Mobile Robot Temperature Sensing Application via Bluetooth

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Abstract

The issue of flu outbreak especially influenza H1N1 has been widely discussed nowadays. For those medical personnel who are exposing to measure temperature of a potential patient is recognized as a risky mission. Besides the medical personnel, firefighter also facing the similar risk related with temperature in their career. Heat injury is the major problem for the firefighter since they wear insulated clothing which is not able to shed the heat generated from physical exertion when they extinguish fire. Hence, a temperature sensing mobile robot via Bluetooth is proposed as an alternative solution for temperature measurement. In this project, a prototype mobile robot with simple locomotion mechanism and temperature sensor has been developed to measure human and environment temperature. This prototype includes KC-21 Bluetooth module as a platform to communicate with mobile Bluetooth, and LM35z temperature sensor to measure temperature. The mobile robot can move around and measure temperature according to the command or instruction of the user using mobile Bluetooth. The control range of this mobile robot is around 10m and it can measure temperature up to 150℃. A circuit controller board based on PIC16F877A is developed. Results show that, the temperature sensor has about 2.356% error when measuring human temperature while 0.88% error for measuring environment temperature.

Keywords: *Bluetooth; Mobile Robot; Temperature sensing*

1. Introduction

Nowadays application of Bluetooth wireless technology has become popular among the collaboration between short range communications such as computing, mobile phone and automotive markets. A device must be able to interpret certain Bluetooth profiles in order to use Bluetooth technology. Hence, a KC-21 Bluetooth module is used as a Bluetooth transceiver between microcontroller unit and mobile phone. The user can use the mobile phone to send all the instructions to the mobile robot. When the temperature sensor detects the temperature, the measurement will be send to the mobile phone through the microcontroller unit and Bluetooth module. This mobile robot is applied in places that acquired tedious temperature measurement such as in an airport and hospital. This mobile robot can also be used by firefighter to have early detection of the heat temperature for a burning case before the cause of action is consider.

2. Literature Review

A. Summary of Case Study

The following three cases in Table I have one thing in common that is accuracy. In case study I, the radio controlled robot car needs to receive an instruction from a PC and do the task accordingly [5] while Bluenurse wireless link in case study II need to read the patient ECG using a PDA or laptop [9]. As for the case study III the robot need to communicate with the PC and the connection is bi-directional [2]. All this case is similar to this project where Bluetooth is used to control the mobile robot for measuring the temperature and send the reading back to the mobile phone. The comparison of the case studies in Table I with the project title are described and summarized as follow:-

TABLE I : Summary for Case Study

Case study	I	II	III	This project
Objective	Create a point to point connection between a robot car with PC	Remotely monitor and log patient vital signs	Establish and interface a wireless connection between the mobile robot and PC	Survey temperature remotely
Bluetooth hardware	Bluetooth starter kits	Ericson Bluetooth module	Ericson Bluetooth application and training tool kit	SKKCA-21 Bluetooth Module
Bluetooth software	THciInterface C++	ANSI C	Visual Basic 6.0	JAVA and MPlab
Type of sensor	-	ECG sensor	Fiber optic sensor	Temperature sensor

3. Methodology

A. Control System Overview

The block diagram of the overall system for this project is shown in Figure 1. Mobile robot consists of one MCU as the main brain of the control system. The MCU gathers the temperature measurement from LM35z (temperature sensor). The system has a serial communication with the KC-21 Bluetooth module. The user will communicate or control the robot using this communication link. One of the outputs links is used to control the motor via H-bridge motor driver. A brief explanation for each of the robot component are described and summarized in Table II.

