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An implentation of IoT for environmental monitoring and its analysis using k-NN algorithm

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ABSTRACT

Environmental monitoring is a process for observing around with various conditions. Recently, internet of things (IoT) and wireless sensor network (WSN) technologies support to solve these problems. In this paper, we implemented a system to monitor environmental conditions using IoT and WSN technology. The data measure is temperature, humidity, carbon monoxide (CO) and carbon dioxide (CO2) sensors. All sensor data will be sent and stored to the cloud through the internet in real-time. We provide applications for monitoring website and mobile phone-based environmental conditions, so users can access wherever and whenever. Furthermore, we also confirm the evaluation of analyst data that used k-NN method is better than other methods with an accuracy rate of 99.0657%.

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1. INTRODUCTION

The environmental conditions at this time are very important for monitoring every activity in some important activities. At this time, environmental conditions often occur erratic changes so conventional predictions do not go well and effectively. Recently, there have been several technologies that can monitor and predict environmental conditions such as the internet of things (IoT) [1]. IoT is produced a lot from applications such as to conduct human health monitoring in real time which is better known as e-Health [2], military [3], smart city [4], [5], agriculture [6], [7], and so on [8]. The various applications of IoT technology are used to make predictions using various methods such as fuzzy logic [9]-[11], support vector machine (SVM) [12], decision tree [13], and so on.

IoT technology provides a solution for monitoring environmental conditions in accordance with the conditions and locations taken as observation objects. Some studies measure the conditions of temperature, humidity, light intensity, CO, and CO2. All these sensors will be connected to the Arduino microcontroller as a sensor node, then the data will be sent and stored gateway using the Raspberry Pi [14]. So that users can monitor environmental conditions in real time. Many methods are used in monitoring environmental conditions, in [15], a website for monitoring air pollution in real time that is information to the public both in graphical form and in the form of data. Hudhajanto *et al.* [16], studied Twitter was used to disseminate information about agriculture such as soil moisture to followers and also Facebook is a social media that is used to convey information to users about environmental conditions such as temperature, humidity, CO, and CO2. Souza *et al.* [17], it provides information about the height of the volume of water to monitor flooding. Short message service (SMS) is used to deliver an early warning about flooding to the user continuously.

Nowadays, many studies make predictions with different methods to test the accuracy of classification. Karakostas [18], applied a system for the prediction quality of data transmission for flight delay using the Naïve Bayes algorithm. Furthermore, in this research, this paper shows system monitoring by real-time for fungal detection in crop fields. The support vector machine (SVM) method to process and prediction such as temperature, relative air humidity, and wind speeds [19].

In this paper, we propose a system to implement IoT technology for environmental monitoring by continuously. We use temperature, humidity, carbon monoxide (CO) and carbon dioxide (CO2) sensors. The data sensors will be sent to the gateway using communication ZigBee 802.15.4. All the sensors data will be saved to the database provider and will be sent to the cloud by real time. So, users can directly access the environment condition by web-based application or smartphone. Furthermore, the result the data collection we will compare several methods to prediction environmental based on previous research using Naïve Bayes [18], support vector machine (SVM) [19], neural network (NN) and the last k-nearest neighbor (k-NN)

2. RESEARCH METHOD

2.1. Architecture system

In monitoring environmental conditions consists of several nodes to take measurements around it. Sensor nodes can measure environmental conditions such as temperature, humidity, CO and CO2. All sensors will be merged into one module to the Arduino microcontroller [20]. To communicate between sensor nodes and local servers using Xbee 802.15.4 [21]. In local servers, the Raspberry Pi 3 [22] used to develop because it is low-cost and easy to use and open source [23], [24]. Users can access information data environmental conditions by real-time through Websites and/or smartphone. And also, we provide to analyze accuracy using some algorithm such as Naïve Bayes [8], support vector machine (SVM), neural network (NN) and the last k-nearest neighbor (k-NN). Figure 1 shows the architecture system for environmental monitoring using IoT.

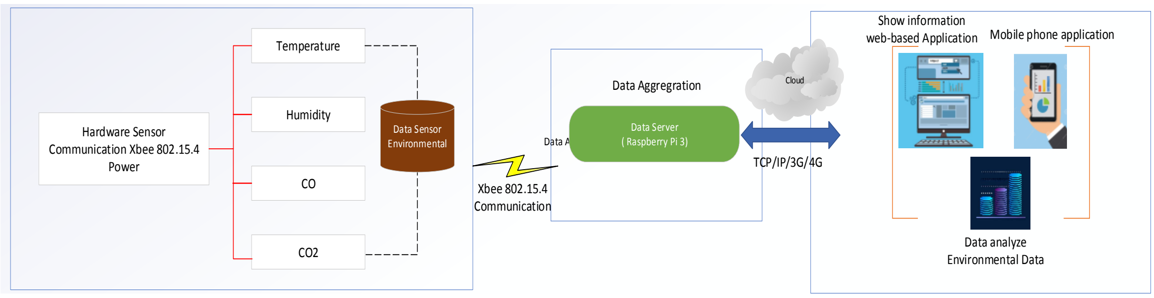

Figure 1. Architecture of the system for environmental monitoring using IoT

2.2. Sensor node configuration

Figure 2 shows the hardware configuration used in this project. In this experiment, we use some sensors to put at microcontrollers such as temperature, humidity, CO and CO2 sensors. For communication, we use Xbee 802.15.4 because we know it is low-cost, low-power and easy to use.

