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Proposal for weather stations on raspberry pi to measure climate in micro-zones

Cesar Augusto Guerrero Mateus[1], Dr. Juan Francisco De Paz Santana[2]

[1]Doctoral Student; PhD in Engineering; Engineering; University of Salamanca;Email:id00771251@usal.es
https://orcid.org/0000-0001-6646-0278
[2]Universidad de Salamanca
fcofds@usal.es

Abstract
The introduction of technology into various aspects of human life has been a long-standing and ongoing endeavor in the modern era. The study of climate behavior has been a concern of human beings for millennia. However, in the past two centuries, significant advancements have been made in the field of climate prediction, aiming to enhance the accuracy and efficiency of this process. Nevertheless, in the country, it occupies a marginal position and is even less utilized. In some cases, the necessity for precise atmospheric data, which can be obtained through the use of cutting-edge technologies, as well as a substantial network of meteorological stations that measure and determine values with greater accuracy and precision, has led to significant investments in these technologies. In the contemporary era, these perspectives have undergone a transformation, with the climate field now perceived as a potential source of economic growth and development in the country. In light of the aforementioned considerations, the objective is to present a proposal for the use of cutting-edge technological solutions, namely artificial intelligence (AI), which is based on machines that are capable of self-learning (machine learning) and are adept at analyzing vast quantities of information, thereby facilitating the advancement of knowledge in this field and enabling more accurate climate behavior prediction in Colombia. The principal objective is to facilitate the utilization of technologies as a predictive tool for climate behavior, with the aim of accurately simulating climate predictions and analyses through computational technologies and expert input. This will entail the convergence of multiple variables to present values that are as close to reality as possible.The objective of this paper is to present a technology based on the Raspberry Pi, software, and sensors, including the configuration of a basic and cost-effective weather station for the collection of climate data on a large scale. This project aims to ensure that technology is utilized with a defined objective to facilitate the study of climate from academic to practical contexts.
Keywords: Self-learning machines; Predictive algorithms; Raspberry Pi; Historical climatological data; Weather stations.

Resumen
Traer tecnologías a los diferentes ámbitos del ser humano, ha sido una apuesta permanente en el mundo moderno. El comportamiento climáticoha sido preocupación del ser humano desde siempre, pero se ha venido dando un desarrollo en este campo desde hacen más o menos unos 200 años que buscan predecir con eficiencia el clima. Sin embargo, en nuestro país es una postura lejana y más aún, de bajo uso. En algunos casos porque la medición y precisión de los datos atmosféricos requieren de inversiones importantes de uso de tecnologías de punta, así como una gran población de estaciones meteorológicas que midany determinen valores más cercanos a la realidad, así como su periodicidad y precisión en el terreno. Hoy se han transformado tales

perspectivas y se empieza a ver el campo climático como una fuente de desarrollo y crecimiento económico del país. Por lo anterior, nuestro trabajo busca presentar una propuesta de uso tecnológico de gran desarrollo cual es la inteligencia artificial, basado en las maquinas que auto aprenden (Machine Learning) yque analicen grandes volúmenes de información que puedan desarrollar conocimiento en este sector que permita predecir con mayor exactitud el comportamiento climático en Colombia.Se busca esencialmente, acercar el uso de las tecnologías como una herramienta para predecir el comportamiento climático con mucha precisión y poder simular mediante confluencia de diferentes variables las predicciones y análisis del clima por tecnologías computacionales, así como de expertos, para poder mostrar valores lo más cercanos a una realidad cierta.La apuesta del presente artículo es mostrar una tecnología basada en raspberry pi, software, sensores como montar una estación meteorológica sencilla y de bajo costo para recopilar datos climáticos a gran escala. En este proyecto se busca lograr que la tecnología tenga un propósito planeado y cierto para ayudar en el estudio del clima desde la academia hacia el sector real.

Palabras clave: Máquinas de auto aprendizaje; Algoritmos predictivos; Raspberry Pi; Datos climatológicos históricos; estaciones meteorológicas.

Introduction

The objective of this paper is to construct weather stations with Raspberry Pi that are capable of storing data in a database and subsequently cross-referencing this data with information from IDEAM (the Institute of Hydrology, Meteorology and Environmental Studies of Colombia) stations.

