IoT-Based Grapevine Watering System Design and Soil Condition Monitoring

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Abstract. Cultivating grapevines can be in the yard or together with other plants so that grapes are a plant product that needs to be developed. If you cultivate grapevines by knowing the evaluation of the environmental conditions of the soil, to the need for nutrients and water consistently. Grape plants can be predicted for their quality and yield, and can even identify their development from bud to fertilization. By using an Arduino Nano microcontroller as a control system equipped with sensors to measure and monitor soil environmental conditions. The sensors are NPK, soil moisture sensor, temperature sensor, and pH sensor that complement the Arduino Nano microcontroller. Utilizing the lower and upper limit values to automatically water the water and liquid nutrients based on the measurement results. So that the pump is active according to the condition of NPK and soil moisture. Through the use of IoT technology, this research has monitored the condition of the soil environment. With a strong internet connection, this sensor has collected accurate measured information of soil environmental conditions and can also be seen on the Android App. This has contributed significantly to the development of grape farming. Grape vines are more easily monitored and watered regularly.

1 INTRODUCTION

Grapes are one of the fruits that many people really like since they have a fantastic flavor whether they are fresh, sweet, or sour. In addition, it contains significant amounts of the vitamins A, B1, B2, B6 and C [1]. In general, grapes can be grown in your own yard or in a greenhouse along with other plants, so they are a commodity that has to be cultivated. Land preparation, planting, fertilizing, watering, and trimming are just a few of the preparations needed to develop grapes [2]. Based on these procedures, watering and fertilizer are essential to grape cultivation since they directly affect the plants development and fruiting [3]. Water must be supplied in appropriate quantities but not get stagnant for grape plants because it is essential for watering both during the vegetative growth phase and the generative fertilization period [4]. At each stage of growth, grape plants require a different amount of nutrients or

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fertilizer [2]. The vines are watered with a reasonable amount of water twice a day, in the morning and the evening, when they are in the field. In the vegetative period, nitrogen fertilizer needs to be applied at a higher rate based on the farmer's estimations. Grape cultivation will be related to cultivation. The selection of rootstock that is appropriate for the grape variety and soil characteristics is one of the ways that grapes are produced in tropical locations differently from other climates [5]. The Central Bureau of Statistics of Indonesia reports that over the last five years, the nation's wine production has undergone substantial changes. 10,867 tonnes of grapes were produced in 2018, 13,724 tonnes in 2019, and 11,905 tonnes in 2020 over the three years. Following that, it started to rise once more, reaching 12,164 tonnes in 2021 and 13,516 tonnes in 2022. When compared to data from 2018 between 2022, the production increase is insignificant.

So the right thing to do is to improve the condition of the soil or planting medium and to water grape plants with clean water according to their needs. Grape plants that can provide production estimates, quality evaluation [6], and quickly identify plant growth can help the grape farming sector flourish by utilizing embedded systems with the Internet of Things as a way to convey data across great distances. Embedded computer systems are designed expressly to do particular tasks or processes in a complex device or system [7]. This system is not meant for mass use, unlike PCs and laptops. An Arduino Nano microcontroller is attached to sensors for this study that detect NPK, soil moisture, soil temperature, and soil pH. This method determines how many nutrients are present in the soil where grapes are grown. Farmers will find it simpler to provide the right nutritional doses for grape plants as a result.

Additionally, the Internet of Things has a big impact on this study. The Internet of Things (IoT) concept can be integrated with both hardware and software since it can wirelessly send sensor reading data. e.g., scientists [8] with equipment that can be controlled and monitored from fields of crops. By utilizing IoT, researchers [9] promote intelligent agriculture. Software-using applications and Android devices can meet these research needs. According to the Internet of Things (IoT) idea, Android smartphones might be used to check the status of all household appliances as well as operate them [10]. The use of Android smartphones is easier, they have a larger user base, and they support more open source application development. The technique created is meant to make it possible to cultivate grapes properly and effectively, increasing production and reducing grape imports into Indonesia.

2 METHOD RESEARCH

The procedure used in this study begins with a review of the relevant literature, followed by data collecting, system design, testing, and implementing the system.