2.3. Sensor node configuration

In this gateway, a mini personal computer (PC) provided by Raspberry. The type used is Raspberry pi 3. Figure 3. Shows the gateway use configuration as a local server. To communicate between the sensor node and the gateway, Xbee 802.15.4 is used, plugging Xbee 802.15.4 by using a dongle via the raspberry USB port. The operating system used is Raspbian which can be downloaded provided by the Raspberry site for free. In this project, using a memory card with capacity 32GB as data storage. Furthermore, we also install some supporting application, such as python, java, web server, open port java and so on.

2.4. Cloud

To accommodate sensor data that has been received from Java-based applications, a system is designed using the my structured query language (MySQL) database. The application is built using the personal home page (PHP) programming language and uses structured query language (SQL) syntax to access data on the database. This application aims to bridge system. applications on gateway devices in storing data to external storage media (cloud storage) as well as serving data access in JavaScript object notation (JSON) format on web-based and/or Android-based applications [25]. Figure 4 shows the system in the cloud.

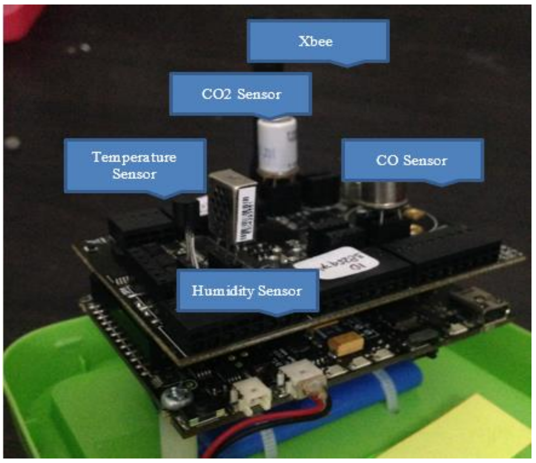

Figure 2. Hardware use to environmental monitoring conditions

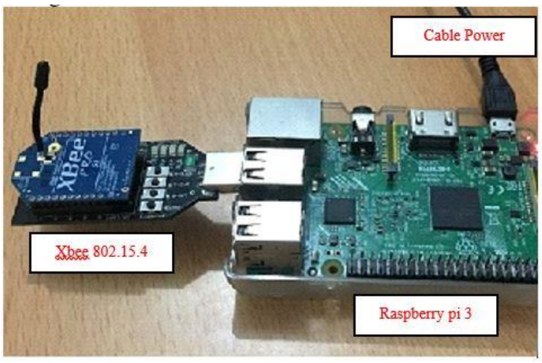

Figure 3. Gateway used Raspberry

2.5. Real-time classification

Real-time classification uses analyzes using some method based previous research [18], [19]. In this study, we use algorithm k-nearest neighbor (k-NN) used classification towards objects based on learning data the distance closest to the object. Based previous work [18], [19], we use 4 classification algorithm to compare for the discuss this project. Classification used is Naïve Bayes, SVM, neural network and k-NN methods. In the experiment, in this experiment, the test sample will be taken live sensor by taking the nearest neighbor class. Near or far neighbors are usually calculated based on Euclidean distance,

$$D(a,b) = \sqrt{\sum_{k=1}^{d}(a_k - b_k)^2} \tag{1}$$

where, $D(a,b)$is a scalar distance of two data vectors a and b in the form of dimension D dimensions.
Let $R = (x_1, y_1), \ldots \ldots, (x_n, y_n)$ a sequence of the training example. For every $x \in X$, let $\pi_1(x), \ldots \ldots, (x_n, y_n)$ be an arrangement of $(1, \ldots \ldots .. n)$ base to the distance to $\rho(x, x_i)$. For all $i < n$,

$$\rho\left(x, x_{\pi\, i(x)}\right) \leq \rho\left(x, x_{\pi\, i+1(x)}\right) \tag{2}$$

