Technology for Soldier Support

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***Abstract*—The paper contains the details of project Technology for Soldier Support in Inter IIT TechMeet 2017 held at IIT Madras. The host organisation of the project was DRDO and it is the ongoing project of DRDO.**

I. Introduction

The project was oriented to create tech which will upgrade the gear of the soldiers. This gear will be part of the soldiers suit or baggage. The gear should be updated in a manner so that the soldiers can do (i) Out of sight communication, (ii) Indoor localization of soldiers, (iii) VHF/UHF encrypted communication to base camp from battlefield, (iv) MEMS sensors for phsylogical signal detection of soldiers for faster first Aid.

II. Soldier Command and Control Software

Design :-

Basically it consists of two gloves with flex sensors integrated in all the fingers and a few other areas. This will be used to identify different configurations of the fingers. An inertial measurement unit consisting of an accelerometer and a gyroscope is placed on the wrist to detect gestures that involve complex hand movements. All the data from the flex sensors and the IMU is processed in the arduino Nano mounted similar to the IMU, that is on the wrist itself. This is possible because of the very small size of the arduino Nano and the IMU.

Algorithmic Development and Research :-

Using basic KNN with the help of DTW (Distance Time Warping), works like a charm for a single person i.e. if the gestures are trained by the same person (even a single gesture is enough to train the model) who is going to use them. However fails miserably if trying to generalise i.e. trained by one person and a second tries to test the gestures. KNN (k-Nearest Neighbours) takes almost no time in training and in our case since it is trained using just one example from each gesture, even the implementation of KNN hardly takes any time at all. Although in order to compute the distances between any 2 instances of gestures we use a novel technique called Distance Time Warping (DTW) which is used to compare the similarity between 2 time series and tells us if the 2 sets of data are significantly different from each other or just time shifted versions of each other.

The 2 sequences are arranged on the 2 sides of a matrix (as similar to a graph, one on the left vertical axis and another to the right on the horizontal axis) while starting from the bottom left of the grid. Each cell of the matrix is computed by the absolute value of the difference of the corresponding axis values plus the minimum value from the 3 values the left, the lower and the lower left (assumed zero in case not present). DTW[i, j] := — s[i]-t[j] — + minimum(DTW[i-1, j], DTW[i , j-1], DTW[i-1, j-1])

To compute the overall distance between the two sequences we start from the top right corner and then select the least value from its neighbouring (left, lower, lower left) values. Then using this minimum value we compute the next minimum value from its neighbouring values and so on. The final distance is the weighted sum of all of these minimas. DTW[i, j] := distance + minimum(DTW[i-1, j], DTW[i , j-1], DTW[i-1, j-1])

The Fast Fourier Transform (FFT) values along each axis (Yaw, Pitch and Roll as well as the acceleration along X, Y and Z, sampled at 10ms) was used to obtain the characteristic Fourier Spectrum and also as a filter to extract features from our data and present a filtered down version of only the useful aspects of the actual data. As we can see from fig. 3 the fft values are significant only for the lower frequencies(they die down well before 30 Hz or so). Now these FFT values (along all the angular axis as well as acceleration axis) were used as an input to a Artificial Neural Network. Now in order to use Machine Intelligence we needed a training dataset.

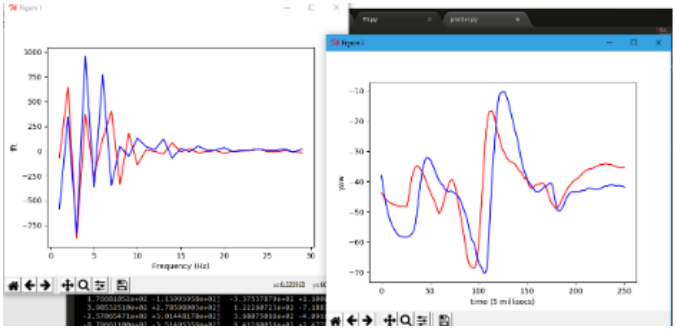

Fig. 1. (left) the FFT values of the yaw values, (right) The graph for Yaw values of a gesture.

