A Smart Healthcare Tracking and Monitoring System

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***Abstract*—Although technology advances cannot help in limiting the dreadfulness missing-in-action that occurs either in war or in dangerous sports, they could at least help in reducing its effects and casualties. One way to help in this aim could be by tracking and monitoring the location and health situation of the concerned persons. The main objective of the work presented in this paper is to design and implement a complete tracking system. The system is composed of a mini portable server, defined as a central unit hosted on a Raspberry Pi and used to monitor members' location, state, and health information. This will be done through wireless communications to small devices equipped with the necessary sensors and attached to the member's arm. Moreover, the system provides an emergency button to request help if pressed when the member is facing an urgent situation. A set of test cases has been applied and the results achieved by our prototype have presented a promising accuracy and efficiency when applying such a system.**

Keywords-Healthcare monitoring; tracking system; Raspberry PI; Arduino; WIFI Communication.

I. INTRODUCTION

As we already stated in [1], on September 28 1951, Daniel Hunt, from Columbiaville was a member of the 1st Battalion conducting operations near an area referred to as Heartbreak Ridge. The Chinese launched an attack, which the army repelled. Prior to their attack, the Chinese launched a barrage of mortar fire against the Americans in which survivors withdrew to friendly lines. Hunt was reported missing in action. During an investigation by the U.S. Army Casualty office, three members of Hunt's unit reported him been killed during the fight. The Army therefore declared him deceased. Today, 7780 Americans remain unaccounted for from the Korean War [2].

On the other hand, on February 13 2017, an avalanche in France has left four skiers dead and five missing when a mass of snow swept them away in the resort of Tignes. Resort workers reportedly witnessed the disaster, which struck an off-piste slope at around 10.30am local time, alerting emergency services. Mountain security authorities in nearby town Albertville said those who are unaccounted for are believed to be "buried under a large amount of snow" [3]. Thousands of cases like "Hunt" and the skiers are encountered around the world, showing that the issue of unaccounted people is a common in wars, sports and other even of our daily life.

Some people believe that known communication tools can help to avoid problems encountered in the previously mentioned cases and save lives. In these cases and in all scenarios in this paper we define members as a group of people in a mission with a leader on the head of the mission. Monitoring members by their leader is not an easy task because of natural factors, lack of knowledge about the place of accident, loss of connection between the leader and the members, power failure of the tools, barrage jamming, and snow swept and so on, constitute obstacles limiting communication between members and their leaders.

These and many other problems have led researchers to think about new solutions benefiting from the evolution of technologies. Throughout the years, many technologies have been invented to solve the Missing-In-Action problem, but they remained weak. Most of these systems are based on tracking the movements of people in missions, which is not always an efficient way to detect threads and does not give the real status on the group on the ground. Navigating and situating are important, but need tiring activities which GPS (Global Positioning System) makes easier. The GPS has turned out to be a significant technology for the U.S. military and other defense forces around the world since the 1980's [3]. With the ability to provide accurate positioning continuously, day or night, in any conditions, GPS has helped ground troops in Iraq and Afghanistan navigate across expansive, barren deserts that have few markers or distinguishable features. Although GPS provides the position of skiers and hikers, it is still considered weak and far away from healthcare when any of health issues are faced during any type of missions.

From all the previously-mentioned issues, the objective of our paper is to present the design of a new "smart healthcare tracking and monitoring system" that would significantly reduce the effects of problems encountered through the literature review we conducted. Our system grants the leader the ability to track his team members on a map based application and monitor their health statuses in a continuous and real time way, even in upper mountains and hard conditions. This is done via a web interface installed on a stand-alone server or via a mobile application. This paper is an extension of the work presented in [1]. The rest of it is

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organized as follows. In Section II, we talk about some similar applications to our system. Section III gives an overview of the system architecture and design. Section IV talks about the used components and describes the implementation in detail, and we conclude in Section V with a summary about the main contribution of this paper.

II. Related Works

Medically, health statuses of members with critical conditions are a great concern for leaders who seek new and innovative healthcare systems. In the past, sports leaders were monitoring their members with the aid of primitive communication systems, such as the walkie-talkie, until the technological development enabled tracking systems using satellites.

