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A Microcontroller Based Smart Helmet Using GSM &GPS Technology in Construction Sites

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Abstract: Nowadays due to the regular increase in population number that leads to building a new city to accommodate the extra number of people so, there will be more sites that contain a lot of workers, and to save workers life we have to make a tool with smart actions to keep workers life safe. Many techniques were offered before based on different technologies like Zigbee, Radio Frequency identifications (RFIDs). The smart helmet is the proposed solution that will keep track the worker health conditions, environmental conditions, and locate his place in the site by using ARM microcontroller, GPS, GSM modules and a group of sensors.

Keywords and abbreviations: Global system for mobile (GSM), Global Positioning System (GPS), Low Drop-Out Advanced Risk Machine(ARM), ATtention (AT), Digital Cellular systems(DCS), Printed Circuit Board (PCB)

1. Introduction

New cities attract a lot of workers. To guarantee safety for huge amount of workers in an efficient way, we need smart solutions to keep safe the life of the workers and to decrease the accidents rates. So the smart helmet has been created to be able to save a human life while working by taking into consideration four main parts such as environmental conditions, helmet removal(the worker wearing the helmet or not), health conditions and if the worker is hitting by any object. Making smart solutions will help in finding the location in work site by using the GPS, and tracking the health level of the worker by measuring his heart rate using heart rate sensor to guarantee that in case of any dangerous level the helmet will send a message to provide the help for the workers.

Most of the previous projects based on two types of implementation, the first one is a smart helmet for accident prevention by a microcontroller connected with some sensors to detect rider's head, the safety belt was set or not, and to alarm the rider if the speed exceeds 100 km/h.[1] The second one is the smart helmet for underground mines safety which has three modules. The helmet module which is the intelligent part, the control room module that contains antennas, decoder, etc. The third one is the localizer module which used to locate the worker's location during work. Also, the sensors are used

to get the temperature, pressure, humidity, and make decisions based on the measured values[1,2]
The idea of the newly proposed system is to give information about the worker wearing the helmet and to decrease the number of casualties by fall. The design is based on a connected helmet, tracked by GPS, using the wireless technique for communications, sensing environmental conditions, sense human conditions, and make smart actions. Most of the tasks that the helmet is doing are accomplished by using some peripherals like GPS module, GSM module, heart rate sensor, digital humidity with temperature sensor, and lock sensor(Rest of the paper is organized as follows Section 2 introduces the newly proposed system, section 3contains the technical description, section 4 shows the operation sequence, section 5 explains the system commissioning and testing, section 6 shows the cost analysis, section 7 concludes research work with future direction).

2.The newly Proposed System

The block diagram of the proposed system is shown in figure 1. The main unit in the proposed system is the microcontroller that transmits and receive all the

commands that control and manage all I/O sensors. The following part is the GPS module that locates the worker position by getting his x-y-z dimensions, then the GSM module used for remote communication with the microcontroller. Two conditions will be discussed. First, if the worker in the ground station needs to know the health condition of a specific work in the site, then it will send a message through the GSM module to the microcontroller to reply with the requested health information.Second condition if the microcontroller detects any risk facing the worker then it gets the information and the location for the worker and send them through the GSM module to the ground station. The next part is a collection of sensors like temperature sensor (measuring the temperature condition), heart rate sensor (following up the heartbeat of the worker), and Accelerometer sensor (for detecting the free fall and shock). Finally, the power management part of the proposed system, as the voltage varies from 5 volts down to 3.3 volts so, two kinds of voltage regulators will be used. DC/DC voltage regulator with efficiency nearly to 90% and that used with the most important modules in the proposed system like GPS and GSM modules. The second type of the regulators is low-dropout voltage (LDO) which is step down voltage regulator with efficiency nearly around 50%, and it is of small size and low cost.

