A Smart Wearable for Sudden Infant Death Syndrome Monitoring

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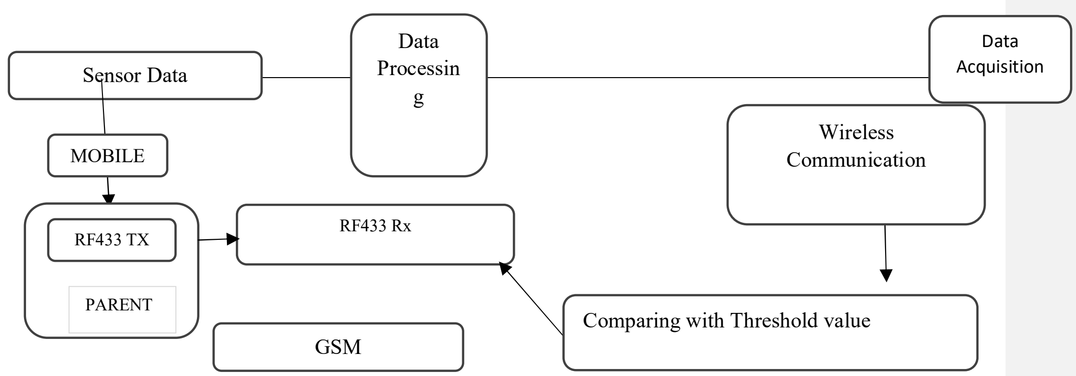
ABSTRACT-- One of the main causes of newborn deaths, while they sleep, is Sudden Infant Death Syndrome (SIDS). For the creation of Baby Night Watch, we matched many emergent research fields to boost the safety of infants. A Wearable IOT Device, a Gateway, and the H Medical Interface make up its components. Body temperature, heart and breathing rates, and body position can all be monitored by the Wearable IOT Device, which is a wireless sensor node built into a chest belt. This piece of data is processed only enough to send it to the Gateway via Zig Bee technology, where it is then made available to the user via the H Medical Interface. In the event of a critical occurrence, the device will sound an alarm that is audible and visible nearby and transmit a distress signal to a mobile application. Experiments have shown that the SWS has the potential to identify situations that could endanger an infant's life.
Keywords: SIDS, H Medical Interface, Chest belt, Zig bee, SWS

I.INTRODUCTION

The fundamental driving force for creating a Smart Wearable System (SWS) capable of enhancing the newborn's safety was Sudden Infant Death Syndrome (SIDS), one of the leading causes of infant death. The "Baby Night Watch" project integrates a variety of emerging technologies, including wearable's, smart fabrics, embedded systems, wireless communications, web interfaces, and mobile applications, to keep an eye on the babies as they sleep. This SWS is made up of a Wearable IOT device, a Gateway, and an H Medical Interface. The Wearable IOT Device is the sensor component, and it acts as a chest belt to track body posture, heart and breathing rates, and body temperature. This set of criteria is essential for both identifying SIDS scenarios and assessing the quality of sleep. Infants are particularly susceptible to SIDS because of the risk of asphyxiation, thus doctors advise that they sleep on their backs rather than their stomachs. To continuously track the position of the baby as they sleep, we have created an algorithm. This program, which is based on accelerometer data, can recognize the baby in all four sleep positions—sleeping on his stomach, laying on his side, and resting on his back. Moreover, abnormal breathing patterns and heart rates are two of the key indicators that SIDS may be on the horizon. We employed the same 3D accelerometer for the detection of breathing rate, and we created a low complexity, low overhead algorithm. Our technology measures the heart rate using textile electrodes that are stitched into the chest band and have a specific electrical. The newborn's typical heart rate is greater than 100 beats per minute. We use a tiny contactless infrared temperature sensor to detect body temperature
In this paper, we designed a system to track an infant's activity and health to provide parents with essential information. To avoid causing the infant any discomfort, the prototype of the entire system should be developed to be minimal. By expanding the usage of wireless communication technologies, it resolves the majority of the problems experienced by the infant and parents will receive up-to-date information in real time.

