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Electronic Glove for Troops to Interpret Hand and Arm Gestures in Close Combat Scenario

Vinod Kumar Pundir, Rashmi P Mahajan, Sheetal Bhandari

Abstract*: *In a close combat situation several types of non-verbal communication are available. However these signals have limits of range and reliability, particularly when line of sight is disrupted. This paper proposes the system for troops to interpret hand and arm military gestures applicable in close combat scenario. In the proposed system, signals are transmitted through secured Bluetooth connections and interpreted at the receiver end. k-NN algorithm, Lookup Table (LuT) and Decision Tree algorithm are used to determine the exact classification of the gestures. This paper presents a system keeping only one fellow trooper in picture and reported 94.6 percent accuracy of the military gestures interpretation.

Keywords: Electronic glove, flex sensor, motion sensor, troopers, gestures classifier

I. INTRODUCTION

Non-verbal communication known as visual signals consists of fingers, hand and arm posturing in which bodily gestures are utilized to communicate a vital messages [1]. Hand and arm gestures are one of the most common forms of communication used by soldiers or group of soldiers when a radio silence is in effect or if the soldiers need to remain undetected. Troop leaders use these hand and arm gestures to control the movement of individual trooper, teams, and squads. These gestures are used by infantry and combat service support elements organized for infantry missions [2]. The main problem associated with this type of communication is visibility range limit and reliability. In some cases gestures can be misunderstood and may become problematic. Lastly, hand and arm gestures may be vulnerable to enemy interception and allow the possibility that the visual communication is received and may get interpreted by the adversary. Figure 1 below presents commonly used military hand and arm gestures which have been used in the proposed system [2].

Previous study reports about two approaches for gesture interpretation techniques [3]. Wherein, vision based interpretation techniques are not feasible for military's non-verbal communication due to its complex and bulky hardware for image processing concept. Hence the non-vision based method could be an alternative approach for military gesture interpretations. This method typically utilizes flex sensors and motion sensors to measure the flexion of fingers and the orientation of the hand and arm, respectively. Detection of hand and the correct coordinates of location of palm and fingers is to be find out using the sensors on the glove [4]. Dawane *et al.* [5] attached five flex sensors on a glove with respect to each finger to identify hand gestures by matching the motions with those in a stored database. In this system, signals from all sensors are provided to the microcontroller. The microcontroller matches the motion of hand with the database and message will be displayed on LCD as well as it produces the speech signal. Preetham *et al.* [6] also proposed a similar technique of using flex sensors. Here gesture characters are mapped with the sensor data. This mapping is achieved using a minimum mean square error (MMSE) algorithm. With the help of Bluetooth, the recognized character is transmitted to an Android phone, which performs a text to speech conversion. This technique was improved by Patil *et al.* [7]; here, the bending of each sensor is further divided into three flexions, namely, a complete bend (finger close), partial bend, and straightening (finger open). Each sign language alphabet is then mapped according to the bend flexions to be used for template matching.

Fig. 1. Common military hand and arm gestures [1]

Much work has already been focused on the sign language interpretation for deaf and dumb persons; however the proposed system aims at the development of the accurate hand and arm gesture interpretation technique, which can be used among the troopers in a close combat scenario for military purpose. Furthermore the system can provide its usefulness in all weather conditions, particularly in nil visibility area with enhanced range and reliability of passing real time information. Implemented result proves its significance in military applications with enhanced security and accuracy.

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* Correspondence Author

Vinod Pundir*, masters, Electronics and Telecommunication Engineering from Savitribai Phule Pune University, Pune

Rashmi Mahajan, PhD, Kavayitri Bahinabai Chaudhari North Maharashtra University (KBCNMU), Jalgaon in Electronics Engineering.

Dr. Sheetal Bhandari, PhD, Shivaji University, Kolhapur

The rest of the paper is organized as follows: Section II explains the system designing. Section III presents the proposed system processing. In Section IV we discuss the proposed classification approach that is based on k-NN algorithm, Lookup table and Decision tree algorithm. Section V explains the experimental results and Section VI concludes the work.

