Error rate control in Humidity and Temperature sensors using IoT and ThingSpeak

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Abstract

Internet of things (IoT) in recent years became widely spread over several applications, and use different types of sensors, actuators and software tools. This paper focuses on DHT11 humidity and temperature sensor accuracy; many experiments were conducted to measure readings in different environments and on different sensors.

Readings were uploaded over online server (thingSpeak), from NodeMCU ESP2566 board. Uploaded data were analyzed for different cases. Results showed that in normal conditions, the temperature variance between three sensors was below 0.3 Celsius degrees, and below 2% for humidity. But when added external source of heat and humidity for 10 minutes, the temperature variance increased to 1.4 Celsius degrees and 11% for humidity. To verify the measurements of temperature, an LM35 sensor was added to compare with DHT11 temperature readings, it was found that the readings were almost the same and difference is less than 0.8 Celsius degrees.

It found that accuracy in DHT sensors is fair, especially with applications where readings change in a normal pattern. To alleviate error rate in fluctuating environments, averaging for multiple readings is required to get more accurate values.

Keywords— IoT Device, Humidity sensor, Temperature sensor, NodeMCU, DHT11, LM35, ThingSpeak.

I. INTRODUCTION

Sensors are being used in many devices like healthcare monitoring, for example, body temperature has a direct indication of the human body. Normal human temperature is (98.6˚ F/ 37˚C). A temperature above (100.4˚F/ 38˚C) means that the person is having a fever or illnesses [1]. Sensors generate useful information, making predictions and decision making. The data analysis is used in many rapidly emerging fields like weather conditions, media, agriculture, education, industry, and E -commerce [2].

The goal of this research is to measure the correctness of temperature and humidity sensors (DHT11) practically, detect the variance for the different sensors, and ranges of values, find out ways to alleviate error rate, and to minimize variance between the readings come from the sensors.

II. Related work

Correction and measurement of readings came from sensors were discussed in different aspects. In [3], an IoT Trainer Kit was used, the accuracy of the DHT 11 temperature sensor on the I-Kit was improved. Improvement was carried out using the linear regression method, to find out the correlation between the temperatures of the thermometer with the reading on the sensor in the I-Kit. The standard deviation of the error, which represents the sensor results, has decreased by 20% from 0.88 to 0.704 Celsius degrees.

Authors in [4], highlight an insightful trend of retrieving indoor environment data (temperature and relative humidity) for an office building in a hot and humid climate condition. The indoor parameters were monitored using a combination of a single board microcontroller with an active sensor with well calibrated thermal microclimate devices, it was found that proactive adjustment can be conducted in order to minimize waste.

In [5], a weather station was used, the measured weather parameters include temperature and humidity using DHT-22 sensors, rain sensor, and air pressure sensor. Air pressure measurement results are used to predict the weather. The measurement results of all sensors are stored in memory card and website using ESP8266 Wi-Fi module. The difference of measurement result with an average error of 3.74% for temperature, 2.14% for air humidity.

Design and applications of IoT prototypes with sensors, and software tools like ThingSpeak and similar services are being used in industry, healthcare, smart homes, agriculture, and covering all life aspects [6, 7, 8, 9, 10, 11, 12].

III. RESEARCH METHODOLOGY

A prototype was built to measure the accuracy of humidity and temperature sensors using different scenarios, to explore the ranges where the readings are within the correct values for the sensor module DHT11 shown in figure 1.

DHT sensors are made of two parts, a capacitive humidity sensor and a thermistor. There is also a very basic chip inside that does analog to digital conversion and generates a digital signal with the temperature and humidity. DHT11 temperature range is good from 0 to 50 degrees Celsius with

+-2 degrees accuracy, and humidity range is good from 20 to 80% with 5% accuracy, the accuracy will be less out of these ranges [13].

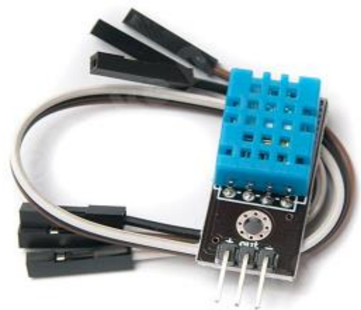

Figure.1: DHT11 module

The connectivity between the prototype and the user was established using Wi-Fi module that is built in NodeMcu ESP8266 microcontroller. NodeMCU shown in figure 2 was programmed to read values from the sensors, and upload the readings to the online website to be analyzed.

