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ORIGINAL ARTICLE

IoT enabled tracking and monitoring sensor for military applications

Brijesh Iyer[1] · Niket Patil[1]

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Abstract The paper reports an internet of things enabled monitoring and tracking sensor for military applications. The proposed sensor is specially designed to cater the safety requirements of soldiers on the battlefield. It employs an Aurdino board for its operation along with various sensors to gauge the remote human vital sign. With the help of global positioning system based location tracking, the sensor provided the accurate location of the human subject in terms of longitude and latitude of place. Further, the designed sensor accurately provided the body temperature of the subject under test. This sensor is a low cost, portable and reliable solution for the military applications.

Keywords Aurdino · Battlefield · GPS · Healthcare, IoT · Security · Soldiers · Vital signs

1 Introduction

Soldiers are the indispensable part of any nation's security mechanism. The present day situation demands the use of the soldiers in peace as well during insurgencies. The modernization in the military science and warfare mechanisms developed very sophisticated weapons of mass destructions. Hence, the possibility of casualties has been increased manifold in comparison with the wars in last century. During the wars and combat operations, soldiers may get injured, which can be fatal. In the twentieth century, millions of people have died or got permanently disabled in wars. According to The Hindu (Indo-Pak war 1971), 54 soldiers were declared 'missing in action' during India-Pakistan war in 1971. Till date, the status of these 54 soldiers is unknown. Crossing the international boarders unknowingly, during patrol, is another reason of mishap with soldiers due to which they may put life on stake.

The environment and battle situation in the combat zone is highly uncertain and fatal. In military operations, it may be possible that the entire troop or an individual solider may get misplaced or injured in combat zone. This can be minimised by the uninterrupted communication with control room, real-time information regarding the present location and health, fleet mobilization during the emergency situations. A highly uncertain and fatal battlefield condition limits the possibility of physical tracking of the troops or individuals. Such tracking may put the rescue team in danger. Hence, remote and non-invasive monitoring is highly advisable.

Many surveillance technologies are available in the area of soldiers health monitoring and tracking systems on the battlefield. Different communication technologies such as Bluetooth, ZigBee, RF transceiver, GSM, Wi-Fi and Telephone lines are famously used for the remote tracking of the human being (Bluetooth; Ambala et al. 2012; Iyer et al 2013; Patil et al. 2014; Kumar and Sekhar 2015; Bennett and Gardner 2005). Table 1 provides the brief comparison of different remote monitoring techniques.

However, these technologies suffered from one or other drawback such as limited bandwidth, high operative cost, complex infrastructural requirements or compromised accuracy of prediction. Owing to these drawbacks, it is the need of the hour to have sensor which is accurate, real-time

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Table 1 State- of- the -art remote monitoring and tracking system for soldiers

Contribution	Wireless communication technology	Bandwidth requirement	Operation range
Bluetooth	Bluetooth	15 MHz–2.4 GHz	100 m
Ambala et al. (2012)	Zigbee	3 MHz–2.4 GHz	10–100 m
Iyer et al. (2013)	RF transceiver	WLAN	Up to 5 m
Patil et al. (2014)	GSM	890–915 MHz (uplink) 935–960 MHz (downlink)	35 km
Bannet and Gardner (2005)	Telephone lines	400 Hz–3.4 kHz	–

and of low cost. Hence, this paper reports a soldier's health tracking and monitoring sensor based on IoT concept.

The rest of the paper is organised as follows: Section 2 of the paper describes the review of existing technologies and reported efforts in the area of soldier health monitoring and tracking sensor. Section 3 presents the operation of the proposed sensor whereas Sect. 4 focuses on result and discussions. The paper is concluded in Sect. 5 along with the future scope of enhancement in the reported methodology.

2 The review of existing mechanism

Portability, high degree of accuracy and robustness are the need of hour for the surveillance mechanism in modern warfare sensor. Considering the importance of the application, many researchers and academicians reported different mechanism for the remote tracking of soldier health.