A. *Walkie-Talkie*

During the Second World War Donald L. Hings, radio designer Alfred J. Gross, and engineering teams at Motorola, invented a walkie-talkie. The hand-held, compact, two-way radio handset, utilized for field artillery and tank units. After the war, the basic walkie-talkie idea quickly expanded into a family of devices, the forbears of later citizen's band radios in the 1970s and the first analog cell phones in the early 1980s [5].

This device improved the leader-members communication during and after a mission, however, this technology has a limited usage because it can't be used in a low-profile situation or in the case of injury. In addition, this device is energy consuming and sensitive to natural factors and man-made noises.

B. *Movement/tracking system*

The United States Army invented a Movement Tracking System (MTS) that is a logistics communication platform under the Program Executive Office for Enterprise Information Systems (PEO EIS) [6]. It is designed for commanders (leaders) to track assets (members) on the battlefield with encrypted text messaging. It is a satellite-based tracking and communicating system designed to provide command and control between the leader and the soldiers.

This device can continuously monitor the soldier's location during battle, which improves the leader's control of the troops without the need for primitive communication tools which require manual usage. MTS's main disadvantage is that the health statuses of members remain absent from such systems.

C. *Smart systems for healthcare monitoring using communication means*

In recent years, health monitoring systems have rapidly evolved recently, and smart different systems have been proposed to monitor patient's current health conditions. In a recent work [7], authors are proposing a "Smart real-time healthcare monitoring and tracking system using GSM/GPS technologies", which concentrates on checking the patient's blood pressure and body temperature. This system was built for social healthcare in the light of GSM and GPS innovations and as a compelling application for real time health monitoring and tracking. In case of emergency, a short message service (SMS) will be sent to the doctor's mobile number along with the measured values through the GSM module. Moreover, the GPS gives the location data of the patient who is under observation all the time. While this system covers the issue of healthcare status provision, it cannot continuously track the person's required information. In addition, the usage of GSM to send short messages is more expensive and can face some limitations, such as when the doctor's phone is out of service or due to natural conditions in case of ski, etc.

In another work [8], authors proposed "Patient Health Management System". This system is based on smart devices and wireless sensor networks for real time analysis of various parameters of patients. This system is aimed at developing a set of modules which can facilitate the diagnosis for the doctors through tele-monitoring of patients. It also facilitates continuous investigation of the patient for emergencies looked over by attendees and caregivers. A set of medical and environmental sensors is used to monitor the health, as well as the surroundings, of the patient. This sensor data is then relayed to the server using a smart device or a base station.

Each of the systems discussed in this section provides a required and specific feature needed before, during and after a mission. Walkie-talkie system provides the aural communication between leader and members but the tracking of members functionality is missing. MTS provides continuous tracking of members' movements, but their health statuses are missing, "Smart real-time healthcare monitoring" system provides health statuses tracing, but not continuously, "Patient Health Management System" provides health monitoring using smartphones over the Internet or using servers to extract information.

In our design, we try to take full advantage of existing systems by combining their features in one small wearable device. An important advantage of our system compared to other products is manifested in its ability to simultaneously keep an eye on members' health status alongside their locations without the need for manual control, which facilitates leader-members communication, even on Upper Mountains and under hard conditions. Moreover, the central unit, unlike the systems discussed, is a small portable device to be held by the leader. It hosts the information locally without any need of larger servers or connecting devices between members and their leaders.

III. System Design

In this section, we present a thorough description of our system design. This description encompasses four parts: the first, presents the use case and activity diagrams; the second, presents the system architecture; the third, shows the state diagram and the last one, contains the conclusion about the system overview. This description allows seeing the system from different perspectives and fosters a better understanding of its functionalities.

