Four Different Modes to Control Unmanned Ground Vehicle for Military Purpose

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***Abstract* - this paper illustrates the prototype Unmanned Ground Vehicle (UGV) developed for the military purpose. There are four different modes to control UGV: command controlled mode, self-controlled mode, gesture controlled mode and raptor controlled mode. Our prototype UGV is built to undertake missions like border patrol, surveillance and in active combat both as a standalone unit (automatic) as well as in co-ordination with human soldiers (manual). A person from a remote place can comfortably control the motion of the robot wirelessly (manual mode) and in situations where manual control is not prudent, the vehicle is capable of reaching the pre-programmed destination on its own (automatic mode). In few other cases, UGV can use gesture mode and raptor mode. The complete set up and working of the UGV are described in the paper.**

***Index Terms* - Unmanned ground vehicle, robots, motion tracking, Arduino, GPS**

I. INTRODUCTION

Most prominent problems today are terrorism and insurgency. Governments, researchers and scientists are working on new defense systems which are capable of safeguarding citizens from terrorist threats. Some major advancements have taken place in the field of vehicle automation. This motivated our group to work on Unmanned ground vehicle (UGV) which could serve military operations [4].

UGV is a vehicle that operates on open land with or without humans presence for giving navigation commands and decision making. In this paper, we have considered four different modes to control the UGV. They are

- **Command control mode:** In this mode, we have considered humans decision making and providing navigation commands based on the live video signal received from the camera mounted on the UGV [11] [14].
- **Self control mode:** In this mode, we have considered self-decision making and self-navigation based on the GPS co-ordinates, magnetic compass, path planning and obstacle detection algorithms [12] [14].
- **Gesture control mode:** In this mode, we have considered the hand gesture signals, where the UGV will be controlled using commands sent based on the hand movements mapped by the IMU unit [13] [14].
- **Raptor control mode:** In this mode, we have considered the motion tracking system implemented through advanced image processing algorithms to locate and eliminate targets in the field vision [14].

The complete introduction and motivation for the Unmanned ground vehicle are explained in detail in our previously published papers [11], [12], [13], [14] and [15]. The major motivation for our group are Foster-Miller TALON robot [5] and DRDO Daksh robot [6]. We drew some inspiration from their contributions.

An autonomous UGV [1], [2] and [3] is essentially an autonomous robot but is specifically a vehicle that operates on the surface of the ground. A fully autonomous robot in the real world has the ability to:

- Gain information about the environment.
- Work for extended durations without human intervention.
- Travel from point A to point B, without human navigation assistance.
- Avoid situations that are harmful to people, property or itself, unless those are part of its design specifications
- Repair itself without outside assistance.
- Detect objects of interest such as people and vehicles.

A robot may also be able to learn autonomously. Autonomous learning includes the ability to:

- Learn or gain new capabilities without outside assistance.
- Adjust strategies based on the surroundings.
- Adapt to surroundings without outside assistance.

Autonomous robots still require regular maintenance, as with all machines.

In gesture controlled mode, gesture means movement of hand (specifically fingers and arms) or face which conveys some information. Gestures can be classified into static gestures (using hand shapes) and dynamic gestures (using hand movements) [7] and [8]. Gesture recognition needs a good interpretation of the hand movement to effectively execute the commands [9]. There are two approaches: Data Gloves Approach and Vision based approach [10]. In this paper, we will be using the former.

In this paper, we explain the set up and design of the unmanned group vehicle which will be controlled by four different modes. It uses various algorithms for different modes. The rest of the paper is organized as follows. In Section II we explain all the four modes: command control mode, self-control mode, gesture control mode and raptor control mode for operating UGV. In Section III, we explain the applications followed by limitations in the section IV. Section V explains the results followed by conclusion and future works in section VI and VII.

II. FOUR MODES TO CONTROL UGV

UGV operates on open land with or without humans presence for giving navigation commands and decision making. Our UGV has four different modes to be controlled. To design this UGV, we have considered components both hardware and software.