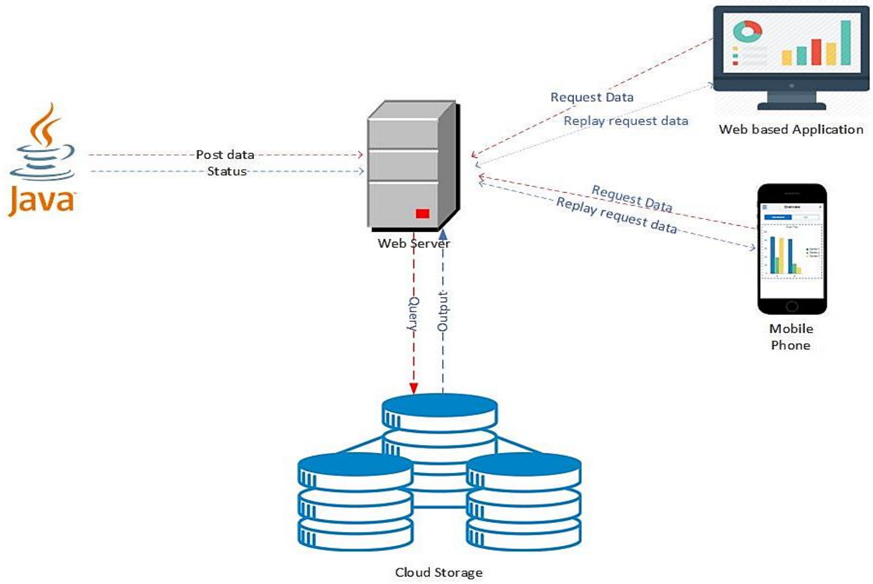

Figure 4. System in the cloud

3. RESULTS AND ANALYSIS

In this section, we explain the result of our implementation and show the analysis we provided. In this project, we show the topology in Figure 5 with software and hardware we used in this experiment. In this experiment, Table 1 we show software and hardware use. Our experiment of environmental monitoring using IoT technology which can be monitoring environment condition by real-time. We manage to send data from the sensor node to the gateway every 10 seconds through Xbee 802.15.4 communication.

We manage to send data from the sensor node to the gateway every 10 seconds through Xbee 802.15.4 communication. All data will be processed at the gateway (Raspberry Pi) through a java program that has been developed. In this process, the data will be parsed first, after which it is saved to the MySQL database. Furthermore, it will also be done simultaneously to send sensor data to the cloud via the internet network. The aim is so that users can access environmental conditions in real time wherever they are, environment conditions through websites and/or mobile phones. Figure 6 shows the website we provide for environmental monitoring.

