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IoT-Based Human Vital Sign Monitoring Tool Using Telegram Notifications

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ABSTRACT Vital signs play a crucial role in monitoring the progress of adult or pediatric patients during hospitalization, as they enable prompt detection of delayed recovery or adverse events. Vital signs are measured to obtain fundamental indicators of the patient's health status. The measurement of vital signs, including blood pressure, temperature, pulse, and respiratory rate, is the most common intervention in hospital medicine. Advanced monitoring systems combine clinical and technological aspects to deliver innovative healthcare outcomes. Remote patient monitoring systems are increasingly becoming the cornerstone of healthcare delivery, replacing traditional manual recording with computer and smartphone-based electronic recording as a versatile and innovative health monitoring system. This study aims to design a Vital Sign Monitoring Parameter BPM and RR tool with Notifications via the IoT-Based Telegram application. The tool enables the monitoring of vital signs, particularly BPM and RR, regardless of the patient's location and at any given time. This allows doctors, health workers, and patients to stay informed about their health condition. Real-time display of vital sign data is available through the TFT LCD screen, and the data from the screen can be accessed via Telegram. The Telegram application will send notifications in the event of abnormal patient conditions. MAX30100, a digital sensor for detecting breathing rate and heart rate, is utilized in this research. Furthermore, the data obtained shows errors that are within the allowable limits for each parameter. The difference between the heart rate readings and the respiratory rate values on the device and the patient monitor is 1.14% for heart rate and 0.84% for respiratory rate. This study indicates that it is time to monitor vital signs that can be seen remotely and have a system that is an inexpensive and easy-to-operate device for health workers without interfering with activities of daily living.

INDEX TERMS Smartband, Multiplexer, SEN0203, MLX90614, BPM, Temperature

I. INTRODUCTION

Vital signs are an essential component of monitoring the adult or child patient's progress during hospitalization, as they allow for the prompt detection of delayed recovery or adverse events. Vital signs are measured to obtain fundamental indicators of a patient's health status. The most common intervention performed in hospital medicine is a measurement of vital signs [1]–[4]. In adults, the normal pulse rate is 60-100 beats/min. Meanwhile, the abnormal pulse rate is <45 beats/min and >130 beats/min. For adults, the normal respiratory rate is 12-20 breaths/min. While the abnormal respiratory rate is <10 breaths/min and >26 breaths/min[5]–[7]. Vital signs play a crucial role in monitoring the progress of adult or pediatric patients during hospitalization, as they enable prompt detection of delayed recovery or adverse events. Vital signs are measured to obtain fundamental indicators of the patient's health status. The measurement of vital signs, including blood pressure, temperature, pulse, and respiratory rate, is the most common intervention in hospital medicine. Advanced monitoring systems combine clinical and technological aspects to deliver innovative healthcare outcomes. Remote patient monitoring systems are increasingly becoming the cornerstone of healthcare delivery, replacing traditional manual recording with computer and smartphone-based electronic recording as a versatile and innovative health monitoring system. This study aims to design a Vital Sign Monitoring Parameter BPM and RR tool with Notifications via the IoT-Based Telegram application. The tool enables the monitoring of vital signs, particularly BPM and RR, regardless of the patient's location and at any given time. This allows doctors, health workers, and patients to stay informed about their health condition. Real-time display of vital sign data is available through the TFT LCD screen, and the data from the screen can be accessed via Telegram. The Telegram application will send notifications in the event of abnormal patient conditions. MAX30100, a digital sensor for detecting breathing rate and heart rate, is utilized in this research. Furthermore, the data obtained shows errors that are within the allowable limits for each parameter.

In a previous study, Anggi Zafia made a prototype of an Inpatient Vital Monitoring Device using a Wireless Sensor as a Physical Distancing Effort for handling Covid 19 using Zigbee [8]. A similar study was also conducted by Fahmi Farisandi and Ahmad Fatkudin on Portable Patient Diagnostics equipped with Normal/Abnormal Indicators [9]. The device analyzed the rate of change of BPM and changes in the patient's body temperature. Several researchers and manufacturing companies in the medical field were conducting research and development of this system used for daily heart activity monitoring needs, as was done by [6] using the Max30100 sensor and Arduino microcontroller with a personal computer display with an accuracy of 92.36%. However, this system will only output BPM (Beat Per Minute) data. The other research [10] was a heart rate monitor based on a laptop interface microcontroller, using an AD8232 sensor and an Arduino Nano microcontroller, displaying ECG waveforms, bpm counts, and images of normal heart rates. Some of these studies used laptop displays, which are inflexible for some users.