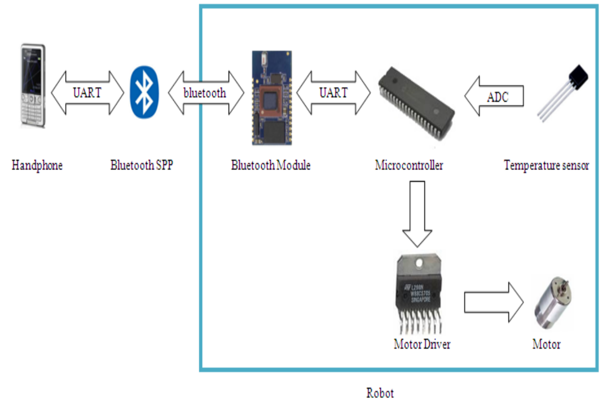

Figure 1: Block Diagram of Overall System

TABLE II : Material Specification

System Module	Material	Specifications
MCU	PIC16F877A	20MHz operation speed, PWM module, consists of USART
Temperature sensor	LM35z	Ranging from -55°C to 155°C., accuracy 0.5°C at room temperature, Linearly proportional to the Celsius temperature with +10mV/°C scale factor
Motor Driver	L298	2.5V to 46V dual full bridge driver, low saturation voltage, over heat protection
DC Motor	C36S	Speed (sec/60deg): 0.16/4.8V Torque (Kg-cm): 3.50/4.8V
Bluetooth module	KC Wireless Bluetooth Module Starter Kit SKKCA-21	5V UART interface (ready for microcontroller interface), default baud rate of 115.2Kbps, range up to 20 meters
Indicator	LED	3mm
Power supply	LM7805	Output voltage 5V

B. Software Development

Figure 2 and Figure 3 shows the flowchart for developing the Java coding and MPlab coding respectively.

