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Innovative Design Idea for Smart Safety Helmet for Seafarers

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ABSTRACT

This paper aims at presenting a possible idea for enhancing the safety culture that has always been an important aspect at maritime industry particularly man overboard situation and while during ships operations. This helmet can help the mariners to detect all the possible red signals onboard. Red signals which include, man overboard and any kind of health issues onboard. The authors have tried using the evolving modern technologies to contribute towards the safety measures of the industry. An attempt has been made to bring up the prototype with required research which can be helpful in increasing the safety measures just by wearing safety helmet. Interestingly, this smart safety helmet is capable of sending signals to various sections like Bridge to alert other crews about some unwanted incident and accidents etc. for quick rescue.

1. Introduction.

Safety in maritime industry holds paramount interest and is of utmost importance, majority of the accidents happen due to the intentional/unintentional carelessness of the crew members, improper monitoring or insufficient information about the situation are the contributing factors.

Work accidents, according to Heinrich 88% are caused by human factors so that they can be prevented, so improving the behavior of workers becomes very important. (Husan, 2019). Helmet or Protective Cap is used to make head protection from exposure to hazards such as falling objects or exposure to electrical hazards. Many studies are carried out on the topic of seafarer's safety issues (Akindehim, 2015). It is observed many times that despite vital role of safety helmet many seafarers tend to take off their helmet because of discomfort caused by weight and higher temperatures in engine room and deck. Wearing a safety helmet can reduce the risk resulting in head injury. (Zhong, 2019). ILO code of practices published in the year 2019 on safety and health in ship building and ship repair proposed lots of very useful safety norms. (ILO,2019). According to Marine Insight (Mohit, 2019) during every shipboard operation, the three prime factors that should be focused on by the onboard personnel are the safety of the crew, safety of the ship and cargo, and protection of marine environment. However, under some unfortunate incidences such as man overboard etc. identifying a missing person, even though wearing safety tools, is extremely difficult, particularly at night time.

In this paper we emphasize the new design of helmet not just as a head protective device but also gives alert messages by the use of different sensors to the navigational bridge in case of accident such as man overboard. (kamal and Selmy, 2016). To overcome this issue and to improve the ship's safe operation and prevent the loss of life at sea, this paper proposed a state-of-the-art method based on Arduino uno microcontroller board based on ATmega328P (Arduino store)) model of smart safety helmet for automatic and real-time detection of seafarer?s health for working environment and identifying his GPS location. Arduino Uno is an open-source microcontroller board based on the processor ATmega328P. There are 14 digital I/O pins, 6 analog inputs, a USB connection, a power jack, an ICSP header, and a reset button. It contains all the necessary modules needed to support the microcontroller. Just plug it into a computer with a USB cable or power it with an adapter to get started. (Flyrobo blog).

This paper aims to reduce many such risks such as man over board, consumption of alcohol etc. by making use of a smart

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safety helmet that could effectively monitor and send alarms to alert the bridge of untoward incidence to enhance safety. This paper comprises of the details of such a prototype developed by the author. We used various types of sensors fitted inside the helmet which detects many parameters while working on board.

According to safety precautions onboard the ship a person working on deck is supposed to wear a safety helmet at all the times as a personal protective equipment (SHM ShipCare, 2018). Hence, adding smart features to the traditional helmet would solve the monitoring and alarm raising problems on board ship. The embedded sensors would trigger the alarm on the bridge which is always manned. The helmet would be connected to the monitoring unit through Wi-Fi direct/blue tooth or GPS system. Since each unit will have an assigned identity code every individual would be identifiable when on deck.

Any error or message received from the helmet will be displayed here along with the crew members name and this will activate the desired buzzers and alarms to draw the attention of the Officer-on-watch.

Such smart safety helmet can be used in many areas such as onboard a ship, dock labors, dry docking and ship building and ships are repairing and repairs of the ship and many other places including mining railway workers etc.

