RESEARCH PROGRESS IN MECHANICAL AND MANUFACTURING ENGINEERING VOL. 4 NO. 2 (2023) 1 – 9

RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN: 2773 - 4765

Enhancement of Electrospinning Machine Process Using IoT

Tan Wei Hong[1], Koh Ching Theng[1]*

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rpmme.2023.04.02.001
Received 01 December 2022; Accepted 01 April 2023; Available online 15 December 2023

Abstract: Due to pandemic Covid-19, we were unable to monitor the condition of electrospinning machine as we need to practice social distancing. To solve this problem, we need to design an IoT unit to monitoring the temperature and humidity inside the machine. The performance of the IoT unit needed to be evaluate in this research. The capability of the IoT unit was tested inside the machine and it will alert the operator with notification when exceeding the threshold range. The main board used was Raspberry Pi 4 Model B microcontroller and the sensor used was DHT22. Another module that used was the Raspberry Pi Camera V2 to monitor the condition inside the machine graphically. Temperature sensor, humidity sensor and cameral module was connected to the Raspberry Pi 4 Model B microcontroller. The Python programming language is the official operating system for Raspberry Pi, Raspbian, was used to install the Node-RED and camera interface for monitoring. The data will then send to a website for the user to monitor and send to a cloud database for storage. A code in JavaScript language will write to give the corresponding instruction to ensure the web application to give warning when the data collected is exceed the threshold. The system that has developed in this research is able to reduce the working time for operator in front of the electrospinning machine to monitor the process. Besides, the quality of fibers is able to be optimized by the system in this research.

Keywords: Electrospinning Machine, Raspberry Pi 4, DHT22, Node-RED, Temperature, Humidity.

1. Introduction

IoT allows objects, animals, and humans to communicate and exchange data without direct interaction with a computer. Machine-to-machine (M2M) communications are a part of IoT, providing connectivity in different domains and applications [1].

Due to the COVID-19 pandemic, social distancing measures have led to the shutdown of many facilities, including the electrospinning machine in the university [2]. To address this issue, an IoT-based humidity and temperature sensor system can be implemented in the machine. This system involves strategically placed sensors and a central control unit connected to the internet. There are several objectives in this, which were design a IoT unit to monitor the temperature and humidity,

*Corresponding author: ctkoh@uthm.edu.my

integrate the IoT unit in the electrospinning machine and also evaluate the performance of the IoT unit. At the end of research, we are expecting to create the IoT unit which using the Raspberry Pi platform to monitor the temperature and humidity in the electrospinning machine. The IoT unit will allow us to monitoring the data through the PC website, mobile website and also the mobile application. IoT MQTT panel also been used in this research to allow us to manage and visualize our IoT research, based on MQTT protocol. MQTT (message queuing telemetry transport) is a lightweight messaging protocol which is commonly used in IoT application for efficient communication between devices [3].

Continuous monitoring of humidity and temperature during the electrospinning process can improve the quality consistency of the nanofibers produced [4]. Implementing IoT in the electrospinning machine allows for more precise control of the process by collecting data and identifying trends and patterns. This optimization can lead to higher quality nanofibers. Additionally, implementing IoT can help reduce waste, prevent accidents or equipment failure, and enable remote monitoring and control of the process.

2. Materials and Methods

In this case study, there were two main equipment, or we can call it material was use to build up the whole system. The main equipment was the Raspberry Pi microcontroller and the Node-RED platform. Besides, DHT 22 sensor and camera module will connect using the jumper wire and flex cable to the Raspberry Pi to complete the whole system.

2.1 Materials

2.1.1 Raspberry Pi 4 microcontroller

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip. There are two popular microcontrollers in the market which is widely used by student to develop new technologies. The Raspberry Pi microcontroller is chosen in this research [5].