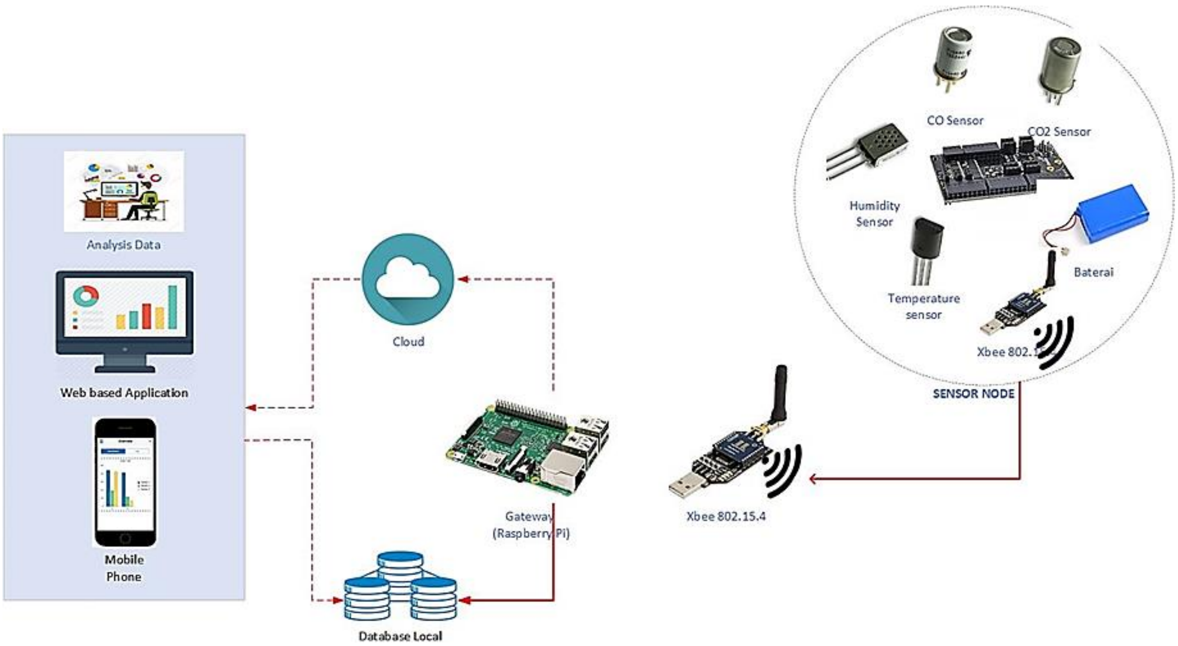

Figure 5. Proposed topology our experiment

Table 1. Software and hardware use in implementation

Sensor Node	Gateway
Microcontroller, xbee 802.15.4, Temperature MCP9700A, Humidity 808H5V5, Carbon Dioxide (CO) Sensor TGS2442, Carbon Monoxide (CO2) TGS4161 sensors, battery 3.7 Volt, Xbee shied	SoC: Broadcom BCM2837, CPU: 1.2 GHZ quad-core ARM Cortex A53, GPU: Broadcom VideoCore IV @ 400 MHz, Memory: 1 GB LPDDR2-900 SDRAM, Network: 10/100 MBPS Ethernet, 802.11n Wireless LAN, Bluetooth 4.0, Memory 32GB, OS Raspbian, Web Server, Phyton, Xampp, Java

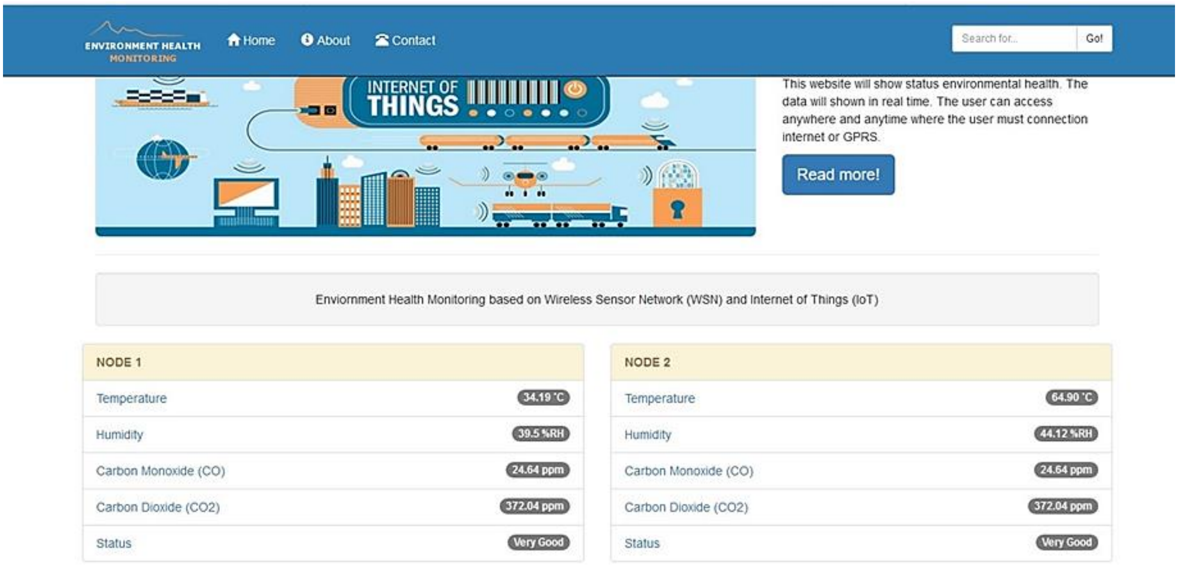

Figure 6. Information environmental condition through web-based application

Figures 7-10 are example data sensor which used to measurement environmental condition such as temperature, humidity, CO and CO2. All data we collect indoor room start 08.00 AM until 20.00 PM. in this experiment, we measurement all the data sensors in 3 condition is morning, afternoon and evening. Figure 7 show the measurement condition temperature data sensors with 3 condition is morning, afternoon and evening. Figure 9 shows the data sensor humidity. The sensor will be measurement every 10 second with 3 condition is morning, afternoon and evening. Figure 9 and Figure 10 shows the data sensor CO and CO2. The data CO and CO2 data have the same concentration with ppm concentration.