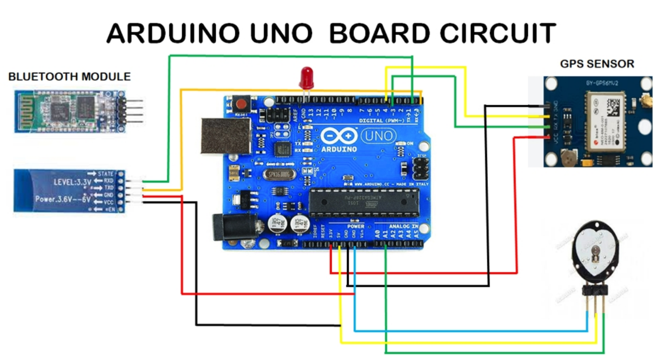
2. Designing of the Safety helmet.

Smart helmet comprises of following components:

A Safety helmet, microcontroller Unit with Wi-Fi/blue tooth and GPS, Alcohol and Gas sensors, Pulse sensor, accelerometer sensor, water sensor, GPS module and Li-Po battery (9 V).

Block diagram of the circuit components is shown in the Figure 1. Water and alcohol sensors and connections are shown in Figure 2.

Figure 1: Lay out of sensors and Arduina uno.



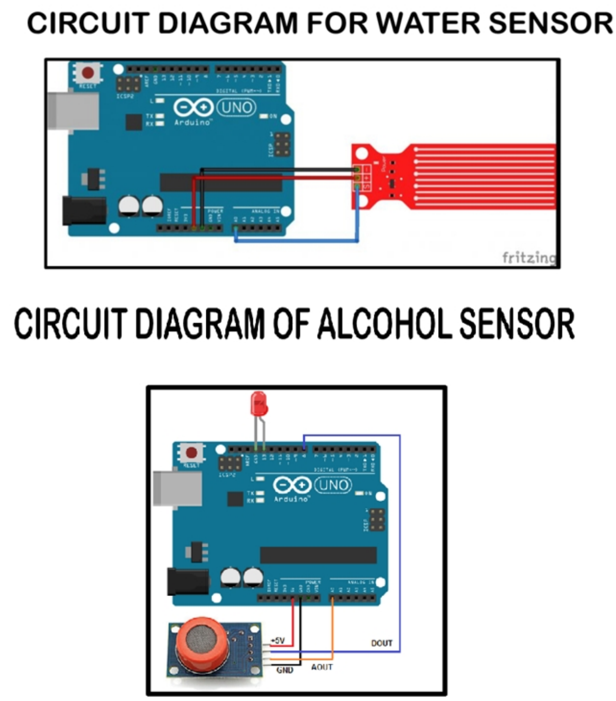
Source: Arduino Uno JavaT point.

3. Working of the Smart Helmet.

(a) Alcohol/Toxic gas Sensor.

Alcohol sensors such as MQ3 used here can measure as low as 0.04 mg/liters of alcohol presence. This sensor detects the

Figure 2: Water and alcohol sensor connections.



Source: Circuit digest.

presence of alcohol in the air as well as its concentration. The MQ3 sensor is one of the most widely used in the MQ sensor series. It is a MOS (Metal Oxide Semiconductor) sensor. Metal oxide sensors are also known as Chemiresistors because sensing is based on the change in resistance of the sensing material when exposed to alcohol. The MQ3 alcohol sensor operates on 5V DC and consumes approximately 800mW. It can detect alcohol concentrations ranging from 25 to 500 ppm.(Patel, 2022). It would be able to sense from the breath of the crew member. If the person is found drunk, the helmet will send a message to the bridge and the LED on helmet will glow along with the buzzer sound to alert the bridge and other personnel in the vicinity. This will be able to reduce the accidents caused by drunken crew members and hence in compliance to the no drinking policy of the shipping companies.

The Analog output pin (AOUT) gives Analog Voltage Output in direct ratio to the amount of alcohol detected by the sensor which then triggers the Digital Output(high/low) based on the values received though the analog output. The Higher the amount of alcohol in a person's breathe the higher will be its analog output and viceversa [1]. Once the Analog Value crosses its set threshold limit the digital output is triggered 'high' and the sensor will next activate the buzzer on the bridge and on the helmet as a warning signal.

The Toxic Gas sensors can detect gases like Ammonia, Benzene, Methane, Hexane, LPG and Carbon Monoxide thus giving an early warning to the person wearing it along with alerting the bridge. For the demonstration of concept MQ3, MQ135 sensors were used. There are sensors capable of detecting as low as 20 ppm of alcohol. Thus, a system with foolproof detection of alcohol is viable. The Alcohol and Toxic Gas sensors housed close to Mouth.