Neural Network Architecture :-

We use a 4 layer model with 2 hidden layers and an input and output layer. Hyperbolic tangent is used as the activation function for the 2 hidden layers and a softmax on the output layer. This network gives a training accuracy of 88.41

Software Architecture for Gesture and Workflow :-

In order to minimize the cost and circuit footprint, there needs to be a compromise in prediction accuracy. But, we circumvented that limitation by training the models on a high performance computer and then storing the model in a Single Board Computer which does the prediction and conveys the gesture over the network. The data samples are collected using a AVR based Atmega32U4 and are transferred to the Single Board Computer via an Universal Serial Bus

connection. There is also an option to send the data over Universal Synchronous/Asynchronous Receiver Transmitter interface providing an added layer of robustness to the system.

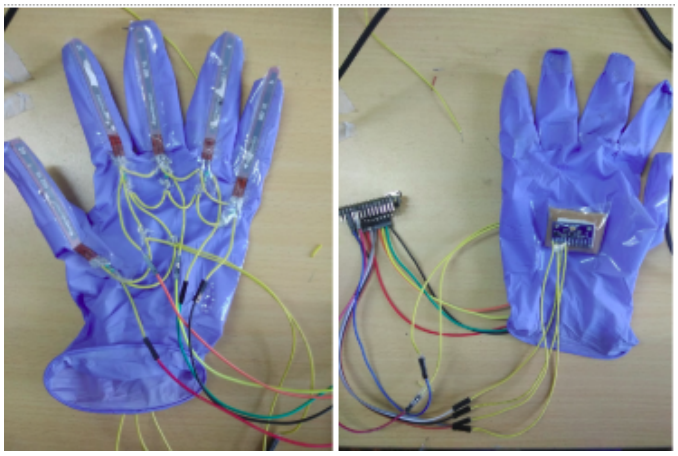

Fig. 2. (left) Flex sensors on the fingers, (right) the Inertial Measurement Unit is placed below knuckles.

The data collected is crunched using a Tensorflow based Python script which loads a precomputed model with the custom soldier data. The gesture thus predicted is sent over to other soldiers through the Ad Hoc Wireless Network which is covered in the next section.

PCB Designs of the proposed device :-
The following design can be fabricated on Printed Circuit Boards made of flexible polymeric substrates like Polyimides, PEEK. The PCB will contain only SMD components to ensure greater mobility. This PCB will be embedded between two layers of rugged gloves worn by the soldier on his action hand. The circuit connections can be made by either physical wires, conductive ink or conductive threads, with conductive threads being the most preferred option as that will not have excess overhead.

III. Soldier Ad-hoc Wireless Network

Technology Used :-
We have proposed an efficient and ad-hoc network for calculating distances between the soldiers and thus localising them on map which is generated dynamically and can be viewed on screen attached to his arm. A lot of work has been done in the past to calculate distance effectively and accurately using Relative Signal Strength Indicator(RSSI) value in Indoor as well as in Outdoor environment. We have also proposed our algorithm based on Wifi Rssi to calculate distance between two soldiers. Instead of using various other algorithms for localisation such as Time of Arrival technique which requires high precision and high frequency clock, Time Difference of Arrival which has additional hardware requirements and is not very accurate, Global Positioning System which is not at all ad-hoc approach for localisation of soldiers.
Modules Used :-