Table 1: Specification of the Raspberry pi

Characteristics	Raspberry Pi 4 Model B
Board Types	The Raspberry Pi 4 is a series of single-board microcontroller which able to fully function as a computer with its dedicated memory, processor and it runs Raspberry Pi OS (operating system).
Connectivity Abilities	The Raspberry Pi 4 consists of Bluetooth, Ethernet and Wi-Fi, which allow it to connect to devices and the Internet directly without external modules.
Ports available in the board	Raspberry Pi 4 microcontroller consists of 4 USB ports, camera port, LCD port, HDMI port and audio port which are easy and suitable for media application
Board Applications	The Raspberry Pi 4 is a microcontroller with Broadcom BCM2711 SoC that are able to performs multitask several programs. Raspberry Pi 4 can be used to build a complex project it needs multiple actions at a time easily.
Area of usage	When the user wants to control a more complicated automated robot, complex calculations or multiple tasks system, Raspberry Pi is the most suitable microcontroller to perform it.

2.1.2 DHT22 sensor

The IoT based Temperature and Humidity System was designed to measure the air temperature and humidity. DHT22 is a temperature and humidity sensor with temperature range falls between -40-80°C was chosen, as it has the range required for electrospinning (around 45°C) [6].

Table 2: Specification of DHT22 sensor

Characteristics	DHT22
Operating voltage	DC 3.3V to 5V
Max operating current	2.5mA
Temperature reading range	-40°C to 80°C with ±0.5°C
Humidity reading range	0% to 100% RH with ±2%RH
Sampling rate	Less than 0.5 Hz
Dimension	15.1mm x 25mm x 7.7mm

2.1.3 Camera module

The Raspberry Pi Camera Module v2 is a top-notch, specially created add-on board for Raspberry Pi with an 8-megapixel Sony IMX219 image sensor and a fixed focus lens. It can produce static images with a resolution of 3280 x 2464 pixels and supports video in 1080p30, 720p60, and 640x480p60/90. It was connected to the Raspberry Pi via one of the tiny ports on the top surface of the board and interfaces with cameras using a unique CSI interface. The board's dimensions are approximately 25 mm by 23 mm by 9 mm. It was ideal for mobile apps and other uses where size and weight are critical. It weighs just over 3g as well. A brief ribbon cable was used to connect it to the Raspberry Pi [7].

2.1.4 Node-RED

Node-RED is an open-source visual programming tool designed for building event-driven applications and integrating hardware devices, APIs, and online services. It provides a browser-based flow editor that allows users to create and deploy flows by connecting nodes together in a visual manner.

In this research Node-RED was the core to control the flow of the system as all the coding and function needed to insert in the Node-RED workplace as a node. By wiring all the node starting from inject node until the debug node, the whole research was able to run properly [8].

2.1.5 Firebase Realtime Database

Firebase Realtime Database is a cloud-hosted NoSQL-based database provided by Google's Firebase platform. It was designed to store and sync data in real time between clients and servers, making it ideal for building real-time applications such as chat apps, collaborative tools, and live data updates [9,10].

In this research Firebase Realtime Database was chosen as the cloud to save the data because it is free of charge when the data is not exceeded 1GB per month. Besides, it is easier for user to setting up as we only need to key in the credentials of our Firebase Realtime Database in Node-RED firebase out node then the data collected will be sent to the database without complicated coding.