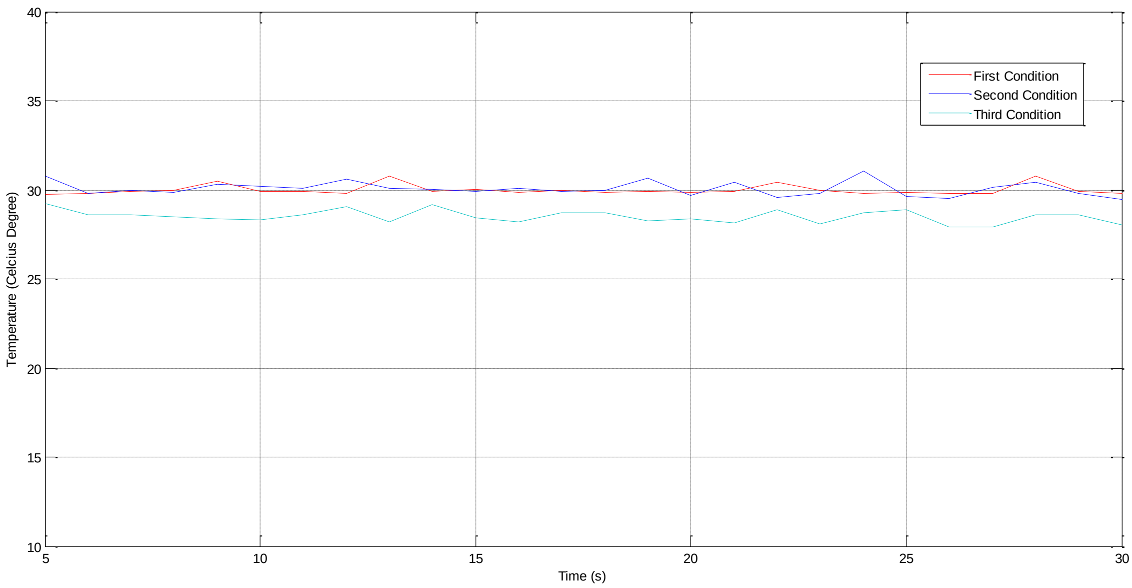

Figure 7. Temperature data sensor from the measurement

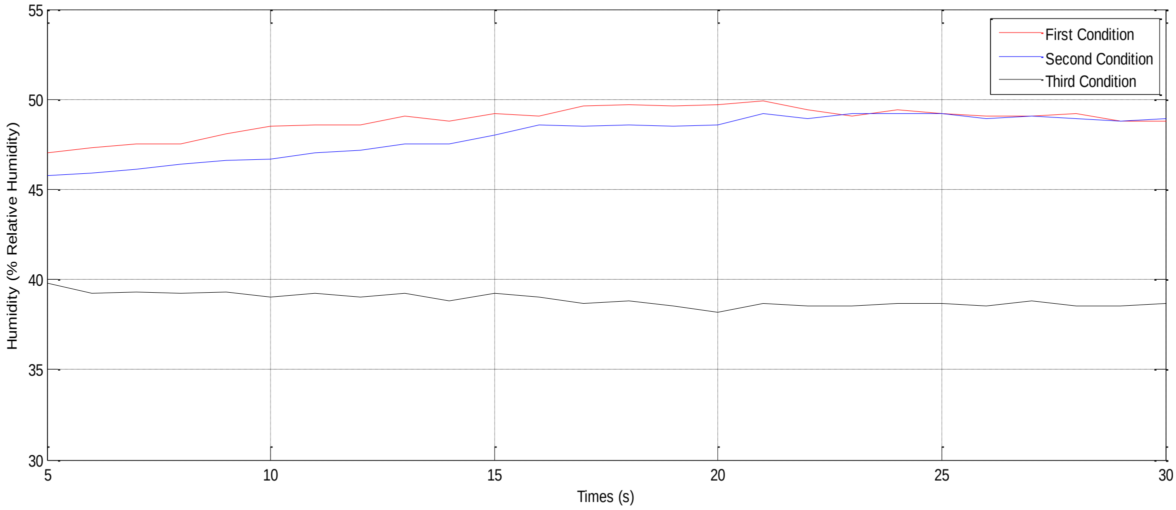

Figure 8. Data sensor humidity sensors

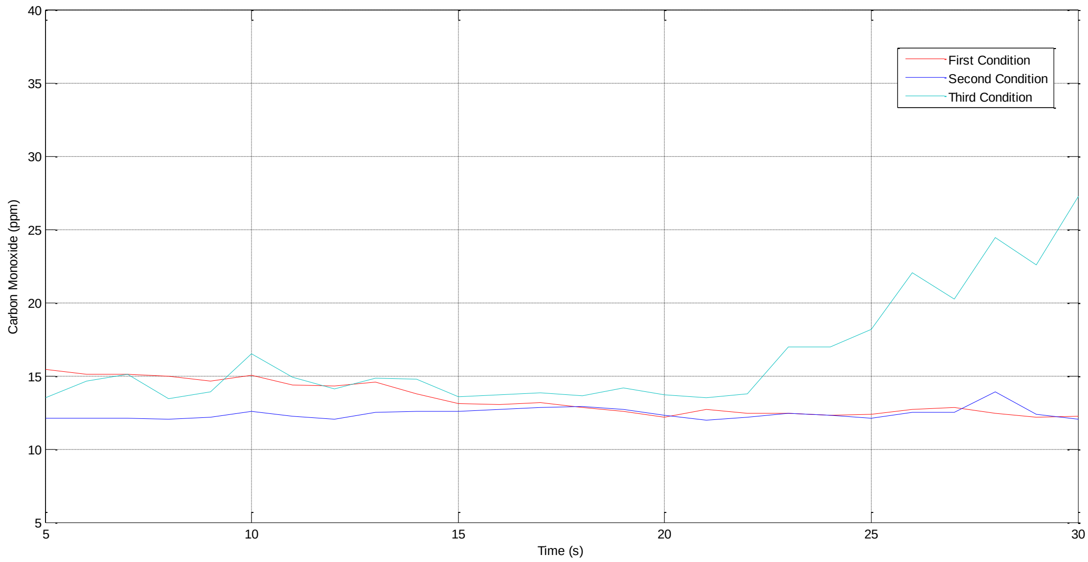

Figure 9. Carbon monoxide (CO) concentration

Furthermore, our experiment was managed by testing the performance of Naïve Bayes, support vector machine (SVM), neural network and k-nearest neighbor (k-NN), using default parameters used for monitoring the environmental condition. we test the data from measurement of the condition environmental by real-time. In the four datasets, we test the accuracy rate, mean squared error (MSE), and shows the total data instances. The performance every algorithm shows the accuracy with Naïve Bayes MSE 0.1199 and accuracy 97.3579%, SVM with MSE 0.2885 and accuracy 95.8687%, neural network (NN) with MSE 0.0629 with accuracy 98.5749%, and the last algorithm k-NN with MSE 0.0078 with accuracy 99.0657%. The result from the compare some algorithm, the k-NN is better from the other algorithm with accurate up 90%. Table 2 shows some sensor we use, MSE and accuracy.