2.1 Literature Review

This research refers to several previous studies on the topic of IoT-based coverage. One of them researchers [11–13] utilize IoT to create a system that is integrated into hydroponics and soil monitoring with ph values and others. By utilizing raspberry Pi and phyton as a programming language, it will be connected to the temperature sensor and ph sensor. Raspberry Pi is connected to the internet. There is also an application that is useful for monitoring. However, in this system, researchers only utilize it for monitoring ph, temperature and humidity values. In the same modeling variation, researchers [14] designed smart vertical hydroponics to monitor ph, temperature and humidity using sensors. Arduino Uno R3 as a microcontroller and Raspberry Pi as a system control. This system will be monitored in real time using an application. The parameters to be monitored are Ph value and electrical conductivity and carbon dioxide concentration. In this study [15], researchers developed a garden using IoT technology to investigate its benefits compared to a regular garden. Lettuce was chosen as the test crop. The system can monitor the growth environment and adjust the nutrient solution, air temperature, and air humidity according to the situation automatically. The results show that the lettuce from the smart garden has an average weight of about 36.59% higher, 17.2% more leaves, and 13.9% larger stem diameter than those from the ordinary garden. The nitrate content of the smart garden lettuce was also 8.24% better.

The researchers [16] reported having difficulties in growing chili peppers, ranging from soil moisture problems, lack of nutrients, and watering the plants, according to a study on the Internet of Things. Therefore, the researchers used soil moisture sensors and Internet of Things technology, and there will be automation to water the plants as needed. The data is then communicated to the database using pH [17], EC, and temperature sensors. This automated watering and monitoring system improved plant growth; as a result, the height and number of leaves of the chili pepper plants increased every day. Based on sensor detection data, the system also allows farmers to monitor the plants in real time, and the monitoring can be accessed from anywhere at any time using a smartphone. Researchers [18] are among those who utilize the Internet of Things and use sensors to pass their data cooperatively through the network. By doing this, they are helping farmers overcome various challenges such as water shortage, land monitoring, cost management, and increased consumption based on the data provided. During times of water scarcity, irrigation sprinklers are activated based on readings from soil moisture sensors. Mobile phone-based SMS can be used even in emergencies, and weekly yield reports are also generated.

The use of NPK sensors and moisture sensors used to monitor the NPK content and moisture of the soil that is the growing medium for grapevines is what distinguishes this research from other studies that have been done. Because coupled with IoT, the use of NPK can accelerate the delivery of nutrients and automatic watering so as to facilitate farmers while monitoring soil conditions in real time [19–21].

From the description of the research that has been done about microcontrollers and IoT systems can be the basis of this research. The research seeks to utilize IoT and sensors to design an instrument for measuring nutrients and plant environmental conditions. By designing and developing a microcontroller configuration and several sensors to implement an instrumentation tool. This system can be used for various measurement parameters. Arduino Nano as a microcontroller was chosen in this research because the price is quite economical compared to others and also enough pins. In addition to using several sensors, it will be equipped with an android application as a monitor of the measurement results. The concept is a development, incorporation, and refinement of the use of sensors from previous research.

2.2 Data Collection

Sensor readings with different growing media to collect data for this study. NPK value data from soil NPK sensor, moisture content from soil moisture sensor, temperature from temperature sensor, and acidity level from soil pH sensor using comparison measuring instruments. So that the output can be directly triggered from the input conditions. Continuous and real-time data collection.

2.3 System Design

The system design for IoT-based automatic watering and soil condition monitoring consists of hardware design, electrical circuit schematic, and android-based software design.

2.3.1 Systems

The architecture of a watering system and soil condition monitoring is shown in **Error! Reference source not found.**, which is separated into two categories: hardware and software.