The block diagram of the UGV consists of various components. They are

1. **Base station:** It's a computer system located at a remote place away from the UGV which controls it using keyboard, mouse for mode control and movement and live video feedback for monitoring the environment.
2. **Keyboard and mouse:** They are used to handle the motion of the UGV and the movement of the turret for wide angle vision.
3. **3G Internet:** Communication medium for system to system interaction so as to control the UGV wirelessly.
4. **On-board system:** A computer system placed on the UGV itself which receives the commands and delivers it to the control Unit.
5. **Camera:** An image acquiring device which provides the video required for UGV vision.
6. **Control Unit:** It's the Arduino microcontroller which receives signals from the user and other sensors and performs tasks such as turret movement and UGV movement.
7. **GPS Unit:** A navigation system used in the autonomous mode for obtaining location co-ordinates.
8. **Compass:** To acquire the direction to which the UGV is facing.
9. **IR sensors:** Infrared Sensors used in the obstacle avoidance mechanism incorporated into the autonomous mode.
10. **Servo motor:** they are used to control the direction turn of the UGV and the 2 axis movement of the turret.
11. **DC motor:** These are used mainly for the UGV movement.
12. **Li-PO Battery and voltage regulator:** the power source supplying the entire UGV with voltage regulation to provide optimum power ratings.
13. **Wireless modem:** Zigbee to provide wireless data transfer for the ArmCon mode.
14. **IMU:** An inertial measurement unit which tracks the orientation of the hand used for hand Gesture control (ArmCon mode).
15. **Ni-Cd battery:** Used for powering up the Control Unit, Zigbee and the IMU.

The major hardware components used are:

1. ARDUINO MICROCONTROLLER
2. SERVO MOTOR
3. DC MOTOR
4. INERTIAL MEASUREMENT UNIT (IMU)
5. ZIGBEE RADIO MODEM
6. 78XX IC'S
7. ELECTROMAGNETIC COMPASS MODULE
8. GPS RECIEVER SYSTEM
9. H-BRIDGE
10. LITHIUM POLYMER BATTERY
11. FTDI CHIP
12. WEBCAM
13. 2X RELAY BOARD
14. IR SENSORS
15. NICKEL-CADMIUM BATTERY

Now the function of four different modes will be explained in detail.

A. Command Controlled Mode

The aim of this mode is to enable operation of unmanned ground vehicle using inputs which could vary from a simple computer keyboard to other self-designed input devices. The commands are sent over to the UGV remotely using wireless communication technologies such as ZigBee or internet, while it transfers live video feedback to the user. ZigBee is a wireless technology designed to connect simple high-tech devices for useful purposes.

The main tasks of the command control mode are:

- Maneuver the UGV wirelessly by transmitting navigation commands from the base station based on the video received from the on-board camera.
- Control the turret wirelessly in order to locate and eliminate targets in the field of vision.

For these tasks to be performed, we considered "Arduino". It is an open-source software and easy-to-use hardware. Writing code and uploading it to the i/o board is very easy and simple. The other parts around arduino are built systematically as shown in the block diagram fig 1.

Algorithm design for command control mode

The algorithm design for command control mode is quite easy and straightforward. We considered two sides for building a prototype UGV: Base station/user side and UGV side.

Base station/user side:

Navigation commands such as up, down, left and right arrow keys in computer keyboard have been assigned for rover (UGV) movement. The keys pressed have been mapped into specific characters which are sent as control signals to the arduino controller. The characters sent have their unique function assigned to them which is shown.

UGV side:

UGV transmits video signals from the on-board camera to obtain navigation commands. Once the navigation commands are obtained, 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. Also, in this mode, turret is wirelessly controlled in order to locate targets in the field of vision. At the base station side, commands controls from the computer keyboard will be given as shown in fig 3. Based on the commands from computer keyboard such as up, down, left and right arrow keys have been assigned for rover (UGV) movement. The specific keys pressed are been mapped into arduino controller. Once the control signals are obtained, the following functions will be executed by the UGV. The flow chart of command control mode for operating unmanned ground vehicle is shown in fig 2. The role of both base station side and UGV side are shown.