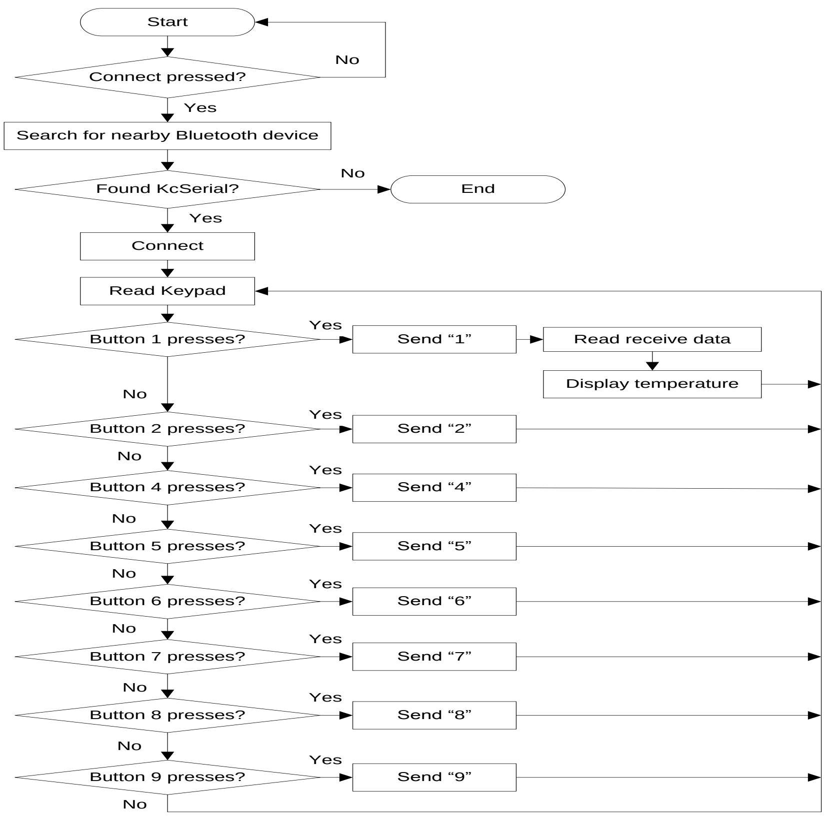

Figure 2: Flowchart for Java Coding

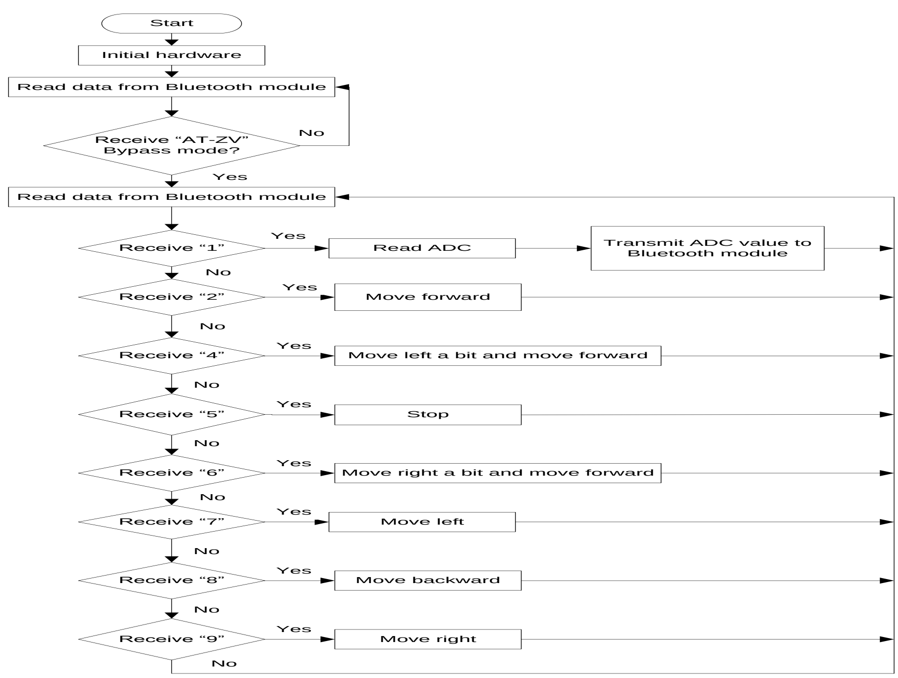

Figure 3: Flowchart for MPlab Coding

The developed Java coding has to been installed in the mobile phone so that it can communicate with the Bluetooth module. The first step is too clicked the connect button in the mobile phone, so that the mobile phone will communicate with the Bluetooth module. After the mobile phone is successfully connected, the user can start to control the robot. Button “1” is used as a temperature controller while the other buttons are used for navigating the robot.

In Mplab coding, the first command is to declare the bypass mode from the UART. After receiving the accurate bypass mode, the microcontroller will start to receive the instruction from the mobile phone. The temperature measurement is looped for 2000 times to get a more accurate value and the value is calculated using the ADC function.

4. Result and Analysis

The MCU robot will read the instruction from KC21 Bluetooth module via UART protocol. The UART setting is baud rate at 115200 bps, 8 data bits, no parity bit and 1 stop bit. The robot will start to navigates after receive navigation command from the user. The description of the commands and functions is summarized in Table III. The complete design of the robot system is shown in Figure 4.

The temperature sensor will measure a human temperature by touching it with his/ her finger. Once the MCU receive the temperature reading, the data will be sent to the connected mobile phone via mobile Bluetooth and the temperature value will be display on mobile phone screen.

TABLE III : Commands and Functions

Command	Value in ASCII	Value in hex	Function
Read	1	0x31	Lm35z take temperature reading
Forward	2	0x32	Robot move forward
Backward	8	0x38	Robot move backward
Left	4	0x34	Robot move left and walk straight
Right	6	0x36	Robot move right and walk straight
Turn left	7	0x37	Robot move left
Turn right	9	0x39	Robot move right
Stop	5	0x35	Robot stop moving

