller will first read the data from the temperature and humidity sensors before displaying the value. In the next phase, the microcontroller will read the data from the GPS receiver, extract the location information and then display the latitude, longitude and altitude of the current position. This process will then be repeated every 10 seconds until the microcontroller receives an interrupt signal from the user. Figures 3 and 4 show the flow chart of how the microcontroller reads the output from the temperature, humidity and GPS sensors.

IV. RESULTS AND DISCUSSION

This section discusses the results obtained in this work. First, we will discuss the results obtained from calibrating each of the components used in this work. Next, the results obtained from integrating all the modules will be explained. Lastly, the verification of the sensor node will be discussed.

Tables 1 and 2 show the results from measuring the temperature and humidity, respectively. The microcontroller measures the voltage output from these sensors every 5 seconds. Since the analog voltage output from the sensor varies all the time, due to variations in the environment, 10 values will be taken and the average value will be calculated. This is done to ensure that a stable value can be obtained and displayed on the LCD. The average value of the measured voltage will be converted to Celsius (^{o}C) using the formula given in the datasheet [10]. To ensure high accuracy, the measured temperature is calibrated against a mercury thermometer.

Table 1 shows the results obtained from measuring the temperature using our system. In this experiment, the temperature is measured between 31.5 ^{o}C and 38 ^{o}C. This measurement is taken under different conditions, namely, indoor, shaded and direct sunlight. As shown in the Table, the measured temperature obtained using our system give 97.52% accuracy when compared to the results obtained using a mercury thermometer. For the humidity sensor, the measurement we obtained using our system is compared against the results obtained from using a commercial humidity sensor with a humidity range of 40% to 62%. As seen in the Table, the data collected by the humidity sensor in our system shows 99.35% accuracy compared to the commercial humidity sensor.

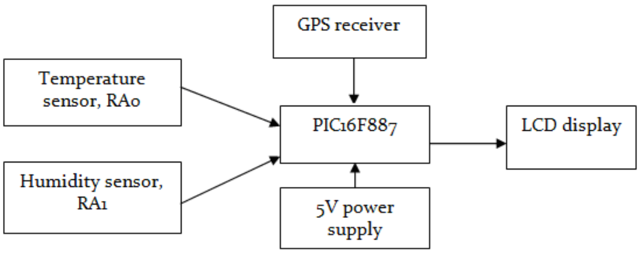

Figure 1: **B**lock diagram of the localised environment monitoring system.

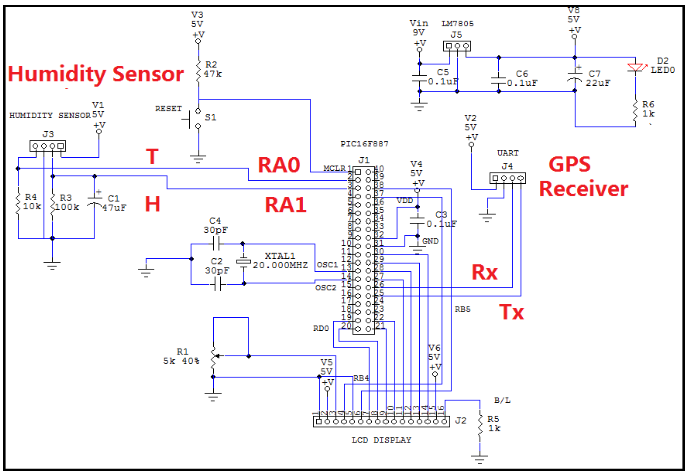

Figure 2: Schematic diagram of the complete localised environment monitoring system.

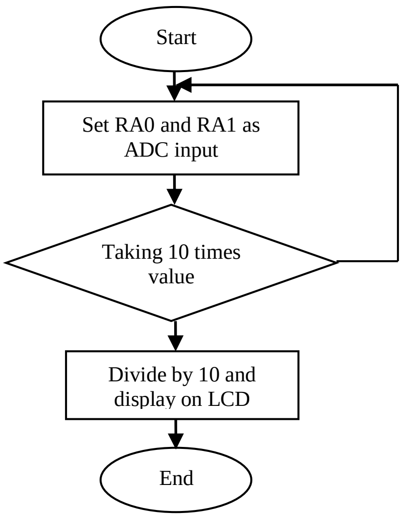

Figure 3: Flow chart for how the microcontroller measures humidity and temperature.

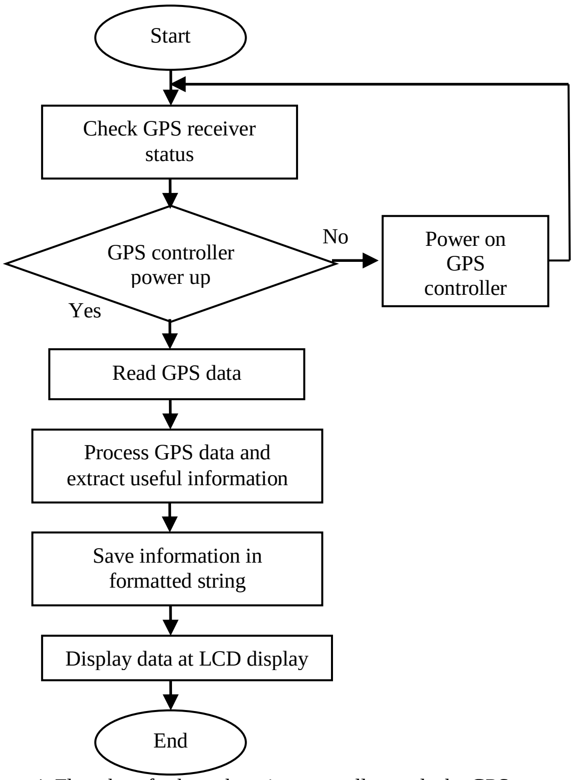

Figure 4: Flowchart for how the microcontroller reads the GPS output data.