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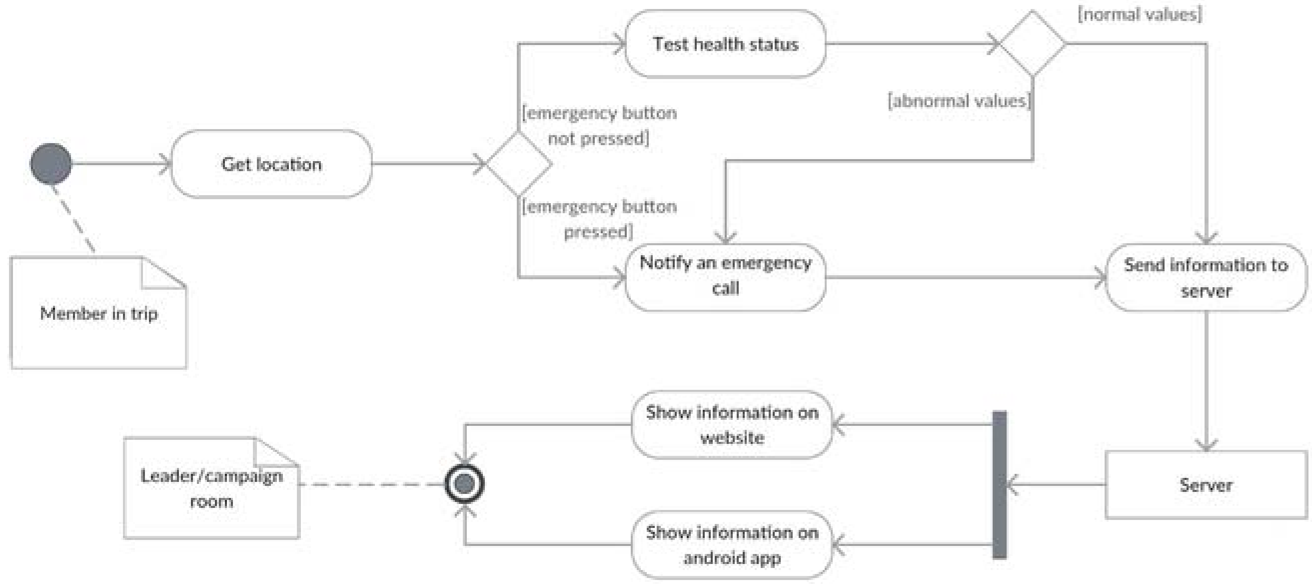

Figure 1: Activity Diagram of the system

A. *Requirements and Specification analysis*

In this section, the overall requirements of the system are defined together with the use cases of members and their leader; it also shows a UML activity diagram of the system.

- Each member requires a wearable device before the mission.
- This device records the heart rate, oxygen in the blood and body temperature of the member and sends data periodically to the server component.
- The device has a button which may be pressed in an emergency situation.
- On the other side, there is a device held by the leader and wirelessly connected with this wearable device.
- The leader requires a web browser or an android device, which are available on the leader's device to monitor his members.
- The system will notify the leader if any of the member's status is abnormal or an emergency request is taking place.
- The leader can track his members by receiving their locations from their wearable devices.
- A suitable decision is taken by the leader or monitoring room depending on the faced situation.

A use case diagram at its simplest is a representation of a user's interaction with the system that shows the relationship between the user and the different use cases in which the user is involved. Figure 2 shows the use case diagram of our proposed system by identifying each user interaction with the system. The device held by a member has the capability of testing the life signs and send all required information to the server, it also provides an emergency button to use it when needed in any encountered issue. The system allows the leader or the monitoring room to closely track the members.

An activity diagram is another important diagram in UML to describe the dynamic aspects of the system. Figure 1 shows the same idea of Figure 2 but as flow chart to represent the flow from an one activity to another between members and their leader.

B. *System Architecture*

The system architecture shows the hardware and software side of the system. It is explained using a figure showing the placement of the equipment used and the role of each part. The software part is related to the server and the website or android application that used to monitor persons on maps.

Figure 3 displays the hardware part in detail by showing the member side as an Arduino, sensors required and the WIFI module. The leader side is shown as a Raspberry Pi, both connected to an access point to transmit and receive data. Note that the access point can be on the PI itself if members are close enough. This figure also shows the software part and how it obtains data from the server.

As depicted in Figure 3, we have two main components. The first one is the central unit that plays the role of a server and it is usually controlled by the leader. The second one holds the monitoring units worn by each member.

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The central unit is portable with light weight and small size. For simplicity of connection, this unit could provide an access point to the members to make sure no intermediate equipment is needed. This server will host all the needed information, such as the database and the Web pages. Hence, data retrieval will be done locally and no need for any external connection such as GSM or Internet will be needed. This will help in increasing the system security, connection speed and data localization, since the information of the members does not need to be published on a large scale. This unit can be controlled via a Web application that could be accessed directly from the PI or via a mobile application that is designed to do the same objective.