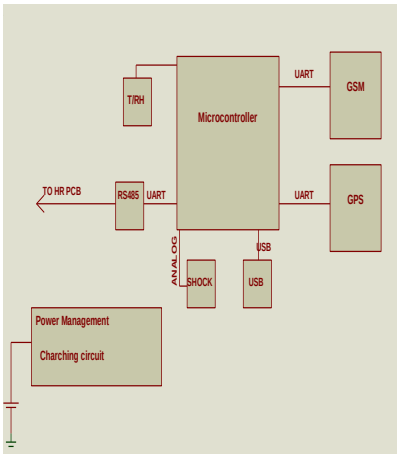

Figure 1.Block Diagram of Smart Helmet

3. Technical Description

A.Microcontroller:

The control unit of the system is the ARM processor. The important reason for implementing the system based on ARM processor is the concern of the speed and load. It has to be taken into account that the response of the system should be very fast. To do this, the ARM processor is preferred over other microcontrollers as the amount of propagation delay is more in the other microcontrollers than in the ARM processor. The power consumption and packaging of the ARM is also better compared to micro-controller. Also, the micro-controller does not provide flexibility of adding more features to the existing block. The STM32F072 is an ARM-based microcontroller from ST Company that has a lot of features like it has 32-bit MCU, up to 128 KB Flash, crystal-less USB. FS 2.0, CAN, 12 timers, ADC, DAC & Comm. interfaces, 2.0 - 3.6 V. Figure 2 shows the pin configuration of the microcontroller [8].

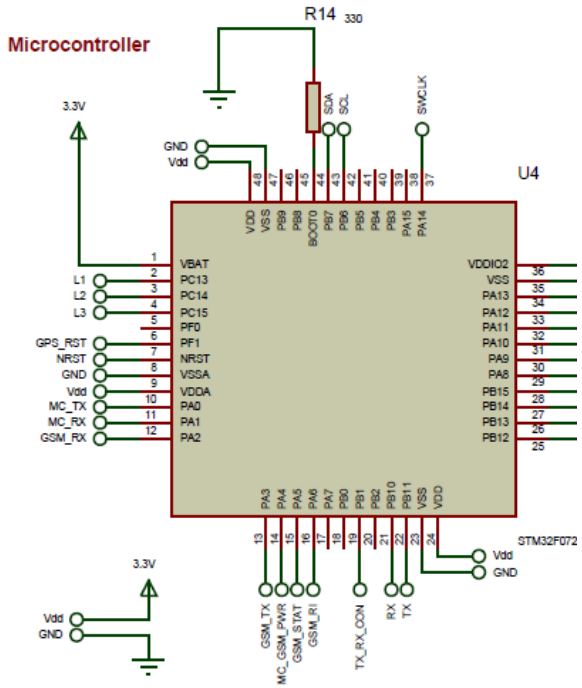

Figure 2. Pin configuration of the microcontroller

B.GSM & GPS modules:

GSM (Global System for Mobile Communications) is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second generation (2G) digital cellular networks used by mobile phones. SIM300 module is a Dual-band GSM/GPRS engine that works on frequencies EGSM 900 MHz, DCS 1800 MHz. It supports features like Voice, Data, SMS, GPRS and integrated TCP/IP stack. It is controlled via (AT) commands and enhanced ATtention (AT) commands and uses DC power, i.e. 3.6 - 4.6 volts maximum and its current consumption in normal operation is 250 mA, which can rise to 1A while transmission. It identifies the phone number when a call is made to it and if it is correct. Figure 3shows the GSM module and its pin configuration[9].