A weather analysis tool that employs predictive data represents a vision of utilizing diverse technologies in conjunction with one another to create a system that can forecast weather patterns. The project relies on the integration of cutting-edge technologies to develop a sophisticated tool for climate prediction in Colombia. By employing these technologies, it is possible to gain insights into and monitor the climate in specific areas, or micro-zones, across the country.

The objective of the Weather Predictive Tool project is to facilitate the use of the product in a multitude of scenarios and instances, as well as in a substantial number of examples developed with this product. The objective is to facilitate highly accurate weather prediction. It is imperative to leverage technological advancements in a way that addresses this critical factor that impacts human well-being.

With regard to the data set, the official data have been derived from the meteorological stations operated by the IDEAM network across the country. These stations were initially installed in the 1940s and continue to provide the data used as the basis for this research. The IDEAM meteorological stations provide a wealth of data on climate measurement, offering a rich basis for significant analyses in the present research. A total of 2,800 weather stations are distributed throughout the country, situated in a variety of locations, including different thermal zones, jungle conditions, and arid areas. This provides a diverse range of geographical locations, enhancing the data collection process for this project.

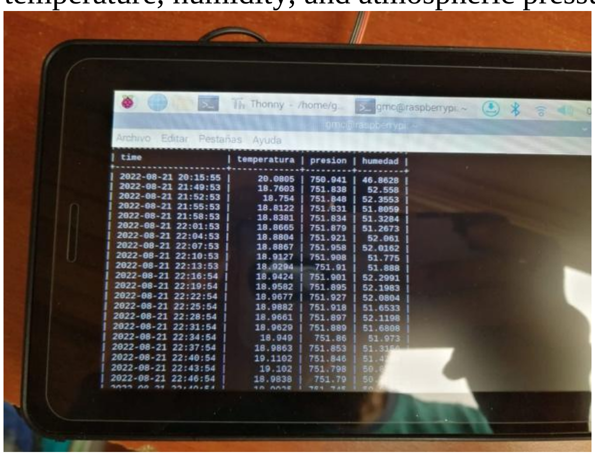
Methodology

Proposal of a climate analysis tool through predictive data

Climate change is a phenomenon that has the potential to unite all of humanity. Consequently, the study of climatological behavior is an indispensable subject for contemporary humanity. It is therefore pertinent to study the behavior of the El Niño and La Niña phenomenon as determinants of climate, in order to gain insight into its influence on the climatological behavior of the planet. The objective of the study is to analyze these behaviors in Colombia, as well as to examine the influence of other variables, including wind patterns, solar radiation, topography, and others. In light of the aforementioned variables, which serve to accentuate or diminish the behavior of the two phenomena, a study of these behaviors is proposed over a period of approximately 40 years, with data collected from Colombia. The data were obtained from official sources within the Colombian state apparatus.

The accumulation of data from weather stations over an extended period gives rise to a substantial volume of information that is challenging to process using conventional methods. It is therefore necessary to develop a method of managing large volumes of data, with a view to analyzing and evaluating the data sets under study and providing estimates of the climatological behavior over a period of time that will allow the climate to be studied in Colombia. The extensive historical data set, coupled with a multitude of observation points, furnishes a substantial repository of information that enables a comprehensive examination of the climatic variations that have occurred over a considerable span of time.

Subsequently, the objective is to analyze climatological behaviors at different points in time, which may result in the identification of climatological patterns of such behaviors. This, in turn, will enable the definition of relevant variables that affect the climate in a significant manner. The objective of this work is to develop a data model extracted from a micro-zone network that can accurately predict the variables of humidity, temperature, and atmospheric pressure over a period of time, thereby enabling the estimation of future climate behavior.
In order to achieve the aforementioned objectives, a network of weather stations was constructed using a Raspberry Pi microcontroller and Bosch bme280 sensors, which are capable of measuring temperature, humidity, and atmospheric pressure at specified time intervals.



Rasberry with Data 1

The objective is to develop a climatological analysis tool that employs a range of technologies, including data management, machine learning, and data analytics, to facilitate the examination of future climate projections based on historical data. This will facilitate the estimation of future climate conditions by cross-referencing multiple climate variables at varying timescales. By identifying the extent to which a variable affects the climate, the tool can predict the nature of future climate variations. It is important to note that the tool can continue to be fed data, which will result in a more refined climate analysis. In conclusion, the most significant outcome of this project is the development of a tool that can analyze data collected over the past four decades and predict future climate patterns based on historical data.