II. SYSTEM DESIGN

The whole system consists of two modules. The electronic glove module is to be worn by the troop leader and the receiver module is to be worn by the fellow troopers. In this system, finger gestures are exploited through the flexion of flex sensors [8] placed on the top of the fingers, motion sensor determines the orientation and position of hand or arm. The motion sensor is MPU-6050 [9]. The figure 2 below shows the full block diagram of the electronic glove system. The hardware in this system constitutes of mainly; Flex sensors, motion sensor MPU 6050, Arduino Nano microcontrollers, HC05 Bluetooth units, voice playback unit, 9 volts batteries, an earphone and a waterproof camouflage color glove.

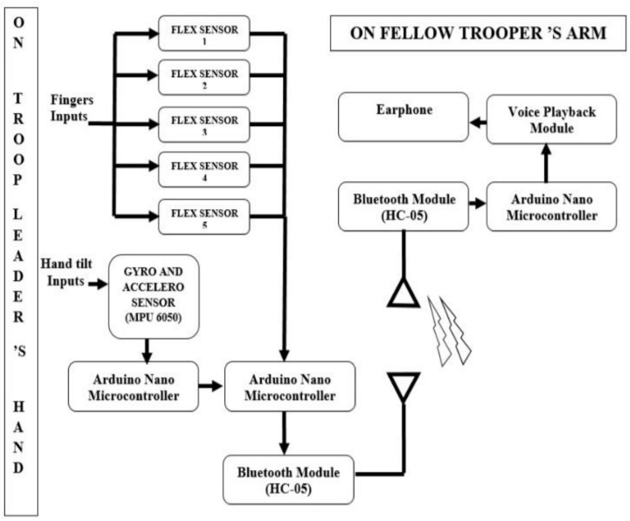

Fig. 2. Block diagram of electronic glove system

The sensor data is collected at the main microcontroller proceeding by the data analysis. Here the microcontrollers used is Arduino nano as the compact size of Arduino Nano microcontroller comes handy to make the system less in weight as well as less cumbersome for troopers to wear. The recorded hand and arm trajectories and finger positions are processed by the combination of k Nearest Neighbor (k-NN) algorithm, Lookup Table (LuT) and Decision Tree algorithm for the identification of the correct gesture. The main microcontroller converts the classified data into ASCII characters. These ASCII characters (coded alphabets) are transmitted wirelessly to the Receiver module with the help of Bluetooth unit. At the receiver end ASCII characters (coded alphabets) are converted into corresponding signals and communicated through voice playback module. Micro SD card is attached with the voice playback module with stored military commands related to hand and arm gestures. Communicated signals from microcontroller activate a particular audio military command through voice playback module, representing the performed gesture. Furthermore this audio signal is communicated to the troopers.

The circuit diagram of flex sensor is presented in the figure 3 below. In flex sensor, the resistance across the terminals rises linearly with bent angle. A voltage divider circuit is used to convert the change in resistance into voltage parameter. Fixed value resistance R1 with 10 KΩ is used with variable resistance Rx i.e. flex sensor. V_O is the voltage at midpoint of voltage divider circuit and is also the output voltage which represents voltage corresponding to changed resistance. Equation 1 is generic voltage divider equation where, Rx is flex sensor resistance, R1 is fixed value resistance and Vcc is fixed supply voltage [10].