The last decade witnessed remote human health monitoring by virtue of monitoring its physiological signs using transmission over telephone line (Bennett and Gardner 2005; Vaz et al. 1991; Gardiner et al. 1994). Though these systems provided real-time operation, it suffered from drawback such as limited bandwidth, signal degradation and high operational cost.

Microcontroller based soldier health tracking and indication system was proposed in Patil et al. (2014). The system used Google Map for the location mapping of the soldiers. Lim et al. (2010) reported an on-going effort to develop a system consisting of interconnected body sensor networks (BSNs) for real-time health monitoring of soldiers. They suggested the use of various wearable, portable, light weight sensors to monitor human physiological parameters. ARM processor based mechanism was proposed in Nikam et al. (2013) for the safety of soldiers. The ARM processor is supported with various sensors and GPS module to track the position of a soldier on the battlefield. A mobile health monitoring system was proposed by Walker et al. (2009). It employed a BSN comprises of a microcontroller and RF transceiver from Texas instrument.

A web based remote monitoring system for pervasive healthcare system was proposed in Yuan and Herbert (2011). However, the system in Yuan and Herbert (2011) stuck-up by the requirement of a central server for the processing purpose. An IoT based approach was reported by Kumar and Rajasekaran (2016). The authors used Raspberry Pi board to collect the human vital signs which further added to the cloud-based website.

It is evidenced from the reported methodologies that very few efforts are initiated in the direction of soldier's health and location tracking on the battlefield. Further, the reported system suffers from one or more limitations like implementation cost, slow response and bulky nature. These drawbacks can be overcome by using a portable wireless real-time system. Table 2 provides the state-of-the art technology in terms of remote health monitoring and tracking systems.

The reported sensor will also provide the real-time data of soldier's health and exact geographical position to control room using internet of things (IoT). This feature will help to overcome the problem of "soldier missing in action".

3 The proposed sensor mechanism

The aim of the proposed sensor is location tracking to assist the soldiers on battlefield. The sensor consist of two unit namely soldier unit and control room unit. Figure 1 depicts the block diagram of the proposed sensor.

The Soldier unit (Fig. 2) consists of *ATmega328* microcontroller board. It controls the entire processing and decision initiation part of the system. Various sensors such as pulse rate, body temperature, gas detector along with a panic or emergency buzzer button are attached with the processor board. The *16 × 2 LCD* is used to display the values measured by the sensors. A GPS receiver is used to identify the real-time location and orientation of the soldier. The communication between the control room and soldier unit is achieved using IoT with the help of *Node MCU ESP8266* Wi-Fi module. The sensor unit has dimension 15 × 4 × 2 cm (L × B × H) which is very

Table 2 State-of-the-art remote monitoring and tracking system for soldiers

Contribution	Transmission technology	Processing technology	Battlefield approach
Patil et al. (2014)	Zigbee	LPC2138 microcontroller	No
Nikam et al. (2013)	GPS	ARM 7 TDMI processor	Yes
Walker et al. (2009)	Zigbee enabled wireless sensor	MSP 430	No
Yuan and Herbert (2011)	Web based monitoring	Atmel AVR Atmega microcontroller and Nordic RF 2401 transceiver	No
Kumar and Rajasekaran (2016)	IoT	Raspberry Pi board	No
Proposed method	IoT	Aurdino board	Yes