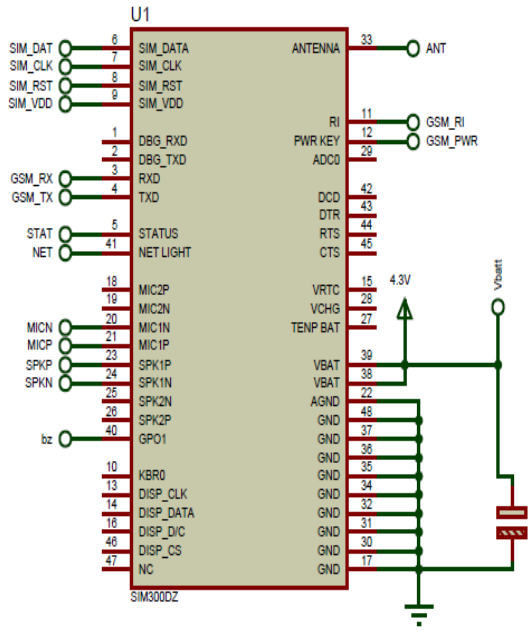

Figure 3. GSM module and its pin configuration

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil and commercial users around the world. In the proposed system the GPS module provides latitude and longitude for the location of the worker which can be traced using mobile application. Figures4(a,b)shows the GPS module and its pin configuration [10].

Figure 4a.GPS module and its pin configuration

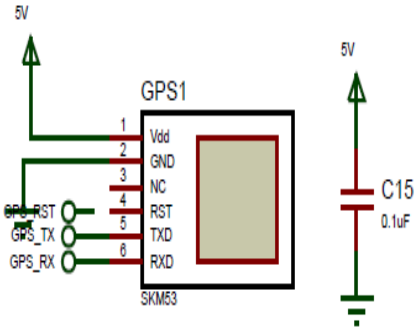

Figure 4b.GPS module and its pin configuration

For, GSM and GPS a UART protocol will be used to connect between these modules and the microcontroller

C. Sensors:

The sensor is a device that detects and responds to some input from the physical environment. The specific input could be heartbeat, temperature, pulse oximeter, or any other environmental phenomena. The output is a signal that is converted to human readable display at the sensor for location or transmitted electronically over a network for reading or further processing[11].

1) Heart Rate Sensor (MAX30100):

MAX30100 is a pulse oximeter and heart-rate sensor integrated circuit (IC) for wearable health monitoring systems or devices. It detects pulse oximetry and heart rate signals with a combination of two LEDs, red and infra-red. Also, this type of sensors has low-noise analogue signal processing techniques. MAX30100 can operate from either 1.8V or 3.3V power supplies and can be powered down programmatically by software with negligible standby current, thereby presenting the possibility of leaving the power supply connected all the time. It is typically used in fitness assistant devices, medical monitoring devices and wearable devices. Figure 5 below shows the pin configuration of MAX30100 and the top and bottom views of the chip. The LEDs (red and infra-red) are located on top while the pins are located at the bottom [12].

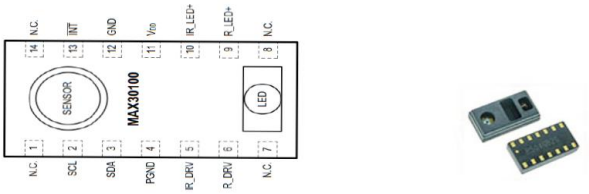

Figure5. Heart rate sensor pin configuration

2) Accelerometer sensor (MMA8653FC):

Implementation of this sensor has been done to determine the three dimensions axis of the worker, and if anything hit the sensor, there will be a flag turn from 0 to 1 to warn the microcontroller.
Figure 6shows the pin configuration and Printed Circuit Board (PCB) design of the accelerometer [12].

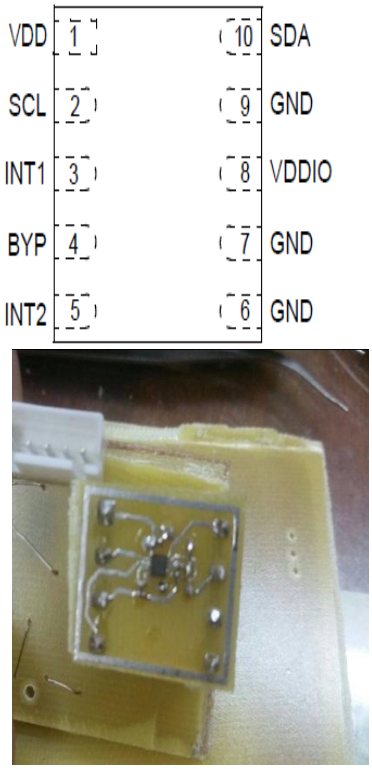

Figure 6. Pin configuration and PCB design

D.Software Description:

In the proposed system there are three different types of the used software: Proteus, It is a software suite containing schematic, simulation as well as PCB designing.CubeMX, Is a graphical software configuration tool that allows generating C initialisation code using graphical wizards, and Kiel micro-Vision which is an integrated development environment which enables the program to be written either in assembly or C language and simulated on a computer before being loaded into the microcontroller.

