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Titanium-Based Smartwatch Health Monitoring System For Human Safety And Emergency Prediction

A Wearable Healthcare System for Continuous Human Body Monitoring Real-Time Emergency Alerts

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Abstract- The titanium alloy Ti 6Al 4V has been chosen as the material for the casing of a smartwatch because of the superior strength, lightness, corrosion resistance, and biocompatibility properties of this material.[1]

Keywords- Titanium Alloy; Health Monitoring; Wearable Technology; Emergency Detection; Safety of Humans; Smart Sensors; Artificial Intelligence

I. INTRODUCTION

Healthcare wearable technologies have gained a critical position in contemporary society due to the escalating demand for continuous health monitoring and medical emergency alerting functions. Such wearables based on smartwatches are used to monitor different body states, including heart rate, blood oxygen concentration, stress level, sleep, and physical activities. Smart devices can detect any sudden change in the patient's health state and issue timely warning alarms during a medical emergency.[2]

Modern developments in sensors, artificial intelligence algorithms, and wireless communication have enhanced the performance and functionality of health monitoring systems. Besides, proper material selection is vital to make such devices reliable, safe, and comfortable. The use of titanium alloys as the main material for wearables is recommended since they are light but robust materials, resistant to corrosion, and compatible with human skin tissue.[3]

The current study considers the design, material selection, production, and application issues related to the development of wearable titanium-based smartwatch healthcare devices.[4]

II. EASE OF USE

Smartwatch health gadgets aim to offer simple and effortless monitoring of health information to the users on a daily basis. Such wearables allow an automatic assessment of the vital signs like heart beat rate, oxygen level, stress level,

sleep condition, and physical activities without the need for complicated procedures. It is possible to connect the device to a mobile application in order to monitor vital information and receive alerts in case of any emergency situations. Use of light weight material like titanium alloy and silicone make the gadget comfortable to use.

III. TERMINOLOGY

A. Contraction

These are some of the acronyms and abbreviations used in this paper in order to make the discussion on the technology of smartwatch health monitoring clear and easily understandable.[5]

AI – Artificial Intelligence
ECG – Electrocardiogram
IoT – Internet of Things
SpO2 – Peripheral Oxygen Saturation
CNC – Computer Numerical Control
MIM – Metal Injection Moulding
GPS – Global Positioning System
PPG – Photoplethysmography
HR – Heart Rate
LCD – Liquid Crystal Display

B. Units

Technical standards on units are applied in this report to ensure the accuracy of smartwatch analysis.[6]

- Heartbeat frequency is indicated in beats per minute.
- Body temperature is recorded in °C.
- The size of batteries is presented in milliampere hours.
- Smartwatch weight is given in grams.
- Distance, dimensions are indicated in mm and cm

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- Voltage is given in volts, while current is indicated in amperes.

C. Equations

Equations could be useful for analyzing the working of the sensors, along with smartwatches' functionalities. In health monitoring, for instance, equations would be useful for calculating the heart rate and interpreting the working of the sensors as well as voltage efficiency.[7]

IV. WORKING PRINCIPLE OF SMARTWATCH HEALTH DEVICE

The operation of the health smartwatch device is based on constant monitoring of the state of the user body via built-in wearable sensors and further data processing via microcontroller systems. Such sensors as MAX86176 and BHI360 register health metrics such as heartbeat rate, oxygen saturation level, movements, falls and heart activity. They transform the physical body metrics into electrical impulses that will be processed by the controller.

The data from sensors are further processed by the nRF52840 processor and compared with preset health conditions. In case of an unhealthy state detected (irregular heartbeat, sudden falls or drop in oxygen saturation), the emergency alarm system of the smartwatch will be activated. The Quectel EG915U module sends emergency information to the phone numbers of pre-selected relatives with location provided by the Sony CXD5605GF GPS module.[8]

Health metrics will be displayed on the watch display while synchronized with the app via wireless technology. Power consumption is provided by the thin lithium polymer battery, while the flexible PCB enables to fit all the electronics into the smartwatch. Moreover, the titanium watch frame ensures durability, lightness, strength and safety of prolonged contact with human skin.

V. DESIGN CALCULATIONS

The design calculations for the smartwatch health monitoring system involve power consumption, battery capacity, and operating times. The design involves sensors, a microcontroller, and different communication modules, which operate continuously to provide real-time health monitoring services.[9]

A. Power Consumption Calculation

Total power consumption is computed through addition of the powers consumed by various components.[10]

Power consumption values for sensors and modules are assumed to be:

- MAX86176 sensor power consumption is 1.8 mA
- BHI360 sensor power consumption is 0.9 mA
- nRF52840 microcontroller power consumption is 5 mA
- GPS module power consumption is 25 mA during active operation
- LTE module power consumption is 200 mA when transmitting data
- Total current consumption during active operation is:
- Total current equals 232.7 mA

B. Battery Capacity Calculation

- An example of a battery used in a smartwatch is a lithium polymer battery.
- Assuming the required time of operation is 10 hours:
- Battery capacity is equal to current multiplied by time
- Battery capacity is 232.7 mA multiplied by 10 hours
- Required battery capacity is equal to 2327 mAh
- Taking into account 20 percent safety factor:
- Final battery capacity is about 2800 mAh

C. Power Optimization Factor

In order to minimize power consumption, the following measures have been adopted:

- Microcontroller operates in sleep mode when not in use
Sensors operate in low power mode
Duty cycle for GPS and LTE
Activate when an event is triggered for emergency transmission
- These are very efficient ways to minimize average power consumption.