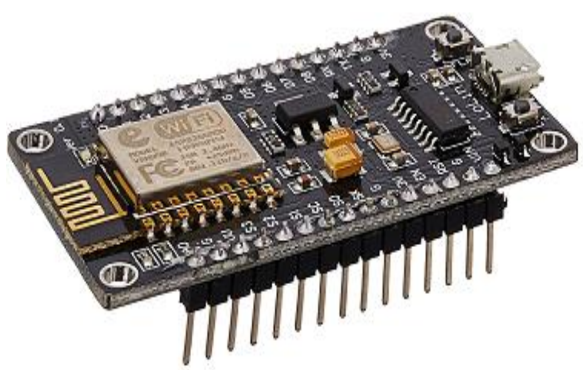

Figure 2: NodeMcu ESP8266 module.

The following steps explain how the procedure work in general:

1. Connect multiple sensors to a microcontroller, and make sure that all sensors experience the same environment.
2. Locate the circuit in a place to record readings for a period of time, it needs about 25 minutes to read 100 values from each sensor.
3. Change the conditions to have different readings.
4. Add other types of sensors to assure that the readings are within the expected values.
5. Record and analyze the results.

Figure 3 illustrates the main parts of the prototype, to connect the NodeMCU with three DHT11 sensors, these sensors are connected through digital IO ports. NodeMCU is equipped with a built-in Wi-Fi module that is used to connect the prototype to the internet. NodeMCU can be powered by batteries to facilitate the mobility of the prototype.

IV. SOFTWARE AND CONFIGURATIONS

NodeMCU was programmed to read the sensors every 15 seconds, and through the wireless connection, reading were uploaded on ThingSpeak website. *ThingSpeak* is the open IoT platform with MATLAB analytics that allows to aggregate, visualize, and analyze live data streams in the cloud. It is used to send data to ThingSpeak from devices, create instant visualization of live data [11].

In the following experiments, ThingSpeak and the code on NodeMCU, were integrated using software keys to upload readings, and store them on the server.

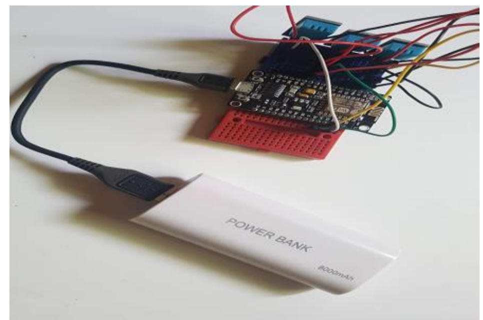

Figure.3: System Components

V. EXPERIMENTS AND RESULTS

To measure readings for different conditions and environments, the prototype was measuring temperature and humidity every 15 seconds. Table 1 shows a sample of three rows out of a 100 rows generated from each experiment, it includes a time stamp, a sequence number to represent the entry_id, and the 6 values of temperature in Celsius degrees (T#) and humidity percentage (H#) from three sensors. The average for each column is calculated, and the average variance is considered between the values from the same type, and the maximum variance was calculated to detect the extreme values.

Table 1: Sample values generated from the prototype

created_at	entry_id	T1	H1	T2	H2	T3	H3
2020-04-17 17:37:19 UTC	34	25	82	25.2	88	22.8	82
2020-04-17 17:37:34 UTC	35	24	79	24.4	84	22.6	80
2020-04-17 17:37:49 UTC	36	23	73	23.7	85	22.4	83

Four experiments were conducted to measure DHT11 accuracy, LM35 sensor was added in the last two experiments as a second sensor to compare results with DHT11 temperature only, since LM35 does not measure humidity. The experiments are:

1. Normal conditions

The first experiment was used to measure the sensor values in a moderate environment in normal conditions inside a room, three DHT11 sensor modules were reading values, and these values are uploaded to the server sequentially.

Figure 4 shows the curves for one hundred readings from 3 different sources and the average, the readings are T1,T2,T3 and the average is T. It is noted that all curves follow the same pattern, and the average temperature (T) is 21.83 Celsius degrees (for 100 readings x 3 sensors), with average variance of 0.169 degrees, and maximum variance of 0.22 degrees.

Figure 5 shows the humidity for the same experiment, the average humidity (H) is 72.47 %, with average variance of 1.32 %, and maximum variance of 1.88 %. The readings are stable with reasonable difference between the sensors.