The actual photograph of smart helmet and its use by wearing on head is depicted in the following figures:

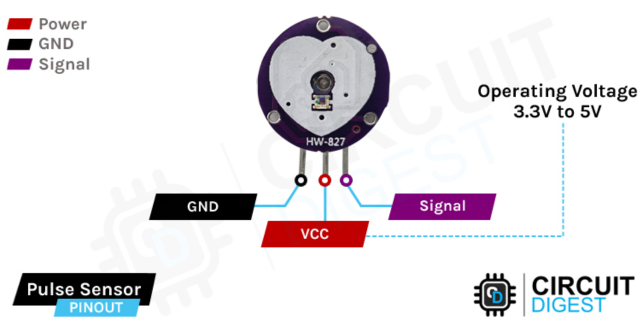
Figure 3: Authors prototype of smart safety helmet.

Source: Authors.

(b) Pulse Sensor. The pulse sensor interface, MAX30102, is a well designed plug and play heart rate sensor for Arduino.

The pulse sensor comes with a flat ribbon cable with three male header connectors. The Pin out of the Pulse sensor is given below.

Figure 4: Pulse Sensor Pinout.



Source: Circuit digest.

An optical pulse sensor shines a green light with 550 nm wavelength through the skin and measures the reflected light; this method of pulse detection is called Photoplethysmogram. (Das, 2022)

This pulse sensor used to read the pulse of the person wearing the helmet. The LED on the front side of the sensor is to be placed on a vein (here the ear tips). Veins have blood flow inside them only when the heart is pumping thus the pulse sensor monitors this blood flow to monitor the heartbeat. According to the data received by this sensor various aspects about a person?s health in general could be calculated like sleep tracking, anxiety, and consciousness. An example of received data is depicted in screen shot below.

Benefits of pulse sensor.

It would confirm if the crew is **wearing a helmet** since it starts getting the pulse input from the nerves near our ears/from the smart watch and hence ensure compliance of safety regulations.

If it finds the pulse rate of the person is too low or too high, during enclosed space operations, it will alert the officer (both him and the watch keeping officer on bridge) of his **abnormal health**. If it fails then it will direct the ESP8266 WIFI module on the helmet to send a message to the bridge indicating his retarding wellness during the operation and needs immediate rescue.

This will then combine the data from the toxic fumes sensor so as to **warn the incoming rescue party** about the atmosphere in the enclosed space.

(c) Accelerometer Sensor.

Accelerometer is an electromechanical device that measures the force of acceleration due to gravity in g unit. It can be used in applications requiring tilt sensing. The ADXL335 measures acceleration along X, Y and Z axes and gives analog voltage output proportional to the acceleration along these 3 axes.

An accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static (gravitational) or dynamic - caused by moving or vibrating the accelerometer. These forces can be detected based on Axis-wise rotations. So, we try to set a parameter that after a specific Rotation (i.e., how much does the person receives an impact after falling in an accident) it will detect an accident.

The basic work of the accelerometer in the helmet is to detect a fall i.e.,it calculates a fall based on the acceleration in all the three directions- x, y and z axis.

Once fall is detected either by free fall due to gravity method in the accelerometer or by change in the angle of the helmet method it sends out this data to the bridge alarming the officer on watch to take adequate actions immediately. The prototype has been adequately programmed to detect such cases (e.g., Man overboard) using the free fall and direction angle algorithm**.**

There have been a lot of cases where the person has become overboard and no one was able to detect this for hours resulting in never finding the person again, or maybe finding him dead because of drowning in the sea or animal attacks. Using the helmet this can be easily countered as the detection will be done as soon as the man falls overboard and hence the crew members will have enough time to take proper and effective actions.

The helmet will also have an additional water sensor so as to accurately detect that it Isa case man overboard. considering the situation where maybe by some error the buzzer goes on or where the crew member has fallen on the deck and is in no danger i.e. the fall isn't crucial then he will have a kill switch mechanism on the helmet to kill the buzzer alarm to prevent misinformation.

(d) GPS module sensor.

