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The Development of IoT Based BBT Charting and Monitoring using ThingSpeak

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Abstract. Family planning is necessary for individual and couples to manage their desired number of children or spacing timing of their births. Fertility can be planned by using Fertility Awareness Method (FAM) or others like medicine. FAM is a natural family planning method that based on body signs changes during each menstrual cycle in response to the hormones that cause ovulation. This method allows a woman to know their ovulation time using the ovulation chart by plotting body temperature at the exact time every day in the early morning. This method requires a device to measure basal body temperature (BBT) and a chart to plot the temperature every morning, which is a tedious way of charting. Therefore, through this research, a BBT monitoring system has been developed using Arduino Yun Mini and ThingSpeak as the Internet of Things (IoT) platform in order to create a medium of sharing information for fertility monitoring and consultation purposes; where the data management and control can be done conveniently through the internet with secured environment. While the basal body temperature measurement has been done using a fast response time 503 ET-3H NTC thermistor-type temperature sensor from Semitec Corporation and the BBT data are successfully charted and monitored through the ThingSpeak.

INTRODUCTION

Family planning services in Malaysia have been provided by various family planning associations, and the services are largely confined to the large urban area [1,2]. The family planning is the method involves in controlling or planning a pregnancy and has become official policy in Malaysia when a national planning program was launched in conjunction with the First Malaysia Plan in1966 [1,2]. An effective family planning is important in reducing the risk of maternal mortality, improving health for children and allowing women to gain more control over their fertility in order to enhance or reduce the possibility of pregnancy [1].

Some methods can control the fertility which are medications, surgical procedures and Fertility Awareness Method (FAM). The use of medication and surgery in planning the fertility give health problems for the couple, especially woman. Taking medication could cause side effect such as spotting or irregular periods, nausea (feeling sick at the stomach), often headaches, mood changes (feeling down), breakouts (get acne), sore or enlarged breasts, gain or lose weight, and imbalance hormones [3,4], whereas the surgical method is costly, may not be reversible and can be vulnerable to infection. While FAM is an inexpensive method based on fertility body sign monitoring which is basically through Basal Body Temperature (BBT) monitoring that will be plotted on ovulation chart. Therefore, most of the couples preferred the FAM for their family planning.

Nowadays, there are several BBT devices sold in the market with the objective to help in tracking and monitoring fertility through the ovulation chart. However, most of the commercial BBT device cannot directly derive the information needed, where the users inconveniently need to plot the temperature chart manually and need to interpret the changes in BBT chart by themselves or to set several appointments with a medical practitioner for further consultation.

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Therefore, this research will eventually help them effectively monitor their menstrual cycle and conveniently share the data with a doctor for consultation by integrating the BBT monitoring system using an IoT. The IoT will be the platform for the user to monitor their fertility chart and for the doctor to know the user period regulation status for further consultation about the fertility regulation [5]. In addition, the IoT is also one of the best solutions for data storage and protection through its high-tech cloud computing system [6].

DESIGNING OF IOT BASED BBT CHARTING AND MONITORING METHOD

Temperature Measurement using NTC Thermistor 503 ET-3H

The temperature measurement from thermistor NTC 503 ET-3H has been done according to voltage divider equation to get the thermistor resistance value based on the changes in the input and output voltage and the Steinhart-Hart equation to derive the temperature reading according to the resistance value.

In other words, a thermistor indicates temperature by a change in electrical resistance. However, a microcontroller does not have a resistance-meter built in [7]. Instead, it only has a voltage reader known as an analogue-digital-converter (ADC). Then, the resistance must be converted into a voltage by adding another resistor and connecting them in series [8]. Figure 1 shows the series connection between the thermistor, R_t and the fixed resistor, R_1 to represent the voltage divider circuit in order to measure the changes in the thermistor resistance value based on the changes of the body temperature, where there will be a voltage drop V_{th}, measured between R_t and R_1. According to the circuit, as the resistance of the thermistor R_t changes, the voltage changes too; where resistor R_1 should be at a fixed value, thus the R_t can be derived as Equation 1. Here, the V_{th} is according to 10-bit ADC from the Arduino port.