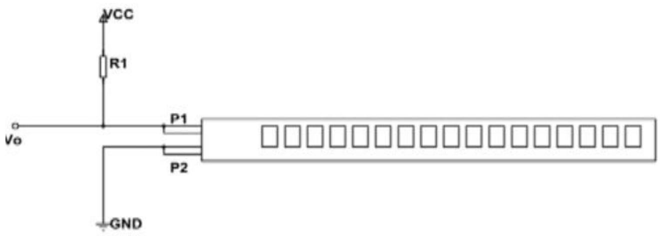

Fig. 3. Circuit of flex sensor using voltage divider circuit

V_O = VCC (Rx/ (R1+Rx)).. (1)

Motion sensor MPU 6050 combines 3-axis Gyroscope, 3-axis Accelerometer and Digital Motion Processor all in small package. It has I2C bus interface to communicate with the microcontroller. The 3-axis Gyroscope and 3-axis accelerometer with Micro Electro Mechanical System (MEMS) technology is used to detect rotational velocity and angle of tilt or inclination along the X, Y and Z.

III. SYSTEM PROCESSING

When the Troop leader performs a particular gesture, analog signals from flex sensors are captured by the main microcontroller and further converted into the digital values. Inbuilt ADC with 10 bit resolution is used for this conversion which converts input analog voltage. The motion sensor MPU6050 signals are in digital forms and given to a separate microcontroller. This separate microcontroller is used to speed up the computations and also to reduce overload of the main microcontroller. Furthermore the data from this microcontroller is given to the main microcontroller which stores all the data into simple state matrix. The figure 4 below shows the full hardware implemented electronic glove system. The processing hardware and the power supply are housed into a small box which will be worn on the wrist by the troopers.

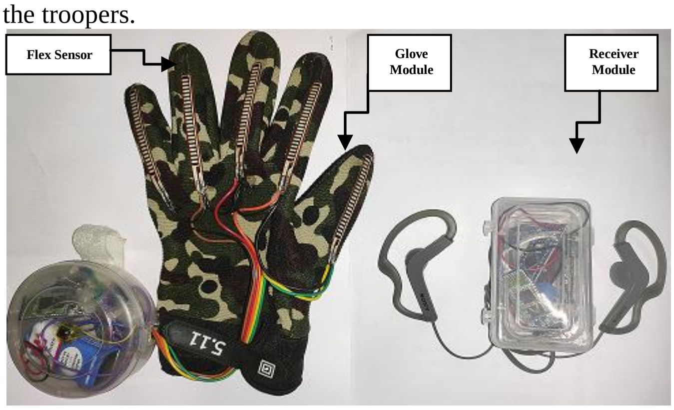

Fig. 4. Designed Electronic Glove System

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IV. GESTURE CLASSIFICATION

Data has been collected by testing the designed system on five troopers and they were made to engage in a military style exercise to identify the accuracy of the system. The average reference value of 845 in decimal number system for the five flex sensors was calculated with which the measured values are compared for gesture classification. The k-NN algorithm classifies the finger as bent if the flex sensors value exceeds from the set reference value and if the flex sensors value remains below the set reference value, then the algorithm classifies it as straight finger. Similarly if there is a movement of hand or arm, the motion sensor output is classified as 1 otherwise 0 for no movement. Further a Lookup Table (LuT) is made of all possible states of the flex sensors as well as motion sensor; a record in this table represents a combination of the binary values of the flex sensors and motion sensor corresponding to the gesture and will activate a specific military audio command to be played in the receiver module. The Decision Tree algorithm logic decides if hand or arm is in motion or not while performing the gesture. The classified binary data values in main microcontroller are given a specific alphabet name and converted into American Standard Code for Information Interchange (ASCII) characters. The main microcontroller sends these ASCII characters through the TX pin to the Bluetooth unit and further to the Receiver module. The flow of the functioning of the glove system is given in the flowchart represented in figure 5.