4.Operation Sequence

Figure 7 shows the flowchart of the proposed system. The setup is the first stage which has all the initializations parameters that need to set, then a new message coming from the ground station through the GSM module into the microcontroller to respond with the health information of the worker, save and send his location by using GPS module. After that, if the microcontroller detects any hazard facing the worker by analyzing the data coming from the sensors it will send a message through the GSM module to the ground station.

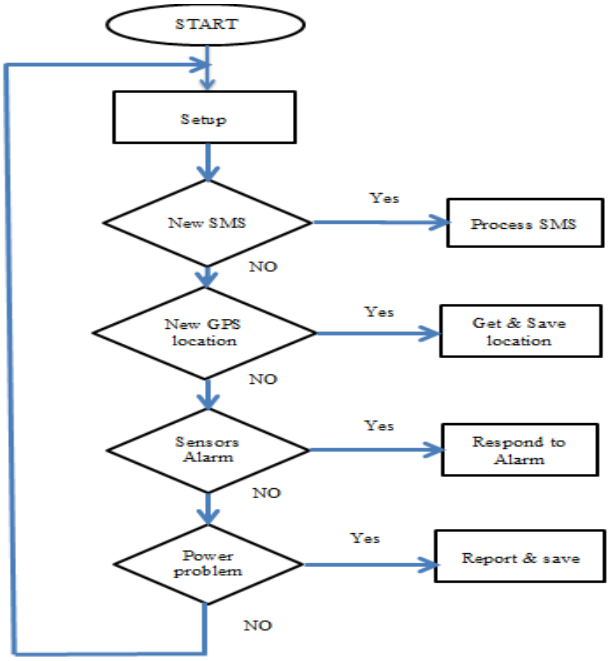

Figure7. Flow chart of the proposed helmet

5.System Commissioning and Testing

Figure 8 shows the real, fabricated PCB circuit that contains all integrated components for the proposed system.

Figure 8. PCB design

Figures (9,10) show the final hardware implementation of the smart helmet prototype model

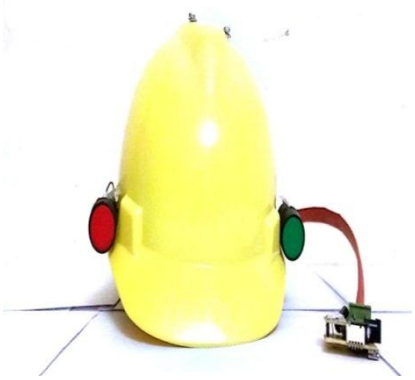

Figure9. Helmet forward view

 https://doi.org/10.22362/ijcert/2018/v5/i2/v5i210

Figure10. Helmet backward view

The main problem facing the proposed design is the output signals coming from the heart rate sensor with a lot of noise around them, so to overcome this problem three subjects must be fixed, and they are:

1-DC element removal.
2-Averaging techniques instead of using digital filtering.
3-Faulty peaks removal.

The way to remove the DC value is to get the minimum value and substrate it from the signal to get the AC signal and the noise. For example, if we have the value of (-3,1,3). The minimum value is -3 that will be substrate from every value.That will get (0, 4, and 6). Then get the average which will be equal to 3.3, and that number is closer to the x=4 value. So, it means that the noise signal positive half cycle will cancel the negative have to cycle, and that is the first stage of filtering the signal and removing the DC value. Figure11 shows the original signal for the heart rate samples with the noise signal. Figure12, and figure 13 respectively show the two stages of the filtering process.