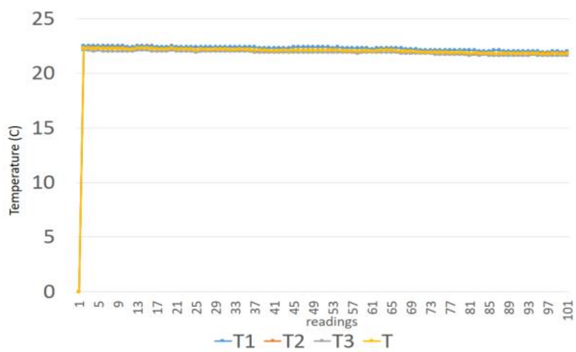

Figure 4: Temperature readings in normal conditions

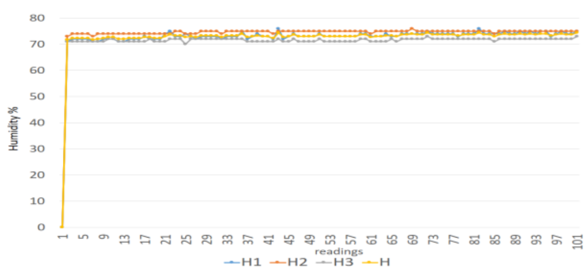

Figure5: Humidity readings in normal conditions

2. Adding hot water

Adding external source of heat and humidity changed the readings significantly, hot water provides additional source of heat and humidity, and the sensors were affected differently. A cup of hot water was placed near the circuit for about 10 minutes, then removed as shown in figure 6.

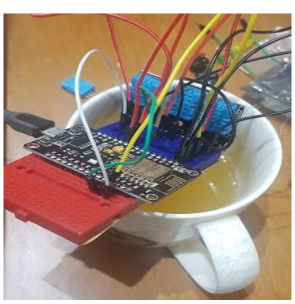

Figure 6: A cup of hot water increased heat and humidity

The hot water changed the readings significantly, sensors reacted differently with a noticeable variance in values for the same type of sensor. Figure 7 shows a significant rise in T1 value from reading 22 to 32 Celsius degrees, and it was over 30 Celsius degrees during the hot water effect was applied, while other readings were below that value, larger variance in the middle compared with other parts. The average temperature variance increased to 0.368 degrees, and the maximum variance approached 1.416 degrees as shown in table 2.

The humidity curves is figure 8 shows much more variance, and readings are highly fluctuating, where humidity exceeded 95% from one sensor, and around 80% at the same moment from other sensors, and the maximum variance around the average was about 10.87 % when the effect of the hot water was applied.

Later, readings were getting closer for both temperature and humidity after the hot water effect was removed.

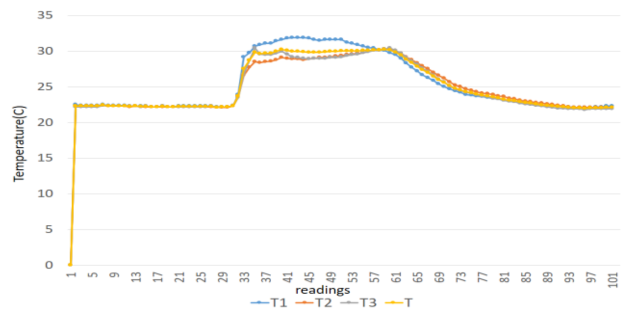

Figure 7: Temperature readings near hot water

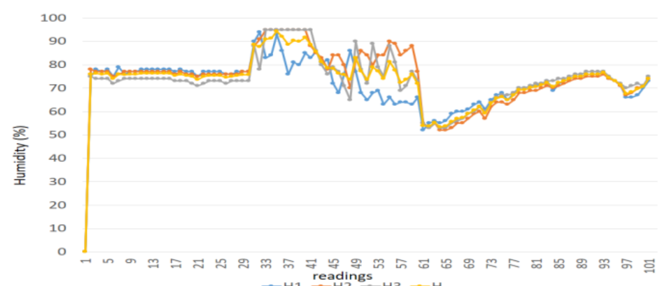

Figure 8: Humidity readings near hot water

Table 2 illustrates a clear increase in variance for both temperature and humidity, from normal to hot water case, the maximum variance in hot water case was more than 5 times the normal case. After the external effect was removed, it took about 10 minutes to stabilize again to similar readings between the different sensors.