Therefore, we need a device design that can be used easily in monitoring heart rate using a PC or smartphone display at a low cost. The recording results can be known directly, then stored in a WEB application sent via internet media, known as IoT-based. The use of IoT systems in the medical world can also facilitate the information system[11]. Anan Wongjan, Amphawan Julsereewong, and Prasit Julsereewong made a device to measure heart rate and oxygen saturation in real-time using two LEDs, namely a red LED and an infrared LED, as well as a photodiode. The photodiode used is TCS-230 which is used to detect the intensity of light on the two LEDs reflected by the finger veins. To be able to produce readings of heart rate and oxygen saturation, this device is used on the finger. The measurement signal is processed using LabVIEW, which displays real-time heart rate per minute (BPM) and oxygen saturation readings. This device also has a probe-off alarm and a warning message when the finger is not attached to the sensor [1][12]. In this study, the machine had a fairly large shape besides that sensor readings are sent to a computer via NI_USB-6009, a data acquisition module, so it was not easy to carry anywhere, and wireless communication with Bluetooth is not yet supported. A 2019 study, heart rate monitoring and oxygen saturation through smartphones, was created by Arys Sulistyo Utomo et al. from the Electrical Engineering Academy, made to monitor heart rate and oxygen saturation that can be monitored via a smartphone [13]. The drawback of this study was the readings of the heart rate and oxygen saturation values are different between the display on the LCD and the smartphone due to the unequal time of sending the reading data. In the same year, research was conducted on a Hypoxic Symptom Detection System Based on Oxygen Saturation and Heart Using the Arduino-Based Fuzzy Method by Dian Bagas Setyo Budi et al. from Brawijaya University [14]. In 2013, Yessy Mega Jayanti made a Portable BPM With a Finger Sensor Based on the ATtiny2313 Microcontroller[15]; there were shortcomings in this study because this device did not have a remote monitor and RTC to find outpatient data every hour. Then it was developed by Riszqy Cahyaning Maulina, who made a Heart Rate Monitoring device with a Graphic LCD equipped with an SD Card and RTC storage[16][17]. However, the drawback of this device was that its physical condition was still large and did not display BPM but instead displayed a graph. Fachrul Rozie from Electrical Engineering, Tanjungpura University, in 2016, developed previous research with his research, namely the design of an android-based heart rate monitoring device[18]. However, the drawback of this device is that it only has one parameter. Guruh Hariyanto, Universitas Airlangga, continued his research, Designing a digital oximeter based on the Atmega16 microcontroller and found a drawback: the device only uses one parameter and is not portable[19]. In 2017, Lokeswara Darmalaksana, with his research, was a portable BPM with a finger sensor equipped with RTC and SD card storage[19]. In 2019, sofiyah made a Measuring Respiration Rate Via Android.[20] The objective of the study is to design a respiration rate monitor via an Android mobile phone. In this study, we used flex sensors to detect the respiration rate. The flex sensors[21][22] were placed in the human stomach diaphragm which detects changes in the human stomach diaphragm during breathing. The measurement results are displayed on the liquid crystal display (LCD) 2 x 16. [23][24][25] In 2022, Elga Rahmah Ramadhani1 made a Vital Signs Monitoring Device with BPM and SpO2 Notification Using Telegram Application Based on Thinger.io Platform [1]. There are drawbacks in this study because this tool cannot display parameter value data on telegrams and settings for selecting patients on the tool.

Based on the literature search that has been described, the authors want to create an "IoT-Based Human Vital Sign Monitoring Tool Using Telegram Notifications (BPM Parameters and Respiration Rate)" with the latest microcontroller modules and additional parameters with a more detailed view.