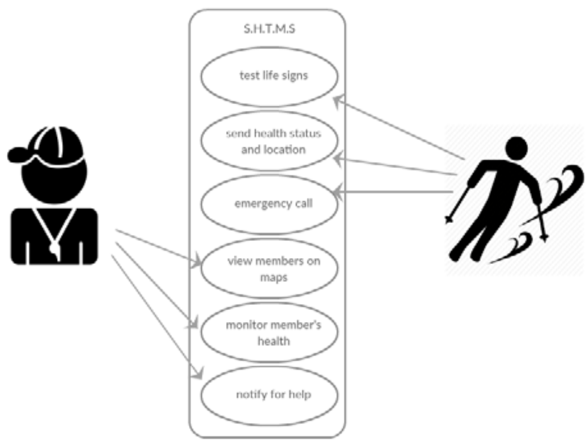

Figure 2: Use Case Diagram of the system

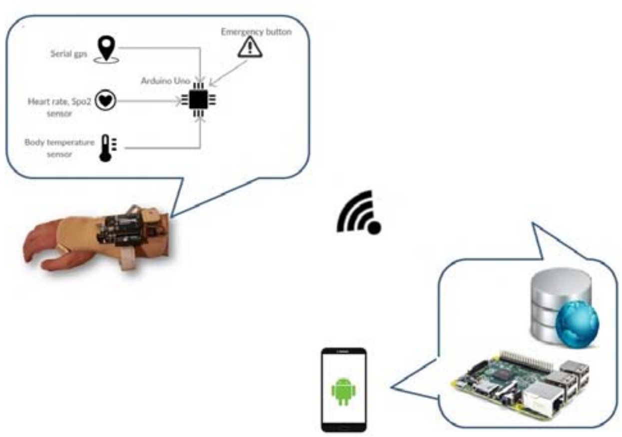

Figure 3: System Architecture Diagram

The other main component of our system is a small wearable glove that is equipped with all the sensors and detectors to connect members to their monitoring campaign or leader. This will be done by detecting body temperature, oxygen level in the blood, heart beat rate, speed and location of each member. All this information will be sent periodically and automatically to the central unit notifying the leader of any issue, injury or maybe death. Additionally, system provides an emergency button that gives the member the possibility to request help when facing a non-medical urgent problem.

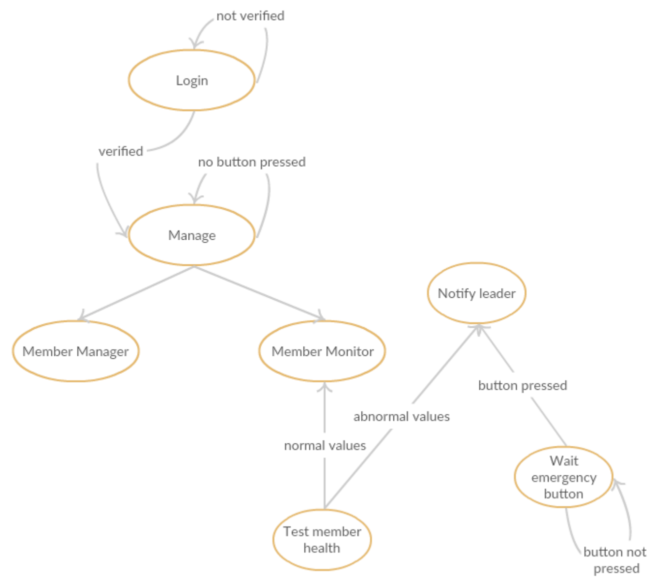

Figure 4: State Diagram of the system

Figure 5: Arduino Uno

C. *State Diagram*

The state diagram in an additional design documentation needed to outlining the different stages of the system. A state diagram is used to model the dynamic nature of the system. It defines different states of an object during its life time, and describes the control from one state to another. In this part, the function of the system depends on the health status of members as shown in Figure 4. In addition, the leader after login in can either manage members or monitor them during the mission.