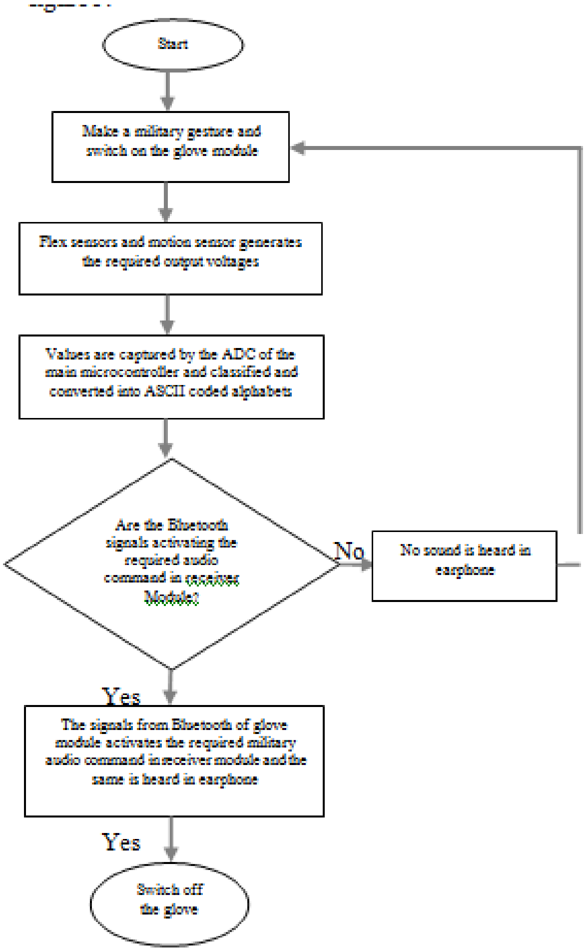

Fig. 5. Flow chart of the Electronic Glove system

In Receiver module, the MP3 voice playback unit has micro SD card in which various audio military commands is loaded in .wav file format and is given a similar alphabet names as given to the classified binary data values of the main microcontroller in the glove module. The microcontroller in the Receiver module analyzes the received ASCII characters and sends a specific alphabet name signal to MP3 voice playback unit. The voice playback unit activates the required audio military command and starts playing it into the earphone. The coding for the algorithms, MPU 6050 unit and receiver microcontroller is written as a sketch in Arduino integrated development environment (IDE) platform.

V. RESULTS

Five troopers were requested to participate in the data acquisition and testing phase to verify the correctness of the gestures interpretation by the designed electronic glove system. They were made understood how to perform the gestures wearing glove system. A military style exercise was performed by employing each of the gestures 10 times. The interpreted military gestures in the form of audio were heard in the earphone. The figure 6 shows the data acquisition setup for the designed system.

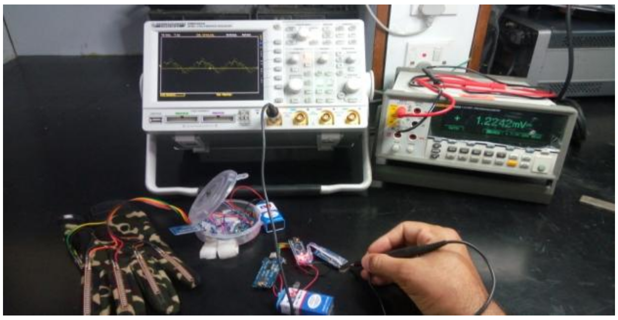

Fig. 6. Data acquisition setup for the designed system

The observed data in the table 1 below is the analog voltages and its corresponding ADC values and Binary value for each flex sensor and motion sensor (MPU6050). An approximate integer analog voltage and ADC value is taken for all the Flex sensors as slight change of values will always be there while performing the gesture. The pictorial representation of the static military gestures with its ADC values of flex sensors are shown in figure 7, however gestures with motions and its corresponding ADC values of flex sensors are plotted in figure 8. Figure 9 represents all 20 gestures with its analog values of the motion sensor. It can be observed from the figure 9 that the gestures with motion are having increased voltage levels as compared to the static gestures.

