Fuzzy Logic for an Implementation Environment Health Monitoring System Based on Wireless Sensor Network

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***Abstract*—Internet of Things (IoT) has become popular with the development of technology, which allows each physical device identified, managed and recorded by computer. In the context of Wireless Sensor Networks (WSNs), it is important for everyone to know the latest information of the status of human health, for example the condition of the surrounding environment. In the paper, we proposed an implementation of environmental health conditions monitoring through WSN with fuzzy logic that could be monitored in real time anywhere and anytime. In our proposed system, we used a sensor temperature, humidity, Carbon Monoxide (CO) and Carbon Dioxide (CO2), luminosity, noise for node sensors. For decision-making environmental health conditions with fuzzy logic, we have 5 categories, such as Very Good (VG), Good (G), Medium (M), Bad (B) and the last is Dangerous (D). The data were sent from the sensor node to the gateway using ZigBee IEEE 802.15.4 standard. The data received from the sensor node were stored into the database provided by the gateway and to be synchronized with external databases (database server) using TCP/IP. Users can access the data sensor via the website or mobile application such as Desktop, PCs, Laptop, and Smartphones.**

***Index Terms*—Internet of Thinks (IoT); Fuzzy Logic; ZigBee, IEEE 802.15.4; TCP/IP.**

I. INTRODUCTION

In recent years, research in Wireless Sensor Networks (WSNs) has experienced significant growth. A topic of interest used in WSNs for detecting health environmental is the common phenomenon, such as air pollution disaster, which it a serious threat for humans. Much available mechanism for monitoring health environment in the literature used WSN and other methods. Researchers have conducted research in various fields, such as military, medical, industry, water quality, habitat, greenhouse, fires forest, and environmental monitoring [1]. Environmental monitoring has become a very important part of WSN application, and it has grown concomitantly with the latest technological developments. To perform the environmental monitoring, data and information for measurements in the field and laboratory analysis are needed.

Air pollution is becoming an important issue that can threaten human life. There are many human activities that cause air pollution. The nature of the air resulting the impacts of air pollution can be directly and locally, regionally, and globally. Many researchers are doing research about air pollution. For example [2][4][5], they proposed a monitoring system that monitors environmental conditions using multiple sensors, such as Carbon Dioxide (CO2), Carbon Monoxide (CO), NO2, and Oxygen (O2), Temperature, Humidity, as well as implements human health monitoring, such as body temperature, heartbeat, and oxygen in blood [3]. Other researchers [4] proposed an approach to measure temperature and humidity with Arduino module and Raspberry Pi. The results of the data retrieval were saved to the database and shown on the website. To display data sensor that has been done by [6], the authors used PHP (Hypertext Preprocessor), MySQL database and display the location web-based in the form of graph.

More recently, a lot of software/hardware have been used to transmit data such as Bluetooth, wifi, 3GPRS / 3G. In this research [3][4][5][9][10]. They used the IEEE 802.15.4 standard ZigBee communication, where the technology is low cost, low power, low data rate, highly reliable, wireless networking protocol that is very secure. This communication has become popular in the development of application systems.

From the explanation [1][2][4][5][6], they measured and knew the environmental monitoring of surrounding, and data shown through a website. It has been helping people to know the condition of environment surrounding, but this system could not make a decision whether the condition is good, moderate, or bad. However, [7] in this system has been using a fuzzy logic algorithm for a case of fires forest, wherein, the sensor used in this system are sensor temperature, humidity, light, distance, and smoke. Then, input membership in each sensor categorized the results, such as Very Low (VL), Low (L), Medium (M), Height (H), Very Height (VH). Further [8], monitored the Indoor Air Quality (IAQ) of the subway in Greece and they proposed a fuzzy algorithm to determine air quality.