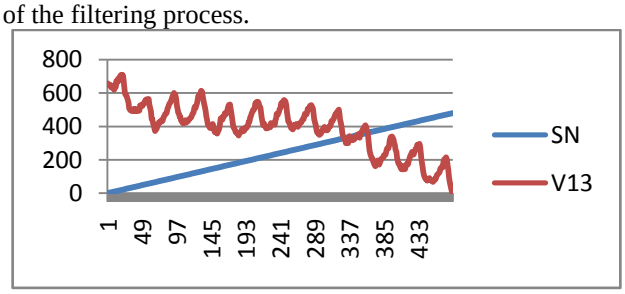

Figure11. The original heartbeat signal

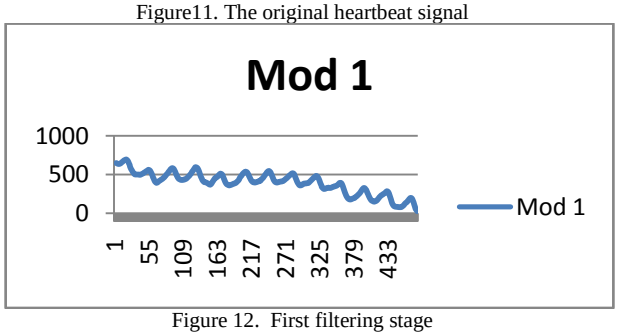

Figure 12. First filtering stage

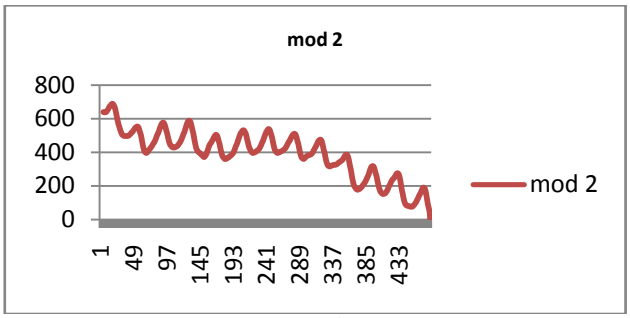

Figure13. Second filtering stage

Figures14,15,16,17 show the testing process of each system function.The first step is to send SMS to the GSM module to know the health information of the worker.Figure 14 shows the message that will be taken by the microcontroller. The Microcontroller will send an instruction to the sensors and GPS module to get the data required to be sent to the GSM module which in turn takes this information and send it back to the base station. The response time of the system reply in just 60 seconds and this indicates the quality of the system.

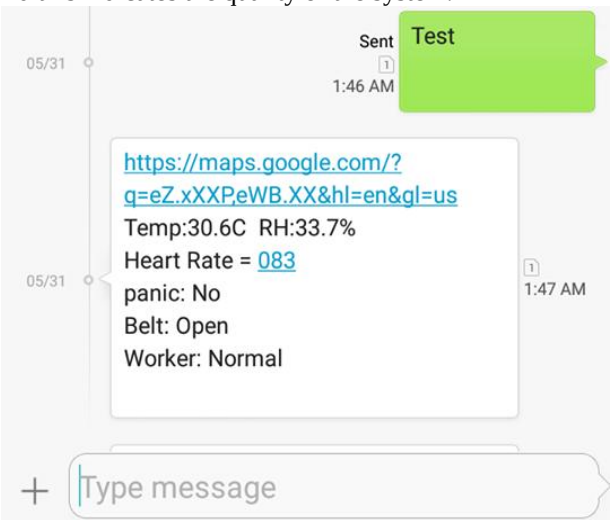

Figure14. General worker health information

The proposed system has three cases with three different messages that will be sent automatically if any one of them have been activated.In the first case, a panic switch will be used if the worker feels any dangerous situation by pressing the switch of panic to send a warning message. The second case is when the belt of the helmet is closed then the system will send a message to tell the ground station that the worker wears the helmet.The third case, if the accelerometer sensor feels any change of worker conditions then it will send message to report this condition, and also if the worker in a free fall condition it will send an SMS to the ground station. The following figures 15, 16, 17will illustrate the three conditions starting with the panic situation.