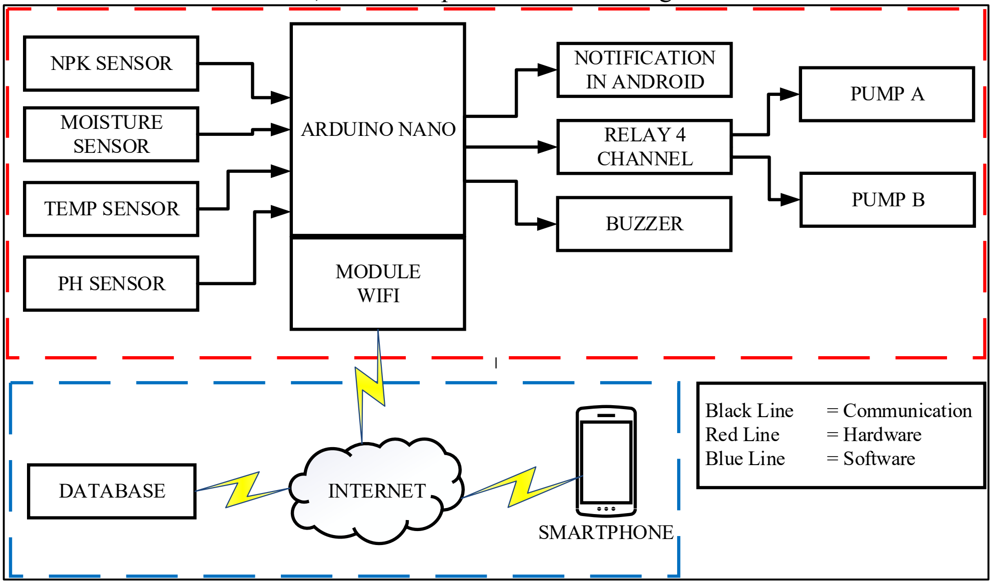

Fig. 1. Block Diagram

The system block diagram is shown in Fig. 1 NPK sensor is used to measure macro nutrients N, P, K. The output of the NPK sensor will trigger the liquid nutrient watering pump. The soil moisture sensor is used to help water the vine by detecting the moisture in the soil. A temperature sensor to measure the temperature of the soil near the vine. A pH sensor to measure the acidity of the soil for grape vines. Arduino Nano, used as an automatic sensor control system. Wi-Fi module as an additional module to access the internet. Notification from the android application as an indicator of soil pH that is rated neutral or not. Buzzer to signal when the temperature reaches the upper and lower limits. Relay, which regulates the on and off of the pump. There are two pumps for watering water and watering liquid nutrients. Database, which serves as a database container for sensor data storage and will be downloaded from the Android app. Internet, which allows the hardware and software to communicate with each other. Finally, a smartphone as a device on the user side to access the monitoring and automatic watering.

2.3.2 Hardware Design

These are the mechanical design drawings,

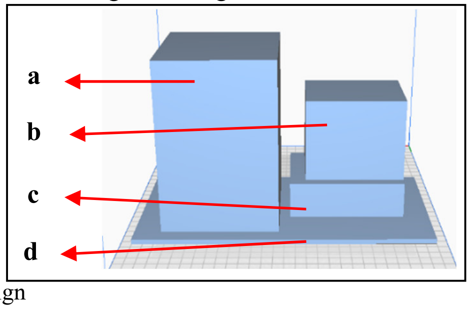

Fig. 2. Hardware Design

The mechanical design is shown in Fig. 2 from the front side. Descriptions of the parts indicated by arrows and letters are as follows, NPK Container is marked "a", Hardware Container is marked "b", Power Supply is marked "c", and Field Board is marked "d".