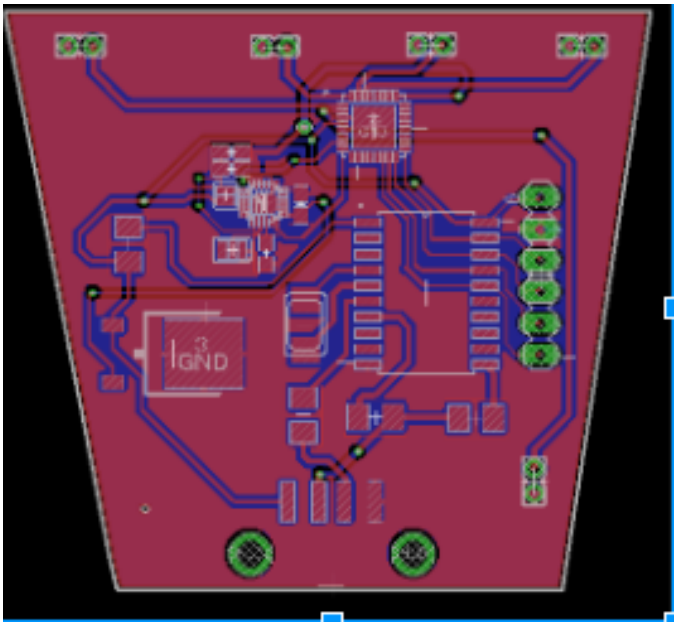

Fig. 3. (PCB Design.

Each Soldiers Prototype Gear consists of following modules/ICs:
(I) ESP8266 12e Module - 2 (II) Raspberry Pi - 1 (III) Display Screen for Pi - 1 (IV) XBee Pro Series - 1
Techniques Used :-
From Friis transmission formula:
d=distance between antennas =wavelength of antenna
For common radio applications, FSPL equation becomes:
Each soldier has two ESP8266 NodeMCU modules. One module is used for creating an Access Point and the other is used to measure RSSI value with other soldiers Access Point.
The radio propagation model given by the Texas Instrument is as follows:
RSSI(dB)= -10n*log10d + A
Where n stands for signal propagation exponent, d is the distance from sender, the A value is acquired in a non-obstacle one meter distance received signal strength measurements from the reference nodes. This is an abbreviated version of the model. According to a power law distribution, the exact definition is given by:
RSSI(dB)= -10n*log10d + A+NN
NN is a zero-mean normally distributed random variable corresponding to the coefficient of multipath fading. It is found that the multipath propagation greatly affects the accuracy of the measured distance.
If we let NN=10n*log10c Then: d=10((-A-RSSI)/(10n))*c
The variable c can be estimated for all distances by observing its value for first few distances and then applying Exponential Regression to obtain a function which can be used for all distances.
Once the RSSI has been mapped to the distance between the soldiers, a soldier can obtain its distance from the other soldier. In this way a soldier will get all its distances from other soldiers. But in order to generate a map of all the soldiers we

need each and every soldiers distance from each and every soldier, details about this is given below.

When the distances broadcasted by the soldiers is received by all the soldiers, the coordinates are calculated using the following formula which can be obtained by using Coordinate Geometry.

X[i]=(d[0]2+d[i-1]2-d[n+i-3]2)/(2*d[0]) Y[i]=(((d[2]2+d[i-1]2-d[2n+i-6]2)/2)-(x[2]*x[i]))/y[2]

Where, n = no. of soldiers X = x-coordinate Y = y-coordinate

d[i]= distance at the ith index in the array: [1-2,1-3,1-4,1-5,...,2-3,2-4,...,r-k,..,(n-1)-n]

Where, r-k is the distance between rth and kth soldier.

Once the coordinates have been obtained for all the soldiers, it is ready to be displayed on the screen of the soldier. The soldier using the device is placed at the origin. Relative to him all the soldiers are shifted accordingly to maintain their geometric formation.

Communication and Coordination between soldiers :-

In order to achieve this we have used XBee Pro Series modules to create an end to end cipher block encrypted Ad-Hoc mesh network of all the soldiers so as to communicate Gesture, Distances and Health status of all the soldiers with each other. The XBee modules are used in order to obtain long range and lossless mesh networking between the soldiers which cannot be achieved with Bluetooth and Wi-Fi. The soldier broadcasts his Gesture, Distance and Health status to all other soldiers so that every soldier can have real time data about his teammates that is also stored for future correspondence and analysis.