To verify the operation of the GPS receiver, NMEA data obtained during the experiment were inputted into the microcontroller through UART before being displayed on the LCD. The location data output from our system is compared against the data measured by a commercial GPS device embedded in a smart phone (model Samsung GT-S5570). The smart phone is an Android version 2.2.1 and it uses the GPS Locator Utility application to display the GPS information. In this experiment, latitude, longitude and altitude data were measured while travelling from Ulu Pauh, Perlis to Kampung Wai, Kuala Perlis. This route covers a distance of 18.6 km. Figure 7 shows the traveling map taken from Google Map. On the map, the point A–J shows the position where the location information is recorded. The data output from our system and the smart phone were recorded at the same time.

Tables 3 and 4 show the comparison between the data collected from our system against the data collected using the smart phone. As shown in the Table, the latitude and longitude information recorded by our device matches the information recorded by the smart phone with 99% accuracy. For altitude information, our system gives 96% accuracy compared to the commercial device. Figure 5 and Figure 6 show the displayed value of the LCD during the temperature, humidity and location measurements.

Figure 5: Temperature and humidity readings displayed on the LCD.

Figure 6: GPS receiver output displayed on the LCD.

Table 1: Data comparisons between the measured temperature sensor and the mercury thermometer

Mercury Thermometer	Temperature Sensor		Accuracy (%)
Temperature (°C)	Measured Voltage (V)	Displayed Temperature (°C)	
31.5	2.65	31.0	98.41
32.0	2.65	31.0	96.88
32.5	2.75	32.0	98.46
35.0	2.90	34.0	97.14
36.0	3.00	35.0	97.22
37.0	3.10	36.0	97.30
38.0	3.20	37.0	97.37
38.0	3.20	37.0	97.37
Average			**97.52**

Table 2: Measured humidity values

Commercial Device	Humidity Sensor		Accuracy in %
Humidity (%RH)	Measured Voltage (V)	Displayed Humidity (%RH)	
40.0	1.66	39.9	99.77
41.0	1.70	40.7	99.37
42.0	1.71	41.8	99.42
43.0	1.75	43.0	99.96
44.0	1.78	44.0	99.93
50.0	1.95	49.6	99.24
51.0	2.00	50.9	99.78
61.0	2.30	60.2	98.73
62.0	2.35	60.7	97.91
Average			**99.35**

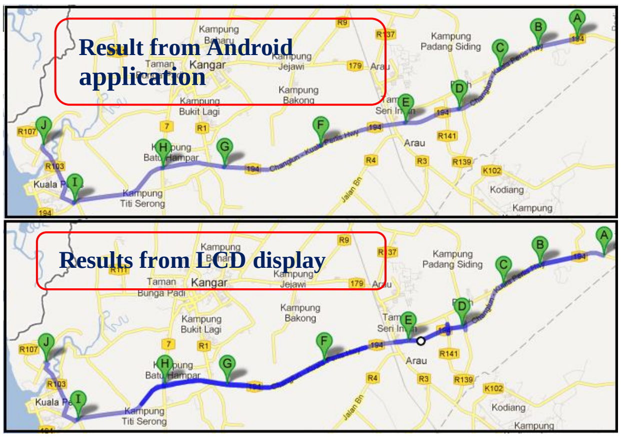

Figure 7: Traveling point for the GPS measurement.

Table 3: Latitude and longitude data comparison

Point	Result output using commercial GPS		Results displayed on the LCD display		Average Error (%)
	Latitude	Longitude	Latitude	Longitude	
A	6.45637	100.35602	6.45673	100.35626	0.0029
B	6.45238	100.33083	6.45266	100.33125	0.0024
C	6.44437	100.31595	6.44445	100.31663	0.0010
D	6.44474	100.2996	6.42861	100.29998	-0.1250
E	6.42257	100.27842	6.42304	100.27863	0.0038
F	6.41401	100.24478	6.41446	100.24543	0.0038
G	6.40552	100.2068	6.40565	100.20697	0.0011
H	6.40497	100.18223	6.40554	100.18251	0.0046
I	6.39134	100.14726	6.3914	100.14803	0.0009
J	6.41379	100.13495	6.41414	100.13523	0.0029
Average					**-0.0102**

Table 4: Altitude data comparison

Point	Altitude (feet)		Accuracy (%)
	Result from commercial device	Displayed Altitude on LCD	
A	164	169	96.95
B	100	95	95.00
C	95	100	94.74
D	87	90	96.55
E	72	76	94.44
F	59	60	98.31
G	56	55	98.21
H	78	82	94.87
I	55	58	94.55
J	42	41	97.62
		Average:	96.12

V. CONCLUSION

This paper discusses the design and analysis of a localised environment monitoring system. The system consists of a temperature sensor, a humidity sensor, a GPS system, a microcontroller and an LCD display. In order to achieve good accuracy, rigorous experiments were conducted to verify the operation of each component of the system. From our experiments, our system is able to collect data with 96% to 99% accuracy when compared to the existing commercial devices. The next step of this work will include an evaluation of our system's wireless capability, as well as determining how to reduce the system's size and minimise its power consumption so that it can be used effectively in a wireless sensor node application.

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