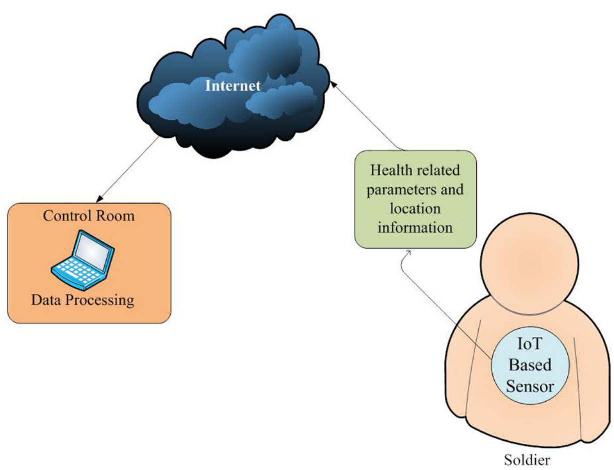

Fig. 1 Conceptual diagram of the proposed sensor

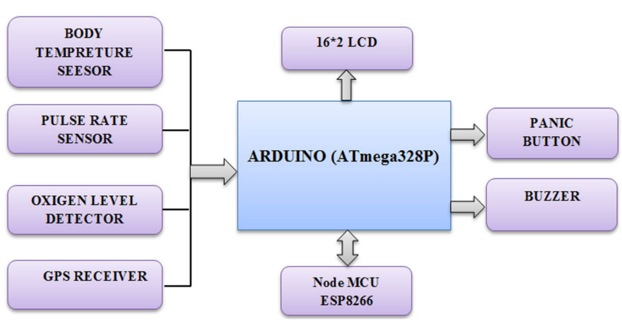

Fig. 2 Block diagram of soldier unit

compact. Hence, it can be easily deployed along with the soldier's kit.

During the experimental analysis, body temperature and heart beat rate is predefined for the verification purpose. Whenever the temperature and heart beats are deviated from the set threshold value, system gets alert and correspondents the data to the control room with a buzzer beep. At that same time, location and orientation of soldiers are also communicated to the control room.

The current status of the soldiers can be accessed at the base station via IoT based tracking systems. In this system the information is transmitted via Wi-Fi module. This information will be stored on the Cloud and can be extracted on the PC of control room. The Control room unit (Fig. 3) keep track of the soldier health and the real-time location with the help of a desktop or a monitoring screen with an internet connection. A graphical user interface (GUI) is designed for displaying the data received from the soldier unit. The soldier unit and control room unit gets connected with each other by using Wi-Fi module. Control room will extract actual information of the soldiers using its unique IP address with the help of internet.

4 Results and discussion

4.1 The flow chart

The working principle of the proposed unit can be described with the help of the flow chart as shown in Fig. 4.

1. Whenever sensor is on, the GPS receiver track the particular location in the form of latitude, altitude, longitude, speed, time, date, satellite in count etc. and send it to control room.
2. LM35 temperature sensor is used to measures body temperature of soldier. Here a temperature threshold level (TEMP) is set between 31 to 37 °C. Whenever