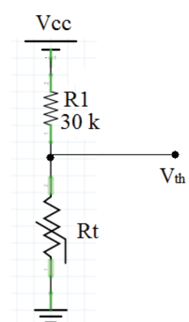


FIGURE 1. The connection between thermistor and resistor.

$$R_t = \frac{R_1}{\left(\frac{1023}{V_t} - 1\right)} \tag{1}$$

To calculate the temperature based on the NTC thermistor 503ET, Steinhart and Hart method as in Equation 2 is used [9]. Here, T is the temperature value in Kelvin, R is the resistance value of the thermistor according to the temperature changes and, A, B and C are the Steinhart-Hart coefficients.

$$\frac{1}{T} = A + B\ln(R) + C(\ln(R))^3 \tag{2}$$

Here, the coefficient A, B and C as in Equation 3, Equation 4 and Equation 5, respectively are derived using three temperature and resistance values of the thermistor 503ET provided in the datasheet. R_1, R_2, and R_3 are the values of resistance at the temperature T_1, T_2, and T_3 [7,8].

$$\frac{1}{T_1} = A + B\ln(R_1) + C(\ln(R_1))^3 \tag{3}$$

$$\frac{1}{T_2} = A + B\ln(R_2) + C(\ln(R_2))^3 \tag{4}$$

$$\frac{1}{T_3} = A + B\ln(R_3) + C(\ln(R_3))^3 \tag{5}$$

NTC Thermistor 503 ET-3H Temperature Sensor Calibration

Before a complete IoT-based BBT measurement can be run, several experiments have been done by conducting a calibration temperature measurement using the NTC thermistor 503ET, along with the measurement using a mercury laboratory thermometer and an Omron BBT device (MC-272L) as a reference temperature measurement. The measurement is conducted according to the procedure, where the thermometers are dipped into hot water. The measurement started when the mercury thermometer is at 42°C and several readings of the temperature are taken while the water is cooling down. Then the readings from the thermistor are compared with the Omron thermometer and mercury thermometer for validation of the temperature measurement.

The aim of this experiment is to get an optimal coefficient value of *A*, *B,* and *C*; as to calibrate the NTC thermistor 503ET. The first coefficient value of *A*, *B,* and *C* are calculated using the temperature and resistance values in the Semitec Corp datasheet of ET Thermistor. After several experiments conducted, a new coefficient value of *A*, *B* and *C* are calculated again. The result of the experiments is shown in the topic of results and discussion part.

BBT Prototype with ThingSpeak System Connection

Figure 2 shows the general system architecture of the IoT-based BBT charting and monitoring system. The Arduino Yun Mini that is integrated with a thermistor is suitable to be implemented as the BBT measurement device on the IoT because of the compatibility on the Arduino Yun Mini in terms of its physical size and the system provided. It will be directly connected with surrounding Wi-Fi when the system is on, and the data can be transmitted to *ThingSpeak* as the IoT platform. The data can be displayed using a computer or a smartphone. *ThingSpeak* is an open source IoT application and application programming interface (API) to store and retrieve data from things using hypertext transfer protocol (HTTP) over the internet or via applications, location tracking applications, and social network of things with status updates [9,10].

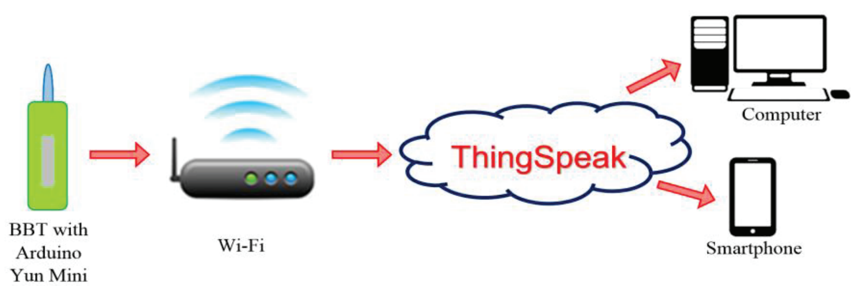


FIGURE 2. General system design of IoT-based BBT.