Table 2: Normal and hot water conditions

Condition	Avg. Temp (C)	Avg. Humidity (%)	Avg. Temp. variance	Avg. Humidity Variance	Max Temp. variance	Max Humidity variance
Normal	21.83	72.47	0.169	1.329	0.216	1.885
Hot water	24.916	73.267	0.368	2.794	1.416	10.873

Note that the average temperature and humidity include all the 100 reading, and not for the period of hot water effect only, so the average was during the whole 25 minutes.

3. Adding LM35 temperature sensor

To make sure that readings are realistic, another sensor (LM35) was added to compare temperature results. LM35 is an electronic component which has the function to change the value of temperature to be electrical value in a voltage form. LM35 has characteristic of calibration directly into Celsius value, linier scale factor +10mV/C, accuracy level 0.5 C when room temperature (25 C) [14].

Four sensors measured the temperature at the same time as curves shown in figure 9, the DHT sensors behaved the same within the measured values, and the difference between them was less than 0.1 Celsius degrees on the average. LM35 readings were within the range most of the times, some values were accidently higher than the average for a while, but with a maximum variance of 0.8 Celsius degrees as listed in table 3.

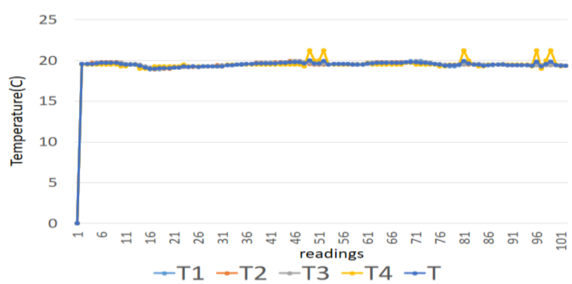

Figure 9: Temperature readings with LM35 sensor added

4. Four sensors under the sun

The last experiment was to change the place, to read temperature values under the light of the Sun, the values jumped from 20 degrees to around 33 Celsius degrees, and the readings varies significantly, for both DHT11 and LM35 as shown in figure 10. It is noticed that the range of readings was from 27 to 35 degrees along the experiment in 25 minutes.

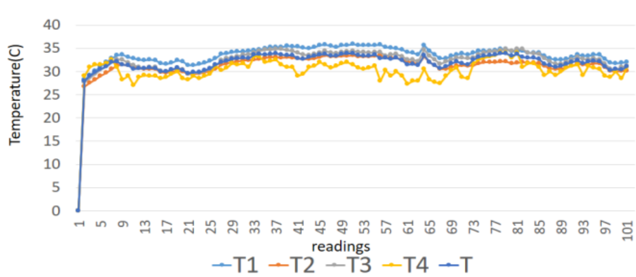

Figure 10: Temperature readings with LM35 sensor added under the sun

The average of all readings (100 readings x 4 sensors) was about 32.32 Celsius degrees, and the maximum variance around the average was 2.935 degrees, especially for LM35 sensor, but all readings were also affected.

The results listed in table 3 clarifies that the variance is affected significantly from shadow to sun light, the heat came from the sun light affected the readings differently, even if sensors from the same type. DHT11 readings were close to each other if conditions are normal, but varied significantly if external source of heat was applied.

Table 3: LM35 sensor added

Condition	T1 (C)	T2 (C)	T3 (C)	T4 (LM35) (C)	T (Avg) (C)	Max Temp. variance
With LM35, Shadow	19.321	19.325	19.346	19.415	19.331	0.801
With LM35, Sun Light	33.372	31.232	32.356	30.138	32.32	2.935

VI. CONCLUSIONS

- A prototype to measure temperature and humidity was built using different DHT11 sensors and NodeMCU microcontroller.
- The variance in normal cases was very small, it was less than 0.2 Celsius degrees on the average for temperature, and less than 2 % for humidity, and that is due to the same fabrication for all sensors.
- The variance was much larger when external source of heat and humidity was added. It was about 5 times the variance for both temperature and humidity. The sensors reacted differently when sudden changes applied, especially when humidity exceeded 80%, and the error rate became greater.
- DHT11 and LM35 reading were close to each other in normal cases, with variance of 0.8 Celsius degrees maximum. This variance increased not only between DHT11 and LM35, but also between the DHT11 sensors.
- Error rate and variance are reasonable for stable environments, where readings change in normal pattern.
- Error rate and variance are high and accuracy decrease in fluctuating environments, to alleviate the effect of alternating readings:
  - Take multiple readings from the same sensor to average them with a value.
  - Adding more than one sensor in sensitive applications will decrease the error rate, because some sensors behave differently in the same environment.
  - The longer periods, and the more values, the better accuracy.

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