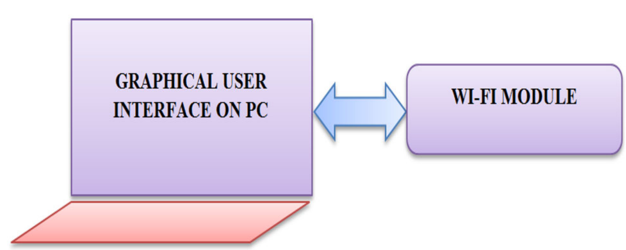

Fig. 3 Block diagram of control room unit

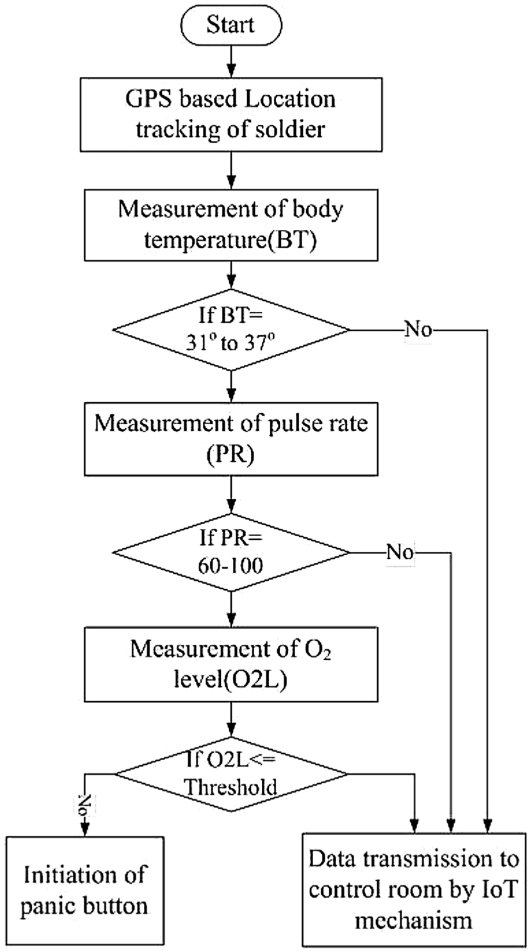

Fig. 4 Operational flow chart for the proposed sensor

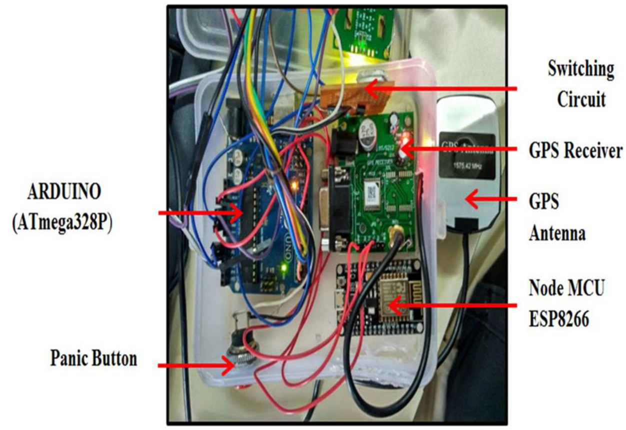

Fig. 5 Hardware setup of the proposed sensor

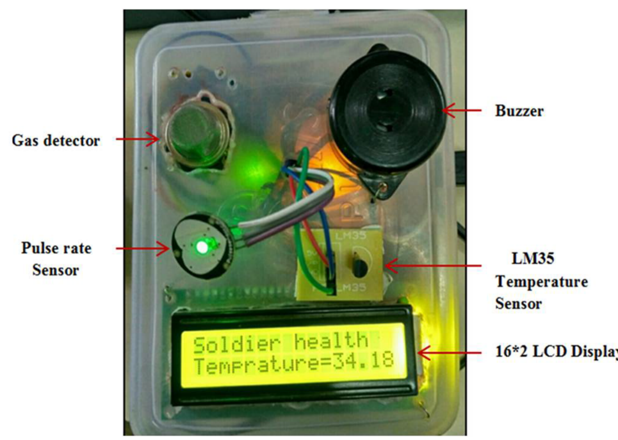

Fig. 6 Characterization of the proposed sensor

the body temperature of the solider increases beyond or below this level, the sensor generated alert will be sent to the control room.

3. Soldier's heartbeat is continuously tracked and recorded with the help of *V1.1* pulse rate sensor. The heart rate for a person of normal physic ranges between 60 to 100 bits per minutes (BPM). If the heartbeat crosses both extremes, a sensor generated alert will be transmitted to the control unit.
4. The oxygen (O2) saturation is measured with the help of *Grove-Gas* sensor in the proposed sensor. Whenever a drastic variation in the environmental parameter is observed, a sensor generated alert will be transmitted to the control unit.

4.2 The sensor prototype

The hardware setup of the proposed sensor is shown in Figs. 5 and 6. It consists of *AT-mega 328P* Microcontroller board. LM35 is used as a body temperature sensor to detect body temperature of army persons in degree centigrade.

Further, the heart rate of the solider is measured by using *V1.1* pulse rate sensor. It operates on the principle of light modulation by blood flow through the finger tip. The gas detector detects the concentration of gases in the environment so that the smoke level can be detected around the solider. The Node *MCU ESP8266* Wi-Fi module is used to generate a specific IP address for each solider. Each soldier is connected to the control room with his/her unique IP address generated by this module.

The real-time location is displayed on the LCD display with the help of GPS. In this way, both the soldier and the control room will come to know the current situation and position. Provision of a panic button is kept on the proposed sensor. A solider may use this button to generate an alert under an emergency condition to draw the attention of the nearby soldier.