2.3.3 *Circuit Design*

The circuit design drawing is as follows,

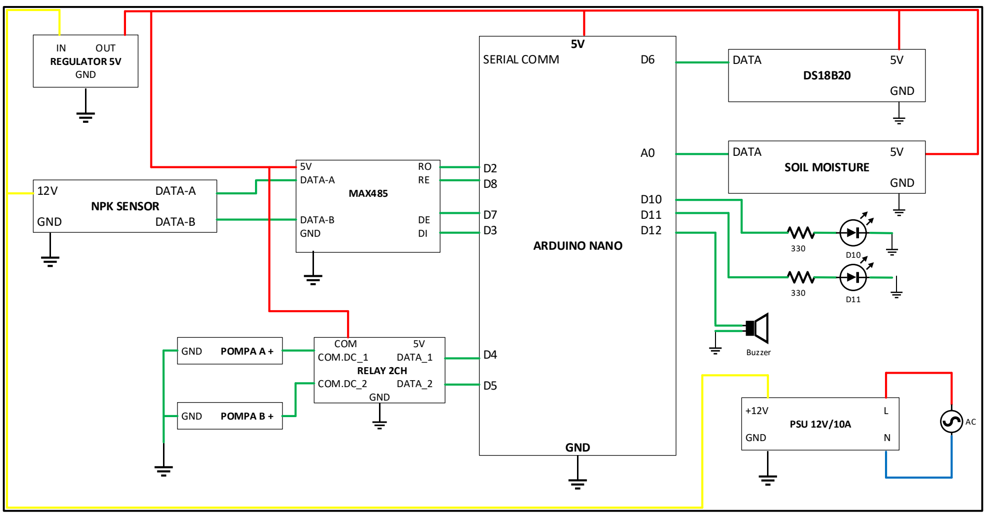

Fig. 3. Circuit Schematic Design

2.3.4 *Software Application Design*

The design drawing for the watering and monitoring application is as follows Fig. 4.

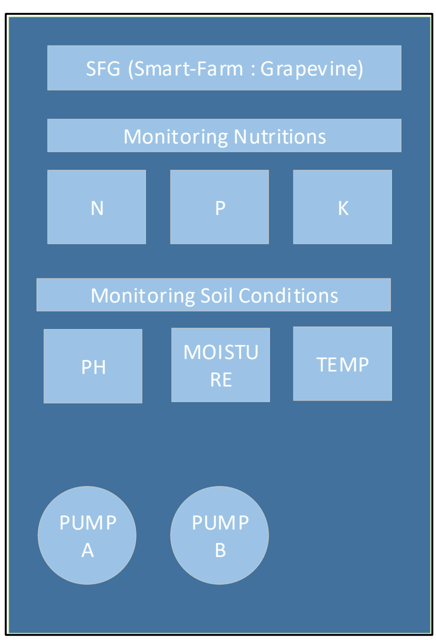

Fig. 4. Design of Software Application

2.4 System Implementation and Testing

This sub section involves combining the tools by putting all the hardware together and connecting it with the software. The app can display the data in a user-friendly manner. After that, in sub section Testing, an explanation of the testing process. That after all the hardware and software are integrated until they are connected to the internet network, the sensors will measure the temperature, pH, NPK, humidity used by the plants. The database will receive the data. Real-time data will be stored in the database so that users can access it using the Android application on a smartphone.

3 RESULTS AND DISCUSSION

In this study, the assembly results, sensor test results, system testing, and analysis serve as the foundation for the results and discussion.

3.1 Assembly Design Results

After preparing the electrical circuit schematics, hardware and software design. The following are the results of the implementation of the hardware design and the results of the overall design (Fig. 5).

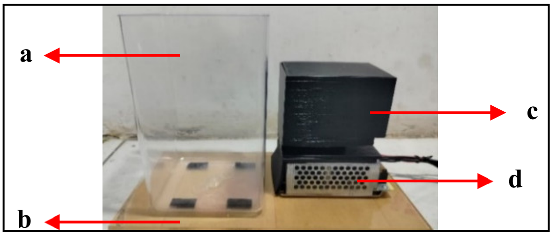

Fig. 5. Result Implementation of The Hardware Design

Fig. 6. Result Implementation of the Overall Design.

Fig. 6 is the result of the implementation of the system and sensors that have been integrated. The explanation of the parts indicated by arrows and letters is as follows, NPK container is marked “a”, Hardware Container is marked “b”, Power Supply is marked “c”, Field Boards is marked “d”, Webcam is marked “e”, Hose and Pump DC 12V 0.4A is marked “f”, Soil NPK sensors is marked “g”, Soil Temperature sensor is marked “h”, Soil pH sensor is marked “i”, Soil moisture sensor “j”.

3.2 Testing Sensor

The following test of the NPK sensor is shown in Table 1. The table explains the comparison between plant media A and B, with measurements of the N, P, K nutrient content as well as pump conditions when the N, P, K nutrients are not suitable.