Weather Network with Raspberry Pi

The advent of reduced license plates has precipitated a transformation in the way in which computers are perceived, utilized, and deployed. This is an indisputable example of a reduced license plate that has significantly impacted the learning, use, and management of these technologies. In the present study, a Raspberry Pi will be utilized with a Raspbian operating system, a database of BME280 from Bosch, connectivity cables, and a weather station that will measure the weather at intervals of one minute. These data will then be stored in the database of each Raspberry Pi and subsequently collected and graphed with Grafana in a dashboard that will illustrate the behavior of the weather at different times and moments of the day or night.

The Raspberry Pi is a low-cost, small-sized computer that has gained significant popularity in recent years. The Raspberry Pi's diminutive dimensions and economical price point render it an optimal choice for Internet of Things (IoT) initiatives and other endeavors where a compact, robust computer is required.

In this instance, the BME280, a temperature, humidity, and pressure sensor, is employed in conjunction with the Raspberry Pi. This sensor is highly accurate and straightforward to use, making it an optimal choice for applications where temperature, humidity and atmospheric pressure must be monitored.

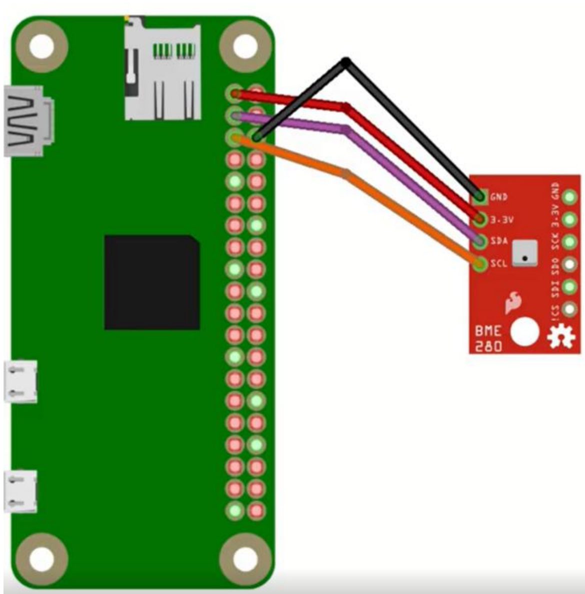
To utilize the BME280 in conjunction with the Raspberry Pi, it is first necessary to establish a connection between the sensor and the GPIO port of the Raspberry Pi. Subsequently, a library such as PyBME280 can be employed to facilitate access to sensor data from the Python programming language. The library is straightforward to use and enables straightforward reading of the sensor data.

Rasberry Pi Connection Map

Once access to the sensor data has been obtained, a number of interesting applications can be undertaken. For example, the BME280 sensor was used to measure the climate in a micro area, thereby enabling the monitoring of climate factors in this area. The sensor can also be used to monitor the humidity level in a garden or to monitor the air in a room for air quality issues.

Rasberry PI + BME280

The assembly of the station is produced by connecting the Raspberry Pi with the BME280 sensor according to the Figure.



Raspberry Pi Sensor BME280 Connection

The connection map enables the transfer of weather data obtained from the BME280 sensor to the Raspberry Pi via the sensor and I/O connections of the Raspberry Pi. In order to enable the connection on the Raspberry Pi, it is necessary to navigate to the Raspberry Pi configuration menu, select the interfaces tab and activate the I2C connection. Once this has been completed, the

interface will be enabled upon startup. Subsequently, within the terminal of the Raspberry Pi, the following command is entered:
The next step is to install the required libraries using the command:

sudo pip install pimoroni-bme280 smbus

This will take a few seconds and then the necessary libraries will be downloaded. At this point, the Python code can be written.

Data, Procurement, Cleanup, and Process
In the current year, a network comprising four stations was constructed using a Raspberry Pi and a BME280. The stations collected data from a limited geographical area in order to ascertain changes in climate conditions within that area. To facilitate the integration of the Raspberry Pi with the Python and MariaDB environments, it is necessary to open a command window on the Raspberry Pi and enter the following command:

The command to install the Python3-MySQLdb package is as follows:

sudo apt-get install python3-mysqldb

This downloads MariaDB and installs the requisite software.The objective is to refine the data and feed a machine learning model so that when the data is cross-referenced with an IDEAM station, the behavior of the climate in a micro area can be predicted.