At the same time an alert will is generated to the control room. This feature helps the effective mobilization of the rescue teams on the battlefield. The graphic user interface

(GUI) is used to fetch real time data of the soldier with the help of internet. This GUI page (Fig. 7) is consciously kept on updating the recent health status of army parson. The data sheets of individual components used on the design board shows that they are capable to operate over military temperature range (– 55 to 125 °C). Hence, the proposed sensor is the best candidate to operate in the extreme temperature battlefields.

A thing is any hardware. Object and sensors with embedded electronics that can transfer data wirelessly over a network without any human interaction is called an IoT. In the proposed sensor, the information from various biomedical sensors are collected and added to the cloud-based websites with the help of IoT. The Wi-Fi module is main part of IoT platform in the addressing sensor. It is used to connect proposed sensor to GUI page using internet. This will help to transmit the real-time information to the control room.

4.3 The analysis

The experiment was carried out in the Dr. B. A. Technological University premises with a human being mounted with the proposed sensor. The human subject was placed at a location with longitude and latitude of 73.3 and 18.17 respectively. The experimental tracking information of the heartbeats and body temperature is depicted in Fig. 7. Experimentally the parameters for the location tracking of a person on a specific location was calculated and the tracking information is verified with the help of Google map navigation tool (Figs. 8, 9). The experimentally verified location information in terms of longitude and latitude of the subject under test was accurately matched with the manual information of the location. Further, to ensure the feasibility of the proposed sensor, qualitative analysis in

Fig. 7 GUI for the proposed sensor

terms of processor, sensors used and total cost of the sensor is given in the Tables 3 and 4.

The approach reported in Patil et al. (2014) and Nikam et al. (2013) are not attractive due to confirmation of the health condition using very few parameters which may generate false positive alerts. Walker et al. (2009) employed only accelerometer sensor for tracking the motion. In the diverse environment of battlefield, this parameter is less attractive as the soldiers have to change their location continuously. The approach reported in Yuan and Herbert (2011) and Kumar and Rajasekaran (2016) are less attractive as it requires very complex encoding and decoding mechanism. Further, the approach reported in Patil et al. (2014), Walker et al. (2009), Yuan and Herbert (2011) and Kumar and Rajasekaran (2016) does not have the facility of panic alert generation. This feature is very vital as in emergency situation; immediate help can be availed by a solider from nearby soldiers.

Further, on the battlefield, the human life can be ascertained by vital signs such as heartbeats, temperature, smoke content due to heavy shelling and availability of Oxygen level at a particular location and time. The proposed sensor ascertains the soldiers condition based on aforementioned parameters.

India is the third largest standing military in the world with 1,325,000 personnel (29 Largest armies in the world). Hence, the sensor used for health and position tracking must be cost effective so that it can be deployed with each soldier. Table 4 provides the qualitative analysis of proposed sensor in terms of implementation cost.

The major cost in such systems is contributed to the use of processor and other accessories. The proposed sensor uses low cost Aurdino board which acts as the heart of the sensor.

It is evidenced from Tables 3 and 4 that the proposed sensor is far better option than the similar reported one in the field of battlefield health monitoring and tracking system.

Table 5 provides the qualitative analysis of the proposed system in terms of the sensor technology. The approaches reported in Zappi et al. (2007), Caicedo and Pandharipande (2012) and Iyer et al. (2015) are based on infrared, ultrasonic and radio frequency technology for sensing purpose. Further, these approaches are stuck-up by one or more limitations such as limited operational range, bulky circuitry and maintenance requirements. However, the proposed sensor is very cost effective, compact and easy to maintain and reproduce with ease. Further, as RF is not used in the detection process, the proposed sensor will be very safe for the human being. Moreover, a simple 9 V battery is used for its operation which is very low cost and durable. Hence, it will be a suitable candidate for next generation sensors for military applications.