The temperature measurement from BBT prototype can only be posted or sent to *ThingSpeak* by using certain important parameters given by *ThingSpeak* itself in *ThingSpeak* channel. Before the data can be posted to *ThingSpeak*, it will enter an automatic fever detection function for reliable temperature measurement. Then, the data will be posted as fever or not fever. Figure 3 illustrates the process flowchart of the BBT data posting to the *ThingSpeak*. Following are three important setting parameters that are used in Arduino Integrated Development Environment (IDE) to post data to *ThingSpeak*:

- [thingspeak_update_API] - This will enable the Arduino to go to the *ThingSpeak* channel and get the update of API key.
- [thingspeak_write_API_key] - The API key should be inserted into the coding to make sure that is the right channel for the data to be placed.
- [thingspeakfieldname] - This will enable data to be sent and placed in the right chart for analysis purpose.

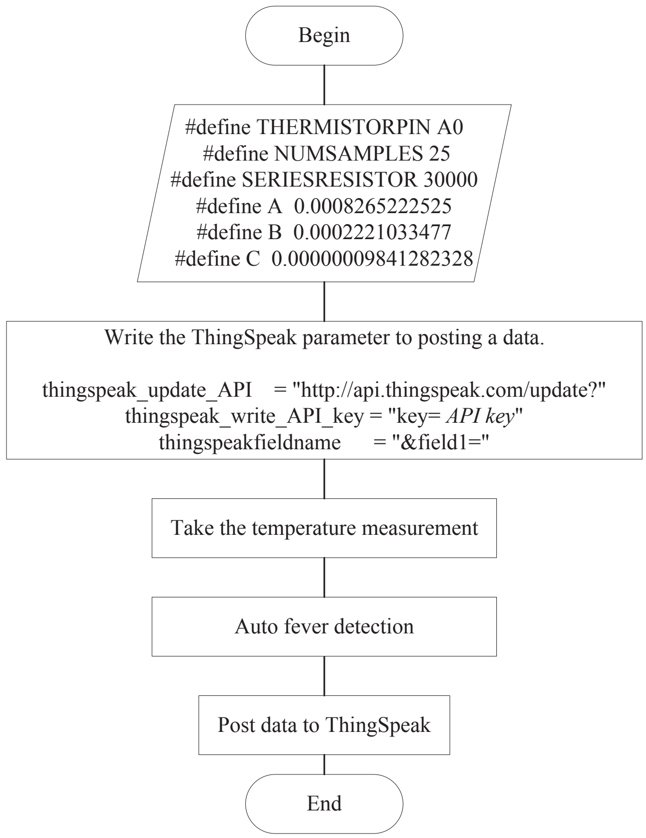


FIGURE 3. Process flowchart of the BBT data posting to the *ThingSpeak.*

RESULTS AND DISCUSSION

Through this research, an IoT-based BBT charting and monitoring system have been developed which is useful for basal body temperature charting and convenient fertility regulation monitoring. This system will be beneficial in improving the conventional BBT charting and monitoring technique in supporting the family planning through the FAM. The data of SUBJECT0113 from a young and healthy female subject with the age of 13 that has experienced a menstrual cycle for about five years will be displayed as a test subject for the BBT prototype with IoT platform. The data also can conveniently be shared with a specific doctor for further fertility consultation.

The NTC Thermistor 503 ET-3H Temperature Measurement and Calibration

Figure 4 shows the first version of the BBT measurement device prototype for the IoT-based BBT charting and monitoring using *ThingSpeak* that has a dimension of 17.5 cm x 3.5 cm x 3.5 cm. It has been designed using SolidWorks software and has been created using 3D printing machine. It has been designed to fit the electronic devices and also the microcontroller; which is the Arduino Yun Mini.

FIGURE 4. A prototype of IoT-based BBT charting and monitoring using *ThingSpeak.*

As mentioned previously, the temperature value from the developed temperature sensor is calculated firstly based on the 503ET thermistor sensor datasheet in order to derive the coefficient values of *A*, *B* and *C*. Table 1 shows the measured data based on the datasheet where the values of resistance R_1, R_2, and R_3 at temperature T_1= 20°C, T_1= 30°C, and T_1= 40°C are used.