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Table 1. Flex sensors and motion sensor data in Analog, ADC and binary values

Military Audio Commands	Flex 1 (Pinky)			Flex 2 (Ring)			Flex 3 (Middle)			Flex 4 (Index)			Flex 5 (Thumb)			MPU 6050		ASCII coded alpha -bet
	Volt	ADC Value	Bit	Volt	ADC Value	Bit	Volt	ADC Value	Bit	Volt	ADC Value	Bit	Volt	ADC Value	Bit	Analog Voltage	Binary output	
Keep Quite	4.34	890	1	4.49	920	1	4.39	900	1	3.89	790	0	4.34	890	1	0.10	0	a
Advance Forward	4.34	890	1	4.54	930	1	3.89	790	0	3.80	780	0	4.29	880	1	0.00	0	b
Freeze	4.39	900	1	4.49	920	1	3.97	814	0	3.93	805	0	3.96	813	0	0.00	0	c
Start Firing	3.93	805	0	3.90	799	0	3.88	795	0	3.90	800	0	4.49	920	1	0.40	0	d
Stop Advancing	3.90	800	0	3.89	790	0	3.89	790	0	3.88	795	0	3.62	742	0	0.30	0	e
More Ammo Coming	4.54	930	1	4.00	820	0	3.84	788	0	3.89	790	0	4.34	890	1	0.50	0	f
Enemy Approaching	4.02	825	0	4.58	940	1	4.00	820	0	3.99	818	0	4.35	891	1	0.20	0	g
Cordon Off the Area	3.95	810	0	4.00	821	0	4.51	925	1	3.95	810	0	4.46	915	1	0.00	0	h
All are OK	3.92	803	0	3.95	810	0	3.90	800	0	4.54	930	1	4.39	900	1	0.50	0	i
Advance Together	4.44	910	1	4.54	930	1	4.46	915	1	4.50	923	1	4.46	915	1	0.30	0	j
Use the Pistol	4.34	890	1	4.49	920	1	4.39	900	1	3.90	800	0	4.34	890	1	2.15	1	k
Mission Accomplished	4.34	890	1	4.54	930	1	3.89	790	0	3.80	780	0	4.29	880	1	3.30	1	l
Use Rifle	4.39	900	1	4.49	920	1	3.97	814	0	3.93	805	0	3.96	813	0	2.00	1	m
Be in File Formation	3.93	805	0	3.90	799	0	3.88	795	0	3.90	800	0	4.49	920	1	1.80	1	n
Stop Firing	3.90	800	0	3.85	789	0	3.89	790	0	3.88	795	0	3.81	782	0	2.96	1	o
Save Your Ammo	4.54	930	1	4.00	820	0	3.84	788	0	3.89	790	0	4.34	890	1	2.58	1	p
Help is Coming	4.02	825	0	4.58	940	1	4.00	820	0	3.99	818	0	4.35	891	1	1.91	1	q
Cover Yourself	3.95	810	0	4.00	821	0	4.51	925	1	3.95	810	0	4.46	915	1	2.79	1	r
You hitting the Target	3.92	803	0	3.95	810	0	3.90	800	0	4.53	929	1	4.39	900	1	3.45	1	s
Board the Vehicle	4.44	910	1	4.54	930	1	4.46	915	1	4.50	923	1	4.46	915	1	3.70	1	t