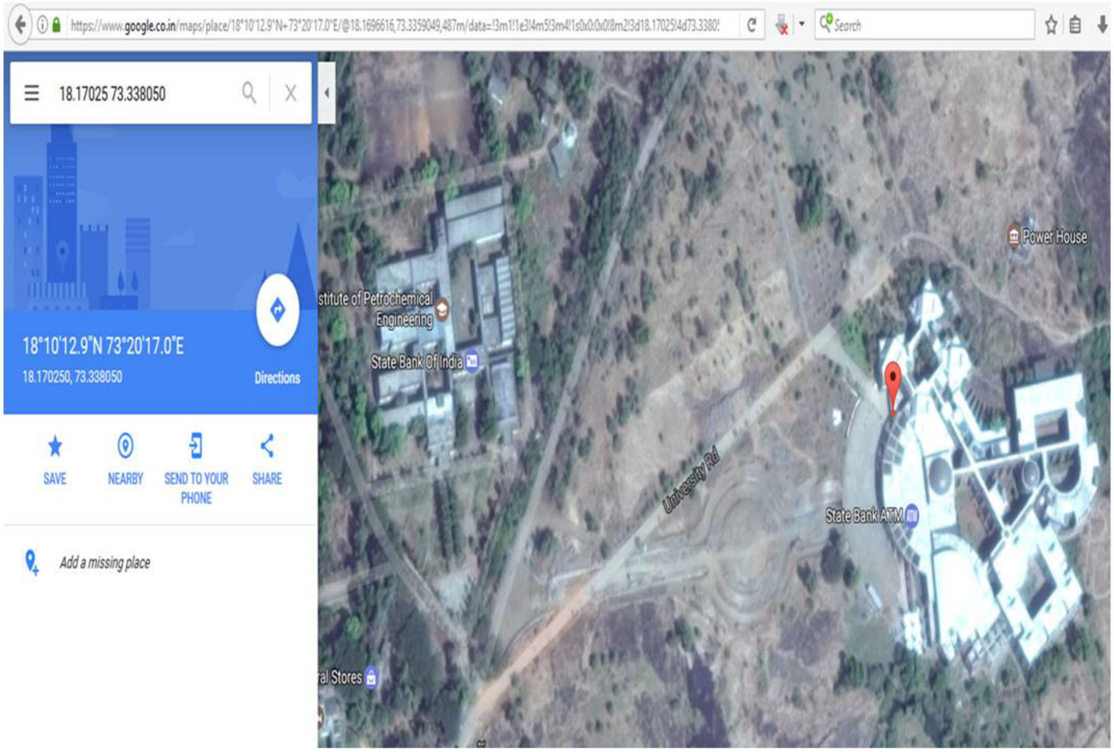

Fig. 8 Experimentally verified location tracking

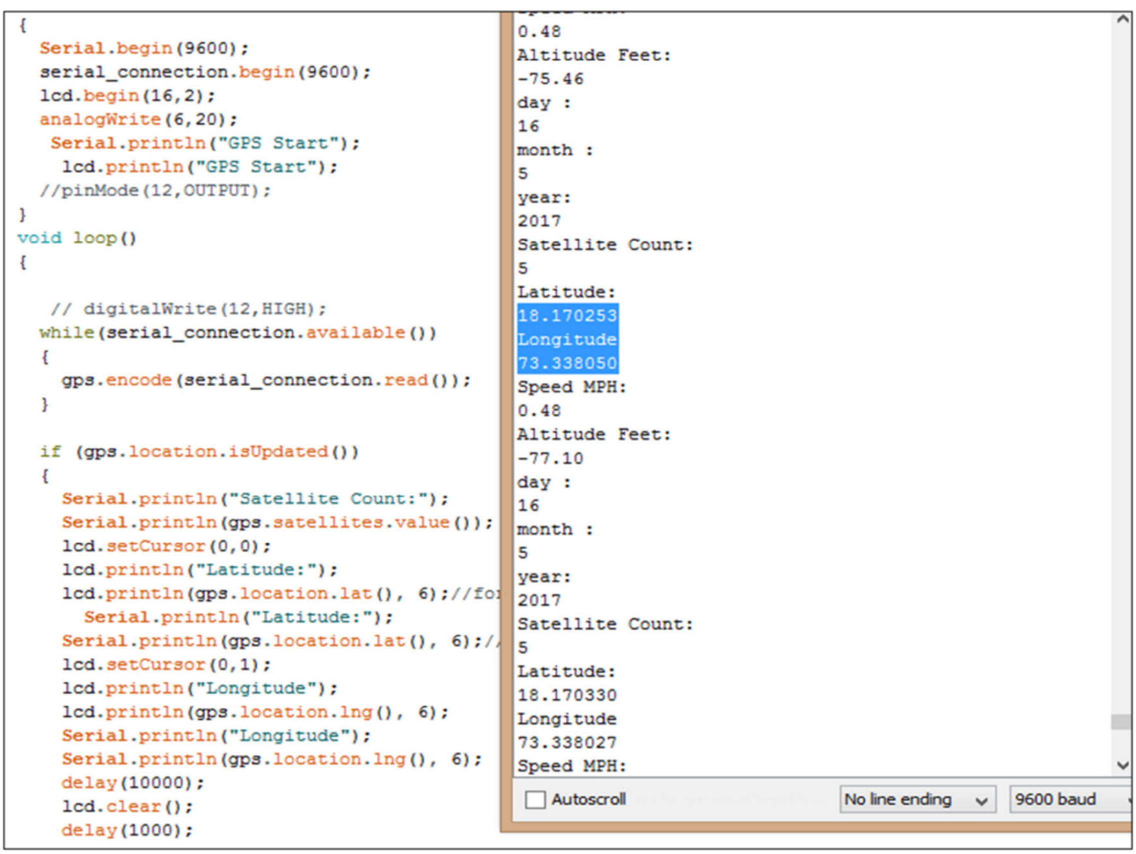

Fig. 9 Experimental calculation of location information

Table 3 Qualitative analysis of proposed sensor: use of sensors and deployment complexity

Contribution	Biometric sensors	Panic alert mechanism	Deployment feasibility
Patil et al. (2014)	Temperature, pulse rate sensor	No	Less feasible due to limited parameter verification
Nikam et al. (2013)	Temperature, pulse rate sensor	Yes	
Walker et al. (2009)	Accelerometer	No	Used for motion tracing only
Yuan and Herbert (2011)	ECG, oxygen level, temperature and mobility sensors	No	Complex transmitting and reception mechanism
Kumar and Rajasekaran (2016)	Temperature, respiration rate, heartbeat sensor and accelerometer	No	
Proposed method	Temperature, pulse rate and oxygen level analyser, smoke detector, panic alert	Yes	Simple and low cost transmitting and reception mechanism

Table 4 Qualitative analysis of proposed sensor: battlefield utility and cost

Contribution	Battlefield approach	Cost in INR (approx)
Nikam et al. (2013)	Yes	3000.00
Yuan and Herbert (2011)	No	3600.00
Kumar et al. (2014)	Yes	3400.00
Proposed method	Yes	850.00

Table 5 Qualitative analysis: sensor technology

Contribution	Sensor technology	Distance coverage	Size of the circuit
Zappi et al. (2007)	Infrared	Limited	Bulky
Caicedo and Pandharipande (2012)	Ultrasonic	Limited	Bulky
Iyer et al. (2015)	Radio frequency	Short to medium	Complex and bulky
Proposed method	IoT	Larger geographical area can be covered	Compact and easy to reproduce and maintenance

5 Conclusions and future scope

The paper reports an IoT based solution for the health monitoring and tracking of the soldiers on the battlefield. This sensor is a low cost and accurate solution for the tracking of the soldiers. Various human vital signs and the battlefield conditions such as body temperature, pulse rate, smoke detection, and oxygen saturation are used for ascertaining the human life. Further, a panic buzzer is also provided which may be useful for the solder to avail the instant help on the battlefield. This information is transmitted to control room using IoT.

This sensor is beneficial in two ways i.e. availability of accurate location to the soldiers and correct situation information to the control room. Such information is useful to the control room to initiate effective rescue operations to save many precious lives on battlefield.

Continuous audio communication and real-time video transmission are the two aspects which may be included in the proposed sensor, in future, to have a better understanding of the battlefield conditions.

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