TABLE 1. NTC Thermistor 503ET temperature measurement based on values of coefficient *A*, *B* and *C* calculated using data provided in datasheet from Semitec Corp for several experiments

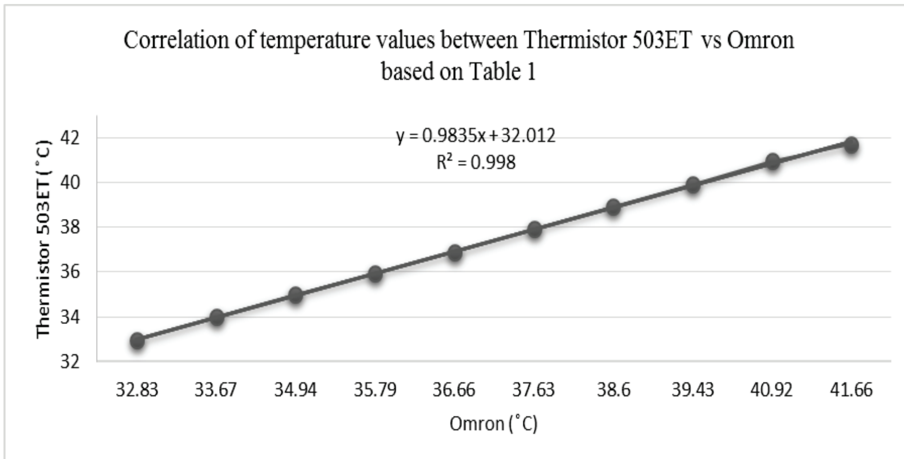
Mercury Thermometer (°C)	Omron Thermometer (°C)	Thermistor 503ET Sensor (°C)	Thermistor Resistance (kΩ)
33	32.83	32.97	35.49
34	33.67	33.98	34.02
35	34.94	34.98	32.63
36	35.79	35.93	31.38
37	36.66	36.90	30.15
38	37.63	37.95	28.91
39	38.60	38.91	27.77
40	39.43	39.90	26.69
41	40.92	40.97	25.56
42	41.66	41.72	24.80

Then, in order to improve the temperature measurement, the results of R_1, R_2, and R_3 from Table 1 are picked at T_1 = 33°C, T_2 = 37°C and T_3 = 42°C to calculate the new values of *A*, *B*, and *C* coefficients. New measured data that are obtained according to the new coefficient values are as shown in Table 2.

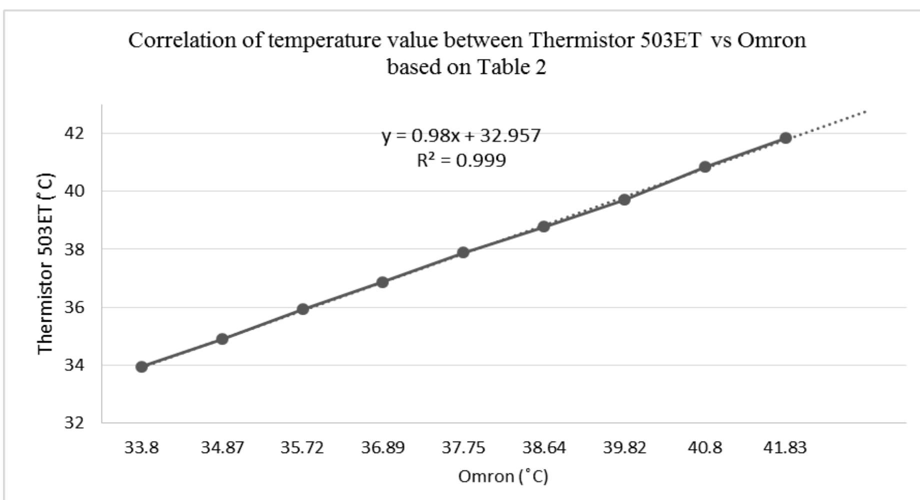
TABLE 2. NTC Thermistor 503ET temperature measurement based on values of coefficient *A*, *B* and *C* calculated using data in TABLE 1