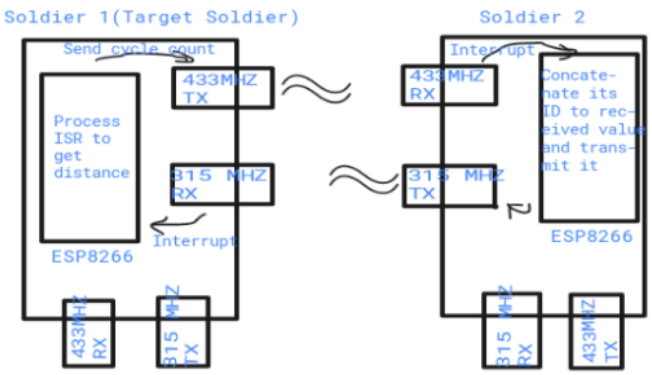

Fig. 4. (Block Diagram.

IV. Image and Video Streaming over V/UHF Radio

Design :-

The proposed Video Transmission module makes use of low cost SDR devices to reduce the overall cost of the transmitting devices. A Raspberry PI and a Pi cam module is used to capture streaming video data which is compressed using H264 (HEVC) compression algorithm and then encrypted using Advanced Standard Encryption (AES) this encrypted video stream is then soft modulated using the communication

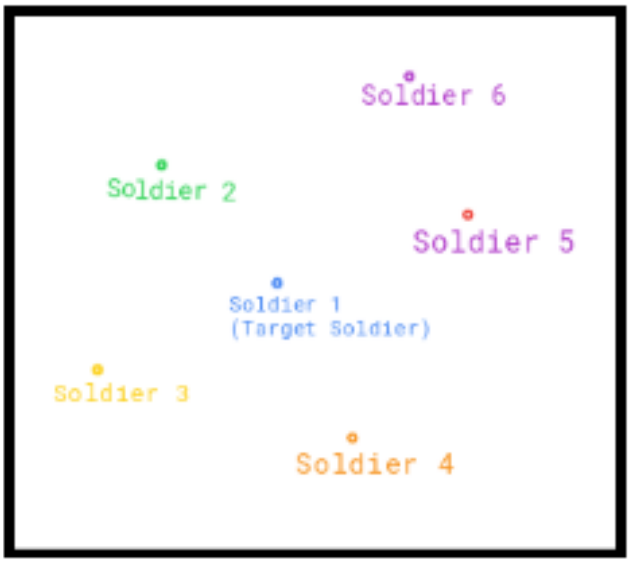

Fig. 5. (Graphic User Interface.

libraries defined in the GNURadio library stack. Each of the encrypted stream of data from the stream is packetized and then modulated using Gaussian Minimum-Shift Keying (GMSK) modulation.

The choice of modulation scheme is so selected as it provides more efficient spectral efficiency compared to the existing QPSK or M-PSK techniques (because of the Gaussian smoothing of waveforms) and QAM techniques as the lack of dependency of the modulated signal over the amplitude allows it to transmit signals over longer distances. We have also simulated using Convolutional, LDPC and Turbo Forward Encoders for the correction of errors in the received packets from the receiver.

Algorithmic Research and Work :-

The proper choice of modulation and detection schemes to enable high-speed wireless indoor data communications has been the subject of extensive study. Study showed that although the m-PSK based modulation scheme has better data rates and noise immunity for lower modulation indices[][] but has a poor bandwidth efficiency. As the data encoded in this modulation scheme is in the form of abrupt phase changes it causes increased bandwidth utilisation for data transmission. QAM or Quadrature Amplitude Modulation modulation scheme combines ASK and PSK modulation schemes for achieving increased data rates and an efficient usage of bandwidth[], but any amplitude based modulation is sensitive to amplitude based noises hence such modulation schemes cannot be used for long distance transmission. Orthogonal Frequency Division Multiplex is a very robust and reliable modulation scheme enabling the system to cope with severe channel conditions like narrowband interference, frequency selective fading and multipath without the use of complex equalization filters[] [] however this modulation scheme is very sensitive to frequency drifts and carrier offsets[]. GMSK modulation scheme was preferred over other schemes as it

is a robust modulation scheme capable of transmission over long distances and the Gaussian filtering in the modulation step reduces the harmonic signal images making it a very spectral efficient transmission scheme. The Symbol Error Rate (SER) and Bit Error Rates (BER) for GMSK shows a better performance in SNR compared to other schemes
Proposed Design :-