In the paper, we proposed an implementation of the health condition environmental monitoring system based on WSN with fuzzy logic to make decision about environmental conditions on the measurement of data sensor. In this work, we collected sensor data, such as temperature, humidity, CO and CO2 from the sensor nodes. The system automatically assigns the decision of the measurement results from data sensor in the form of warning, such as Very Good (VG), Good (G), Medium (M), Bad (B) and Dangerous (D). In this work, we collected sensor data such as temperature, humidity, luminosity, noise, CO and CO2 from the sensor nodes. Then, the sensor data transmitted via communication-based IEEE 802.15.4 to the gateway for temporary storage. Furthermore, the sensor data collected in the gateway and synchronized to Data Center Server via TCP / IP to store permanently. All users can access sensor data via mobile or web-based applications.

II. OVERVIEW FUZZY LOGIC

In this section, we explain the fuzzy logic for monitoring environmental conditions[7][8]. Fuzzy logic was first introduced by Lotfi Zaidah in 1965[7]. This method uses artificial intelligence to make decision based on human thinking in the processing of one or many inputs. Fuzzy logic is divided into three stage, namely fuzzification, fuzzy processing, and defuzzification. Figure 1 shows an architecture fuzzy logic system.

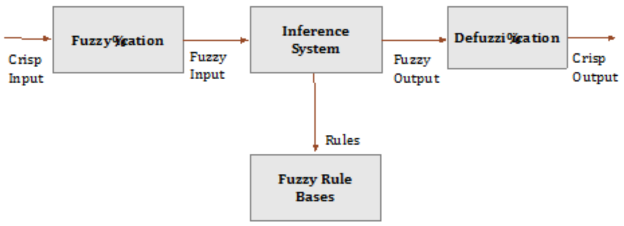

Figure 1: Architecture fuzzy logic system

a) Fuzzification : This phase involves changing the inputs whose truth value is uncertain (crisp input) in the form of fuzzy input.
b) Inference System : This phase is an analysis phase, resulting in the fuzzy output, which utilizes fuzzy input and fuzzy rules which have been determined in the earlier phase.
c) Defuzzification : This phase changes the fuzzy output into a crisp value based on the predetermined membership functions.

III. METHODOLOGY

In this section, we discuss our proposed Fuzzy Logic for Environment Health Monitoring system based on Wireless Sensor Network (WSN). Figure 2 shows the topology for the environment health monitoring.

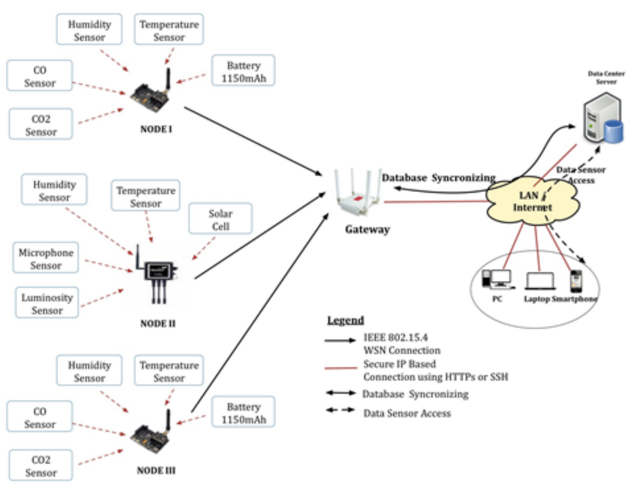

Figure 2: Proposed system for environment health monitoring

In this our proposed system, we proposed an implementation of health condition environmental monitoring system based on WSN with fuzzy logic as the decision making about environmental conditions based on the measurement of data sensor. In this system, we collected sensor data such as temperature, humidity, CO and CO2 from the sensor nodes. The system automatically assigns the decision of the measurement results from data sensor in the form of warning, ranging from Very Good (VG), Good (G), Average (A), Bad (B) and Dangerous (D). In this work, we collected sensor data such as temperature, humidity, luminosity, noise, CO and CO2 from the sensor nodes. Then, the sensor data transmitted via communication based on IEEE 802.15.4 to the gateway for temporary storage. Furthermore, the sensor data collected in the gateway and synchronized to Data Center Server via TCP / IP to store permanently. All users can access sensor data via mobile or web-based applications (PCs, Laptop, Smartphone).

