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Leap Motion Device for Gesture Controlling an Unmanned Ground Vehicle (Robot)

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Abstract - **A new scope of human-computer interaction utilizes the algorithms of computer vision and image processing for detecting the gesture, understanding its objective and making it meaningful for the computer to understand and then interact with the humans. The recent introduction of "Leap Motion" is a big revolution in the field of gesture control technology. Using gesture control mode in the field of robotics is also on the rise. This acted as our motivation to develop a gesture controlled robot using a Leap Motion Device that can sense human hands above it and to keep a track of them and aid in navigation. This independently working gesture recognition system does not rely on any external sensors (motion capturing system) as it has its sensors embedded in itself which recognizes the gesture commands and acts accordingly. The soldiers need not wear any physical device on their body (unlike Kinect and/or MYO Armband) to operate robots to fight against enemies. This work in progress paper illustrates an existing robot designed by us, which can be controlled by hand gestures using a non-wearable (touchless) device called as Leap Motion.**

***Index Terms* - Unmanned Ground Vehicle, Robot, Artificial Intelligence, Leap Motion, Human-Computer Interaction.**

I. INTRODUCTION

Today the buzzing word in robotics is 'gesture-controlled'. Now it's not only in our imaginations that we find magicians controlling objects with hands but we can replicate the same magic live in the present era. Gesture control refers to a type of control directed by the different movements of human body parts especially focusing on hands. Having our tasks and demands fulfilled by merely our gesture commands is fascinating and very comforting. This technology is a breakthrough when combined with robotics. In gesture recognition technology, a camera observes the various gestures and gives it as input to the computer for processing. A new scope of human-computer interaction which utilizes the algorithms of computer vision and image processing for detecting the gesture, understanding its objective and making it meaningful for the computer to understand and then interact with the humans [8].

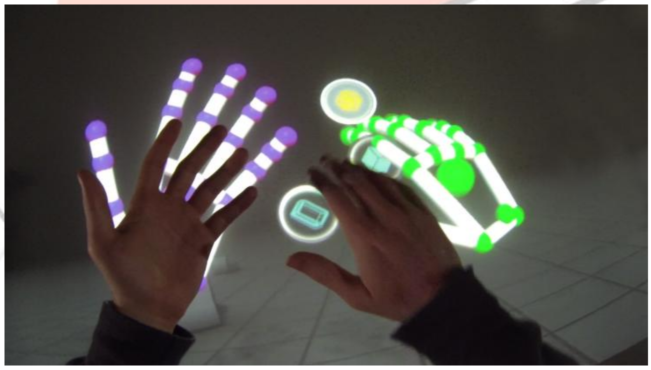

Figure 1. Static gestures. Source: MYO.

We witness two types of gestures in computer interfaces:

- Offline gestures: The processing of such gestures occurs post the user interaction with the object [10].
- Online gestures: The processing occurs simultaneously when the user interacts with the object. Example: Rotating an object with gesture [10].

Segmentation of gestures is highly computational and requires a deep analysis [1]. Gesture recognition is based on a 3D model and an appearance based. 3D model method makes used of the 3D structure of human's body parts with which we can get the position of the required part involved in gesture control [10]. On the other hand, appearance based model takes the videos and images as the inputs and outputs quick results. Its drawback being computational intensive [10]. Skeletal-based models work on algorithms where a skeletal representation of the body is computed and different body parts are mapped to different segments [10]. The position and orientation between segments are the basis of its analysis. Algorithms are faster as the presence of only key parameters focus on the significant parts of body. Appearance-based models don't require any virtual representation of human body, rather they obtain their parameters for computation directly from images and videos [10]. They form a template model where nodes are created on the boundary of the body part to be tracked [10]. Parameters can also be images.

The challenge lies in the accuracy of the gesture recognition software and device. How well the sensors detect the gesture and how quickly they respond to the user with the meaning of the gesture, somewhat similar to the sign language. Hand gesture recognition is emerging with high potential in research industry. In surgical methods, industrial applications, robotics, gaming we have this technology as a boon for us [8].

In this paper we explain how to robots are controlled (Section II) and explain about our previous paper on MYO armband used for controlling a robot (Section III). Later, we explain how Leap Motion works and the design of the unmanned ground vehicle (UGV) which will be controlled by hand gestures using Leap motion device when the situations do not permit the UGV to be operated from the base station (Section IV and V). So, an alternative approach to tackle such problem is to provide gesture control mode for soldiers to maneuver UGV. This prototype will be tested at the military camps in India which forms the centrality in this research. The rest of the paper explains the results in Section VI and the conclusion in the Section VII.