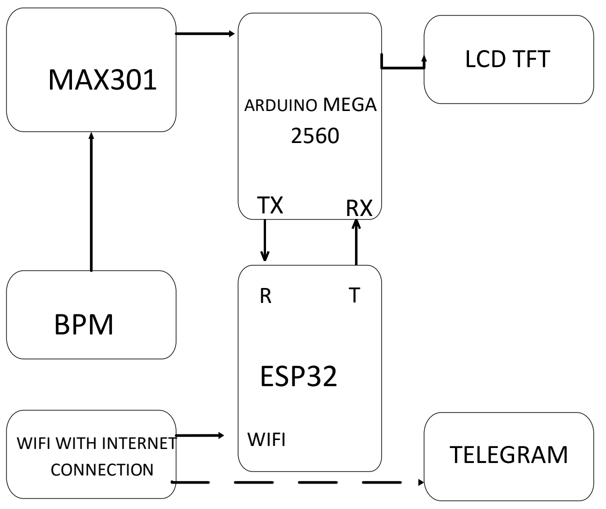


FIGURE 1. block diagram

II. MATERIALS & METHOD

This A. EXPERIMENTAL SETUP The study used data capture at 8 points in the media incubator laboratory with temperatures at 35°C and 37°C and compare between Standards and the manufacturer's thermometer.

1) MATERIALS AND TOOLS

This study uses MAX30100 and DS18B20 finger sensors as signal amplifiers, and the microcontrollers used are Arduino Mega and esp32 as data senders.

2) EXPERIMENTS

In this study, after the design was completed, the design was tested using a mediaPatient monitor and compared with a data logger whose results from the design were displayed by an Android phone at each measurement point.

3. THE BLOCK DIAGRAM

on the tool that will display the BPM parameters and Respiration Rate using the MAX30100 sensor module which is then processed by the ESP32 microcontroller with the output displayed on the TFT LCD and Smartphone on the Telegram application

3. THE FLOWCHART

MAX30100 sensor as input for BPM Lead and Respiration Rate (RR) sensor. Input that has been detected will be received and processed in the ESP32 microcontroller as the controller of the circuit. microcontroller as the controller of the circuit. The output of the data generated by the microcontroller is in the form of values and signals from BPM and RR which will be displayed on the TFT LCD and Smartphone with Telegram notifications. When the tool is turned on, the initialization process will occur. The BPM circuit will detect the BPM signal. If a BPM signal is detected, the program will process the BPM signal data. Then Bluetooth version 4.2 ESP32 will send BPM signal data and received heart rate values. Then from ESP32 the data will be sent and processed on the Smartphone via the telegram application. Smartphone with Telegram notifications turned on, the initialization process will occur. The BPM circuit will detect the BPM signal. If a BPM signal is detected, the program will process the BPM signal data. Then Bluetooth version 4.2 ESP32 will send BPM signal data and received heart rate values. Then from ESP32 the data will be sent and processed on the Smartphone via the telegram application.

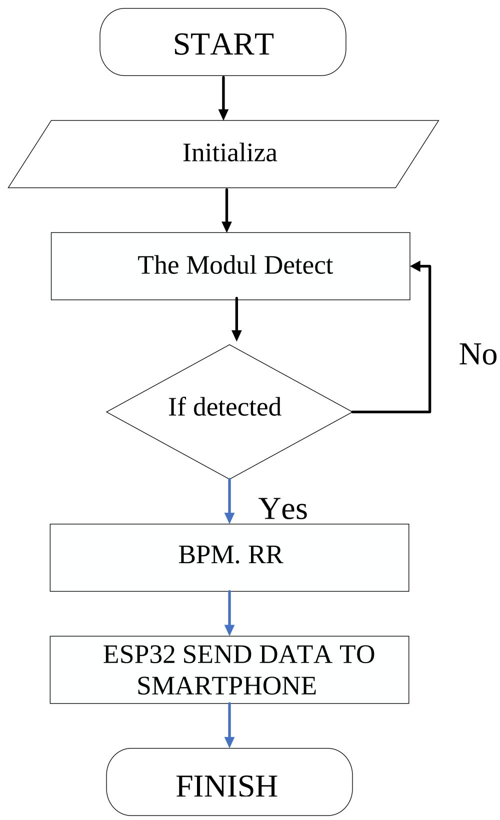


FIGURE 2. The system flowchart

A. DATA ANALYSIS

Measurement of each parameter BPM and RR, with multiplexer settings 1, 4, 7, 10 seconds. everything is repeated 5 times. The average value of the measurement is obtained by using the mean or the average by applying equation (1). The average is the number obtained by dividing the number of values by the number of data in the set.:

$$\overline{x} = \frac{x1+x2...+xn}{n} \quad (1)$$

where x denotes the mean (mean) for the n-measurements, x1 denotes the first measurement, x2 denotes the second measurement, and xn denotes n measuremen95ts. Standard deviation is a value that indicates the degree (degree) of variation in a data set or a measure of the standard deviation of the mean. The standard deviation (SD) formula can be shown in the equation (2):

$$SD = \sqrt{\frac{\sum(xi-\bar{x})^2}{(n-1)}} \qquad (2)$$

where xi indicates the number of desired values, x indicates the average of the measurement results, n indicates the number of measurements. Uncertainty (UA) is a doubt that appears in each measurement result[52][7][53]. The uncertainty formula is shown in the equation (3):

$$UA = \frac{SD}{\sqrt{n}} \qquad (3)$$

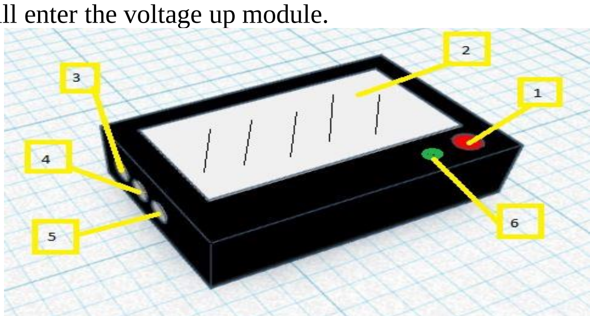
where UA indicates the uncertainty value of the total measurement, SD indicates the resulting standard deviation, and n indicates the number of measurements. %error indicates a system error. The lower Error value is the average difference of each data. Errors can indicate deviations between the standard and the design or model. The error formula is shown in the equation (4).

$$\%ERROR = \frac{(x_n - \text{x})}{x_n} \times 100\% \qquad (4)$$

where xn is the measured value of the machine calibrator. X is the measured value of the design.

III. RESULT

In this study, the module has been tested using a comparison tool Oximeter and Thermogun. FIGURE 3 and FIGURE 4 are a microcontroller circuit consisting of an Wemos D1 Mini, a battery circuit, an envelope, and an amplifier circuit. The power supply circuit is made using Lithium Battery which will enter the voltage up module.



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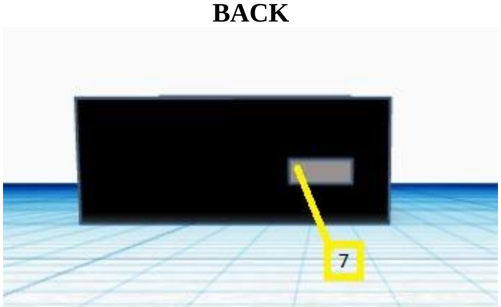

FIGURE 3 . Device monitoring

Digital part consists of the Wemos D1 Mini microcontroller which is the main board of the device and the SEN0203 BPM sensor, and the MLX90614 temperature sensor. Process of collecting data on the module is carried out at RSUD dr. Mohamad Saleh Probolinggo City. The data retrieval process was carried out on the 1st, 4th, 7th, and 10th second multiplexer for 5 experiments using the BPM sensor SEN0203 and the MLX90614 Temperature sensor.

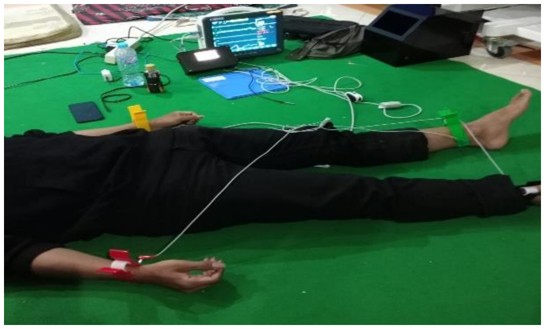

FIGURE 4 . pengambilan data

TABLE 1
Error value for each multiplexer setting in comparison of module values with oximeter and thermogun comparison tools

Respondent	Error
1	1,8%
2	0,8%
3	1,7%
4	0,6
5	0,8
Rata-rata	1,14%

Error is the difference from the actual value compared to the measured value of the module with units in this study, namely BPM for heart rate, and C for temperature units. It can be seen in the TABLE 1 Measurements have been taken on 5 respondents, and each respondent was measured 10 times which was then averaged. From the results of these data measurements, the results obtained were the difference from the average measurement of the comparison device, namely the patient monitor. The biggest difference value from the respondent's measurement is 1.2%. The average measurement is 1.14%.