Mercury Thermometer (°C)	Omron Thermometer (°C)	Thermistor 503ET Sensor (°C)	Thermistor Resistance (kΩ)
33	32.74	32.70	35.54
34	33.80	33.95	34.07
35	34.87	34.90	32.94
36	35.72	35.93	31.38
37	36.89	36.88	30.18
38	37.75	37.89	28.95
39	38.64	38.78	27.93
40	39.82	39.71	26.89
41	40.80	40.84	25.69
42	41.83	41.83	24.71

From the two results with different coefficient values of *A*, *B,* and *C*, the first result from Table 2 is more accurate compared to the second result from Table 1 with the datasheet coefficient value. This can be verified by calculating the percentage error for both experimented result. The percentage of error from the first result is 0.56 %, which is higher than the percentage of error from the second result, which is 0.3 %. According to Fig. 5 (a) and (b), the temperature measured using the thermistor 503ET is highly correlated with the temperature from Omron BBT thermometer for the first and second results with 0.998 and 0.999 of correlation coefficients, respectively, where the latter has given a slightly better result compared to the former. Therefore, the thermistor based BBT prototype measurement is applicable to be used in the IoT-based BBT charting and monitoring system.



(a)



(b)

FIGURE 5. Correlation of temperature values between 503ET Thermistor and Omron based on (a) Table 1 and (b) Table 2.

Data Transfer to ThingSpeak and BBT Charting and Monitoring Application

The IoT platform that has been used in this research is the *ThingSpeak*. Figure 6 represents the data of body temperature of *SUBJECT BT0113* that have been posted to *ThingSpeak* channel at 6:15 am from 26 July until 18 August.

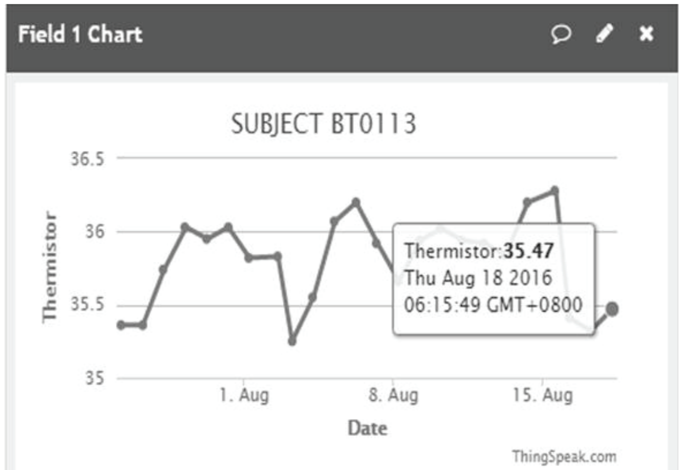


FIGURE 6. *ThingSpeak* channel for the BBT charting

Moreover in Fig. 7 (a) shows the early version of the front page BBT monitoring homepage web application and Figure 7 (b) shows the BBT chart for the *SUBJECT BT0113* which is derived from the *ThingSpeak* channel. It is designed using Notepad++ to design the application using hypertext markup language (HTML). Then, it can be converted to an Android application using Cordova; which is the platform of conversion from the web application to Android application. Meanwhile, in this application, a status of fever or not fever is designed to give the data status as shown in the Fig. 7 (b). The status of data shown is *Not Fever* because the temperature as shown in Fig. 7 (b) is in the range of 34°C to 36°C. Based on these data, the prediction of ovulation and pregnancy also can be done after at least the first trimester (three months) of the data are acquired.