Table 1. Fertilization to Soil NPK Sensor Systems

Num	Planting Media A			Pump B	Planting Media B			Pump B
	N (%)	P (mg/kg)	K (mg/kg)		N (%)	P (mg/kg)	K (mg/kg)	
1	124	44	68	Off	125	45	70	Off
2	116	43	62	Off	124	44	62	Off
3	116	43	62	Off	124	44	62	Off
4	116	43	62	Off	124	44	62	Off
5	111	41	58	Off	115	43	58	Off
6	89	37	50	On	105	37	52	On
7	79	28	50	On	100	37	50	On
8	78	28	43	On	99	35	49	On
9	78	27	41	On	99	34	48	On
10	75	25	37	On	95	31	41	On

NPK sensor testing presented in Table 1. It can be seen that the pump function to water liquid nutrients according to the condition of the NPK requirement measured by the NPK sensor runs according to design. So that it can anticipate the lack of NPK in grape plants. There are still considerations for the calibration factor and the current received by the sensor to be more accurate and real-time. Then Table 2 presents the comparison between plant media A and B, with measurements of soil moisture as well as pump conditions when the humidity is not suitable.

Table 2. Watering to Soil Moisture Systems

Num	Planting Media A			Pump A	Planting Media B			Pump A
	Soil Moisture Sensor (%)	Measuring Instrument (%)	Error (%)		Soil Moisture Sensor (%)	Measuring Instrument (%)	Error (%)	
1	90	89	0.011	Off	100	99	0.010	Off
2	100	99	0.010	Off	92	91	0.011	Off
3	100	99	0.010	Off	88	87	0.011	Off
4	100	100	0.000	Off	88	87	0.011	Off
5	100	100	0.000	Off	88	87	0.011	Off
6	86	87	0.011	Off	80	80	0.000	Off
7	86	87	0.011	Off	80	80	0.000	Off
8	85	85	0.000	Off	80	80	0.000	Off
9	81	81	0.000	Off	80	79	0.013	Off
10	81	81	0.000	Off	78	78	0.000	Off

Testing the soil moisture sensor presented in Table 2 can be seen the function of the water pump to perform watering water according to the condition of the soil moisture content measured by the sensor runs according to design. That when the measured value of the humidity sensor is below 60%, it will turn on the pump every 3 seconds until the humidity value exceeds 60%. Minimizing late and inconsistent watering of grape vines. Given that grape plants need enough water every day. There are still considerations for the calibration factor and the current received by the sensor to be more accurate and real-time to retrieve data from the database. Then Table 3 presents the comparison between plant media A and B, with temperature measurements as well as buzzer conditions as a marker for temperatures that are too high or too low in the soil.

Table 3. Buzzer to Temperature Sensor Test

Num	Planting Media A			Buzzer	Planting Media B			Buzzer
	DS18B20 Sensor (°C)	Measuring Instrument (°C)	Error (%)		DS18B20 Sensor (°C)	Measuring Instrument (°C)	Error (%)	
1	25.81	25.7	0.004	Off	25.81	25.6	0.008	Off
2	25.46	25.3	0.006	Off	25.56	25.3	0.010	Off
3	25.30	25.2	0.004	Off	25.56	25.3	0.010	Off
4	25.19	25.1	0.004	Off	25.45	25.1	0.014	Off
5	25.00	25.0	0.000	Off	24.87	24.9	0.001	Off
6	24.94	24.8	0.006	On	24.87	24.9	0.001	On
7	24.84	24.7	0.006	On	24.75	24.6	0.006	On
8	24.78	24.3	0.020	On	24.56	24.4	0.007	On
9	24.50	24.1	0.017	Off	25.31	24.3	0.042	Off
10	24.50	24.1	0.017	Off	25.31	24.3	0.042	Off

Testing the temperature sensor presented in Table 3. It can be seen that the buzzer function to notify temperatures less than 25 degrees Celsius runs according to design. So that it can monitor soil temperature continuously. There are still considerations for the calibration factor and the current received by the sensor to be more accurate and real-time to retrieve data from the database. Then Table 4 presents the comparison between plant media A and B, with soil pH measurements as well as notification in Android as a marker for soil pH that is not neutral.