Monitoring framework



II.OBJECTIVE

The goals of this study are,

To develop a low-cost monitoring system

- To improve newborn safety by giving them the care that is concentrated around them 24 Hours a day.
- Physically worn baby monitoring items to ensure greater contact with the baby's body, quickly collect baby health vitals and transfer real-time data to connected devices would make this system an effective approach to monitoring the infant in the absence of the parent.
- To effectively address these research issues, this multidisciplinary study will draw on the expert knowledge and abilities of specialists in the fields of material science, chemistry, manufacturing, information technology, and healthcare.

III.LITERATURE REVIEW

L. R. Blackmon, D. G. Baton (2022) Apnea, sudden infant death syndrome, and home monitoring [1]: Apnea occurs frequently in infants as they sleep, especially in preterm infants. Nonetheless, apnea can occasionally result in major health problems, such as SIDS (sudden infant death syndrome).

Comment [s1]:

Comment [s2]:

Comment [s3]:

Hong Zhou, Brad Gold (2021) A Domestic adaptable infant monitoring system using Wireless Sensor Network s [2]: It is a system that keeps track of an infant's environment, behavior, and vital signs using a network of wireless sensors.

Alaric Salah (2020) A Real-time Internet of things based affective framework for monitoring infants [3]: It is the system that analyzes the infants' behavior including movements, facial expressions, and vocalizations to assess their overall affective state.

Xavier Lopez Gallo(2019)MARRSIDS: Monitoring Assistant Reduce the Risk of Sudden Infant Death Syndrome[4]:The goal of MARRSIDS is to offer a non-intrusive, reasonably priced method of monitoring newborns as they sleep and lower the incidence of SIDS.

Philip Winder bank-Scott (2017) A Non-invasive wireless monitoring device for children and infants in pre-hospital and acute hospital environments [5]: These instruments are made to measure several physiological factors like temperature, oxygen saturation, heart rate, and respiratory rate.

D. Fernandez(2016)Energy saving mechanism for a smart wearable system, Monitoring infants during sleep[6]:A smart wearable system that monitors infants while they sleep can incorporate features including sleep detection, power management, low power components, sampling rate, and motion activation.

Chilung-Yao fang (2016) a vision-based Infant Monitoring System using a PT IP camera [7]: It is a system that tracks and monitors an infant's behavior using a PT IP camera and computer vision algorithms.

Gregory .Held (2015) Evaluation of Ultrasound based sensors to monitor Respiratory and Non Respiratory movement timing in infants [8]: Ultrasound-based sensors are an intriguing new technology with intriguing clinical applications that can monitor newborns' respiratory and non-respiratory movement.

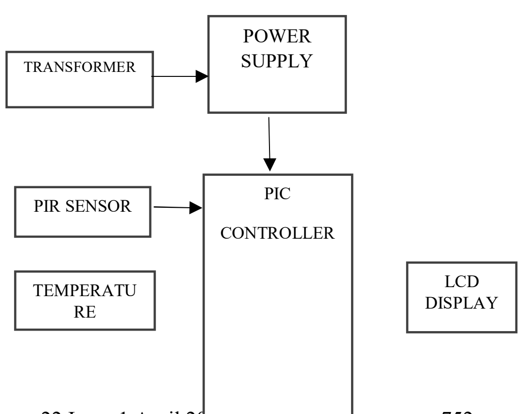
IV.PROPOSED SYSTEM

• The framework for effective baby monitoring proposed in this paper uses wireless communication and wearable sensors.

• The suggested framework makes use of a new, more straightforward design that includes pertinent sensors coupled to a microcontroller and is securely fastened to a baby.

• The infant's heart rate is continuously monitored by a pulse sensor in the proposed system, and if any aberrant readings are detected, a message is delivered to the baby's parents via a GSM module.

V. DATA FLOW DIAGRAM



PULSE SENSOR

VI. WEARABLE TECHNOLOGY

Real-time data monitoring, a lack of fit, and inaccurate information are some limitations of monitoring babies. Technology for wearable infant monitoring has developed to address all of these issues. The main wearable goods with healthcare functionalities now on the market include smartphones, smart watches, and smart clothes. The majority of wearable infant monitoring technology comes in the form of smart clothes or wearable gadgets that can wirelessly connect to smartphones. Baby monitoring gadgets that are worn on the body to make better physical touch with the infant, effectively gather vital signs and transfer real-time data to connected devices. The most widely used smart wearable health monitoring systems, their features, and their operational process are covered in the section that follows.