Figure 11 shown the data comparison some method to calculate accuracy each algorithm. And also, Figure 12 shown the MSE each algorithm. Based Figure 11 we can see the MSE each algorithm to environmental condition by real-time. Based on the classification we use, the algorithm k-NN better than the naive Bayes, SVM and neural network methods, with an error rate 0.0078, while Naive Bayes 0.1199, SVM 0.2885 and finally is neural network 0.0629.

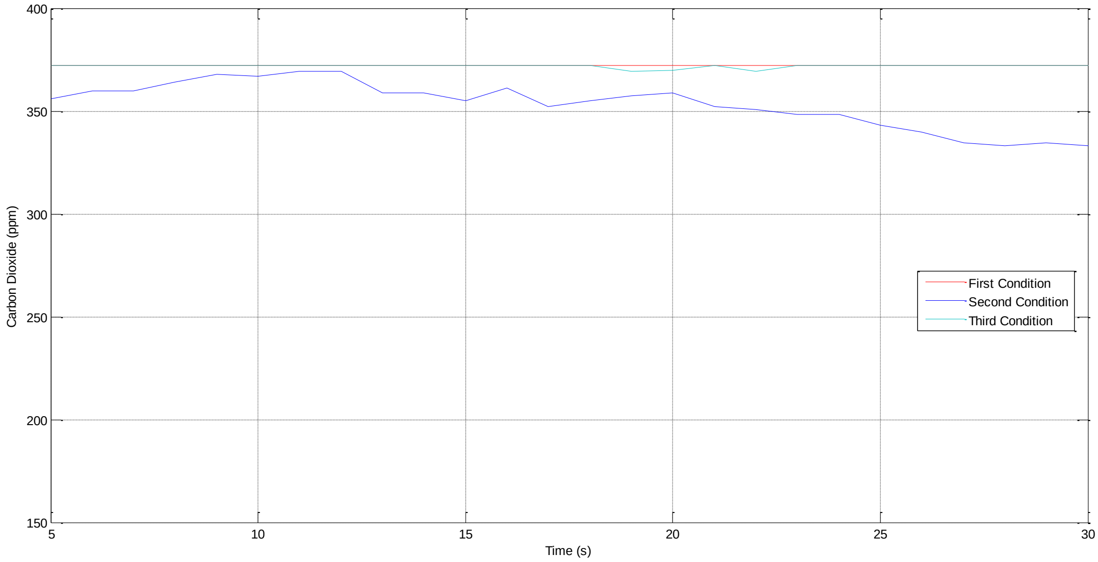

Figure 10. Carbon dioxide (CO2) concentration

Table 2. Comparison f some algorithm

Features	Algorithms	Accuracy (%)	MSE	Total Data Instances
Temperature, Humdity, CO and CO2	Naïve Bayes [18]	97.3579	0.1199	6245
	Support vector machine (SVM) [19]	95.8687	0.2885	6245
	Neural network (NN)	98.5749	0.0629	6245
	k-nearest neighbor (k-NN)	99.0657	0.0078	6245