Table 4. Notification Application Android to Soil pH Sensor Test

Num	Planting Media A			Notificat ion in Android	Planting Media B			Notificat ion in Android
	Soil pH Sensor (pH)	Measuring Instrument (pH)	Error (%)		Soil pH Sensor (pH)	Measuring Instrument (pH)	Error (%)	
1	7.00	6.90	0.014	Off	7.00	7.10	0.014	Off
2	7.00	6.90	0.014	Off	7.12	7.00	0.017	Off
3	7.00	6.90	0.014	Off	7.12	7.00	0.017	Off
4	6.90	6.80	0.015	Off	7.12	7.00	0.017	Off
5	6.81	6.50	0.048	Off	7.12	6.90	0.032	Off
6	6.75	6.60	0.023	Off	7.10	7.00	0.014	Off
7	6.71	6.50	0.032	Off	7.10	7.00	0.014	Off
8	6.71	6.50	0.032	Off	7.10	7.00	0.014	Off
9	6.71	6.50	0.032	Off	7.05	6.90	0.022	Off
10	6.50	6.40	0.016	On	6.95	6.80	0.022	On

Testing the pH sensor presented in Table 4. It can be seen that the notification function of the android application to notify pH that is not neutral runs according to design. There are still considerations for calibration factors with measuring instruments to be more accurate and real-time to retrieve data from the database.

3.3 Testing Systems

After testing the sensors with the system that has been built, the following Table 5 presents the results of the integration of all sensors with the final system.

Table 5. Soil Condition Monitoring Systems

Num	N (%)	P (mg/kg)	K (mg/kg)	Moisture (%)	Temperature (°C)	pH	Pump A	Pump B
1	121	43	60	66	24.19	7.25	0	0
2	113	40	56	79	23.69	12.57	0	0
3	58	20	28	84	24.75	7.51	0	0
4	56	20	28	84	23.44	1.48	0	0
5	0	0	0	4	28.37	14	1	1

Fig. 7 presents the software view of the monitoring system. The sensor readings of NPK, humidity, temperature, and pH are sent to the database and then the software retrieves the data from the database.

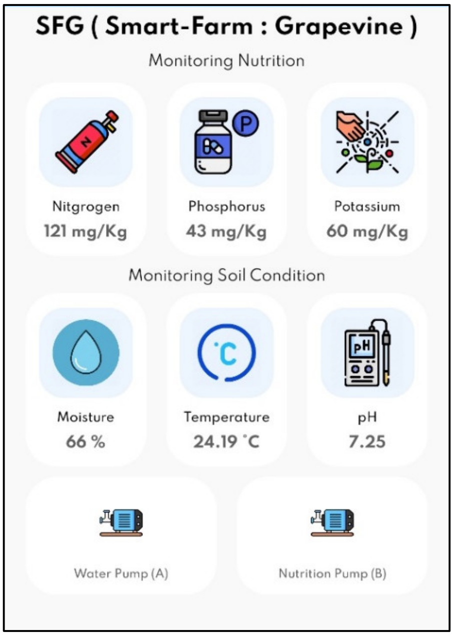

Fig. 7. Monitoring Software

3.4 Discussion

NPK sensors, moisture sensor, temperature sensor, and pH sensors used in the watering system and monitoring of soil environmental conditions run as planned, according to the tables above. The tables found some smooth running of the system. But on the other hand, the factor of calibrating the sensor using a comparative measuring instrument must also be done carefully and consistently. When the sensor measurement results are close to the measurement results of the comparator measuring instrument, it is also necessary to process data filtration on the Arduino Nano. So that the final result of the sensor reading can be said to be accurate for measuring the planned parameters. Internet connection also affects when uploading sensor data. Sensor data is uploaded directly to the database. The latency of the upload process has not been sufficiently resolved as for the process of downloading data to the android application from the database. Unfortunately, this research has limitations for measuring upload and download latency as well as sending and receiving data loads. When it is assumed that the internet is connected stably with the system, it can produce a tool with a low latency system. Then the Arduino Nano microcontroller as a control system can be utilized along with an Android application that functions as a link between the node and the user. The number of analog and digital pins available on the Arduino Nano is sufficient for the use of sensors in this study.

4 CONCLUSION

The NPK sensor and soil moisture sensor used in the automatic watering system for grape vines work as expected. The nutrient pump will activate according to the NPK condition in the soil after the NPK sensor reads the NPK value in the soil by providing a lower limit and upper limit value. The soil moisture sensor with the limit value controls watering, just like watering with nutrients. A database is used as data storage for sensor values that will be provided to the application for monitoring soil environmental conditions is also implemented. The Internet of Things implementation produces monitoring results of soil conditions, nutrient levels, and camera data. One of the limitations of this research is the installation of the Internet of Things which requires an internet connection. Sensor data transmission and will be affected by unstable internet.

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