Figure 3 shows the proposed fuzzy logic algorithm system, which consists of fuzzification, inference system (fuzzy rule bases), defuzzification and the output warning sign for environment health condition, in which we build a decision making with rules.

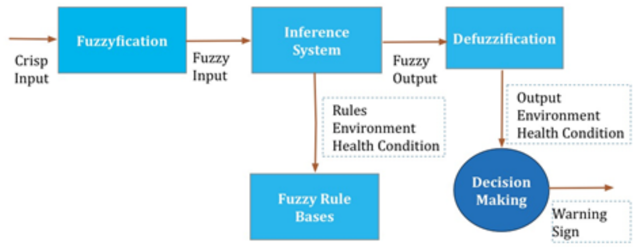

Figure 3: Proposed fuzzy logic system

A. *Fuzzification for Health Monitoring*

Fuzzification is a process of translating output in the form of fuzzy. Fuzzification gives a membership degree value ranges between 0 to 1. Figure 4 to 9 shows membership degrees such as temperature, humidity, Carbon Monoxide (CO) and Carbon Dioxide (CO2) and output to health condition environmental.

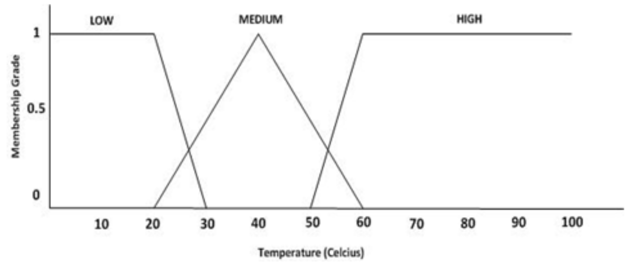

Figure 4: Membership degrees for temperature

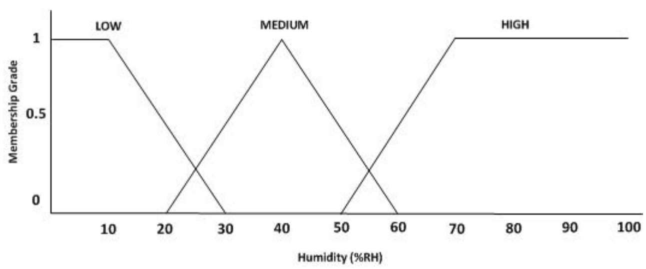

Figure 5: Membership degrees for humidity

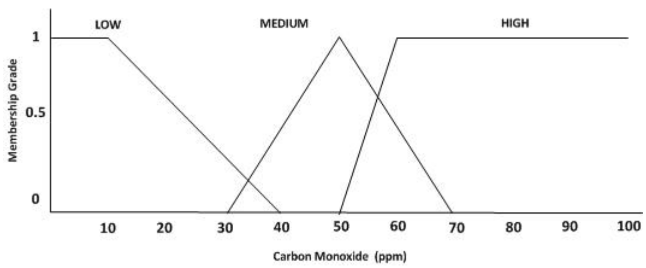

Figure 6: Membership degrees for Carbon Monoxide (CO)

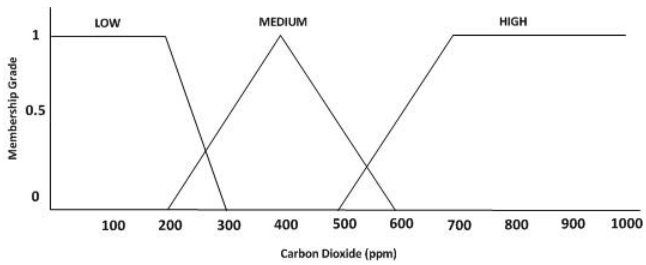

Figure 7: Membership degrees for Carbon Dioxide (CO_2)