1. LEVANA OMA SENSE:

Raj Jain started the Canadian corporation Levant. The business began making baby monitors in 2001 and is the first in North America to offer such a color screen. A wearable infant breathing and movement monitor called Levant Omar Sense has the following dimensions: 2.4 inches (H) x 1.92 inches (W) x 1 inch (D). After detecting no movement for around 15 seconds, the device stimulates the baby using unique wakeup technology. This portable gadget ensures that there is no skin contact by being attached to the front of a baby's nappy, pants, or button-up pajamas. Astra, Alexa, and Ayden are three updated baby monitoring models offered by Levant.

The potential disadvantages are the difficulty to be used with clothing that doesn't have an opening over the belly, the lack of a smartphone app, and the device's restricted functionality while traveling.

2. SNUZA HERO

The wearable Snooze Hero was created to track a baby's abdominal movements. The device is shown to be comprised of medical-grade polycarbonate, silicone, and thermoplastic elastomer (TPE), along with a motion sensor.

The item is readily attachable to the baby’s nappy as shown and measures 1.7 inches (W), 1.1 inches (D), and 2.9 inches (L). The flexible, ultra-sensitive tip is made to be able to detect a baby's sleep activities and the smallest abdominal motions. Typically, it detects more than 8 motions per minute; anything below that triggers an alert. Snooze Hero gently vibrates to rouse a baby while they are motionless for 15 seconds .Co-sleeping or sharing a bed is not recommended when using Snooze because it is made to detect external movements. Also, the motion makes it difficult for Snooze to adequately observe the infant whether he or she is in a car seat or pram.

3.MONBABY

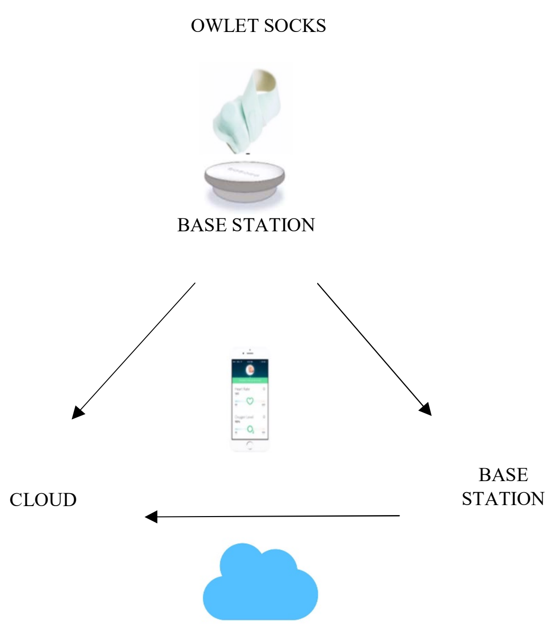
Mon Devices, a maker of wearable Mondays, is a wearable technology firm with headquarters in New York City, USA. A circuit board with tiny surface-mount electronic components and a microprocessor chip with low-energy Bluetooth integration may be found inside the Mon Baby smart button. Regardless of the infant's size, the tiny wireless smart button can be quickly attached to a piece of clothing for a baby. The intelligent button monitors a baby's breathing, level of activity, position when sleeping, and fall detection. Also, it can measure the surrounding air temperature and safeguard the infant from extreme heat or cold. The Bluetooth-connected smartphone, tablet, or other device receives and transmits the bio signals.

However the Mon Baby smart button, a tiny sensor-integrated gadget that emits 1000 times less radio frequency than a regular mobile, effectively monitors a baby's vitals.

4. OWLET SMART SOCKS

Owlet Baby Care was established to provide goods that would make parenting simpler. The Owlet baby monitor is a piece of technology that consists of a base station and a soft Smart Sock. The Smart Sock, which fits securely on a baby's foot, has a hospital-grade noninvasive pulse oximetry sensor implanted in it to track the baby's heart rate and oxygen levels as they sleep. The base station and smartphones or other devices are connected and the Smart Sock uses Bluetooth technology. Vital health signals are gathered and sent to the base station via the sensor affixed to a specially-made Smart Sock. Following that, the data is transmitted straight to linked cell phones and the internet cloud. Everything is well when the base station glows green, meaning that the heart rate (60-220 BPM) and oxygen levels (95%) are within normal limits. In any case, if a baby's heart rate or oxygen levels drop too low or too high, the base station will sound an alarm with a flashing red light and send a notification to the parents' cellphones via an app.