D. *Conclusion*

System design can be a combination of use cases, system architecture, and state diagram, which are useful to give an idea about how this system works, from its start to its end. Also, defining the overall requirement of the system, such as hardware and software is important, and where to place and use them is helpful to know about what the system consists of. State diagram used to model the dynamic overview of the system, describes the control from one state to another, and

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shows the starting and the ending point of the system lifecycle.

IV. IMPLEMENTATION TOOLS AND DETAILS

The proposed system is a smart healthcare tracking and monitoring system in Server-Client architecture. This system is collecting health status and locations of a member from one small wearable device to the server. The wearable device is Arduino UNO based and continuously sends member's statuses via WIFI connection without need for manual controlling to the server based on a Raspberry Pi and controlled by the leader. This system facilitates member-leader communication even in hard conditions.

Figure 6: Pulse sensor

A. Monitoring Unit implementation

In our system, the monitoring unit is composed of a microcontroller connected to a heart pulse sensor, oxygen level and body temperature sensor, serial GPS, emergency button, and ESP8266.

The Arduino Uno is a small, complete, and breadboard-friendly board shown in Figure 5. It has 14 digital pins, and each of them can be used as an input or output. It also has 8 analog pins, each of which provides 10 bits of resolution [9]. In this system, we used this type of Arduino just for simulation, but more practical prototype can be used to minimize the size of the device.

We connected the heart pulse sensor to an analog pin of the microcontroller. The pulse sensor shown in Figure 6 reads a waveform and calculates the BPM (Beats per Minute), as well as the IBI (Inter Beat Interval), which is the time between beats [10].

The oxygen level and body temperature are both measured using the MAX30100 chip shown in Figure 9. The only required connection to the sensor is the I2C bus (SDA, SCL lines, pulled up). The MAX30100 shown in Figure 9 is an integrated pulse oximetry, body temperature, and heart-rate monitor sensor solution [11]. The accuracy of the pulse sensor was better, so we ignored the heart rate value measured by MAX30100 and we used it as a supporter in case of fault within the heart pulse sensor.

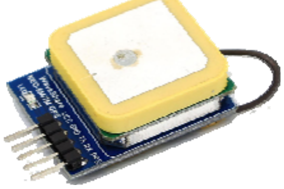

Figure 7: NEO-6M GPS Module

In addition, we used NEO-6M GPS Module shown in Figure 7 to measure the speed of each member beside his location as latitude and longitude values.

Figure 8: Touchable LCD screen with Bluetooth keyboard.

The serial GPS communicates serially with the microcontroller. This GPS Module uses the latest technology to give the best possible position information. Also, it comes with ceramic antenna.

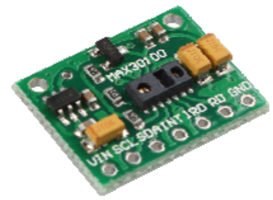

Figure 9: MAX30100 sensor

Finally, the microcontroller sends all measured values using serial communication to the WIFI module, which is connected to digital pins. The WIFI Module (ESP8266) shown in Figure 10 is programmed to get values from the microcontroller following a specific algorithm; then, it sends these values through WIFI to the central unit where the leader monitors. The ESP8266 is a self-contained system on chip with integrated TCP/IP protocol stack that can give any microcontroller access to any WIFI network. The ESP8266 is capable of either hosting an application or offloading all WIFI networking functions from another application processor.

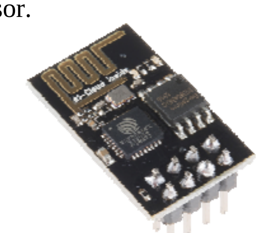

Figure 10: ESP8266 WIFI Module

The whole monitoring implementation board after connecting these components is shown in Figure 11.

B. Central unit implementation

Raspberry Pi with Linux operating system is the central unit. The leader can browse the Web page built for the system to track and monitor his members. In addition, we added a 7 Inch LCD touchable screen and a keyboard shown in Figure 8 to allow the leader to access the Web site directly from the server.

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As shown in Figure 12, the central unit is a portable device with small dimensions (15 cm widths x 15 cm height and less than 10cm depth) so the leader can hold it during the mission. Even if hard conditions according, the metal box that built for this purpose is strong enough and allow the leader to stay connected with his team members.