II. CONTROLLING A ROBOT

Robotics is emerging as a saviour and the best assistance to humans. It's the branch of engineering working towards the invention, development and enhancement of robots. "*We're fascinated with robots because they are reflections of ourselves*" – said Ken Goldberg, Professor and scientist from University of California, Berkeley [2]. It's been 2300 years since the invention of the first so-called robot named "*Steam powered pigeon*", designed by Greek Mathematician, *Archytas* [2]. The steam-powered pigeon was able to fly only 200 meters before it ran out of steam [2]. When it comes to defining the term 'robot', we don't have any fixed definition. For some it is a machine which imitates humans, like the androids in Star Wars while for others it's a replication of humans' imaginations of creating a like-minded slave. However, there are some essential characteristics that helps us to decide what features we will need to build into a machine before it can count as a robot.

A robot has these essential characteristics:

- Sensing: For a robot to identity its location and surroundings, it must be able to sense. There are various sensors for a robot based on its objective. IR sensors, light sensors, sonar sensors, etc
- Movement: A robotic movement is achieved with the help of motors.
- Energy: Human utilize energy in the form of food. Similarly we need a power supply for the robots as well to perform their tasks. A robot might be solar powered, electrically powered, battery powered. The energy source will determine a robot's activity to a large extent.
- Intelligence: For a robot to function autonomously, we need to program it in that specific way. Here comes the entry of programmers who embed the robotic system with their programming to grant intelligence to a robot of its own.

Robots are saving us from doing tedious works. With the advancement of technology, experimentations towards the enhancement of robots are increasing exponentially. Humans are now focusing to upgrade the autonomy of robots to suit human imaginations and demands.

Controls of Robot: Wired , wirelessly and autonomous styles of controlling the robot are explained in brief below:

Tethered: The most simplest form of connection is of a wired connection between a motor or controllers of a robot and the human commands. Manual robots work with the help of humans which are operated by switches on a controller. Signals travel via the wires and the response is immediate as well.

Wireless: Being complex in structure and cumbersome to use wires for control, robots switched to transmitters and receivers. They work on "line of sight" approach. The waves travel in air and require no wired medium in between. This implies the structure of the robot and also increases the efficiency. We also have Bluetooth controlled robots which work through a Bluetooth module but the range is limited making it less efficient.

Autonomous: The introduction of microcontrollers in robotics was the best approach as it increased the efficiency as well as simplified the control system between the robot and the controller. We can program the microcontroller to receive the inputs from the sensors and react accordingly. Autonomous systems use microcontroller for enhancing their autonomy. Arduino, BeagleBone Black, Raspberry Pi and many others today form the base of any robotic system. However we still face several challenges and limitations in controlling the robots. A robot might face any combination of the following failure modes:

- Mechanical Failures. The mechanical failures, broken or jammed parts may restrict the movements of robots.
- Electrical Failures. Incorrect wiring, loose connections or short circuit are failures to be considered for the proper functioning of the robotic system
- Sensor Unreliability. Pretty often sensors provide noisy or incorrect data which hinders the transmission of correct signals. Hence for every controlling device we have associated limitations with it.

Figure 2. Leap Motion Device. Source: Leap [11].

III. MYO ARMBAND

The MYO is an armband equipped with several sensors that can recognize hand gestures and the movement of the arms, placed just below the elbow. It is developed by the company Thalmic Labs, being released in the summer of 2014 as shown in the Figure 3. It is characterized by using a process called electromyography (EMG); identifying the gesture by moving the arm muscles [16]. Based on the electrical impulses generated by muscles, 8 EMG sensors are responsible to recognize and perform each gesture. Therefore, it is necessary for each user to make a calibration step before using the gadget. This is necessary because each user has a different type of skin, muscle size, etc. From these data, and based on machine learning process, the MYO can recognizes the gestures performed [16].

MYO has the potential to offer gesture controls where things like a Kinect sensor wouldn't work. Its working is really simple as the task consists of programming the gestures into the device and defining them as per our requirements, then wrapping the device around one's hand and using our defined gestures to witness the desired effect. The armband can be turned on and off by enabling or disabling respectively. The software development kit (SDK) takes care of all of the low level details related to Bluetooth connections and data transmission. At its core, the MYO armband provides spatial data and gestural data to an application [16].