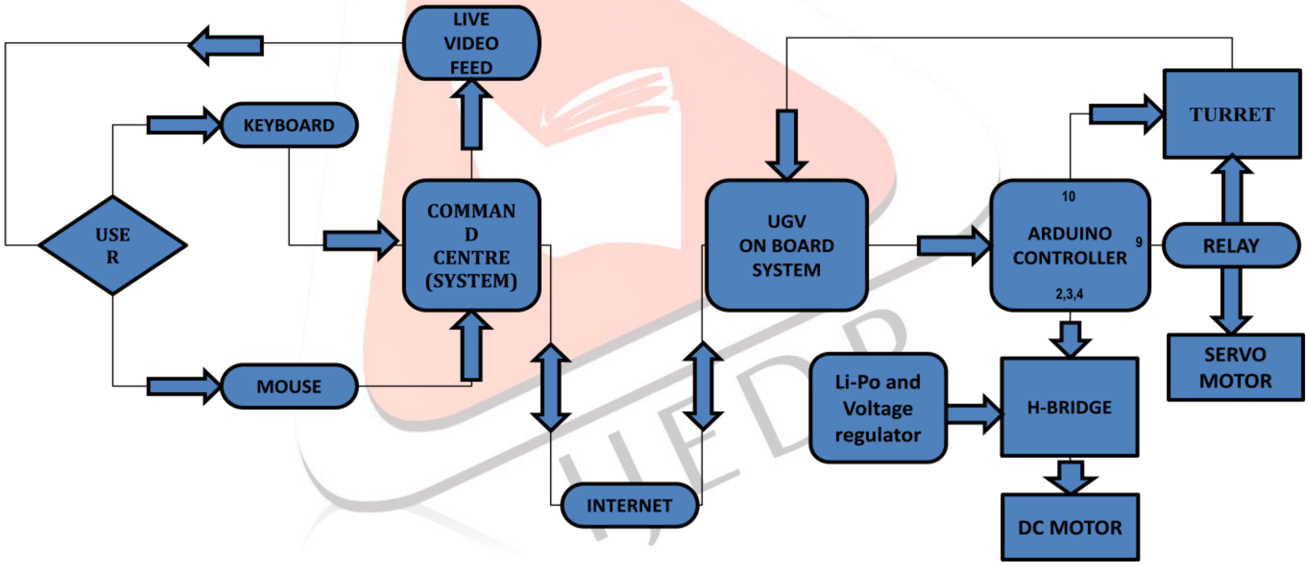

Fig 1: Block diagram for the command control mode

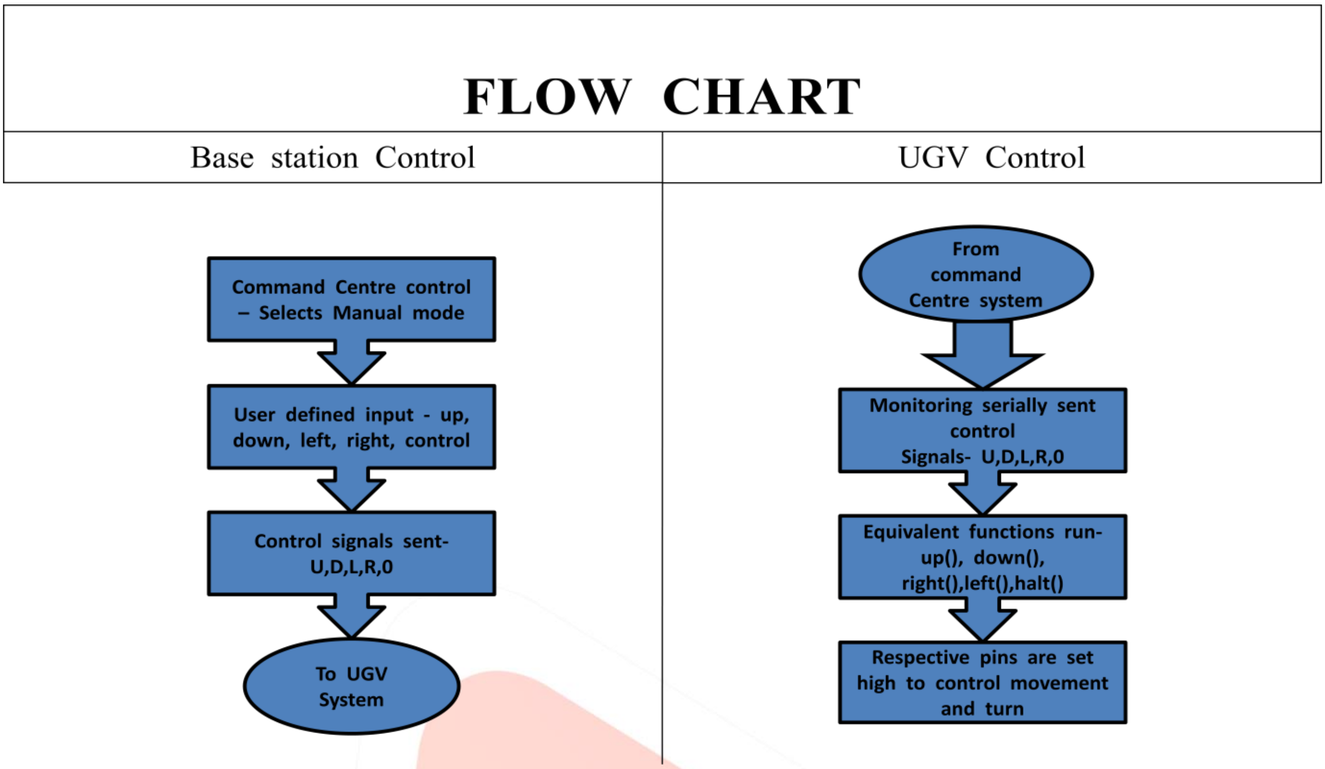

Fig 2: Flow chart for the command control mode

Key Pressed	Character sent	Objective
Up	U	Forward
Down	D	Reverse
Left	L	Turn left
Right	R	Turn right
Ctrl	0	Stop

Fig 3: Navigation commands for the command control mode.

B. *Self Controlled Mode*

The aim of this mode is to enable autonomous functioning of the unmanned ground vehicle without human supervision. To accomplish this operation navigation technology such as GPS, magnetic compass is used to provide the on-board system enough data to operate as a self-navigated system. Other technologies like Infra-red sensors are used in our prototype to provide functional obstacle avoiding capabilities which augment the autonomous operation.

The main tasks of the self-control mode are:

- UGV is capable of travelling from point A to point B without human navigation commands.
- Adjust strategies based on surroundings using path planning and obstacle detection algorithms.

For these tasks to be performed, both path planning and obstacle detection algorithms need to be designed carefully. The block diagram for the self-controlled mode is shown in fig 4.

Algorithm design for the self-control mode

The algorithm design for self-control mode is quite easy and straightforward. We mainly considered two important algorithms: path planning and obstacle detection algorithms for the UGV to navigate automatically. First, user obtains the current GPS co-ordinates and the heading reading from the compass for the UGV. Then the destination co-ordinates are acquired from the user. Angles are calculated by which the UGV orients with the desired direction using simple trigonometric functions. Calculated angle provides the UGV movement control signals. The UGV navigates itself to the desired location based on the IR sensors values which are obtained with respect to the obstacles. Path planning algorithms are used to decide the path taken.

Obstacle avoiding algorithm is also incorporated, which makes sure, the unmanned ground vehicle avoids obstacles while doing task at hand in the most efficient manner based on the IR sensors values which are obtained with respect to the obstacles. At the base station side, user obtains the GPS co-ordinates continuously from the UGV. Destination co-ordinates are given by the user itself. Based on the path planning and obstacle detection algorithm, UGV navigates automatically. The obstacle detection algorithm work based on the figures shown in figure 6. The flow chart of self-control mode for operating unmanned ground vehicle is shown in fig 5.