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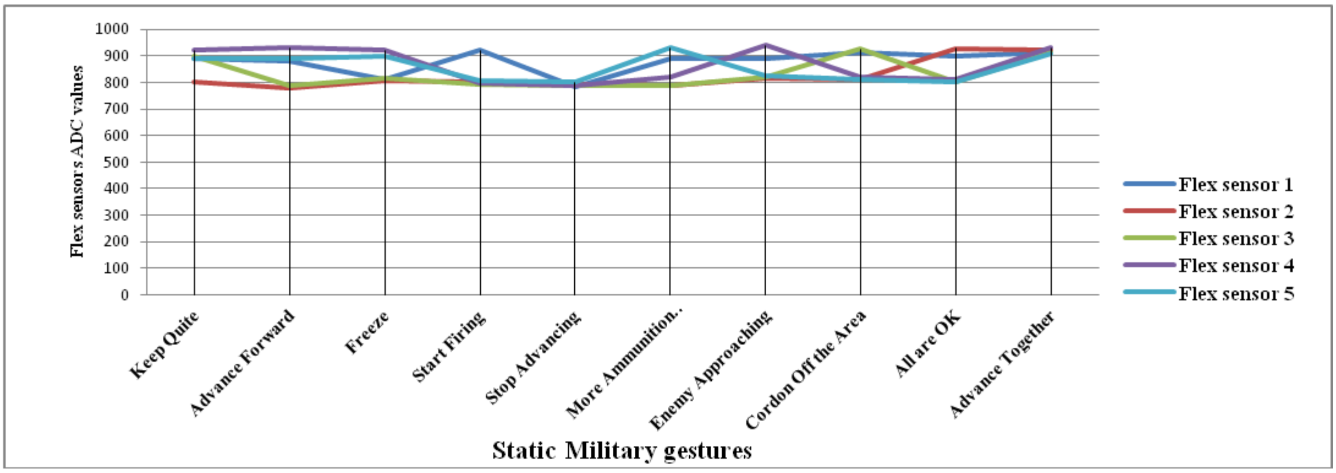