Figure 3. (a) MYO Armband reading electrical signals from muscles. Source: MYO. (b) Structure of MYO Armband. Source: MYO.

IV. LEAP MOTION DEVICE

To make possible our imagination of controlling objects with our hands, we have the Kinect, Myo Armbands, etc. But the introduction of Leap Motion was however a revolution in the field of gesture control technology. Through this new technology we can say good bye to Mouse & Keyboard [3]. Controlling a robot with swipe gestures on the air seems to be an interesting proposition. Leap motion makes this possible by converting our hand movements into computer commands which can be further worked upon to control robotic systems as well. The Leap Motion Sensor is a small USB peripheral device, designed to place on a physical desktop, facing in upward direction. It covers a hemispherical area above it of approximately 1 meter in radius. There is an eight cubic feet of space above the controller that is used to control the computer.

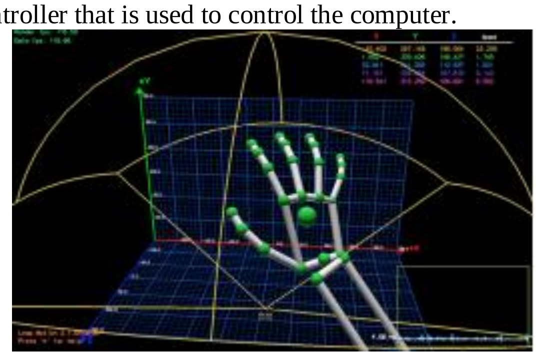

Figure 4. Leap Motion Visualiser [2].

Within it, two monochromatic IR cameras and three IR LED's occupy their position. The LED's emit lights round 850nm while the cameras capture motion of the gesture. The sensor provides the position of our hand and fingers represented in 3D coordinates i.e. (X, Y,Z).The Leap Motion controller tracks all the accompanied "roll", "pitch" and "yaw" orientation angles, thus all information regarding the user palm [6]. The captured data by the camera is fed to the leap motion controller software in the computer. Once the data is streamed in to the computer, the leap motion applies advanced mathematical algorithms for processing the images. The extra background lightings are worked upon and other unnecessary objects in its range are analysed and removed, finally presenting us with a 3D representation of what the device observes. The tracking algorithms extract the position and the orientation of the hands and fingers which is then forwarded to the API [9]. Prior to feeding the data to the API, filtering algorithms are applied to remove noise.

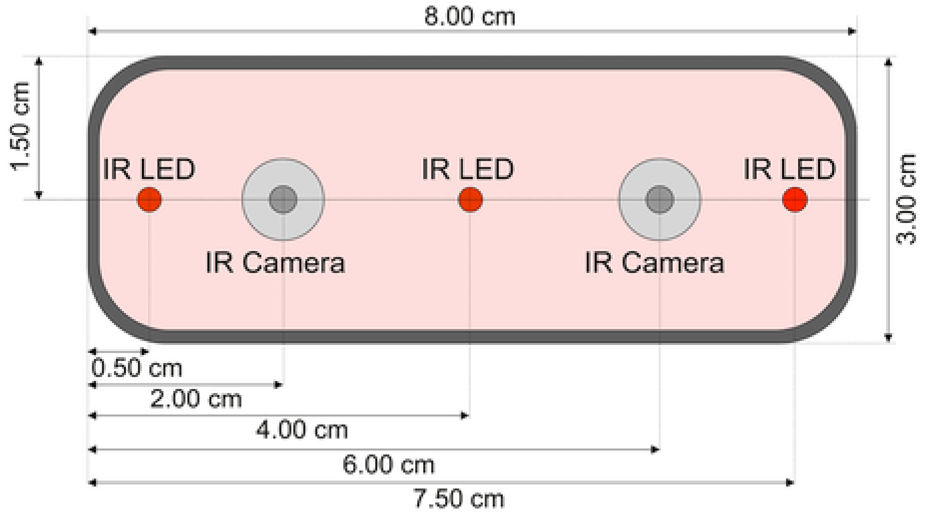

Figure 5. Top view of Leap Motion Sensor [2].

For the interaction of any two device, a set of protocols is required. The transport protocol allows the leap motion service to communicate with the leap motion control panel and the web client libraries through a local socket connection. The libraries organizes the data into a package i.e. API, from where, the application logic ties into the Leap Motion input, allowing a motion-controlled interactive experience. JavaScript, Unity/C#, C++, Java, Python, etc work well with the controller [4]. The following features distinguish Leap Motion from other controllers, making it the most unique and efficient:

⊕ Precision: By tracking all the 10 fingers with a precision of 1/100th of mm, it proves its accuracy [1].