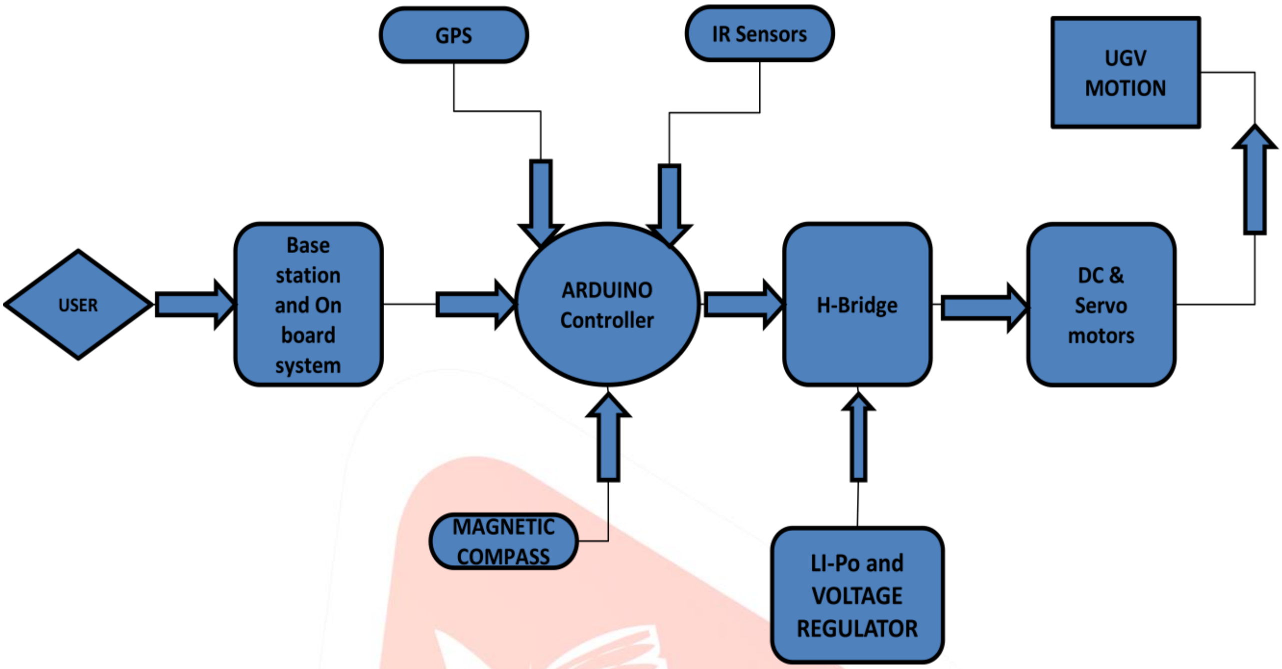

Fig 4: Block diagram for the self control mode

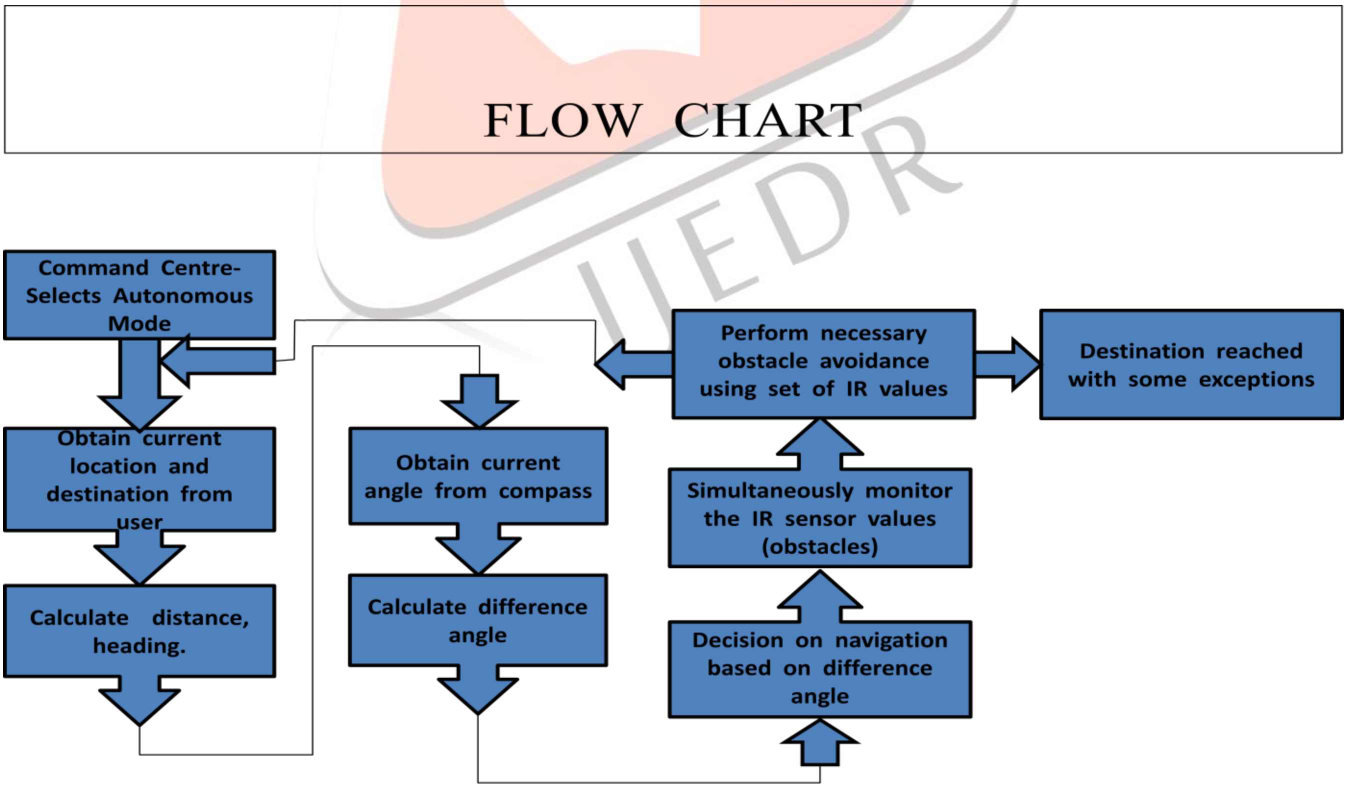

Fig 5: Flow chart for the self control mode

IR(L)	IR(M)	IR(R)	Operations performed
0	0	0	(No obstacles)
0	0	1	Left() and Up()
0	1	0	Random[Right() or Left()] and Up()
0	1	1	Left() and Up()
1	0	0	Right() and Up()
1	0	1	Up()
1	1	0	Right() and Up()
1	1	1	Random[Right() or Left()] and down()

Fig 6: Obstacle detection algorithm

C. Gesture Controlled Mode

The aim of this mode is to enable gesture functioning of the unmanned ground vehicle without base station assistance. To accomplish this operation, hand gesture commands need to be acquired using inertial measurement unit and then be transferred wirelessly using zigbee technology.

The main tasks of the gesture control mode are:

- 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 humans.
- 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 block diagram for the gesture controlled mode is shown in figure 7.

Algorithm design for gesture control mode

The algorithm design for gesture control mode is quite easy and straightforward. We mainly considered two important algorithms: path planning and obstacle detection algorithms for the UGV to navigate automatically.

ARMCON SIDE (Arm Controller Side):

First, user provides pitch and roll values based on the inclination along x and y axis i.e. it senses the tilt motion of the Board. 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.

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 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 algorithm work is based on the figure shown in figure 9. The flow chart of gesture control mode for operating unmanned ground vehicle is shown in figure 8.