However, many parents have also mentioned that their anxiety has increased as a result of frequent false alarms, app crashes, data security, and real-time data transfer**.**



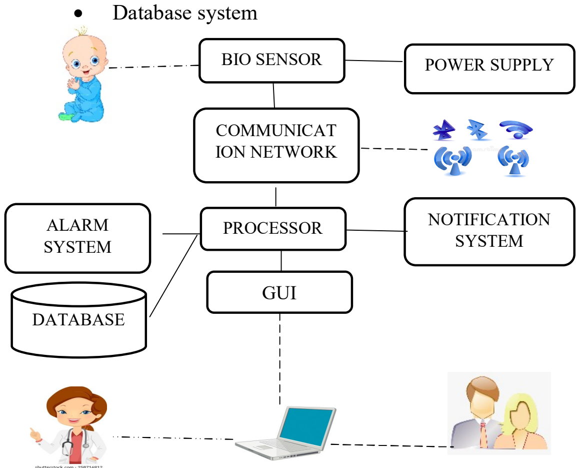
VII.WIHMS

WIHMS-Wearable infant health monitoring system **.**For the purpose of identifying and avoiding several ailments, baby health monitoring must be ongoing. Wearable new-born health monitoring systems have emerged thanks to recent advancements in wearable technology (WIHMSs). These devices offer an advantage over traditional new-born health monitoring systems, which are restricted to clinical settings, cumbersome, and uncomfortable for infants. This paper covers certain cutting-edge WIHMS and discusses their benefits, drawbacks, and difficulties. A wearable is a group of gadgets that typically includes a personal computer (PC) worn on the person's belt or back, a head-mounted display, wireless communications equipment, and an input device like a touchpad. Wearable's can either be tattooed to the skin as E-patches or worn externally on the body as accessories and E-textiles. During the 1960s, wearable technology advanced significantly, changing people's lives and occupations. Throughout the years, these gadgets have become incredibly popular for a range of uses, including industry, mobile learning, fitness, health care, and monitoring.

GENERIC ARCHITECTURE OF WIHMS

A WIHMS is made up of various parts, each of which serves a specific purpose. The several WIHMS components, each of which is described below.

- Bio Sensor
- Network Communication
- Processor
- Graphical User Interface
- Alarm system
- Notification system
- Power supply
- Database system

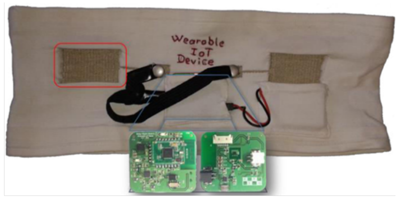


VIII. SYSTEM DESIGN

The Wearable IOT Device gathers several physiological data types and transmits those parameters to the Gateway, which is within the Wearable IOT Device's communication range. The SOC CC2530, an IEEE 802.15.4-compliant wireless transceiver radio, is used for this off-body communication across the 2.4 GHz Industrial, Scientific, and Medical (ISM) band. All of the data sent by the wearable IOT device is analysed by the gateway's software. The Gateway will begin buzzing and transmitting alarms to the Cloud Storage Centre if an unexpected incident occurs. The H Medical Interface and the associated mobile applications are connected to the cloud, which saves the data and exchanges it with them. The H Medical Interface enables users to examine a baby's health, access previously saved information, view the information gathered, and export data in various file formats. The interface was fully implemented in web programming languages (JavaScript, PHP, and SQL), mark-up language (HTML5), and style sheet language to ensure that it is accessible on any device (CSS3).

WEARABLE IOT DEVICE

The Wearable IOT Device uses the Texas Instruments CC2530 SOC and Zig Bee wireless technology to collect the infant's physiological characteristics, parse them, and transfer the processed data to the Gateway. The Z-Stack API was chosen as the Zig Bee stack for this project.