The purpose of inclusion of GPS sensor in the smart helmet is to identify the accurate position of a person at the time of fall so that he can be rescued immediately. GPS sensors can provide real time position data in Arduino projects. By detecting latitude, longitude, altitude, velocity, and heading, they?re an indispensable tool for autonomous working and other devices where the global position needs to be known. This sensor module can easily be interfaced it with Arduino to obtain GPS parameters such as latitude, longitude, altitude date, time, speed, satellites, etc. GPS sensor used in this work is shown below.

Figure 5: GPS sensor.

Source: AmateurRadio.

This GPS module consists of 4 pin, namely, GND, Tx, Rx and Vcc along with antenna (microcontroller lab).

(e) Procedure of Sensors activation in a sequence.

Person wears the helmet alcohol check, if negative continue pulse rate monitoring on toxic gas monitoring on accelerometer active throughout to detect fall water sensor backup for accelerometer.

Accident detection and related actions: fall detected; sound bridge alarm man overboard alarm and lights activated pulse rate error or toxic gas detection activate bridge alarm and call rescue team false alarm sounded due to error person uses the kill switch on helmet to kill alarm.

4. Features of this design.

Some of the design features are listed below:

- Effective placing of all sensors.
- Waterproof casing for battery and board.
- Kill switch on the sides.
- LEDS and buzzers inbuilt with no additional changes to the effective strength of the helmet.
- Modified design to also accommodate the **face shield / mask**.

The Prototype was fabricated using components locally procured. It is possible to engineer the entire circuit as a single hermetically sealed module and shaped it to sit within the helmet without interfering with its basic safety function. The cost of system could be lowered substantially when produced on economic scales. Also sensors with lower detection threshold can be incorporated at marginally higher cost.

All the sensors are interfaced with Arduino Uno microcontroller after necessary coding programs separately for each sensor. Coding programming is illustrated below.

5. Results and Conclusion.

The experiments were performed using prototype and observations are shown in the Table 1 and Table 2 below. Note that Table 1 gives the information regarding pulse rate, GPS location, time of fall, date and direction of fall and speed of the movement of the crew before and after the fall, if it happens. Table 2 shows actual data obtained during the tests.

Table 1: Data to be obtained at different instances.

MONITOR READING BEFORE FALLING	
PULSE RATE	Normal (60-100)
ALCOHOL LEVEL	No alcohol
GPS LOCATION	LIVE - Latitude/Longitude
TIME STAMP	Time of reading
DATE	Date of reading
DIRECTION	Direction of movement of person
SPEED	Speed of movement
ACCELEROMETER READING	No vertical motion detected
MONITOR READING DURING FALL	
PULSE RATE	Slightly higher than normal
ALCOHOL LEVEL	No alcohol
GPS LOCATION	LIVE - Latitude/Longitude
TIME STAMP	Time of reading
DATE	Date of reading
DIRECTION	Direction of movement of person
SPEED	Speed of movement
ACCELEROMETER READING	Vertical motion detected
MONITOR READING AFTER FALL	
PULSE RATE	Slightly higher than normal
ALCOHOL LEVEL	No alcohol
GPS LOCATION	LIVE - Latitude/Longitude
TIME STAMP	Time of reading
DATE	Date of reading
DIRECTION	Direction of movement of person
SPEED	Speed of movement
ACCELEROMETER READING	**Man overboard**

Source: Authors.

Table 2: Data obtained After Testing of smart safety helmet.

TEST – I	
PULSE RATE	96
ALCOHOL LEVEL	No alcohol
GPS LOCATION	19.0179° N, 73.0072° E
TIME STAMP	11:11
DATE	21/12/2022
DIRECTION	Towards North
SPEED	3 km/h
ACCELEROMETER READING	No vertical motion detected
TEST – II	
PULSE RATE	85
ALCOHOL LEVEL	No alcohol
GPS LOCATION	19.0179° N, 73.0072° E
TIME STAMP	12:34
DATE	28/12/2022
DIRECTION	Towards North
SPEED	2.5 km/h
ACCELEROMETER READING	vertical motion detected
TEST – III	
PULSE RATE	105
ALCOHOL LEVEL	No alcohol
GPS LOCATION	19.0179° N, 73.0072° E
TIME STAMP	16:35
DATE	17/02/2023
DIRECTION	Towards North
SPEED	3 km/h
ACCELEROMETER READING	No vertical motion detected

Source: Authors.