2.2 Methods

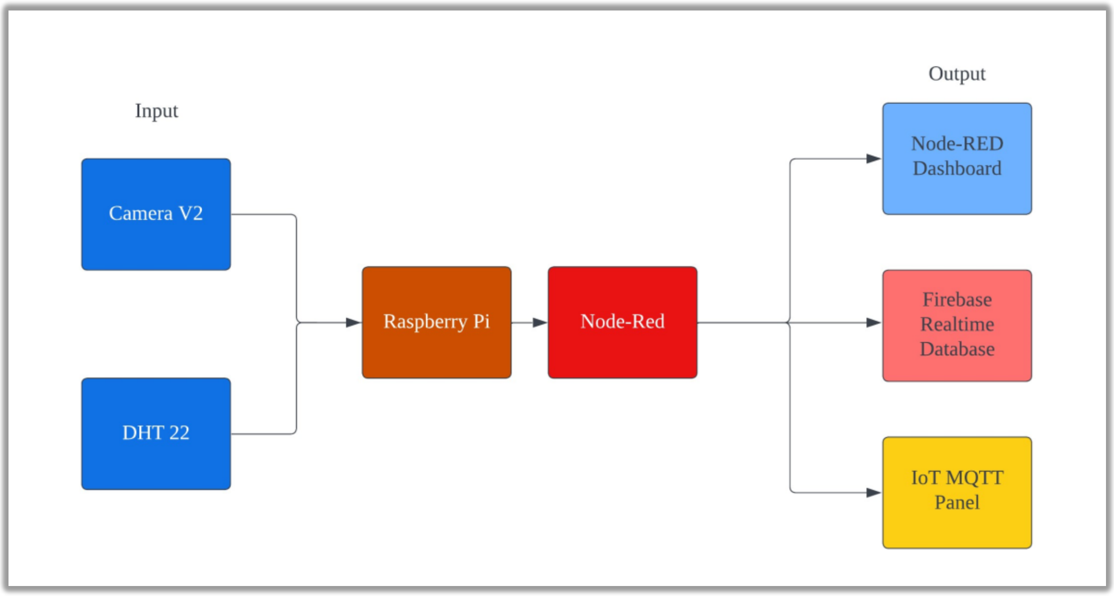

Figure 1: Overall system design

As shown in figure 1, the research starts by connecting the DHT22 sensor and Camera to the Raspberry Pi. After that, Node-RED was installed into Raspberry Pi. Several palettes were installed in Node-RED workspace so that we can access the Firebase node and also to the dashboard. Several function nodes have been inserted to the workspace to set the threshold range to send the alert notification in Node-RED dashboard. Furthermore, Firebase out node has been inserted and configured so that the data collected by DHT22 sensor can be send and store in the Firebase Realtime Database. For mobile application, MQTT node was inserted to send the data to the topic that was created and link to a server. Lastly, the camera live stream was enabled by installing the web interface from raspberry pi terminal.

3. Results and Discussion

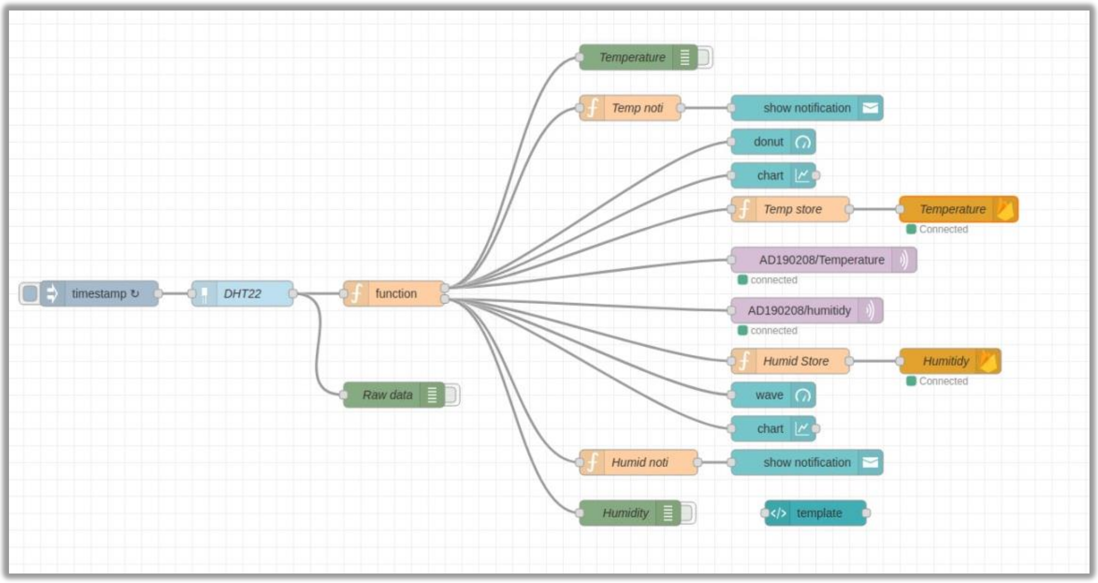

Figure 2: Overall Node-RED flows of whole research

Figure 2 shows the overall function flows that has been create to ensure the temperature and humidity monitoring system can works. The flow consists of all the node that require for this research. First, there is a inject node so that the message will be inject and as a result the system will run. After this is a DHT sensor to manage the connection of either DHT11 or DHT22 sensor on Raspberry pi.