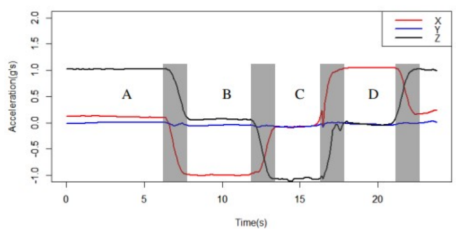


1. HEART RATE SENSOR

The complete ECG acquisition requires a lot of resources. Because it demands a large power source for data transmission or numerous processing resources, which are typically unavailable for wearable devices due to power and size restrictions. We shall therefore only collect heart rate data in light of the needs and limitations of the wearable IoT device. Two textile electrodes were created based on the invention and used as the sensor arrangement for the chest belt.

2. INFANT'S POSTURE

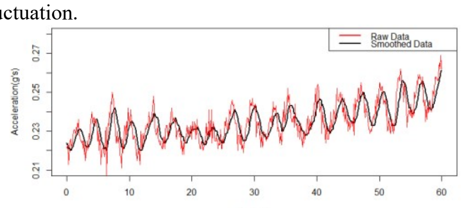
The LSM330DLC inertial sensor fromSTMicroelectronics was employed to track the positions of the infants while they slept. The built-in gyroscope was not utilized in this project. TheLSM330DLC includes an SPI/I2C serial interface, a dynamically user-selectable full-scale range, and three separate acceleration channels. The force that the earth's gravity (1g or 9.81m/s2) applies to each axis makes it simple to distinguish between the newborns' various postures.



Acceleration variation on each axis over positions changes

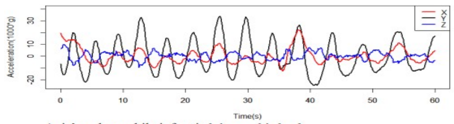
3. BREATHING RATE SENSOR

The same 3D accelerometer mentioned above is utilized to measure breathing rate. Since the 3D accelerometer gathers data at a rate at least ten times greater than the signal's highest frequency, the sampling rate was set at 10 Hz (60 breaths per minute). the information gathered throughout a minute in one of the accelerometer's axes. A sliding window smoothing algorithm was used, with a window of 10 samples or 1 second, due to the significant fluctuations in the original signal between each sample (shown by the red line). As a result of the smoothing algorithm's application, the signal produced is quite reminiscent of a breathing pattern, and there is nearly no data fluctuation.

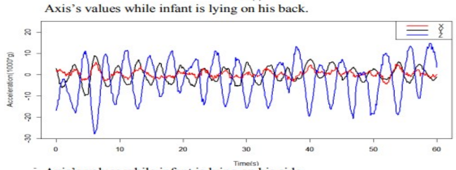


Smoothed and unsmoothed data acquired from the 3D accelerometer

The signal must start on the Middle state, and move through the High state, Middle state, Low state, and Middle state once more to correctly recognize and validate a breathing cycle. The maximum and minimum breathing signal values are set by a threshold interval, which establishes the Middle state. One of the crucial elements in ensuring the proper operation of the breathing rate sensor is the threshold range selection. If this interval is too small, the algorithm may miss the transition from the Middle state to the Low or High state, and if it is too large, the state machine may never reach the Low or High state.The breathing pattern is the signal that remains after the system eliminates the continuous component of our signal using this technique. In addition, the system can employ a static threshold interval, which eliminates the requirement for it to compute the threshold limits regularly. As a result, fewer processing resources are used, which leads to a more energy-efficient approach.



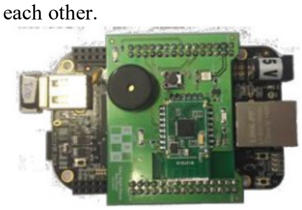
Axis's values while infant is lying on his back.



Axis's values while infant is lying on his side.

4. GATEWAY

A gateway is a BeagleBone Black that has a Debian Wheezy image installed on it. To provide network services, a lighttpd server with PHP 5.1 was deployed on it. A buzzer, RGB led, push-button, and CC2530 were added to a shield for the BeagleBone Black. A serial port communication protocol was utilized for the CC2530 and BeagleBone to communicate with each other.