⊕ Workspace: The hemispherical space above the sensor gives a huge 3D space for the detection of hands covering approximately 227 dm3 [1].

⊕ Real-time interaction: The response time of the device being 200 frames per second enables a real-time interaction [1].

Figure 6. Positional Tracking, Motions and Gestures [12].

The Leap Motion dealing with gestures needs to track hands based on some points defined as objects. The figure illustrates the various points on different regions like fingers, palm, wrist and arm. These all points are then analyzed to give ad hoc meanings to the gestures [11,12]. The physical connection between the sensor and the computer takes place via USB 2.0 (microUSB 3.0 connectors) cable [1]. Now comes the comparison between the Leap Motion Sensor and the popular KINECT cameras. The high precision of the Leap Motion Controller defeats the KINECT. While the Leap Motion has a limited sensing and working space, the KINECT has an enlarged workspace covering the entire human body along with its surroundings [8].

V. WORKING OF A LEAP MOTION

The rapid increase in usage of robotic arms increases the necessity of simpler and interactive environment to control them. Gesture control could be the answer for it and Leap Motion can be the revolution in this industry. The Leap has been used in a sign language translation application, to control a 3-finger gripper and also a 6-DOF Jaco robotic arm. In the robotic arm, the 6 servomotors allows for 6-degrees of freedom, as pointed out by each arrow. Whenever we pinch, swipe, rotate or move our hand in a particular gesture the respective motor responsible for interpreting the gesture gets activated and responds accordingly.

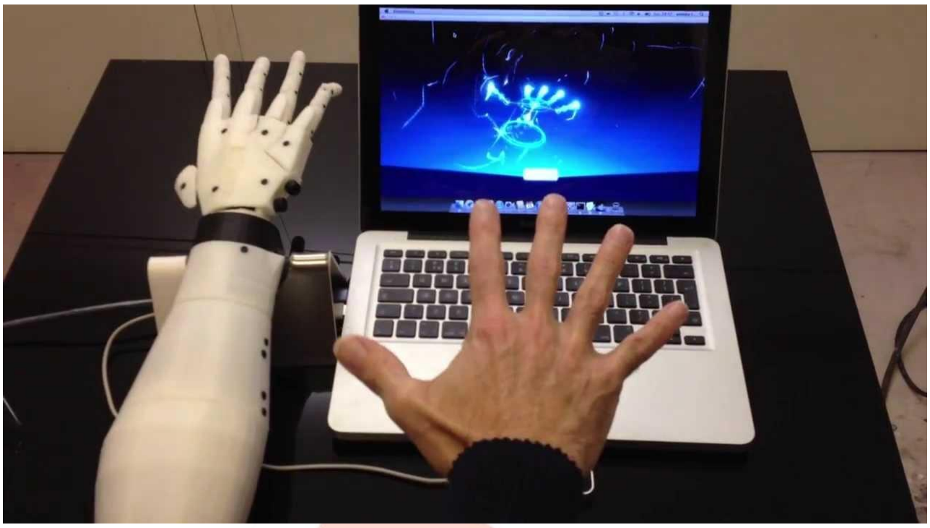

Figure 7. Gesture Control using Leap Motion device [1].

The Mapping Algorithm works in such a way to control each motion type of the robotic arm i.e. Cartesian motion (X, Y, and Z), and Angular motion (roll, pitch, and yaw) [7]. Every time a new frame is received from the Leap Motion controller, the algorithm compares the reading with the previous one (which is saved from the previous frame), and accordingly decides on the next steps that need to be followed. If the absolute difference between the two readings is higher than a threshold value (calculated in advance for each user during the calibration process), this means that the arm will react moving either in the positive or negative direction according to the value of the readings [7]. In case of having an absolute difference that is less than the threshold value, the arm will neglect this motion. To efficiently neglect hand tremor patterns a threshold value for each motion type is extracted during a calibration process. For example, the mechanical arm when interfaced with Arduino microcontroller, then the whole system is connected with processor [5]. The arm will operate using the commands come from the processor to Arduino microcontroller. The tracking software probably uses parallax effect [5] and other algorithms to reconstruct a 3D representation of the orientation and position of the hands and fingers after the algorithm determines to the best of its ability where yours hand is, the data is exported to the API which is ready for you to interface with and pull data from. After obtaining the position of the hand from the sensor we cannot directly send them to the robotic arm, because the arm doesn't know how to reach the position until its joints are turned to specific angles. Here comes inverse kinematics [1,2] that calculates the respective joint angles when the position of the end-effecter is given. Leap Motion API provides us all the required methods to connect with the sensor and retrieve the hand information for processing inverse kinematics. Surgical robots are a breakthrough in medical science and engineering, assisting doctors to monitor patient's health and also to carry out operations with ease and precision. The robots are equipped with enhanced cameras giving a full 3D view of the patients monitored body parts. Robots are prepared to resemble and imitate humans. Having multiple arms, cameras and sensors, they work best for operations reducing the workload and human-errors of doctors.