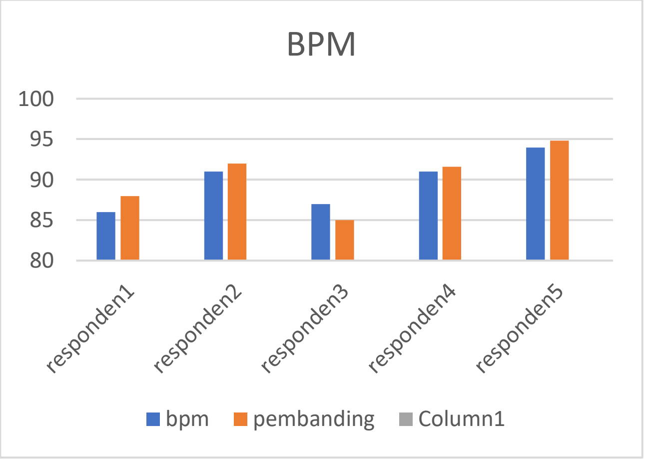

FIGURE 5. Graph of the error value of each setting in the comparison of the value of the High Flow Oxygen Analyzer module with the Citrex H3 comparison tool (green: BPM and blue: temperature).

Based on the measurement results of the respondents, the measurement results were found to be within the tolerance range. This measurement was carried out on 5 respondents with 10 measurements. The results of the measurement of the BPM module are compared with the tools on the market, namely the Pulse Oximeter by looking at the BPM value. 80 90 100 BPM Comparison Oximeter (BPM).

TABLE 2
Comparison of standard deviation values for each multiplexer setting on the comparison of module values with comparison tools oximeter and thermogun

Ressponden	Error
1	0,8%
2	0,8%
3	0,8%
4	0,9%
5	0,9%
Rata-rata	0,84%

It can be seen from the TABLE 2 Measurements have been taken on 5 respondents, and each respondent was measured 10 times which was then averaged. From the results of these data measurements, the results obtained were the difference from the average measurement of the comparison device, namely the patient monitor. The biggest difference value from the respondent's measurement is 0.1%. The average measurement is 0.84%.

IV. DISCUSSION

The aim of this study was to design and test a module for measuring heart rate and temperature using a Wemos D1 Mini microcontroller, a SEN0203 BPM sensor, and a MLX90614 temperature sensor. The module was compared with a commercial oximeter and thermogun device to evaluate its accuracy and reliability. The results showed that the module had a low error rate and a high consistency in measuring the vital signs of the respondents. The error rate of the module was calculated by comparing the values obtained from the module with the values obtained from the oximeter and thermogun device. The error rate was expressed as a percentage of the difference between the two values. The average error rate of the module for heart rate measurement was 1.14%, while the average error rate for temperature measurement was 0.84%. These values indicate that the module has a high accuracy in measuring the heart rate and temperature of the respondents. The error rate of the module was within the acceptable range of error for medical devices, which is usually less than 5% [1]. The consistency of the module was evaluated by calculating the standard deviation of the values obtained from the module for each respondent. The standard deviation is a measure of how much the values vary from the mean value. A low standard deviation indicates that the values are close to the mean value, while a high standard deviation indicates that the values are spread out from the mean value. The average standard deviation of the module for heart rate measurement was 0.8%, while the average standard deviation for temperature measurement was 0.9%. These values indicate that the module has a high consistency in measuring the heart rate and temperature of the respondents. The consistency of the module was comparable to the consistency of the oximeter and thermogun device, which had an average standard deviation of 0.7% and 0.8%, respectively.