Fig. 7. Flex sensors response for static military gestures

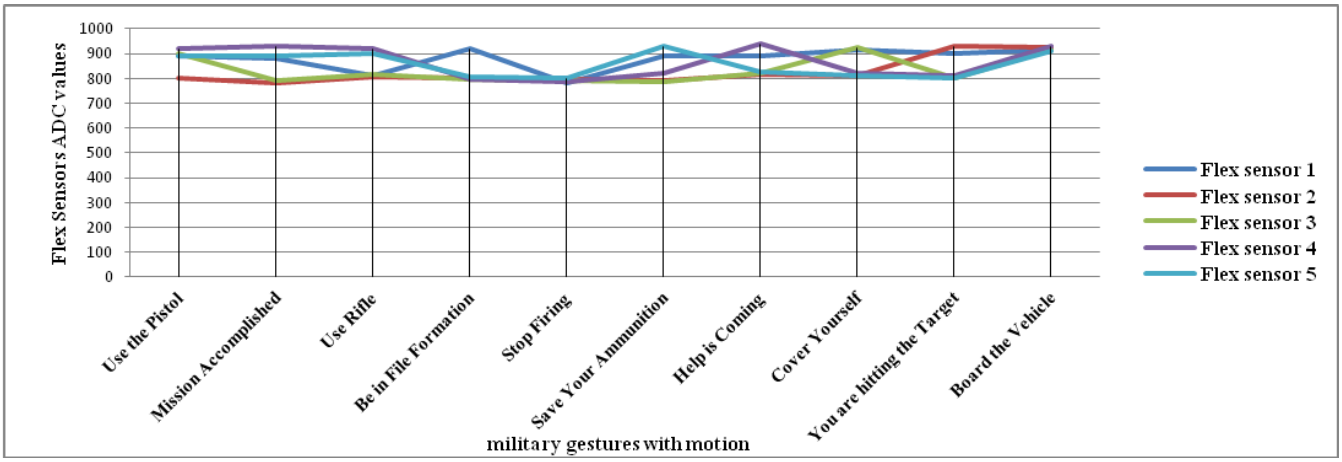

Fig. 8. Flex sensors response for military gestures with motion

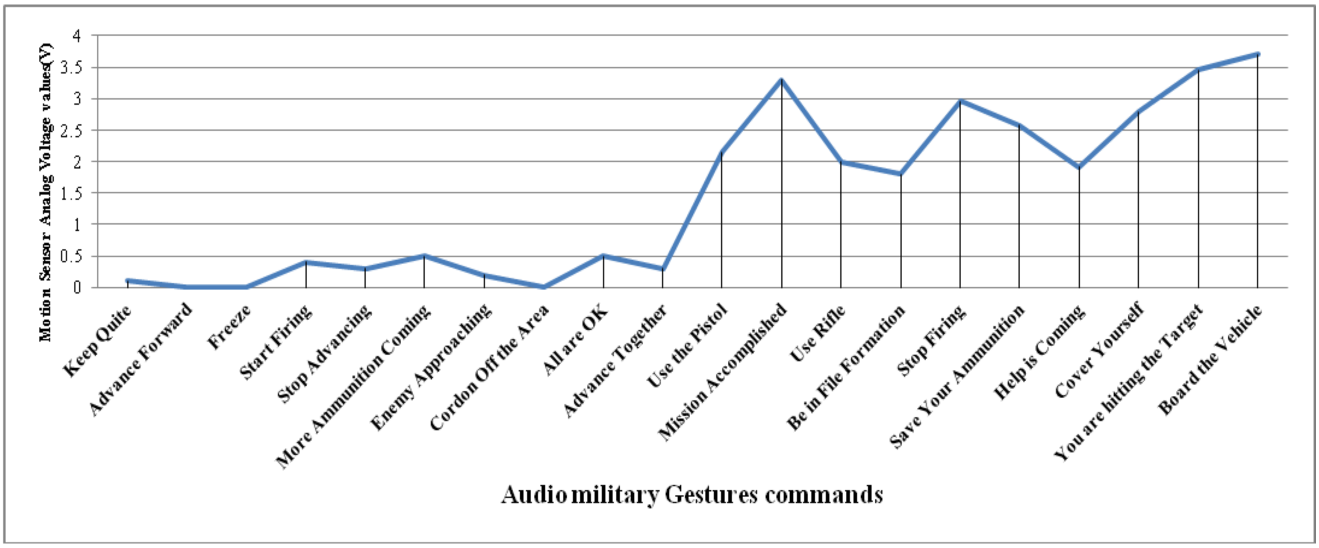

Fig. 9. Motion sensor response for military gestures command

The table 2 shows some of the military gestures, its binary values in Lookup Table (LuT), ASCII coded alphabets and the corresponding military audio command played in the earphone.

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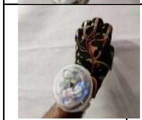
Table 2. Some of the Military gestures, LuT values, ASCII coded alphabets and the corresponding military audio commands

Military Gesture	Corresponding LuT Digital Values	ASCII coded alphabet	Military Audio playing in Earphone
	111010	a	Keep Quite
	110010	b	Advance Forward
	111110	j	Advance Together
 Hand in circular motion	001011	r	Cover Yourself

Total 20 gestures are used in the implemented system and to check its correctness, each gesture is repeated at least 10 times by the five troopers. Table 3 shows the record of interpretation details and represents True Positive (TP) value which is correctly interpreted data and False Positive (FP) values which means incorrectly interpreted value. Also it includes correctly rejected (TN) and incorrectly rejected (FN). Accuracy is calculated with equation 2 [11]. True positive value is calculated with equation 3 and precision is calculated with the help of equation 4.

Table 3. Gesture interpretation details

Total = 1000	Detected	Not Detected
Detected	928 [TP]	18[TN]
Not Detected	38[FP]	16[FN]

The confusion matrix is given as:-

$$\textbf{Accuracy} = \frac{TP+TN}{TOTAL} = \frac{928+18}{1000} = 94.6\ \% \ldots\ldots (2)$$

$$\textbf{True positive rate} = \frac{Tp}{TP+FN} = \frac{928}{944} = 98.\ 3\ \% \ldots\ldots (3)$$

$$\textbf{Precision} = \frac{Tp}{TP+FP} = \frac{928}{928+38} = 96.06\ \% \ldots\ldots (4)$$

The table 4 below has been formed to compare the designed system with the nearly similar system designed previously and to compare about the accuracy of our system with these studies.