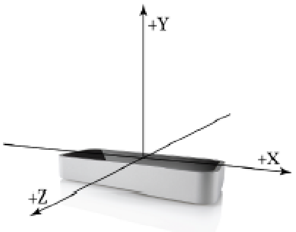

Figure 8. Three axis (x, y and z) in the Leap Motion device [1].

Another important application for using a five-fingered robot is to disarm bombs. This involves Gesture control robotic arm for Bomb Defusing [7]. Using these types of robots in the armed forces could save countless lives when they are operated from a safe distance. Darpa, a robot, has five fingers in each hand that allows to manipulate all types of objects. They also facilitate complex tasks such as handling and picking through wires. Based on these examples, it is clear that Leap Motion has amazing capabilities, which can only grow to unlimited potential. Research in these areas can be very beneficial and lead to abundant income if the technology is bought and implemented by the medial field or armed forces.

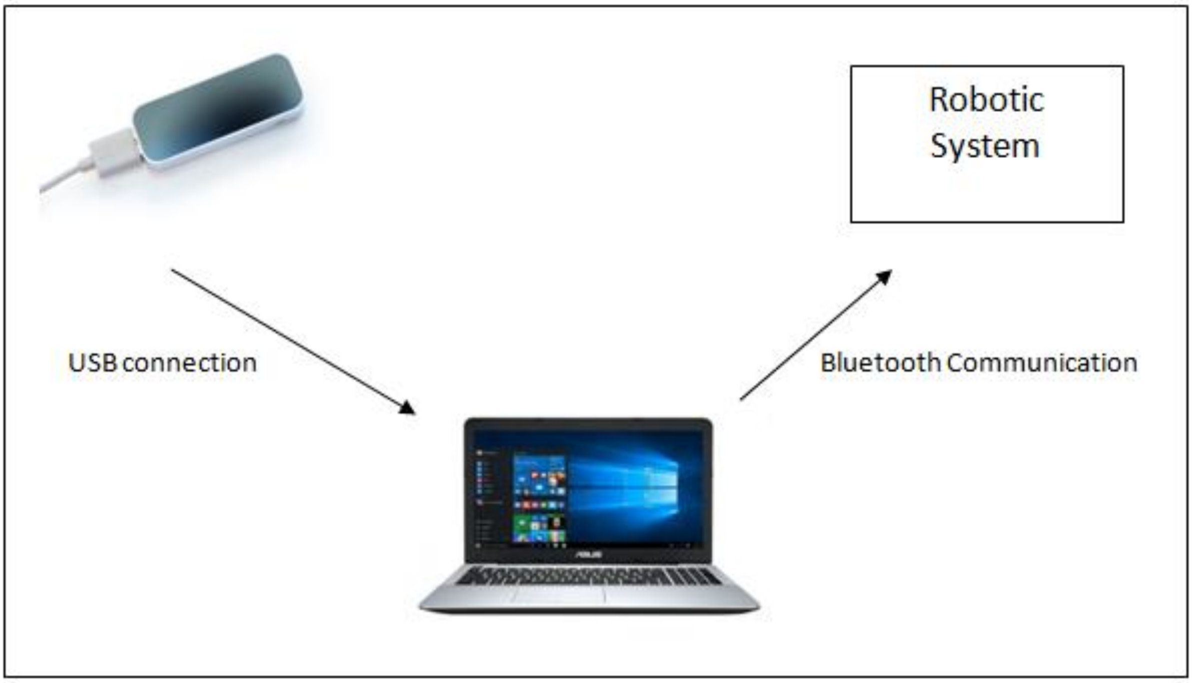

Figure 9. A general set-up of the Leap motion device and the robotic system.