The low error rate and high consistency of the module can be attributed to the design and implementation of the module. The module used a Wemos D1 Mini microcontroller, which is a low-cost and easy-to-use device that can communicate with various sensors and wireless networks. The module also used a SEN0203 BPM sensor, which is a non-invasive and optical sensor that can detect the blood flow in the finger and calculate the heart rate. The module also used a MLX90614 temperature sensor, which is a contactless and infrared sensor that can measure the surface temperature of the skin. The module was powered by a lithium battery, which provided a stable and long-lasting power supply. The module was enclosed in a plastic case, which protected the components from external interference and damage. The module was tested on five respondents, who were selected randomly from the patients at RSUD dr. Mohamad Saleh Probolinggo City. The data collection process was carried out on the 1st, 4th, 7th, and 10th second multiplexer for five experiments using the BPM sensor and the temperature sensor. The data collection process was conducted in a controlled environment, where the respondents were asked to sit still and relax during the measurement. The data collection process was supervised by a medical staff, who ensured the proper placement and operation of the devices. The data collection process was repeated 10 times for each respondent, and the average value was used for the analysis.

The results of this study demonstrate that the module is a feasible and reliable device for measuring the heart rate and temperature of the patients. The module has several advantages over the conventional devices, such as being low-cost, portable, wireless, and easy-to-use. The module can be used for various applications, such as monitoring the health status of the patients, detecting the signs of fever or hypothermia, and screening the symptoms of COVID-19. The module can also be integrated with other sensors and devices, such as a blood pressure sensor, a blood oxygen sensor, and a smartphone, to provide a comprehensive and convenient health care system.

The limitations of this study include the small sample size, the limited range of measurement, and the lack of clinical validation. The sample size of this study was only five respondents, which may not be representative of the general population. The range of measurement of this study was only from 80 to 100 BPM for heart rate and from 35 to 40 C for temperature, which may not cover the extreme or abnormal cases. The clinical validation of this study was only based on the comparison with the oximeter and thermogun device, which may not reflect the true values of the heart rate and temperature of the patients. Therefore, further studies are needed to improve the design and performance of the module, to increase the sample size and the range of measurement, and to conduct a clinical validation with a standard reference device.

This study has successfully designed and tested a module for measuring the heart rate and temperature of the patients using a Wemos D1 Mini microcontroller, a SEN0203 BPM sensor, and a MLX90614 temperature sensor. The module has a low error rate and a high consistency in measuring the vital signs of the respondents. The module has several advantages over the conventional devices, such as being low-cost, portable, wireless, and easy-to-use. The module can be used for various applications, such as monitoring the health status of the patients, detecting the signs of fever or hypothermia, and screening the symptoms of COVID-19. The module can also be integrated with other sensors and devices, such as a blood pressure sensor, a blood oxygen sensor, and a smartphone, to provide a comprehensive and convenient health care system..

The study exhibits several limitations and weaknesses. Firstly, it was conducted on a small sample size of only five respondents, which may not be representative of the larger population. Secondly, the measurements were taken at specific multiplexer settings, and it's unclear how the module would perform under different settings or in real-world conditions. Thirdly, while the error rate is within the acceptable range, the sources of these errors need to be identified and addressed to improve the accuracy of the module. Fourthly, potential biases or inconsistencies in the data collection and analysis processes could affect the results. Fifthly, the module was compared with a commercial oximeter and thermogun, but the performance of these tools may vary, and they may not be the gold standard for measuring heart rate and temperature. Lastly, the module needs further validation with other established methods to confirm its reliability and accuracy. Despite these limitations, the study provides valuable insights into the potential of the module as a portable and affordable tool for health monitoring.

IV. CONCLUSION

This study presents the design of a remote vital sign monitoring tool that uses the IoT-based Telegram application for real-time updates. The tool, which focuses on monitoring Blood Pressure and Respiratory Rate (BPM and RR), allows for continuous health monitoring regardless of the patient's location. The data is displayed in real-time on a TFT LCD screen and can be accessed via Telegram, which also sends notifications for abnormal conditions. The device uses the MAX30100 digital sensor for detecting heart and breathing rates. The data obtained showed minimal errors within acceptable limits, with a difference of 1.14% for heart rate and 0.84% for respiratory rate compared to a patient monitor. The study underscores the need for remote, affordable, and easy-to-use health monitoring systems that do not disrupt daily activities.

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