Then, there is a function node to split the collected data to temperature and humidity so that we can monitoring the data. Both data can be monitoring though a chart and gauge. If the value we collect exceed the threshold limit that we set, an alert will be sent to the Node-RED dashboard to notify the operator to take action to ensure the electrospinning machine can continue the process. The data collected will sent to a cloud storage, which is can Firebase. Since the Node-RED is a web application, in this research I also insert a MQTT broker node so that the data collected will sent through the broker to IoT MQTT Panel, which is a mobile application so that we can monitoring the data more easily.

Figure 3: Node-RED dashboard

Figure 3 shows the Node-RED dashboard that use to monitor the temperature and humidity in electrospinning machine. The dashboard consists of 3 section which are the humidity, temperature and real time camera section. Both humidity and temperature section show the real time data that collected from DHT 22 sensor through graph chart and gauge. In other hand, the real time camera section shows the live stream view inside the electrospinning machine so that the operator can monitoring the situation inside the machine even they are not in the lab.

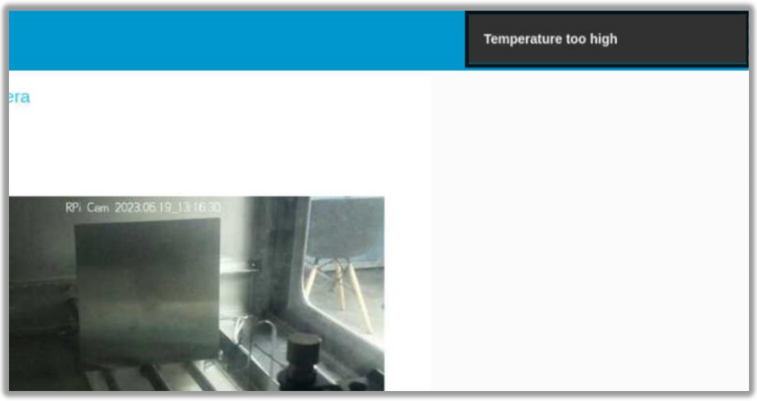

Figure 4: Notification pop-up for temperature in Node-RED Dashboard

Figure 4 show the notification alert that use to alert the operator when the temperature is exceed the threshold limit. The notification will pop up continuously on the top left corner of the screen for humidity and top right corner of the screen for temperature until it falls back within the limit set.

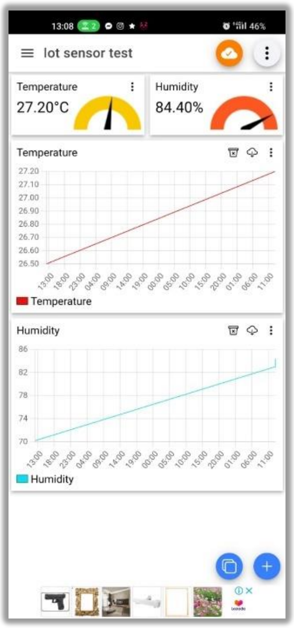

Figure 5: Dashboard in IoT MQTT panel (mobile application)

In figure 5 shown the dashboard of the IoT MQTT panel. The mobile application is connected to Node-RED by MQTT broker. The data and graph shown in the IoT MQTT panel is source by the real-time data from DHT22 sensor.