Red Rasberry Pi IDEAM Station

The data were obtained using a Python-based code that establishes a connection with the BME280 sensor gate via a designated function.
In this code, the input of the information is validated in real time, thereby enabling the user to ascertain the behavior of the three variables in real time, given that the BME280 sensor is measuring.

```python
1  import time
2  import datetime
3  from datetime import date
4  import MySQLdb
5
6  db = MySQLdb.connect(host="localhost",user="raspi", passwd="raspberry",db="clima") #conecta con  MySQL/MariaDB
7  cur = db.cursor() #crea el cursor para las peticiones de  MySQL/MariaDB
8
9  try:
10     from smbus2 import SMBus
11 except ImportError:
12     from smbus import SMBus
13 from bme280 import BME280
14
15 # Inicializa el BME280
16 bus = SMBus(1)
17 bme280 = BME280(i2c_dev=bus)
18
19 # Descartando el primer valor
20 temperatura = bme280.get_temperature()
21 presion = bme280.get_pressure()
22 humedad = bme280.get_humidity()
23 print('Comienzo de lectura en 3 segundos')
24 time.sleep(3)
25
26
27 while True:
28     temperatura = bme280.get_temperature()
29     presion = bme280.get_pressure()
30     humedad = bme280.get_humidity()
31     fecha = date.today()
32     hora = datetime.datetime.now().time()
33     print (fecha), "-", unicode(hora.replace(microsecond=0))
34     print('{:05.2f}*C {:05.2f}hPa {:05.2f}%'.format(temperatura, presion, humedad))
35     time.sleep(300)
36
37     cur.execute('''INSERT INTO BME280_Data(temperatura,presion,humedad) VALUES(%s,%s,%s);''',(temperatura,presion,humedad))
38     db.commit()
39
40
```

Python Code Illustration

The initial four lines import the time library, thereby enabling the user to control the commencement of the sensor's data transmission. The subsequent line imports the data time library, allowing the user to ascertain the time and date of the data transmitted by the sensor, as well as the source from which this data is derived. This is specified in the third line. In the fourth line, the library that facilitates communication with the database where the data obtained from the sensor is to be stored is imported.

On the subsequent line, a database variable is established to facilitate the establishment of a connection to the database in question, encompassing the pertinent server, user, user key, and database name. The subsequent line of code establishes the cur variable, which serves as a cursor for database requests and facilitates communication between the various components. Subsequently, in the event of an error being identified within the code, it is captured in order to prevent the execution of the code from being disrupted (lines 9 to 13). Subsequently, the BME280 sensor lines 16-17 are initialized. Subsequently, the initial value transmitted by the sensor is disregarded, as it provides an outdated measurement at the outset, which would otherwise disrupt the continuity of the process. To address this, a time delay of 3 seconds is introduced using the time.sleep(3) function, allowing for the acquisition of a subsequent value. From line 19 to 24, the values of temperature, pressure and humidity are recorded and added to the data time base in order to save the moment of the data in date and time. Subsequently, line 27 of the while loop is entered to ensure the maintenance of a sequential data collection cycle until the process is terminated manually. Similarly, the data to be transmitted from the date and time to the database is formatted. The print format in the visual component of the command line enables the desired visualization of the data with postfixes denoting temperature in degrees Celsius, pressure in hectopascal, and humidity in percentage. Line 32 contains a time.sleep() function, which is used to determine the optimal cycle time for acquiring sensor values. Subsequently, the data are inserted into the temperature, pressure, and humidity database on lines 37 and 38. The primary value of the table is

a time-stamp field that is automatically updated based on the programmed database settings. This ensures that each sensor record is saved at a designated time interval within the database.
The data has already been stored in a database on each Raspberry Pi. This information can be used to analyze the data in the micro-zone, which is composed of four Raspberry Pis that act as stations for measuring the aforementioned data.

Presentation of Data

This section will delineate the way in which the data are presented for analysis and utilization. The tool used for this purpose was Grafana, which was employed to construct a dashboard for the presentation of the extracted information from the databases that were used to produce our Raspberry Pi stations with the BME280 sensor.