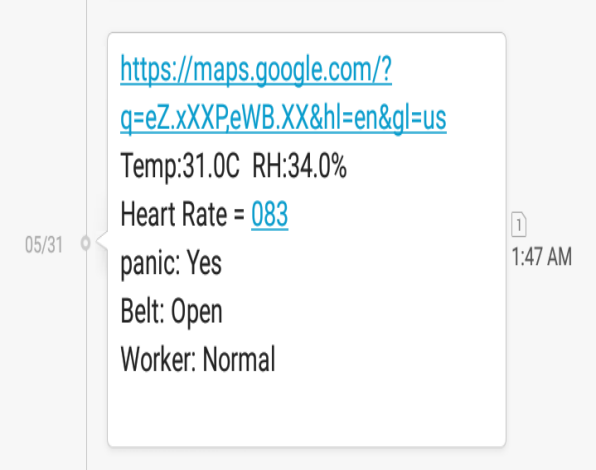

Figure15. Panic condition

Figure 16 shows the condition of wearing the helmet in the right way by close the belt of the helmet.

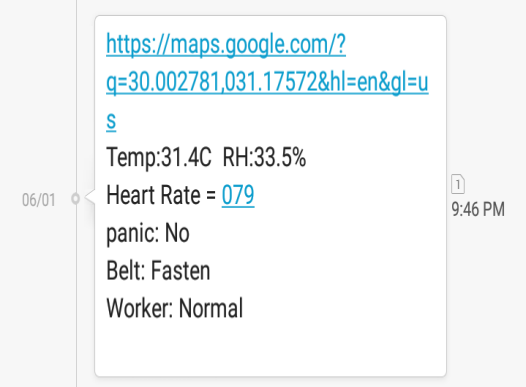

Figure16. Helmet belt condition

Figure 17 will describe the test method of using the accelerometer sensor. The sensor determines whether the dominations have been changed or any object hits worker's head.

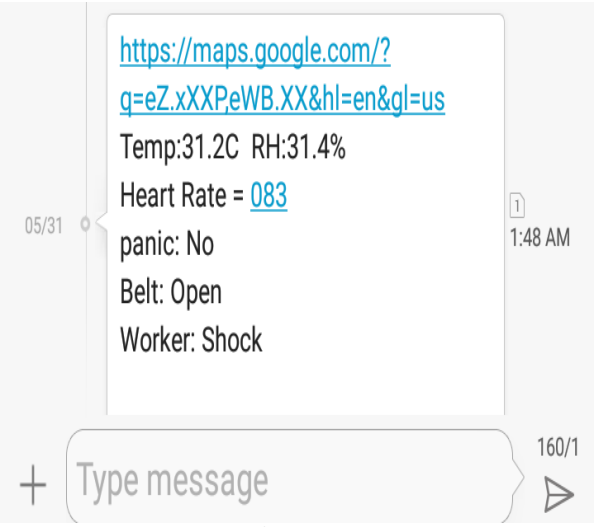

Figure 17. Freefall and shock condition

6.Cost Analysis

Table 1 shows the economic analysis for the Smart Helmet prototype Model.

Table 1 Economic analysis

Component	Cost per unit	Economical cost per 100 units
Microcontroller (STM32F072)	22.50$	4.85$
SIM300	30.25$	5.285$
Two coil	1.5$	0.5$
Passive component	20$	3.50$
SKM53	25.75$	4.20$
HDC1000	12.65$	3.75
MAX30100	8.25$	2.25
Total	110.9$	25$

7.Conclusion and Future Scope

In this paper, a newly proposed smart helmet system is introduced. The design and the implementation of the smart helmet were discussed. The Smart Helmet will provide smart solutions based on using a microcontroller, GSM, GPS modules, and a group of sensors that locate the worker's position and send a conditional SMS if there is any risk of life. Further study will be applied to provide a model with more advanced functions.

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