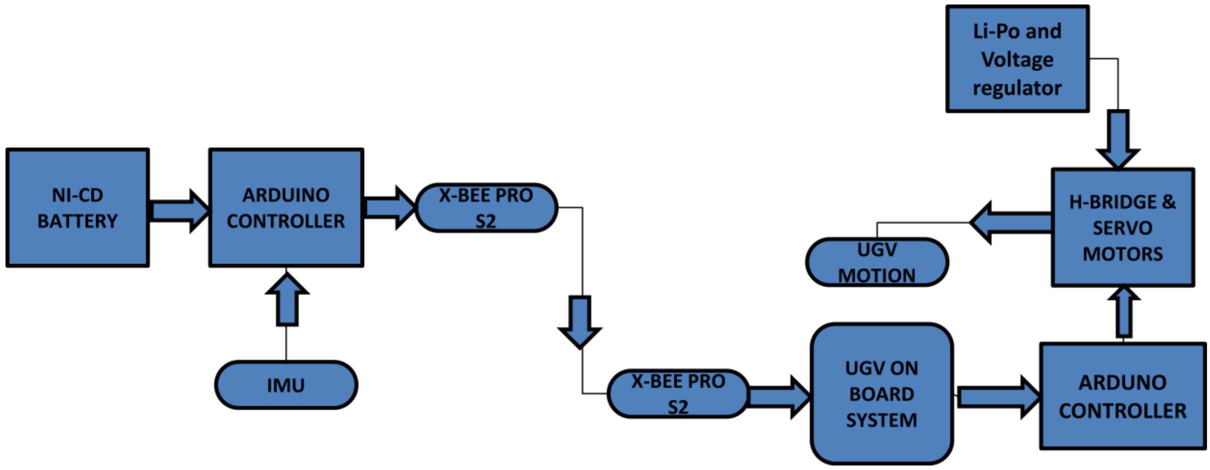

Fig 7: Block diagram for the gesture control mode

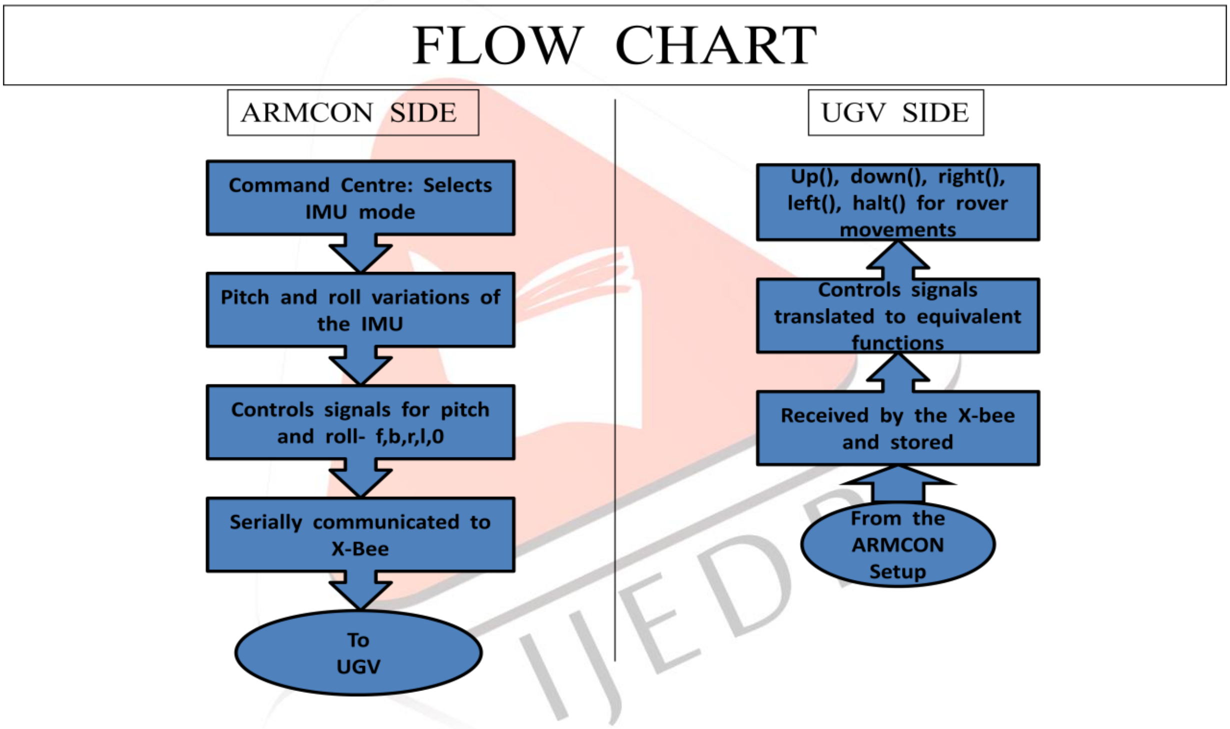

Fig 8: Flow chart for the gesture control mode

Range	Character sent	Objective
Pitch > 30	F	Forward
Pitch < -30	B	Reverse
Roll > 30	R	Right
Roll < -30	L	Left
-30<= pitch >=30 -30<= roll >=30	0	Stop

Fig 9: Pitch and roll movements for the gesture control mode

D. *Raptor Controlled Mode*

The aim of this mode is to provide motion tracking functionality to it using advanced image processing algorithm i.e. optical flow. The camera mounted on servos at the front end of rover acquires the image which is processed by the onboard system corresponding to the computational results of which the servo commands are issued to move the camera thus enabling motion tracking. This mode is showed in fig 10 along with the flow chart in fig 11. Fig 12 shows vector flow diagram of rotating object.