Illustration DashBoard Grafana

As can be observed in the provided graph, the variables of humidity, pressure, and temperature are represented. In order to utilize Grafana as a dashboard, it is necessary to install it on the Raspberry Pi from the Grafana website. ***https://grafana.com/tutorials/install-grafana-on-raspberry-pi/***

In the install Grafana section, follow the steps on the page:

1. *wget -q -O - https://packages.grafana.com/gpg.key | sudo apt-key add -*
2. *echo "deb https://packages.grafana.com/oss/deb stable main" | sudo tee -a /etc/apt/sources.list.d/grafana.list*
3. *sudo apt-getupdate*
4. *sudo apt-getinstall -y grafana*
5. ActivateGrafana server:
   sudo /bin/systemctlenablegrafana-server
6. StartGrafana server:
   sudo /bin/systemctl start grafana-server
7. Finally in a browser run the *ip of the raspberry pi like this: hhtp://<ip_rasberry>:3000*

This section will require the administrator credentials and request that the password be changed in order to enhance the security of the access credentials.

Having completed the installation of the requisite software, the next step is to establish a connection between the MariaDB database and Grafana.

Once Grafana has been installed, the data received from the MariaDB database is subjected to testing on the Raspberry Pi. The next step was to enter the Raspberry Pi console and input the following command:

The command "sudomysql -u root" should be entered, followed by the "Enter" key.

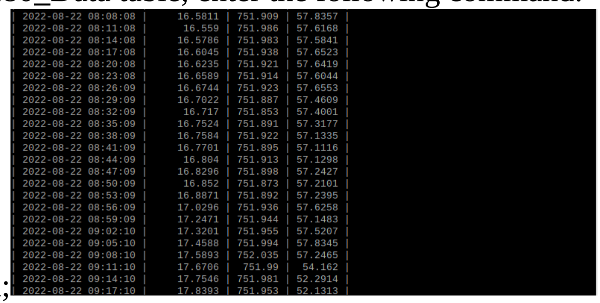
The database can then be accessed via the following command:

The command USE Klima; Enter is then executed.

A SQL query on the base is then executed, as follows:

To view the contents of the BME280_Data table, enter the following command:

SELECT * FROM BME280_Data;



2022-08-22 08:08:08	16.5811	751.909	57.8357
2022-08-22 08:11:08	16.559	751.986	57.6168
2022-08-22 08:14:08	16.5786	751.983	57.5841
2022-08-22 08:17:08	16.6045	751.938	57.6523
2022-08-22 08:20:08	16.6235	751.921	57.6419
2022-08-22 08:23:08	16.6589	751.914	57.6044
2022-08-22 08:26:09	16.6744	751.923	57.6553
2022-08-22 08:29:09	16.7022	751.887	57.4609
2022-08-22 08:32:09	16.717	751.853	57.4001
2022-08-22 08:35:09	16.7524	751.891	57.3177
2022-08-22 08:38:09	16.7584	751.922	57.1335
2022-08-22 08:41:09	16.7701	751.895	57.1116
2022-08-22 08:44:09	16.804	751.913	57.1298
2022-08-22 08:47:09	16.8296	751.898	57.2427
2022-08-22 08:50:09	16.852	751.873	57.2101
2022-08-22 08:53:09	16.8871	751.892	57.2395
2022-08-22 08:56:09	17.0296	751.936	57.6258
2022-08-22 08:59:09	17.2471	751.944	57.1483
2022-08-22 09:02:10	17.3201	751.955	57.5207
2022-08-22 09:05:10	17.4588	751.994	57.8345
2022-08-22 09:08:10	17.5893	752.035	57.2465
2022-08-22 09:11:10	17.6706	751.99	54.162
2022-08-22 09:14:10	17.7546	751.981	52.2914
2022-08-22 09:17:10	17.8393	751.953	52.1313

Database Illustration

Configuring Graphana with the BME280 database

The next step is to enter Grafana in order to configure the visualization with the database, which is accessed via the IP address of the Raspberry Pi and port 3000. The subsequent step is to create a new dashboard within Grafana, which can be accessed from the main screen.