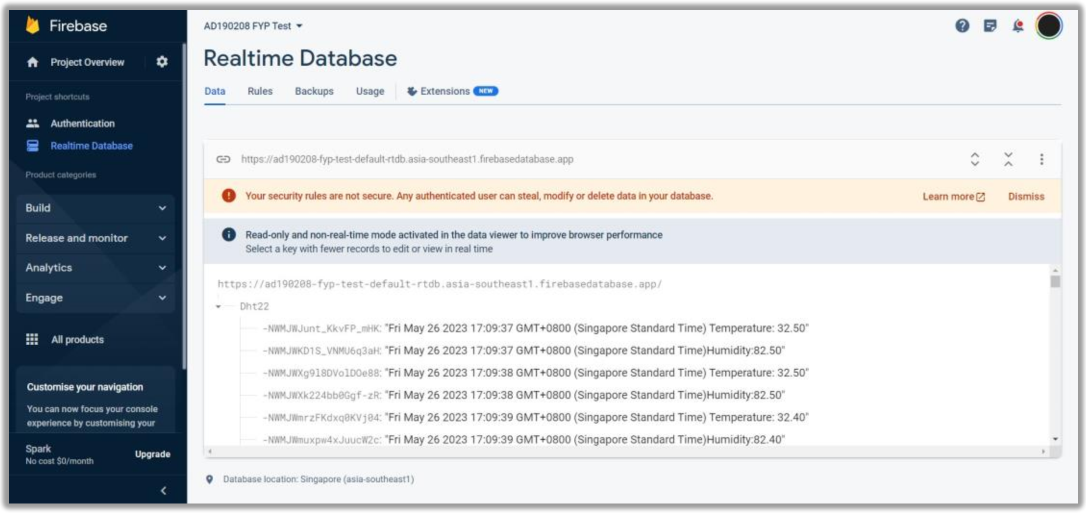

Figure 6: Firebase Interface

Figure 6 show the interface of Firebase. The data collected by DHT22 sensor will send to the firebase every second. In firebase the data collected will including the date, the time and the corresponding data which are temperature or humidity. The data collected can be export as json format file and convert to excel format file. As a results in excel file we can back-up the data collected for the future processing.

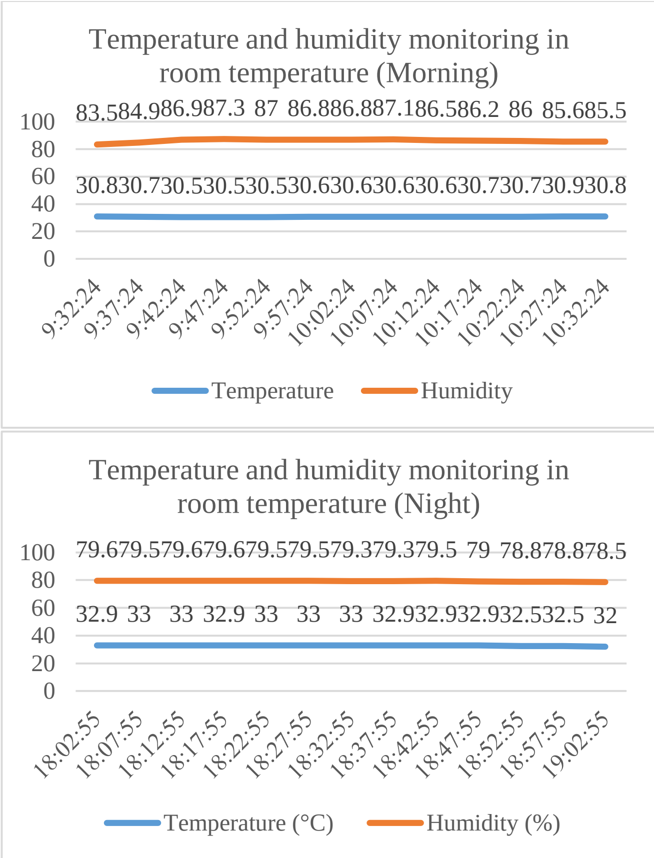

Figure 7: Temperature and humidity monitoring with 5 minute interval

Figure 7 shows the graphical data that collected by DHT22. The interval is set to 5 minute to test the usability of the IoT system. As show in the graph the system is working properly in 1 hours and can send the data to the Firebase Realtime Database with 5 minute interval.

Besides, to simulate the common time that need for the electrospinning process, a 24 hours test has been conduct to test the usability of the IoT system for long time service. As shown in Figure 8, the IoT system is working properly and can clearly detect the temperature and humidity difference and send the data to the Firebase with 1 hour interval.