Figure 8: Output Membership Health Condition

B. Rules Based

This system analysis utilizes fuzzy input and fuzzy rules which have been determined earlier, leading to fuzzy output. In this proposed inference system, we have 4 input variables and each comprise 3 fuzzy output. Here, a total of 81 rules were used to make decisions, in which we used 4 membership degree, where every single membership has 3 output i.e LOW, MEDIUM, HIGH. In this case, we calculated 3 output membership at a time with 4 input membership, resulting a total of 81 rules. Some of the used rules, for example are as follows:

IF Temperature is LOW and Humidity is HIGH and CO is LOW and CO2 is LOW, then Output is Very Good

IF Temperature is LOW and Humidity is HIGH and CO is LOW and CO2 is MEDIUM, then Output is Good

IF Temperature is LOW and Humidity is MEDIUM and CO is MEDIUM and CO2 is MEDIUM, then Output is MEDIUM

IV. Results and Discussions

In this section, we describe the results from our experiment. Table 1 shows the specification hardware and software and Table 2 shows the rule for fuzzy logic which we used in the experiment.

Table 1
Specification software and hardware used in the experimental [11]

Sensor Node	Hardware	Software
NODE 1, 2, 3 (GASES SENSOR)	Microcontroller ATmega1281 14MHz, SRAM 8KB, EEPROM 4KB, FLASH 128KB, Clock RTC 32KHz, 802.15.4/ZigBee 2.4GHz	
Gateway	Geode Integrated AMD PCS x86 Processor 500MHz, cache memory 128KB, RAM 256MB, Disk 8GB, Linux Debian kernel-2.6.30, WiFi Atheros AR5213A 802.11b/g 100mW - 20dBm, XBee Pro 802.15.4 2.4GHz 100mW, Ethernet Controller VIA VT6105M [Rhine III] and GNU C Compiler 4.3	OS X 10.10 Waspmote IDE PHP MySQL

Table 2
Sample output of Condition Health Environment

No	Temp (Celcius)	Humidity (%RH)	CO (ppm)	CO2 (ppm)	Value Fuzzy	Condition Health
1	32	89	15	335	50.00	M
2	31	89	15	335	50.00	M
3	32	89	59	335	52.55	M
4	33	89	59	335	54.41	M
4	35	91	59	335	61.00	B
5	33	91	59	335	61.00	B
6	33	86	59	335	62.33	B
7	31	84	15	335	60.02	B
8	33	83	15	335	59.95	M
9	32	83	15	335	59.95	M
10	31	82	15	335	59.17	M

In the experiment, we captured the data from data sensor every five minutes. Each data sensor sent the data to the gateway by IEEE 802.15.4 standard. The data sensor will be saved to the database, which provide the gateway where the gateway has a small storage. Sensor nodes will measure environmental conditions of several sensors described earlier. To determine the health condition, we used fuzzy logic to determine the condition of the sensor that automatically make a decision, as indicated in Table 3. Each sensor has a value such as the temperature = 32, Humidity = 89, Carbon Monoxide (CO) = 15, Carbon dioxide (CO_2) = 335, value fuzzy = 50.00. Then, the decision of fuzzy for the current health condition is Medium (M). Further, Figure 10 shows the data sensor luminosity and microphone and Figure 11 shows the data sensor temperature, humidity, Carbon Monoxide (CO) and Carbon Dioxide (CO_2), which we take the data at every 5 minutes.