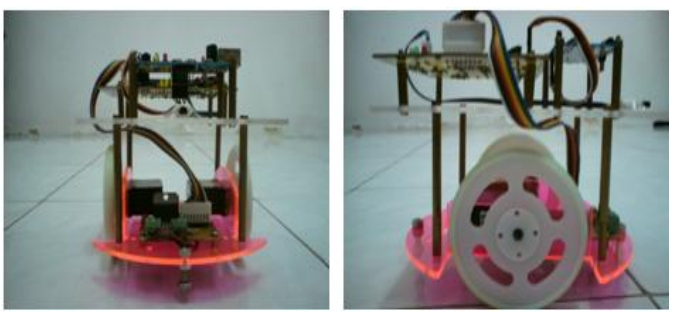

Figure 4: Complete Design of Robot System

A. UART interface between Bluetooth module and microcontroller

The connection between Bluetooth module and microcontroller is measured using an oscilloscope. The Bluetooth module transmit pin is connected to the MCU receive pin while the Bluetooth module receive pin is connected with to the MCU transmit pin. The probe is place at the MCU transmit pin (pin 25) and the measured result is shown in Figure 5. The comparison for the period of 1 bit, for an ideal case, calculation value base on PIC16F877A data sheet and actual value from the measurement are listed in Table IV. Equation (1) is used to calculate the baud rate, while equation (2) is used to calculate the period. Equation (3) is the formula to calculate the percentage error of the system.

$$Baud\ rate = \frac{Fosc}{16(x+1)} \qquad (1)$$

$$Period = \frac{1}{Baud\ rate} \qquad (2)$$

$$\%\ error = \frac{(actual\ value - display\ value)}{actual\ value} \times 100\% \qquad (3)$$

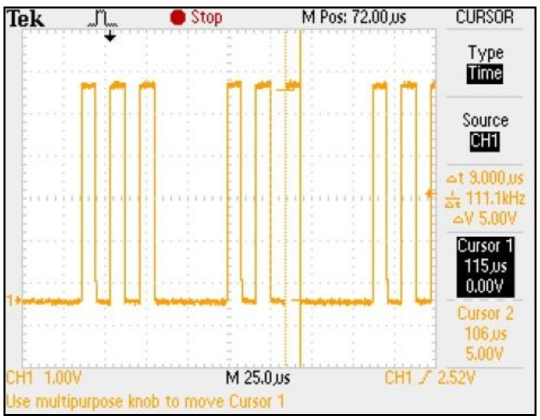

Figure 5: Result for Sending Signal 'A'

TABLE IV : Comparison of the period of 1 bit for ideal case, calculation value base on PIC16F877A data sheet and actual value from measurement

	Ideal	PIC	Measurement
Period	$\frac{1}{115200}$ $= 8.68us$	With Fosc = 20MHz, x=10 Baud rate = 113636.36 $\frac{1}{113636.36} = 8.80us$	$115us - 106us$ $= 9.00us$
Percentage error	0%	$\frac{8.68u - 8.80u}{8.68u} \times 100\% = 1.38\%$	$\frac{8.68u - 9.00u}{8.68u} \times 100\% = 3.69\%$

B. ADC interface between MCU and LM35z

ADC is used to convert the analog value from LM35z to 10 bits digital value. The digital value is store inside the MCU, register ADRESH and ADRESL. The program is modified so that the result of 10bits ADC value will be shown in the hyperterminal. The comparison of analog value at pin RA0 (before ADC) and digital value show in hyperterminal (after ADC) form is listed in Table V. The analog value is measured using a digital multimeter. From the table, the results show that the percentage of error is very low. Hence, it is concluded that the ADC is very accurate. The formula used to calculate the voltage after conversion is shown in equation (4).

$$digital\ value \times \frac{Voltage\ reference}{(10\ bits\ resolution)} \qquad (4)$$