In [12], the average accuracy of 12 subjects for alphabet V comes around 97.48 %. The same orientation of fingers making a gesture with respect to military commands; the average accuracy for the gesture by using implemented design comes around 99%. In [13], the orientation of fingers used for conveying the sentences 'You are super' and 'Victory' are same as we performed the gestures for conveying the messages to fellow troopers as 'all are ok' and 'advance forward'. The both systems achieved almost equal accuracy. In [14], the accuracy of alphabets and numbers are high as compared to words. Similarly in this presented system, the static gestures achieve around 98.74% whereas the average accuracy for the gestures in motion comes around 90.58%. The overall accuracy of our system comes around 94.6%.

VI. CONCLUSION

All the existing hand gestures interpretation systems are designed by keeping deaf/dumb people in picture. There is a wide scope to develop a system for military application which is implemented in the presented system. This implemented system is non-verbal communication which is applicable in a close combat scenario. Troopers can communicate with each other through standard hand and arm gestures without being in the line of sight of each other. This system can be used in any weather conditions as well as in any terrain. Although this prototype system is having some limitations like delay of around 3 seconds before interpretation of each gesture as the glove module is to be switched ON every time after making a gesture and its Bluetooth unit takes some time to pair with the Bluetooth unit in Receiver module. As such it satisfies all the major objectives put forth with acceptable accuracy and precision. With increased attention to the challenges of gesture translation, in near future this system will be beneficial to the troopers.

Table 4. Comparison of some glove based hand gesture recognition systems

Author, Year	Device/components	Methods	Gestures	AC (%)
V Pundir,R Mahajan,2019	Flex and Motion sensors	k-NN,Lookup Table	Military commands	94.66%
B. G. Lee, 2017 [11]	Flex & pressure sensors,IMU	SVM classifier	Alphabets	98.2%
Shahrukh J, 2018[12]	Flex sensors, IMU	ADC Lookup Table(LuT)	Sentences	Not mentioned
Shukor, 2014 [13]	Glove, tilt sensors	Template matching	Alphabets, Numbers, Words	89%
Sriram, 2013 [14]	Glove, accelerometer sensors	Template matching	Alphabets	Not mention

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AUTHORS PROFILE

Vinod Pundir has completed his masters in Electronics and Telecommunication Engineering from Savitribai Phule Pune University, Pune with specialization in VLSI technology and Embedded Systems. He is an associated member of Institution of Engineers (India) and has completed his graduation in Electronics and Communication Engineering from IEI(I). He has completed his associated degree in BSc in Electronics from IGNOU. He has completed three years Diploma in Electronics and Telecommunication Engineering from Govt. Polytechnic Kangra, Himachal Pradesh and Diploma in Electronic Engineering from Ministry of Defense (MoD), India; respectively. He is actively associated with the ministry of Defense (MoD), India.

Rashmi Mahajan has completed PhD from Kavayitri Bahinabai Chaudhari North Maharashtra University (KBCNMU), Jalgaon in Electronics Engineering. She has completed Masters in VLSI Technology from Kavayitri Bahinabai Chaudhari North Maharashtra University (KBCNMU). She has more than 20 publications in various National, International Journals and Conferences. Her research area is VLSI and Embedded system designs. She has guided more than 15 groups at undergraduate as well as post graduate level. She is associated with various funded research projects in VLSI domain.

Dr. Sheetal Bhandari is a Post Graduate in Electronics Engineering from University of Pune with specialization in Digital Systems. She has received her PhD from Shivaji University, Kolhapur in the area of Reconfigurable Computing. She is been in teaching for about 12 years with an entrepreneurial stint of 4 years. She also carries international research experience of three months in Reconfigurable computing at PoliMi, Italy. Dr. Sheetal Bhandari is a professor in the Department of Electronics and Telecommunication Engineering and Dean Students Development and Welfare at Pimpri Chinchwad College of Engineering, University of Pune, India. She has organized and coordinated various activities and training programs for students to ensure their overall development.