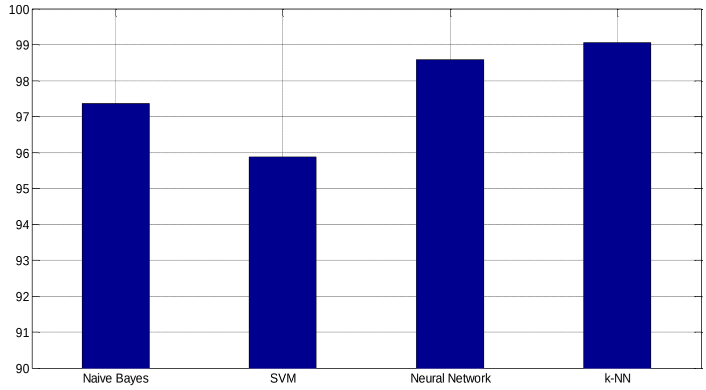

Figure 11. Comparison Naïve Bayes, SVM, NN and k-NN

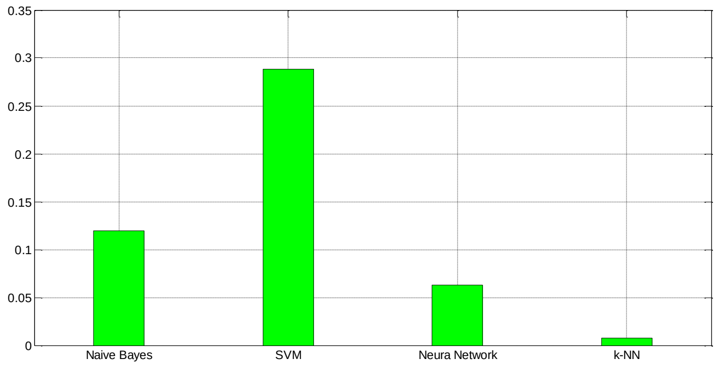

Figure 12. Mean squared error (MSE) each algorithm

4. CONCLUSION

This paper, we propose a system for monitoring environmental condition using IoT technology. We show the information about temperature, humidity, CO and CO2 by real time. User can access that information using web-based and/or mobile applications. Furthermore, the classification we confirm the evaluation of analyst data that the k-NN method is better than other methods with an accuracy rate of 99.0657% and MSE around 0.0078.

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REFERENCES

[1] A. Čolaković and M. Hadžialić, "Internet of Things (IoT): A review of enabling technologies, challenges, and open research issues," *Comput. Networks*, vol. 144, pp. 17–39, 2018, doi: 10.1016/j.comnet.2018.07.017.

[2] A. Muneer, S. M. Fati, and S. Fuddah, "Smart health monitoring system using IoT based smart fitness mirror," *TELKOMNIKA Telecommunication, Computing, Electronics and Control*, vol. 18, no. 1, pp. 317-331 2020, doi: 10.12928/telkomnika.v18i1.12434.

[3] S. Huda, A. Sudarsono, and T. Harsono, "Secure Communication and Information Exchange using Authenticated Ciphertext Policy Attribute-Based Encryption in Mobile Ad-hoc Network," *Emit. Int. J. Eng. Technol.*, vol. 4, no. 1, 2016, doi: 0.24003/emitter.v4i1.116.

[4] M. Eremia, L. Toma, and M. Sanduleac, "The Smart City Concept in the 21st Century," *Procedia Eng.*, vol. 181, pp. 12–19, 2017,doi: 10.1016/j.proeng.2017.02.357.

[5] J. Sahoo and M. Rath, "Study and Analysis of Smart Applications in Smart City Context," *Proc. - 2017 Int. Conf. Inf. Technol. ICIT 2017*, 2018, pp. 225–228, doi: 10.1109/ICIT.2017.38.

[6] N. Fahmi, S. Huda, E. Prayitno, M. U. H. Al Rasyid, M. C. Roziqin, and M. U. Pamenang, "A prototype of monitoring precision agriculture system based on WSN," *2017 Int. Semin. Intell. Technol. Its Appl. Strength. Link Between Univ. Res. Ind. to Support ASEAN Energy Sect. ISITIA 2017 - Proceeding*, vol. 2017-Janua, 2017, pp. 323–328, doi: 10.1109/ISITIA.2017.8124103.

[7] N. Fahmi, E. Prayitno, and S. Fitriani, "Web of Thing Application for Monitoring Precision Agriculture Using Wireless Sensor Network," *J. Infotel*, vol. 11, no. 1, pp. 22, 2019., doi: 10.20895/infotel.v11i1.421.

[8] I. C. L. Ng and S. Y. L. Wakenshaw, "The Internet-of-Things: Review and research directions," *Int. J. Res. Mark.*, vol. 34, no. 1, pp. 3–21, 2017, doi: 10.1016/j.ijresmar.2016.11.003.