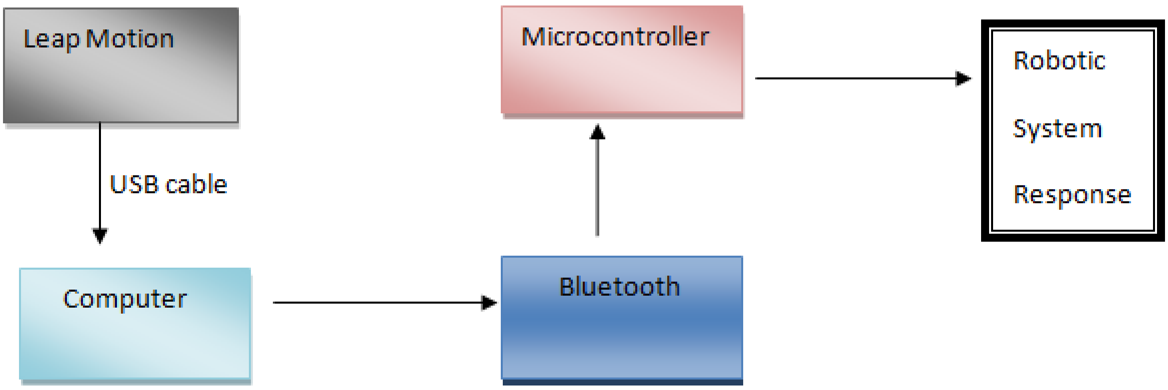

Figure 10. A general block diagram for controlling a robot using Leap Motion

The simplest block diagram in Figure 9 and 10 illustrates the connection between the leap motion and a robot, connected by a USB cable to the computer, it gathers the gestures and transmits it to the computer. The computer uses various algorithms for segmenting the gestures based on various finger points and applies vision algorithms for removing noise and adding filters for better extraction of useful data. The computer then interacts with the microcontroller through a Bluetooth module which then directs the robotic system to respond accordingly.

The aim of our gesture control mode is to enable gesture functioning of the unmanned ground vehicle (UGV) using Leap Motion without base station assistance. To accomplish this operation, hand gesture commands need to be acquired using inertial measurement unit (IMU) and then be transferred wirelessly using Zigbee technology. Other than Leap Motion concept in robotics, rest are from the literature [17, 18, 19, 20, 25]. Sathiyanarayanan et al., [21, 22, 25] successfully built a robot which could be controlled by hand gestures using hand gloves. In this paper, the hand gloves/MYO armband are replaced by Leap Motion device and the efficiency will be tested for practical implications.

The main tasks of the gesture control mode are:

- The hardware components should be connected and tested completely: Arduino Microcontroller, Servo Motor, Dc Motor, Inertial Measurement Unit, Zigbee Radio Modem, 78xx Ic's, Electromagnetic Compass Module, GPS Receiver System, H-Bridge, Lithium Polymer Battery, Ftdi Chip, Webcam, 2x Relay Board, IR Sensors, Nickel-Cadmium Battery.
- Gesture control mode is implemented when situations do not permit the UGV to be operated with base station assistance (manual and auto control).

- UGV is capable of travelling from one point to another using hand gestures commands from users.
- Hand gesture commands are acquired using inertial measurement unit and transferred wirelessly using Zigbee technology.
- For these tasks to be performed, hand gesture commands need to be acquired completely using inertial measurement unit and transferred wirelessly using Zigbee technology.

The proposed gesture control mode is quite straightforward to design theoretically but implementing practically is a challenging one. In this paper, we describe only the theoretical design and the implementation will be the future work.

The two sides of the proposed gesture control mode are as follows:

1. LEAP MOTION SIDE (Leap Motion Controller Side)
   - The user senses the Leap Motion device, calibrates it and starts moving his hand for the robot to move according to his desire.
   - First, Leap Motion provides H-level (horizontal) and V-level (vertical) values based on the inclination along x, y and z axis of the ground.
   - We have assumed a range of 30 degrees along both the positive and negative directions.
   - Values are serially monitored and transmitted by Arduino and Zigbee respectively.

2. UGV SIDE (Robot Side)
   - UGV monitors serial input for the received characters and makes the subsequent decisions.
   - The following functions are executed in response to the character sent [up(), down(), left(), right(), halt()]. We have provided Clockwise and anticlockwise pin assignment for forward and reverse movement of the UGV.
   - Dedicated PWM signal pin for 80 - 120 degrees range of servo turn is maintained and H - Bridge Enable control is being utilized for braking.