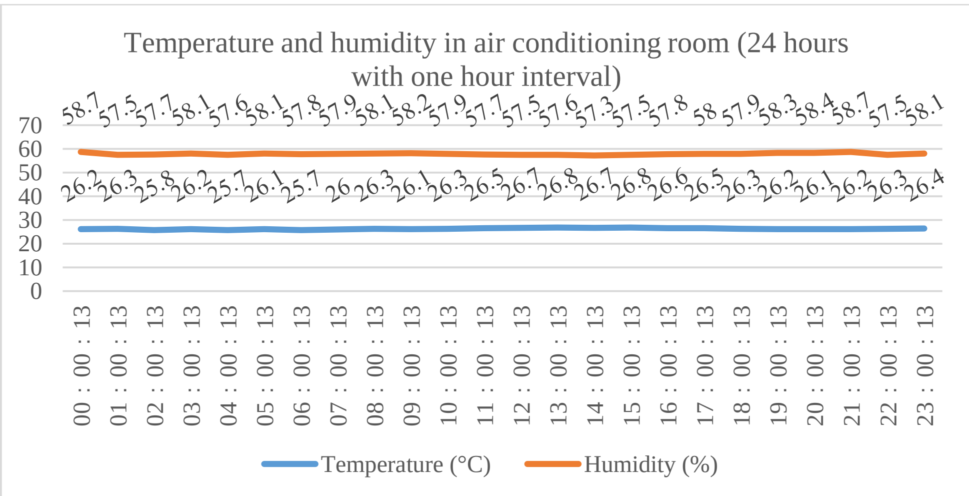

Figure 8: Temperature and humidity in air conditioning room (24 hours with one hour interval)

4. Conclusion

In this research, an IoT based temperature and humidity monitoring system has been designed with a sensor, and camera that is attached to the microcontroller, which can help the operator to monitor and control the environment with ease.

Raspberry Pi is use as the microcontroller to connect with sensor and camera to collect the data and send the data to cloud database, it is successfully integrated into the electrospinning machine so that we can monitoring the condition inside the machine from far end.

In terms of the stability of the developed system, the sensor can perform excellently for each task, without major execution error. All parameters that are plan and design to be monitored can be maintained at the optimal value.

Even though this research has achieved its objectives, there are several further improvements that should be carried out to increase performance, ability, and efficiency. First, a better sensor unit should be used to increase the quality of data we collect. Besides, the research can be designed to be compatible with Ios platform as some of the applications to develop the system are not compatible. Lastly, other database can be considered to replace Firebase as it is limited to 1Gb of storage only.

Acknowledgement

The authors wish to thank to the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia that has supported on the accomplishment of research activity.

References

[1] Höller, J., Vlasios Tsiatsis, Mulligan, C. N., Stamatis Karnouskos, Avesand, S., & Boyle, D. L. (2014). Introduction and Book Structure. From Machine-To-Machine to the Internet of Things: Introduction to a New Age of Intelligence April 2014, 3–8. https://doi.org/10.1016/b978-0-12-407684-6.00001-2

[2] Kanda, W., & Kivimaa, P. (2020). What opportunities could the COVID-19 outbreak offer for sustainability transitions research on electricity and mobility? Energy Research & Social Science, 68, 101666. https://doi.org/10.1016/j.erss.2020.101666

[3] Kundu, R. (2017, August 15). IoT MQTT Panel - Apps on Google Play. Play.google.com. https://play.google.com/store/apps/details?id=snr.lab.iotmqttpanel.prod&hl=en&gl=US

[4] Putti, M., Simonet, M., Solberg, R., & Peters, G. W. M. (2015). Electrospinning poly(ε-caprolactone) under controlled environmental conditions: Influence on fiber morphology and orientation. Polymer, 63, 189–195.

[5] Ghael, H. D., Solanki, L., & Sahu, G. (2021). A Review Paper on Raspberry Pi and its Applications. A Review Paper on Raspberry Pi and Its Applications, volume 2(2395-5252). https://doi.org/10.35629/5252-0212225227

[6] Adafruit Industries. (2019). DHT22 temperature-humidity sensor + extras. Adafruit.com. https://www.adafruit.com/product/385

[7] Ltd, R. P. (n.d.). Buy a Raspberry Pi Camera Module 2. Raspberry Pi. https://www.raspberrypi.com/products/camera-module-v2/

[8] OpenJS Foundation. (2019). Node-RED. Nodered.org. https://nodered.org/

[9] Moroney, L. (2017). The Firebase Realtime Database. The Definitive Guide to Firebase, 51–71. https://doi.org/10.1007/978-1-4842-2943-9_3

[10] Ohyver, M., Moniaga, J. V., Sungkawa, I., Subagyo, B. E., & Chandra, I. A. (2019). The Comparison Firebase Realtime Database and MySQL Database Performance using Wilcoxon Signed-Rank Test. Procedia Computer Science, 157, 396–405. https://doi.org/10.1016/j.procs.2019.08.231