[9] N. Fahmi, M. U. H. Al Rasyid, and A. Sudarsono, "Adaptive Sleep Scheduling for Health Monitoring System Based on the IEEE 802.15.4 Standard," *Emit. Int. J. Eng. Technol.*, vol. 4, no. 1, pp. 91–114, 2017, doi: 10.24003/emitter.v4i1.115.

[10] N. Fahmi, S. Huda, A. Sudarsono, and M. U. H. Al Rasyid, "Fuzzy logic for an implementation environment health monitoring system based on wireless sensor network," *J. Telecommun. Electron. Comput. Eng.*, vol. 9, no. 2–4, pp. 119–122, 2017.

[11] F. Pradityo and N. Surantha, "Indoor air quality monitoring system with fuzzy logic control based on IOT," *Int. J. Sci. Technol. Res.*, vol. 8, no. 8, pp. 1824–1829, 2019.

[12] M. S. Mahdavinejad, M. Rezvan, M. Barekatain, P. Adibi, P. Barnaghi, and A. P. Sheth, "Machine learning for internet of things data analysis: a survey," *Digit. Commun. Networks*, vol. 4, no. 3, pp. 161–175, 2018, doi: 10.1016/j.dcan.2017.10.002.

[13] S. Shakhari and I. Banerjee, "A multi-class classification system for continuous water quality monitoring," *Heliyon*, vol. 5, no. 5, p. e01822, 2019, doi: 10.1016/j.heliyon.2019.e01822.

[14] S. Ferdoush and X. Li, "Wireless sensor network system design using Raspberry Pi and Arduino for environmental monitoring applications," *Procedia Comput. Sci.*, vol. 34, pp. 103–110, 2014, doi: 10.1016/j.procs.2014.07.059.

[15] L. Shkurti, X. Bajrami, E. Canhasi, B. Limani, S. Krrabaj, and A. Hulaj, "Development of ambient environmental monitoring system through wireless sensor network (WSN) using NodeMCU and WSN monitoring," *2017 6th Mediterr. Conf. Embed. Comput. MECO 2017 - Incl. ECYPS 2017, Proc.*, no. June, 2017, pp. 11–15, doi: 10.1109/MECO.2017.7977235.

[16] R. P. Hudhajanto, N. Fahmi, E. Prayitno, and Rosmida, "Real-Time Monitoring for Environmental Through Wireless Sensor Network Technology," *Proc. 2018 Int. Conf. Appl. Eng. ICAE 2018*, pp. 1–5, 2018, doi: 10.1109/INCAE.2018.8579377.

[17] A. S. Souza, A. M. De Lima Curvello, F. L. D. S. De Souza, and H. J. Da Silva, "A flood warning system to critical region," *Procedia Comput. Sci.*, vol. 109, no. 2016, pp. 1104–1109, 2017, doi: 10.1016/j.procs.2017.05.453.

[18] B. Karakostas, "Event Prediction in an IoT Environment Using Naïve Bayesian Models," *Procedia Comput. Sci.*, vol. 83, no. Ant, pp. 11–17, 2016, doi: 10.1016/j.procs.2016.04.093.

[19] T. Truong, A. Dinh, and K. Wahid, "An IoT environmental data collection system for fungal detection in crop fields," *Can. Conf. Electr. Comput. Eng.*, 2017, pp. 0–3, doi: 10.1109/CCECE.2017.7946787.

[20] Arduino, "Arduino Uno Rev3," *Store.Arduino.Cc*, 2018.

[21] I. Digi, "XBee ® /XBee-PRO ® RF Modules," 2009.
[22] Raspberry Pi Foundation, "Raspberry Pi 3 Model B," *Raspberry Pi Website*, 2016.
[23] P. Rycerski, L. M. C. Ibarra, F. Galatoulas, K. N. Genikomsakis, A. Bagheri, and C. S. Ioakimidis, "Field performance analysis of IEEE 802.15.4 XBee for open field and urban environment applications in Smart Districts," *Energy Procedia*, vol. 122, pp. 673–678, 2017, doi: 10.1016/j.egypro.2017.07.368.
[24] P. Baronti, P. Pillaia, V. W. C. Chook, S. Chess, A. Gotta, and Y. F. Hu, "Wireless sensor networks: A survey on the state of the art and the 802.15.4 and ZigBee standards," *Comput. Commun.*, vol. 30, no. 7, pp. 1655–1695, 2007, doi: 10.1016/j.comcom.2006.12.020.
[25] K. Afsari, C. M. Eastman, and D. Castro-Lacouture, "JavaScript Object Notation (JSON) data serialization for IFC schema in web-based BIM data exchange," *Autom. Constr.*, vol. 77, pp. 24–51, 2017, doi: 10.1016/j.autcon.2017.01.011.

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