TABLE V : Comparison of Analog Value and the Digital Value After Conversion

	Analog Value	**Digital Value after Conversion**
Voltage	0.309V	$b0000111111 \times \frac{5}{(1024-1)}$ $= 63 \times \frac{5}{(1024-1)} = 0.308V$
Percentage error	0%	$\frac{(0.309-0.308)}{0.309} \times 1 = 0.324\%$

C. Motor driver

The motor driver circuit is use to drive the motor. Dual full-bridge driver L298 is used as the motor driver for the robot. The measured voltage value at inputs and output of the motor driver are listed (see Table VI). The measurement is done with a digital multimeter. L1, L2, R1, and R2 are the input of the motor driver and MotorL1, MotorL2, MotorR1, and MotorR2 are the output of the motor driver. The results in the table, shows that the motor driver L298 is functioning properly and the robot will move accordingly when instructed by the user.

TABLE VI : Voltage Measurement at Motor

Movement	L1	L2	R1	R2	MotorL1	MotorL2	MotorR1	MotorR2
forward	0.00	4.90	0.00	4. 89	0.78	4.18	0.78	4.18
backward	4.90	0.00	4.89	0.00	4.18	0.78	4.18	0.78
left	0.00	0.00	0.00	4.90	0.18	0.18	0.75	4.20
right	0.00	4.90	0.00	0.00	0.75	4.20	0.18	0.18
stop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

D. Accuracy of temperature sensor

The accuracy of the temperature sensor is verified by comparing the temperature reading between a thermometer and the temperature value show in the phone application. The temperature value from thermometer is assumed as the actual temperature value. The comparison for a human temperature value and percentage error is shown in Table VII while Table VIII is the comparison of environment temperature and percentage error. Fig. 6 shows the comparison for a human temperature measurement from a thermometer and the temperature sensor. The overall percentage error for human measurement and environment measurement is calculated in (5) and (6) respectively.

$$Overall\ \%\ error\ (human) = \frac{23.56}{10} = 2.356\% \qquad (5)$$

$$Overall\ \%\ error\ (environment) = \frac{8.8}{10} = 0.88\% \qquad (6)$$

Since the LM35z has a scale factor of 10mV/1℃, hence the display value in mobile phone is integer.

TABLE VII : Difference Between Actual Value and Display Value for Human Temperature

Actual value (°C)	Display value (°C)	Percentage error (%)
36.9	35	5.15
35.0	34	2.86
36.3	36	0.83
36.4	36	1.10
36.0	36	0.00
36.1	35	3.05
37.1	37	0.27
36.3	35	3.58
35.8	34	5.03
35.6	35	1.69
Total percentage error		23.56

TABLE VIII : Difference Between Actual Value and Display Value for Environment Temperature

Actual value (°C)	Display value (°C)	Percentage error (%)
30.0	30	0
30.5	30	1.64
29.8	30	0.67
29.0	29	0
29.5	29	1.69
31.0	30	3.23
32.0	32	0
32.3	32	0.93
31.2	31	0.64
32.0	32	0
Total percentage error		8.8

Figure 6: Comparison Temperature Reading of Thermometer and Temperature Sensor

5. Conclusion

The main purpose of this project is to develop a mobile robot with temperature sensor and control using Bluetooth technology. The locomotion system was implemented using PIC 16F88A microcontroller while the control system is via Bluetooth module. Meanwhile, the LM35z is the integrated circuit temperature sensor used to measure the temperature. User can control the movement of the robot using a mobile phone which has been installed with the developed Java code and existing Bluetooth application. Serial communication is done between PIC microcontroller, Bluetooth module and LM35z. LM35z will obtain the measurement and the data is send to the PIC microcontroller. The PIC microcontroller processes the data and displays it on the screen of the mobile phone.

Bluetooth technology can be use to perform various applications. The prototype of this project has been successfully completed where the mobile robot can move and measure according to the user instructions from the mobile phone. The idea of implementing Bluetooth technology is for safety purpose and is very useful especially in application where risk is a concern.

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