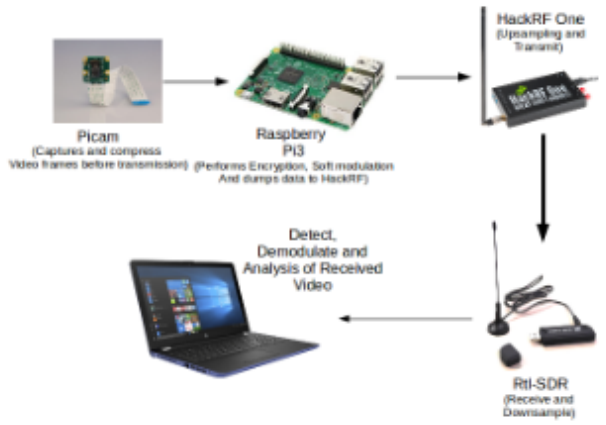

Fig. 6. (Proposed Design.

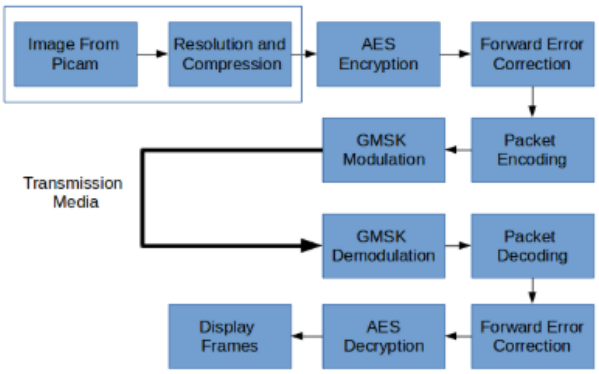

Fig. 7. (Design Flow Graph.

V. MEMS for Physiological Signal Detection and Conditioning

Abstract :-
An ad-hoc embedded system has been developed and specially designed for soldiers to constantly monitor the physiological conditions for faster First Aid. A separate accouterment has been made to provide Faster First Aid by sending distress signals to nearest soldiers.
Selection of Physiological parameters :-
First aid is the immediate assistance provided to a sick or injured person until professional help arrives. It is concerned not only with physical injury or illness but also with other initial care, including psychosocial support for people suffering from emotional distress caused by experiencing or witnessing a traumatic event. In order to provide faster first aid, if one have the measures of the following parameters then the further proceeding become much easier for a professional doctor or even for a neophyte. Electrocardiogram Microchip DSP microcontrollers for powerful processing and digital filtering. Available digital filter design tool makes designing FIR and IIR filters easy and intuitive Low noise analog components for amplification and precision filtering of the sensor lead output. High-resolution graphics control to portable ECG devices with compact displays. Available graphics libraries and design tools help get ECG designs to market quickly. Cost-effective microcontrollers with integrated analog for smaller heart rate and ECG device applications. An electrocardiogram or ECG machine is a device used to monitor and record the electrical activity of the heart. Since each heart beat produces an electrical impulse in the heart, the generated cardiac electrical potentials can be measured with sensors placed in the body at different locations. Abnormal electrical activity can indicate conditions such as heart attack, chest trauma, reduced blood flow to the heart, arrhythmia or heart deformities.

The demand for portable and accurate ECG monitoring has grown substantially. Despite the smaller size of these portable products, ECG devices still require precision filtering, high-performance processing power, and integrated high-resolution graphics control that is separated from the main microcontroller core.

Blood Pressure It is defined as pressure of circulating blood on the walls of blood vessels. It is usually expressed in terms of Systolic and Diastolic pressure. But a more reliable term known as Mean Arterial Pressure has been used to replace Systolic pressure. It is defined as the average pressure in a patients arteries during one cardiac cycle.