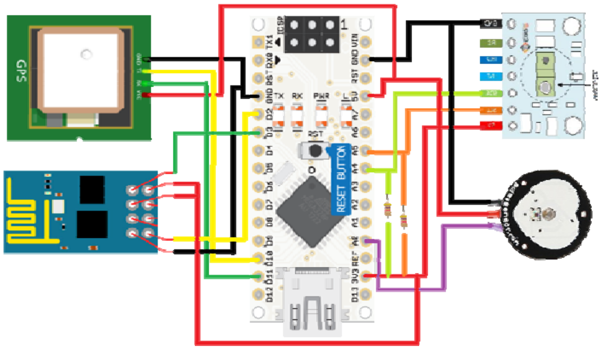

Figure 11: Monitoring unit implementation board

Figure 12: Portable central unit based on Raspberry Pi

The Raspberry Pi is a small computer with a processor, RAM (Random Access Memory) and graphics chip. It has various interfaces and connectors for external devices communication [12]. In our system, we configured it as a server. We used Raspberry Pi V3 Model B which has 512 MB of RAM.

C. *Webpage development*

Each member in the trip held a user-friendly wearable device composed of the microcontroller, sensors required and a WIFI Module. A real prototype of the monitoring unit is shown in Figure 13.

The microcontroller gathers data from all sensors and sends them to the central unit directly using WIFI signals without passing through any access point.

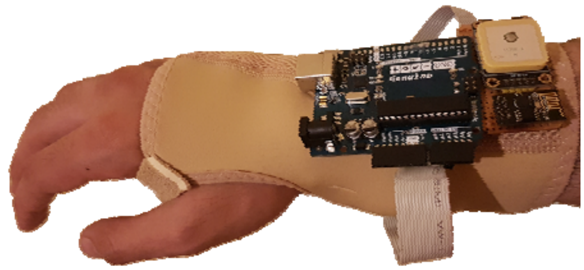

Figure 13: Member's wearable device

Each member must turn on his own device, which is programmed only for his unique I.D., without any need for any manual configuration. This device will send the member's I.D., health status and location information continuously. In addition, any member of the team with normal health status can notify his leader by pressing an emergency button if he needs any help. The leader can track and monitor his team directly from the small portable access unit, or any other PC connected locally to this unit, by accessing the Web page built for the system from any browser. After login, the Web page displays a map showing all the members in the trip or wearing their devices, as shown in Figure 16. The members are represented by markers; on mouse over Marker, a window will pop-up displaying the member's profile information, as shown in Figure 14.

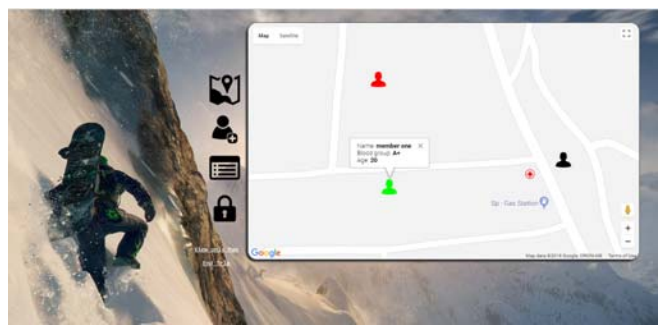

Figure 14: Shows a player in a normal case on mouse over icon

On mouse click on Marker, a window displays the member's health information, as shown in Figure 15.

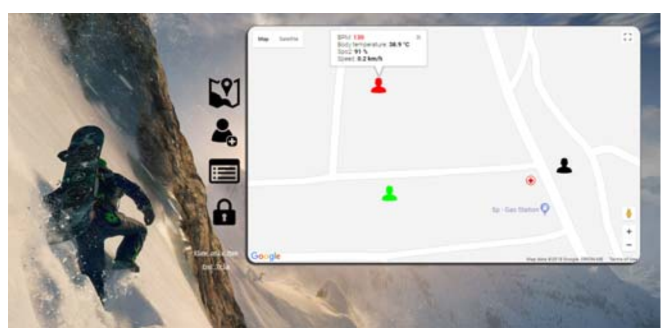

Figure 15: Shows a player in an abnormal case on mouse click on icon

The icon of a marker changes depending on the health status, or in case of an emergency as follows: A red icon indicates an anomaly in one or more value of life signs,