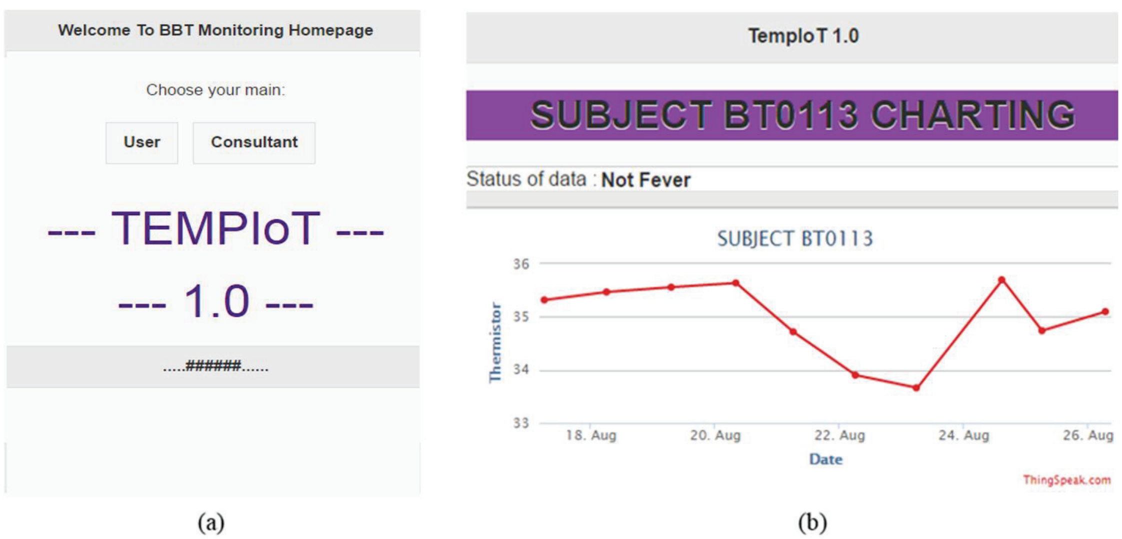


FIGURE 7. Android application for the BBT charting.

CONCLUSION

Family planning is important to a society and it is indirectly related to the development of a country in terms of economy and social aspects. Therefore, actions or supports to facilitate the implementation of family planning are indispensable. Through this research, an IoT-based BBT charting and monitoring system have been developed which is useful for automatic basal body temperature charting and convenient fertility regulation monitoring. This system will be beneficial in improving the conventional BBT charting and monitoring technique in supporting the family planning through the FAM.

The future works will be the development of the fuzzy logic system for the predictions of ovulation and pregnancy, and Android application to complete the IoT-based automatic BBT charting system for fertility monitoring using *ThingSpeak*.

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REFERENCES

1. A.M. Rosliza and M. Majdah, Malaysian J. Public Heal. Med. **10**, 23-27 (2010).
2. N. Ahmad, T. N. Peng, P. Kamarul, and F. Kamarul, "Unfpa - Icomp Regional Consultation," *Fam. Plan. Asia Pacific Addressing Challenges Status Fam. Plan. Malaysia 2010*, pp. 1–30.
3. Health Guides, "Medical Uses of the Birth Control Pill | Center for Young Women's Health," *Center for Young Women's Health*, 2014.
4. Paul Ridden, "Advanced fertility system offers money back pregnancy guarantee," *Gizmag*, 2010.
5. S. Peppet, Tex. Law Rev. **93**, 85-176 (2014).
6. A. Papageorgiou, B. Cheng, and E. Kovacs, "Reconstructability-Aware Filtering and Forwarding of Time Series Data in Internet-of-Things Architectures," in *IEEE International Congress on Big Data 2015,* pp. 576-583.
7. G. Recktenwald, "Temperature Measurement with a Thermistor and an Arduino," *Pdx.Edu*, 2013.
8. W. Storr, "Resistors in Series - Series Connected Resistors," *Basic Electronics Tutorials Site*, 1999.
9. J.S. Steinhart and S.R. Hart, Deep Sea Res. Oceanogr. Abstr. **15**, 497-503 (1968).
10. N. T. Coefficient and W. Rt, "Calibrate Steinhart-Hart Coefficients for Thermistors," 408, pp. 1–3 (2012).
11. Gregg Lavenuta, "An Explanation of The Beta and Steinhart-Hart Equations for Representing The Resistance Vs. Temperature Relationship In Ntc Thermistor Materials Gregg Lavenuta, QTI Sensing Solutions Engineering Department," *QTI Sens. Solut. Eng. Dep.* 2000
12. L. Lawlor, "ThingSpeak," *GitHub, Inc.*, 2016.
13. Krishna Anipindi, Statew. Agric. L. Use Baseline 2015 **1**, 1-4 (2015).