At the Unmanned Ground Vehicle (UGV) side, from user, UGV obtains the complete information to move along which direction. So basically, navigation signals are controlled by the user using hand gestures. The gesture control mode is based on the Figure 11. The flow chart of gesture control mode for operating UGV is shown in the Figure 12. The range and characteristics of using Leap Motion are given in the Figure 13.

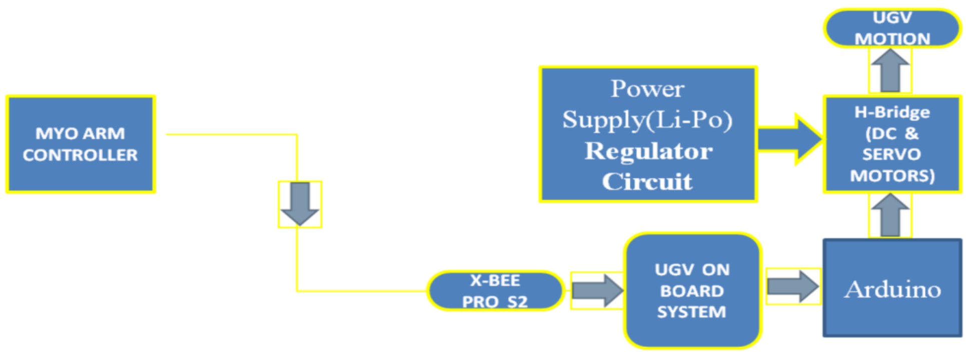

Figure 11. Block Diagram for controlling a robot using Leap Motion.

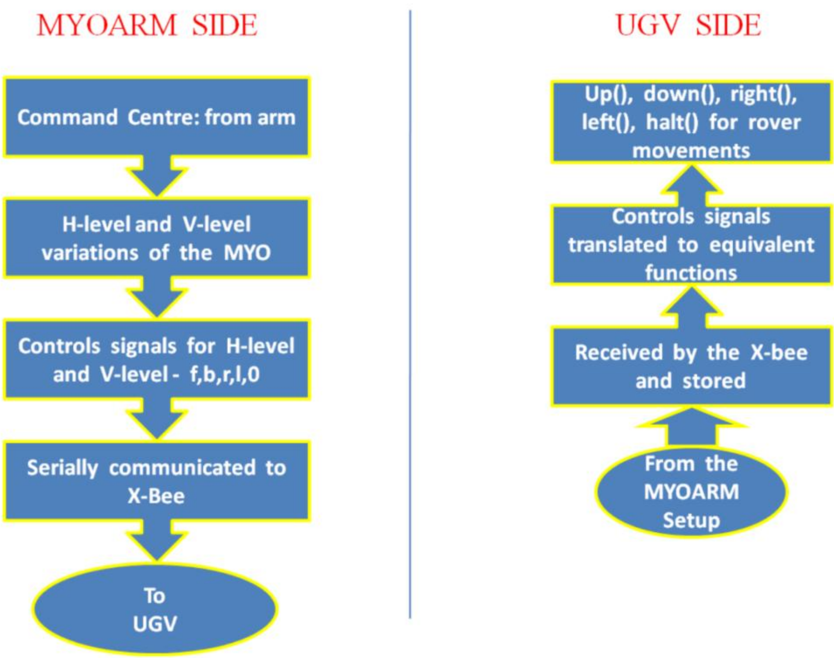

Figure 12. Flow Chart of the Gesture Controlled Robot.

Range	Character sent	Objective
V-level > 30	F	Forward
V-level < -30	B	Reverse
H-level > 30	R	Right
H-level < -30	L	Left
-30<= V-level >=30 -30<= H-level >=30	0	Stop

Figure 13. Range and Characteristics of using Leap Motion

VI. RESULTS

Result 1: We designed and developed a robot capable of performing hand gestures using Aurduino and Zigbee [21, 22, 25] as shown in Figure 14.

Result 2: We measured usability in terms of satisfaction metrics for using MYO armband (hand gesture navigation) to control Apple Maps and various other applications [23, 24]. A simple and widely used System Usability Scale (SUS) questionnaire model was implemented to suggest some guidelines about the use of MYO armband. The user-feedback and observations found during our testing have led us to offer some practical insights to designers and developers on how the prototype software can be extended.