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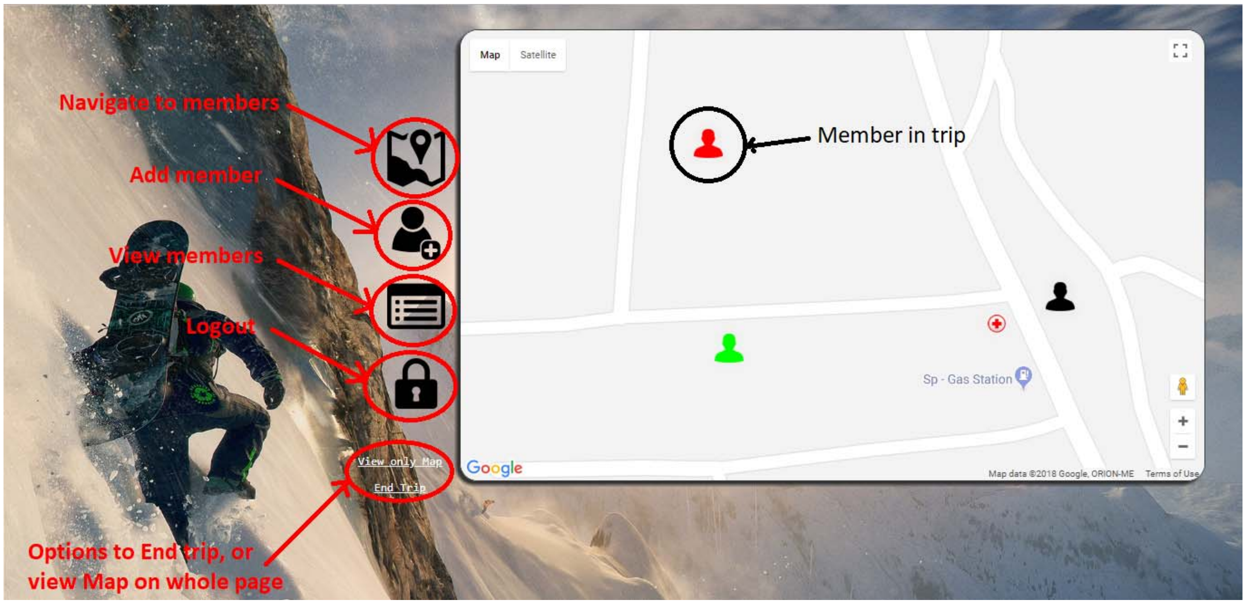

Figure 16: The main webpage shows the maps with markers

a black marker indicates that no more heart beats are detected any longer; an emergency sign indicates that the soldier has a normal health status and needs help. An option of viewing only the Map on a full screen mode is available. The leader can also use the Web page to add, remove, and view any member of his team and their personal information as shown in Figure 17 and Figure 18.

After each trip, the leader must press on End trip to clear the markers from the map.

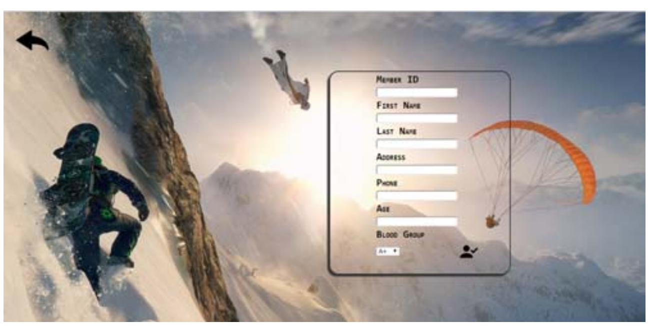

Figure 17: A page to add members to the team

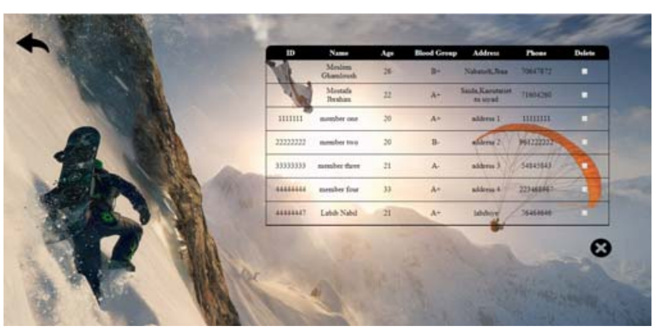

Figure 18: A page to view team members or remove them

D. Android Application Development

We developed an Android application to allow the leader to use it instead of the Web page. This application allows the leader be able to track and monitor his team on a map as well as the website does. Figure 19 shows the main application page and the control panel that can be used by the leader.