Gateway: shield placement on the Beagle Bone Black

H MEDICAL INTERFACE:

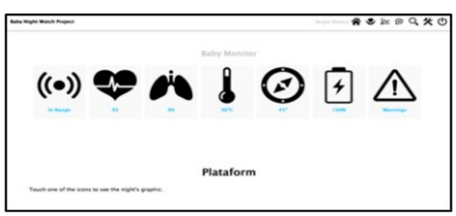
The H Medical Web Interface was created to make it easier for the user to access the data gathered and processed by the SWS. HTML5, CSS3, PHP, SQL, JavaScript, and Java were used to create the web interface. The major goal was to create a fully functional user interface that is OS-independent and will function on any device. Some of the processing power was moved to the user's side to create an interface that operates on a development board like the Beagle Bone Black.

IX. RESULT AND DISCUSSION

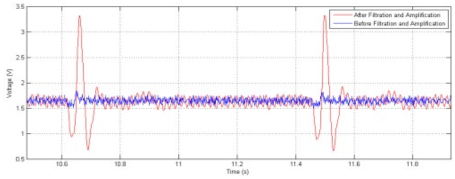
This section describes the experimental experiments conducted to assess each Baby Night Watch SWS component.

A. Heart Rate Sensor

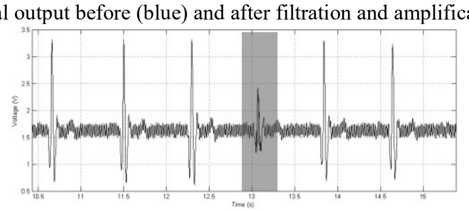
Using the NI-USB-6281 data-gathering device and the MATLAB program, the desired bio-signal was obtained for the infant in various positions. The baby was sleeping on his back when the signals were captured in the image (scenario A). The heart rate monitor's output is shown as waveforms in the earlier description. The analog comparator of the CC2530, when used with a 3 V threshold, proved to be a very reliable source of heart rate pulses. As soon as movement is included, there will be an increase in motion artifacts and missing heartbeat pulses because the electrodes briefly lose touch with the skin.



H Medical Web Interface



ECG signal output before (blue) and after filtration and amplification (red)

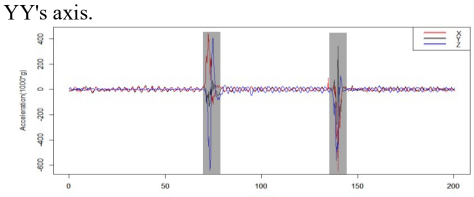


Acquired ECG signal while arms moving vigorously

B. Breathing Rate Sensor

To evaluate the suggested breathing rate sensor, experimental tests were carried out. The methodologies used in these testing were the same as those in the preliminary tests. the analysis of the respiration waveform while the baby's position changes throughout the three axes. The breathing rhythm is disrupted during position changes, as shown on the, but the system was able to quickly respond to that disturbance; it took about 8 seconds. When the system detects a change in position, it disables the breathing rate algorithm until a new position is found to prevent inaccurate breathing rate predictions. The location detection algorithm that was suggested throughout the tests was successful in correctly identifying the new position.

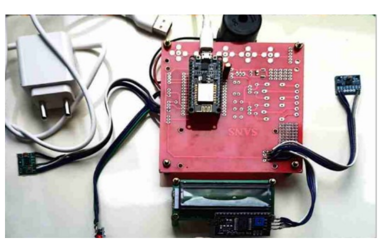
In this case, the algorithm makes advantage of the information gathered from the YY axis. When the baby is lying on his side, the BPM is calculated using the data from the ZZ's axis because we had better results on this axis. Although the outcomes, in this case, were not as favorable as those in the preceding ones, on average, the algorithm only missed one or two breaths. Four breaths in a minute were the worst-case scenario we encountered. Similar results were also obtained with the infant resting on his stomach, except in this case, the data were gathered from the YY's axis.



Breathing waveform during position changes

X. CONCLUSION AND FUTURE SCOPE

The Baby Night Watch is an effective medical tool for understanding SIDS and a dependable real-time monitor of infants due to its capability of detecting unexpected events and registering many physiological indicators. The study demonstrated how a significant number of metrics could be measured with a minimal amount of hardware, enhancing both user experience and child safety. The Wi-Fi-enabled wearable IOT device's data rate.



Future improvements to this SWS must include moving the cloud storage centre to a web server and enabling users to access the data without connecting to the gateway. Enhance the connection between the sensor node and the textile electrodes. Employ a thermophile sensor and a commercial breathing rate sensor to test our system's performance over longer periods.

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