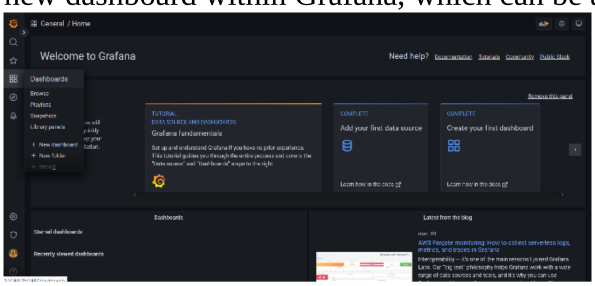


Illustration Grafana Main Screen

The initial configuration of MySQL is achieved through the data source option, which allows for the establishment of a connection.

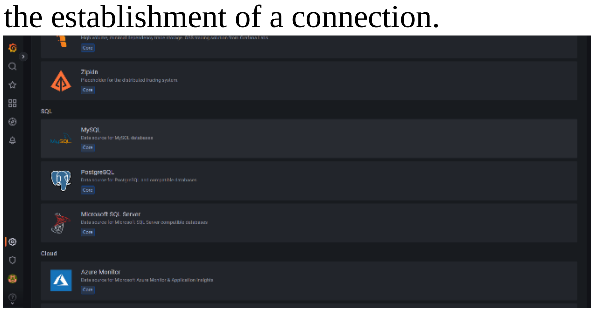


Illustration Configure to MySQL

At this juncture, the connection with the server, database, key, and user password is configured.

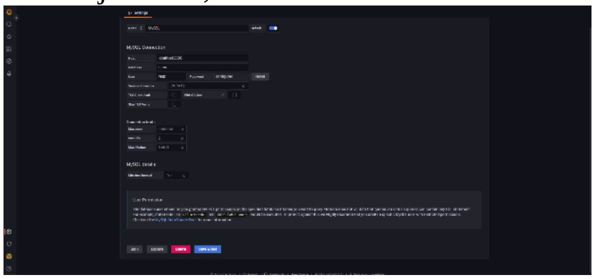
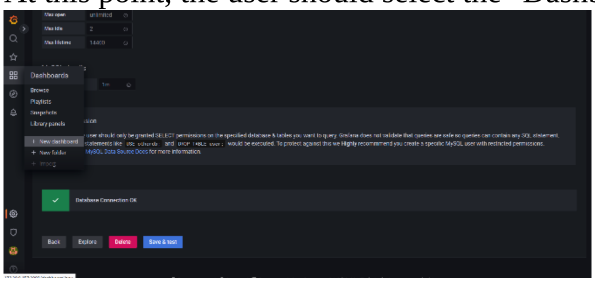


Illustration Configuration Connection to the base

In the event that the data is found to be satisfactory, two green confirmations will be generated to confirm the established connection.
At this point, the user should select the "Dashboard" option once more from the menu on the left.



New Dashboard Illustration

At this juncture, the option to select a new panel becomes available. Once this has been done, a dashboard will be displayed, which must then be configured in accordance with the desired visualization of the database data. The following example illustrates the temperature data.

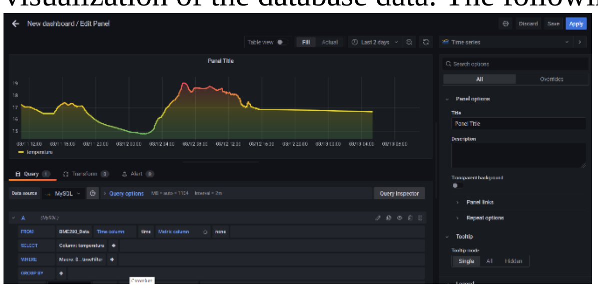


Illustration Temperature Dasboard

The capabilities of the Grafana product allow for a wide range of potential visualizations of the Raspberry Pi in various connected configurations, with the data stored in a database. In conjunction with the IDEAM stations, a micro-zone can be delineated, thereby enabling the precise measurement of climate behavior within this micro-zone.
The potential applications of this project in the real world are numerous, given the diverse range of approaches and working methods that can be employed with the technologies described herein. The objective of this article is to demonstrate how climate measurement can be achieved with a limited budget, and how data can be collected and subsequently analyzed in order to predict climate patterns at the micro-scale. The consolidated information can then be stored on cloud servers for further analysis and comparison.

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