Result 3: We also measured usability in terms of satisfaction metrics for using Leap Motion device (hand gesture navigation) to control Google Earth and various other applications [26]. Again, a simple and widely used System Usability Scale (SUS) questionnaire model was implemented to suggest some guidelines about the use of Leap Motion device. The user-feedback and observations found during our testing have led us to offer some practical insights to designers and developers on how the prototype software can be extended.

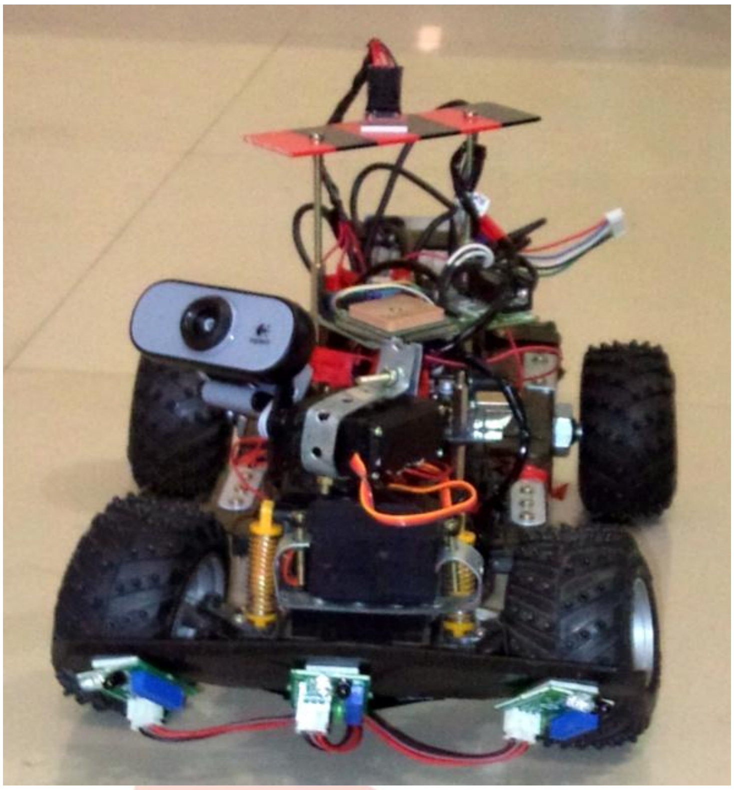

Figure 14. Gesture Controlled Robot [9, 10]

VII. Conclusion

Robotics has invaded almost every field but its tie-up with MYO and/or Leap Motion device is more promising. Myorobotics which witnesses the merge of Cognitive Systems and Robotics has come into existence to make musculoskeletal robots readily available to researchers working in robotics and other domains (e.g. cognition, neuroscience), educators and the industry.

The structurally simple but electronically complicated armband can avoid our dependence on huge control systems. Gone are those days when we had to maintain and manage separate controllers for the robots. This simple wearable band enables us to control and command our robots with our gestures. With the birth of MYO and Leap Motion device, the dimensions of research on robotics has broadened. The optimization of the controller's performance and the simulation of MYO interaction with the environment and the robot will be the key to this research. Practical implementation will help us gain in-depth analysis and optimization techniques.

Leap Motion technology can be very well implemented in video games for shooting enemies using gestures or by triggering fingers. Focusing on the application of such technology, this feature can be very well used by the Defence Department of any country for pointing the enemies and shooting them with the help of Gesture Controlled Robots using MYO and or Leap Motion. This will reduce our dependence on any external tracking system which will first track the happenings of the surroundings, identify the enemy, target them and then shoot making the whole process a time consuming one.

The Clearpath Husky Unmanned Vehicle[1] is a budding example to display the merge of Robotics with MYO and/or Leap Motion. The MYO has been effectively synchronized with Husky to control its movements in all directions. Velocity and braking of Husky are also well controlled using MYO. It’s just the start of experiments with MYO. We are focused on finding new and intuitive ways to program and control collaborative robots. Collaborative robots are those skilled robots that can work side by side with humans and can contribute in the workplace. By combining years of robotic experience with the latest innovative wearable technology like MYO new dimensions of research, experimentation and application can be unlocked.

The soldiers need not wear any physical device on their body (unlike Kinect and/or MYO Armband) to operate robots to fight against enemies. This work in progress paper illustrates an existing robot designed by us, which can be controlled by hand gestures using a non-wearable (touchless) device called as Leap Motion.

VIII. Acknowledgment

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