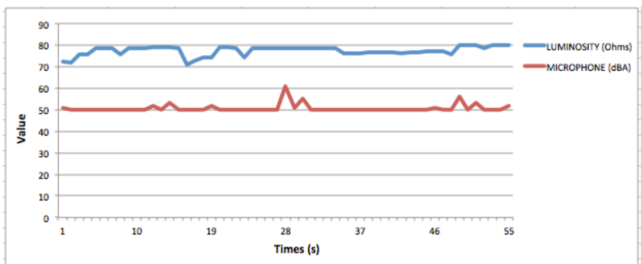

Figure 9: Data sensor luminosity and microphone

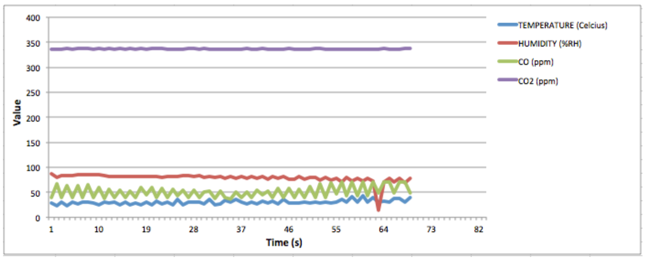

Figure 10: Data Sensor Temperature, Humidity, CO and CO2

V. CONCLUSION

In this paper, we proposed an implementation of environmental health conditions monitoring through WSN with fuzzy logic that could be monitored in real time anywhere and anytime. In our proposed, we used sensor temperature, humidity, Carbon Monoxide (CO) and Carbon Dioxide (CO2), luminosity, noise for node sensors. For the decision making with fuzzy logic, it shows the current state of the environment in accordance with the rules described in this paper. Based on the experiment, the measurements obtained a temperature sensor value = 32, Humidity = 89, Carbon Monoxide (CO) = 15, Carbon dioxide (CO2) = 335, fuzzy value = 50.00 with a decision fuzzy identified as MEDIUM.

VI. FUTURE WORK

For the future work, we will measure the power usage of battery consumption in each sensor node.

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REFERENCES

[1] Othman M. F. and Shazali K. 2012. Wireless Sensor Network Applications: A Study in Environment Monitoring System. *International Symposium on Robotics and Intelligent Sensors 2012 (IR IS 2012), Procedia Engineering* 41. 1204– 1210.

[2] Prasad Y. R. V., Baig M. S., Mishra R. K., Rajalakshmi P.,. Desai U. B. and Merchant S. N. 2011. Real Time Air Pollution Monitoring System. ICTACT *Journal on Communication Technology*. 2: 370-375

[3] Al Rasyid M.U.H., Lee B.H., and Sudarsono A. 2015. Wireless Body Area Network For Monitoring Body Temperature, Heart Beat And Oxygen In Blood. IEEE *2015 International Seminar on Intelligent Technology and Its Applications*. 95-98.

[4] Ferdoush S. and Li X. 2014. Wireless Sensor Network System Design using Raspberry Pi and Arduino for Environmental Monitoring Applications. *The 9th International Conference on Future Networks and Communications* (FNC-2014). 103-110

[5] Lambebo and Hagnani S. 2014. A Wireless Sensor Network for Environmental Monitoring of Greenhouse Gases. ASEE 2014 *Zone I Conference* - April 3-5, University of Bridgeport, Bridgpeort, CT, USA, ScienceDirect

[6] Chen P. and Lu Z., 2013. A Web-based Indoor Environment Monitoring System Using Wireless Sensor Networks. *2013 International Conference on Computational and Information Sciences,* IEEE. 2007-2010

[7] Manjunatha P., Verma A. K. and Srividya A. 2008. Multi-Sensor Data Fusion in Cluster based Wireless Sensor Networks Using Fuzzy Logic Method. IEEE. 1-6

[8] Upadhyaya G. and Dashore N. 2010. Monitoring of Air Polution by Using Fuzzy Logic. *International Journal on Computer Science and Engineering*. 02: 2282-2286.

[9] Al Rasyid M.U.H., Lee B.H., Sudarsono A. and Taufiqurrahman. 2015. Implementation of Body Temperature and Pulseoximeter Sensor for Wireless Sensor Network. *Sensors and Materials*. 27(8): 727-732.

[10] Al Rasyid M.U.H., Nadhori I.U., Sudarsono A. and Luberski R. Analysis of slotted and unslooted CSMA/CA Wireless Sensor Network for E-healtcare System. IEEE. 53-57

[11] Libelium – Connection Sensor to the Cloud, http://www.libelium.com/[Access on November 2015].