MAP = SBP + 2* (DBP)/ 3

It is recommended that mean arterial pressure (MAP) be maintained 65 mm Hg

SpO2 Also known as Oxygen Saturation. It is the amount of oxygen that oxygen carrying molecules in blood(haemoglobin) actually carries. It is generally measured using pulse oximetry. Internally to sensor are two IR and Red LED and Light Detector on other side. A finger pulse oximeter is composed of two light emitting diodes (LED) for sensing blood volume and blood oxygen saturation in the finger. Heart Rate Heart Rate serves as an important physiological measure as that gives an indication of the stress and fatigue level in a individual. This also indicates the rate at which the heart is pumping blood to various organs of the body. Body Temperature The level of heat produced and sustained by the body processes, variations and changes in body temperatures are major indicators of diseases and other abnormalities. Heat is generated within the body through metabolism of nutrients and lost from the body surface through radiation, convection, and evaporation of perspiration. Heat production and loss are regulated and controlled in the hypothalamus and brainstem. Fever is usually a function of an increase in heat generations, however some abnormal conditions, such as congestive heart failure, produce

slight elevations of body temperature through impairment of the heat loss function.

Contributing to the failure to dissipate heat are reduced activity of the heart, lower rate of blood flow to the skin, and the insulating effect of edema. Diseases of the hypothalamus or interference with the other regulatory centers may produce abnormally low body temperatures.

Design of Embedded system :-

We have developed an embedded system compromising of ASIC chips and MEMS sensors capable of monitoring all the physiological parameters simultaneously. The main attraction of this module is that it wearable. We have prepared a T-Shirt having this embedded IC. The design of the chip is made robust and low power consuming so that a soldier can wear this embedded IC in battlefield as well as the T-Shirt is also designed in a manner that it will not produce any hurdle to the soldier and can take all the data from the different sensors embedded on T-Shirt. The soldiers outer outfit need not to be enhanced as the T-Shirt is compact and slim enough that it will not produce any significant effect.The final Printed Circuit board consists of ATmega 32u4 as a core processor for processing all the data which is being collected from different sensors implanted on different part of T-Shirt.

All the associated conditioning sensors and ICs are packaged in the form of a PCB just like the Gesture Recognition Module providing interfacing through USART and USB.

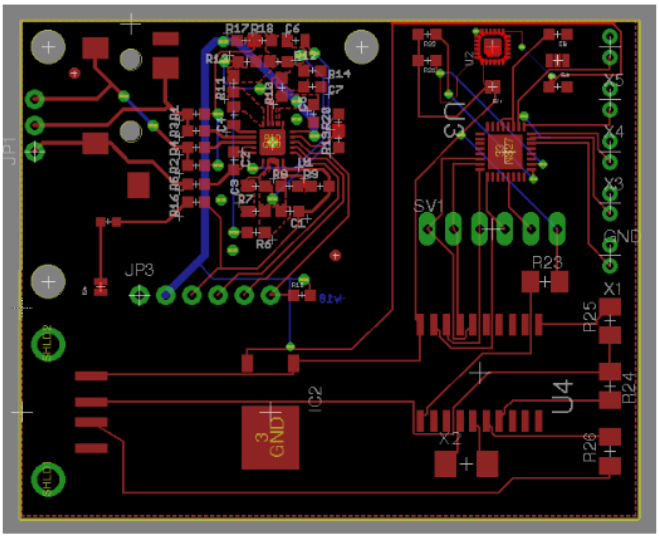

Fig. 8. (Design Flow Graph.

Conduct for conditioning :-

As mentioned in the Localization section that we have implemented mesh network for communication in between soldiers, the same network is being used to send distress signals when needed by a soldier. All the physiological data is also available on soldiers screen so, for first aid doctor does not need to measure all the parameters again. Just on a single click available on screen all the physiological readings can be monitored.

Accouterment :-

We have developed a T-Shirt whose description is given above and this module is designed in way that it can be also used for pre war screening of soldiers. In order to select soldiers and monitor different physiological parameters this T-Shirt can be used to this specific task, as the design of the T-Shirt allow it to use it separately. The data collected from T-Shirt can be used to check the fitness of soldier and the further selection can be made accordingly from the results. This T-Shirt will make the selection process much easier.

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