It should be underlined that all these test readings of the prototype may slightly vary depending upon the Prevailing conditions and circuit components.

In the test results obtained as above, Direction gives the information of man overboard after the fall towards the North direction in this case. Speed suggest that, at what speed the person is moving in that direction and Accelerometer reading suggests vertical motion. Other data has its usual meaning. Note that GPS location shown is same since tests were performed in the campus.

This paper presents the results obtained with this prototype are very satisfactorily and expected.

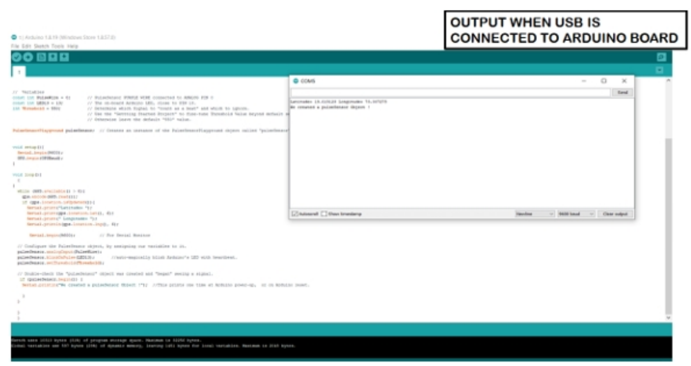
Reducing the chances of accidents and taking effective actions without wasting precious time is essential way of preventing damage to life and property of a vessel while at sea. This paper thus explores the idea of using an advanced advanced technology and sensors in designing helmet that could cater to modern needs onboard. It comprises of various sensors which collect real time data of the crew member and alert others onboard as soon as any unfavorable situation comes up. This paper has outlined the major advancements that are possible in a safety helmet and has tried to promote a safe work environment through innovative ideas by making the right use of currently available technology.

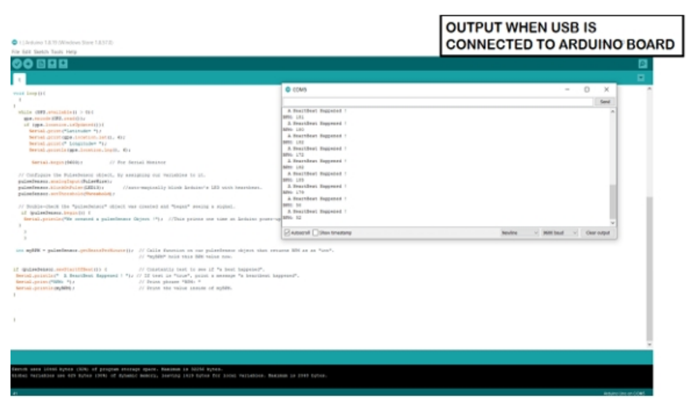
5.1. *Coding for the Arduino Uno board.*

```
#include<TinyGPS++.h>
#include<SoftwareSerial.h>
#defineUSE_ARDUINO_INTERRUPTStrue    // Set-up low-level interrupts for most acurate BPM math.
#include<PulseSensorPlayground.h>     // Includes the PulseSensorPlayground Library.

staticconstint RXPin = 4, TXPin = 3;
staticconstuint32_t GPSBaud = 9600;

// The TinyGPS++ object
TinyGPSPlus gps;

// The serial connection to the GPS device
SoftwareSerial GPS(RXPin, TXPin);

// Variables

constint PulseWire = 0;       // PulseSensor PURPLE WIRE connected to ANALOG PIN 0
constint LED13 = 13;          // The on-board Arduino LED, close to PIN 13.
int Threshold = 550;           // Determine which Signal to "count as a beat" and which to ignore.
                               // Use the "Gettting Started Project" to fine-tune Threshold Value beyond
default setting.
                               // Otherwise leave the default "550" value.

PulseSensorPlayground pulseSensor;  // Creates an instance of the PulseSensorPlayground object called
"pulseSensor"


voidsetup(){
  Serial.begin(9600);
  GPS.begin(GPSBaud);
}

voidloop(){
  {
}
  while (GPS.available() >0){
    gps.encode(GPS.read());
    if (gps.location.isUpdated()){
      Serial.print("Latitude= ");
      Serial.print(gps.location.lat(), 6);
      Serial.print(" Longitude= ");
      Serial.println(gps.location.lng(), 6);

       Serial.begin(9600);         // For Serial Monitor

  // Configure the PulseSensor object, by assigning our variables to it.
  pulseSensor.analogInput(PulseWire);
```

```
pulseSensor.blinkOnPulse(LED13);       //auto-magically blink Arduino's LED with heartbeat.
  pulseSensor.setThreshold(Threshold);

  // Double-check the "pulseSensor" object was created and "began" seeing a signal.
   if (pulseSensor.begin()) {
    Serial.println("We created a pulseSensor Object !");  //This prints one time at Arduino power-up,  or on
Arduino reset.
  }
    }
    }

 int myBPM = pulseSensor.getBeatsPerMinute();  // Calls function on our pulseSensor object that returns BPM as
an "int".
                                               // "myBPM" hold this BPM value now.

if (pulseSensor.sawStartOfBeat()) {            // Constantly test to see if "a beat happened".
 Serial.println("  A HeartBeat Happened ! "); // If test is "true", print a message "a heartbeat happened".
 Serial.print("BPM: ");                        // Print phrase "BPM: "
 Serial.println(myBPM);                        // Print the value inside of myBPM.
}

}
```