Also, this app allows the leader to add members and show health statuses and personal information of members in trip displaying them in a list as shown in Figure 20.

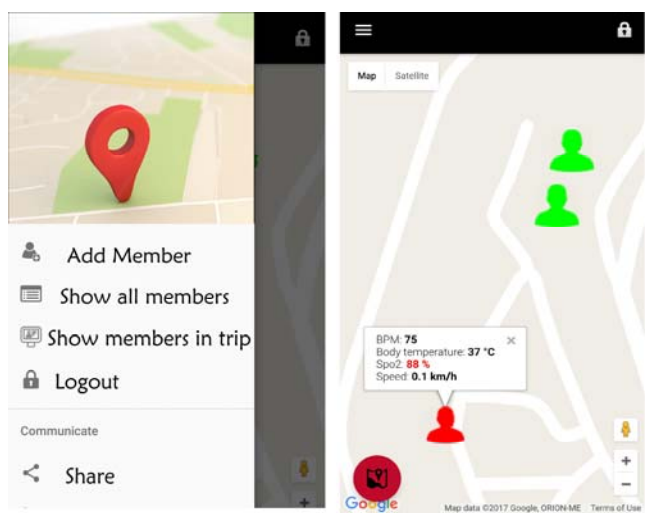

Figure 19: Maps and leader's control panel

In addition, the leader can view all his team members in a list showing if members are in trip or not as shown in Figure 21.

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V. Conclusion

The main objective of this paper was to present the design and implementation of a complete system for monitoring and tracking people's health information and location in a sport trip, battle, patients, etc. Our system provides a wearable device for each member and a portable device for the leader. This enhances the leader's ability to care about the band benefiting from a Web page and an Android application. This system has a humanitarian impact since it can decrease the effects of many issues in trips including unaccounted for and the difficulty of health status monitoring.

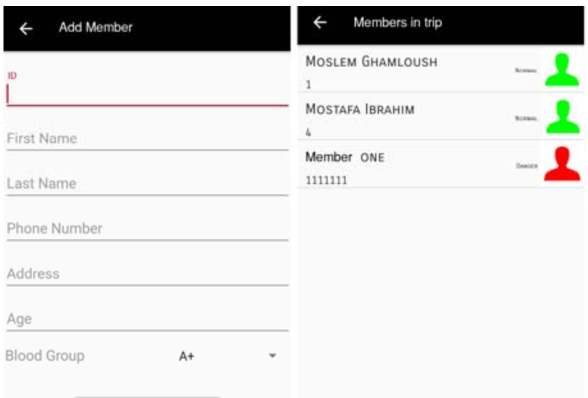

Figure 20: Add and show members in trip pages on Android application

The system security can be addressed using encryption technologies, such as AES (Advanced Encryption Standard) for the data exchanged between the central unit and the members. This system could be tested on real members to prove its applicability.

This system can be enhanced by providing an agreed upon secret code to be sent with the emergency button to prevent anyone from misusing this device. Moreover, the range of the WIFI signals is limited

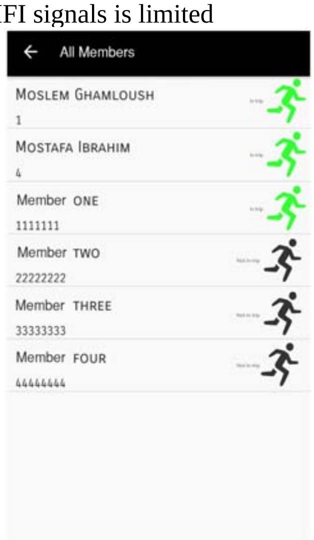

Figure 21: A page shows all members of team

100 m, and the GSM cannot be used because its signals are weak in the sports area or they do not even exist. Our system can also be improved by introducing a new communication system using microwave signals with frequencies lower than WIFI band (around 2.4 GHz).

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