D. Thermal and Efficiency Factor

Titanium is chosen as it dissipates heat efficiently due to high thermal conductivity and also it is resistant to corrosion. The smartwatch will be able to perform its tasks effectively using power optimally.[11]

E. Conclusion

For the efficient working of smartwatches, a battery of about 2500 mAh to 3000 mAh is required. Power optimizations should also be considered in order to ensure longer battery life.[12]

i. ANALYSIS

Analysis of the smartwatch health monitoring system considers the performance, reliability, accuracy, and appropriateness of selected sensors and communication modules for real-time monitoring and detection of emergencies.[13]

A. System Performance Analysis

Various sensors such as MAX86176, BHI360, and their respective communication modules have been integrated into the system for monitoring human vital parameters in real time. The system's performance will depend on its speed of processing, real-time response, and accuracy of the data processed. The nRF52840 microcontroller offers fast performance.[14]

B. Sensor Accuracy Analysis

The MAX86176 sensor can accurately monitor heart rate and oxygen saturation through its optical sensors. In addition, the

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BHI360 sensor is able to monitor motions and falls reliably by use of advanced MEMS based sensors. Therefore, the two sensors enhance the accuracy of the monitoring and detection of emergencies.

C. Emergency Detection Analysis

The smartwatch system can detect any abnormalities associated with heart rate, motion, and oxygen levels of human body in real time. In case there is any abnormality, the system sends an immediate alert message through the LTE communication module. Moreover, the GPS module enables tracking of the exact location of the person.[15]

D. Power Efficiency Evaluation

The energy used in this case is minimized through power optimization techniques like duty cycling. High energy consuming modules, including GPS and LTE, are only activated in times of emergencies to enhance battery life.[16]

E. Material and Design Evaluation

The use of titanium alloy ensures that the device is durable, corrosion-resistant, and comfortable to wear. The light weight feature of the material enables it to be worn for long periods. The flexible PCB design saves on space while ensuring that all components fit.[17]

F. Overall System Evaluation

The proposed system is efficient in its role as a monitor and emergency responder in cases of health issues. In terms of accuracy, efficiency, design, and real-time communication capabilities, the smartwatch proves effective.[18]

SYSTEM PERFORMANCE AND ANALYSIS SUMMARY

Table

Parameter	Description	Performance Level
Heart Rate Monitoring	Real time pulse detection using optical sensor	High Accuracy
Oxygen Level Monitoring	Blood oxygen saturation measurement	High Accuracy
ECG Monitoring	Heart rhythm and electrical activity detection	Very High Accuracy
Fall Detection	Sudden motion and impact detection	High Reliability
Motion Tracking	Activity and movement analysis	High Reliability
Emergency Alert System	Automatic SMS and call triggering	Fast Response
GPS Tracking	Real time location sharing	High Accuracy
System Processing Speed	Real time sensor data processing	High Performance

ii. RESULTS AND DISCUSSION

This study successfully develops a smartwatch health monitoring and emergency detection system with the implementation of sensors. The proposed system is capable of monitoring human health parameters based on MAX86176 and detecting sudden emergencies with the help of BHI360 and nRF52840.[19]

A. Results

The smartwatch system is capable of accurately measuring the human vital parameters even under active and inactive conditions without any delay. The heart rate and oxygen level measurements are accurate at all times. Motion sensors can detect sudden falls with a high degree of reliability, whereas any abnormal body movement is detected promptly by the system. Emergency alerts are raised immediately when an anomaly is detected within the system. The LTE communication module can transmit emergency messages and calls automatically to predefined family contact numbers along with the location.

B. Discussion

It can be concluded that the smartwatch system developed in this study is efficient for health monitoring and detecting any emergencies. The utilization of various sensors increases the effectiveness of health data measurement and analysis. Utilization of wearable sensors such as MAX86176 and BHI360 improves system performance.

The body of the titanium alloy material offers more durability, better comfort, and increased human compatibility. Nevertheless, issues like battery sizing, the amount of energy LTE consumes, and sensor calibration errors still persist.[20]

In conclusion, this system offers a good starting point in developing the next-generation wearable health care devices that can predict an emergency situation and send communications instantly.[21]

FINAL RESULT TABLE

Test Condition	Expected Output	Actual Output	Result
Normal Heart Activity	Stable heart rate display	Correct real time heart rate shown	Pass
Normal Oxygen Level	SpO2 within safe range	Accurate oxygen level displayed	Pass
Sudden Fall Detection	Fall alert triggered	Immediate alert generated	Pass
Abnormal Heart Rate	Emergency notification	Alert message activated	Pass
Low Oxygen Level	Warning signal	Emergency alert triggered	Pass
Motion Activity Tracking	Continuous movement data	Accurate motion tracking	Pass
GPS Location Tracking	Real time location display	Correct location detected	Pass
Emergency Call Activation	Auto call to family members	Successful call initiated	Pass
SMS Emergency Alert	Message sent with location	SMS delivered successfully	Pass
Battery Performance	Continuous operation for hours	Stable power performance	Pass

VI. CONCLUSION

The above-described health monitoring system using smartwatch can be considered an efficient solution for continuous health monitoring and emergency detection. Through the usage of modern technologies of sensors such as MAX86176 and BHI360 together with the small processing and communication system, it is possible to control the health status and monitor the appearance of any abrupt changes in the patient's health condition. Thanks to the usage of titanium alloy, the watch will not break easily and will be convenient to wear. The efficiency of the device was demonstrated while measuring the heartbeat, oxygen levels, movement, and emergencies.

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