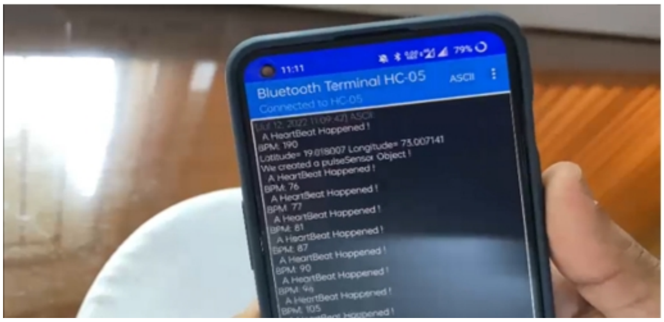
5.2. *Working illustrations of the helmet.*





Following image, Figure 6, depicts the data after wearing the smart helmet. First the location of the institute (IMU-NMC) at Navi Mumbai i..e latitude of 19.018^o N and longitude of 73.007^o E. Moreover data also shows beats per minutes (BPM) with the help of pulse sensor connected to the arduino uno. This image confirms the GPS location of the crew, his physical condition etc. Accelerometer shows the depth of the person inside the water in case of man-overboard condition arises along with his exact location with GPS coordinates.

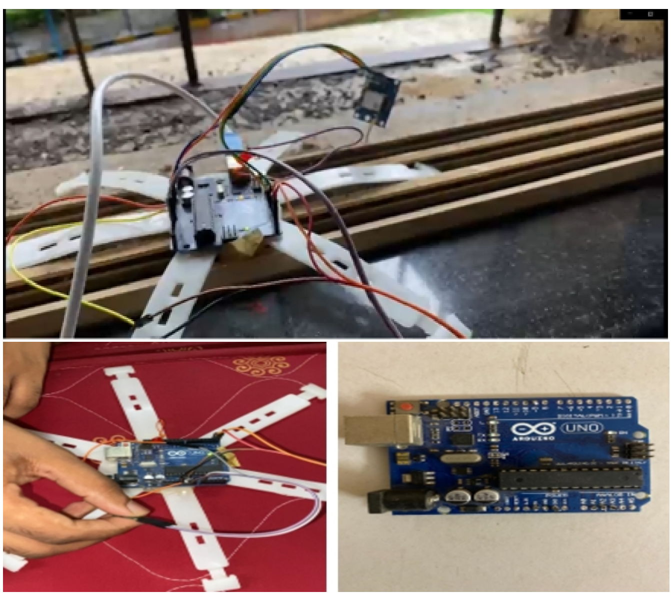
Figure 6: Output via Bluetooth in Smart Phone.



Source: Authors.

Following images shows the internal harness of safety helmet and arrangements of components with battery.

Figure 7: Authors prototype of design and Arduino Uno board.



Source: Authors.

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