Algorithm design for raptor control mode

The algorithm design for raptor control mode is as follows.

- Firstly, the Image frame f1 is acquired at time T1.
- Then the Image frame f2 is acquired at time T2.
- We know T2>T1, markers placed in both the frames at preset locations.
- Both the frames after marking are compared, and the location of the pixel at a marker in f1 is found in the neighborhood of the same marker in the f2.
- If there is a match, a vector is drawn from marker to the new location of the pixel determined.
- The above steps are repeated for the all the markers.
- The magnitude and direction of the vector is used in to find the direction of motion of the pixel in the image and the decision to move the turret position is made on the basis of the observed data.

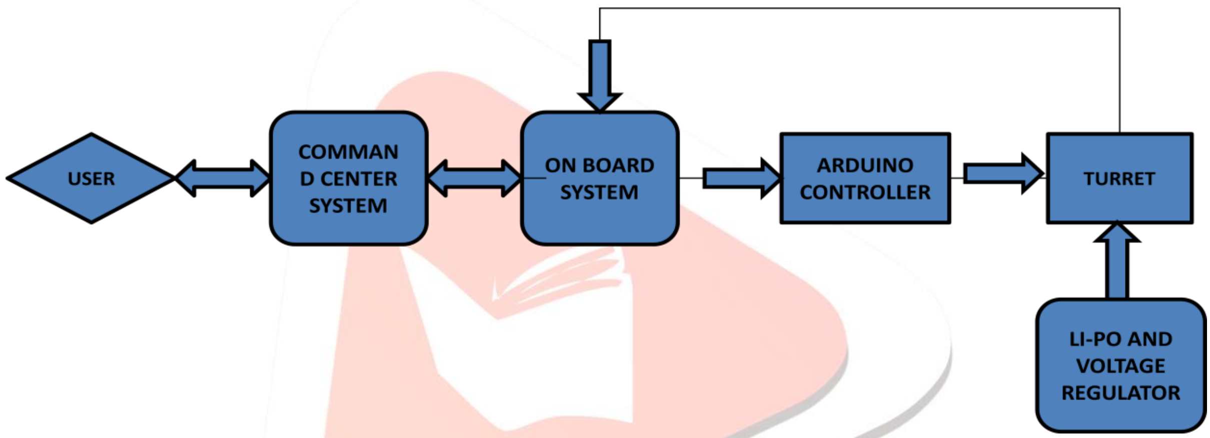

Fig 10: Block diagram for the raptor control mode

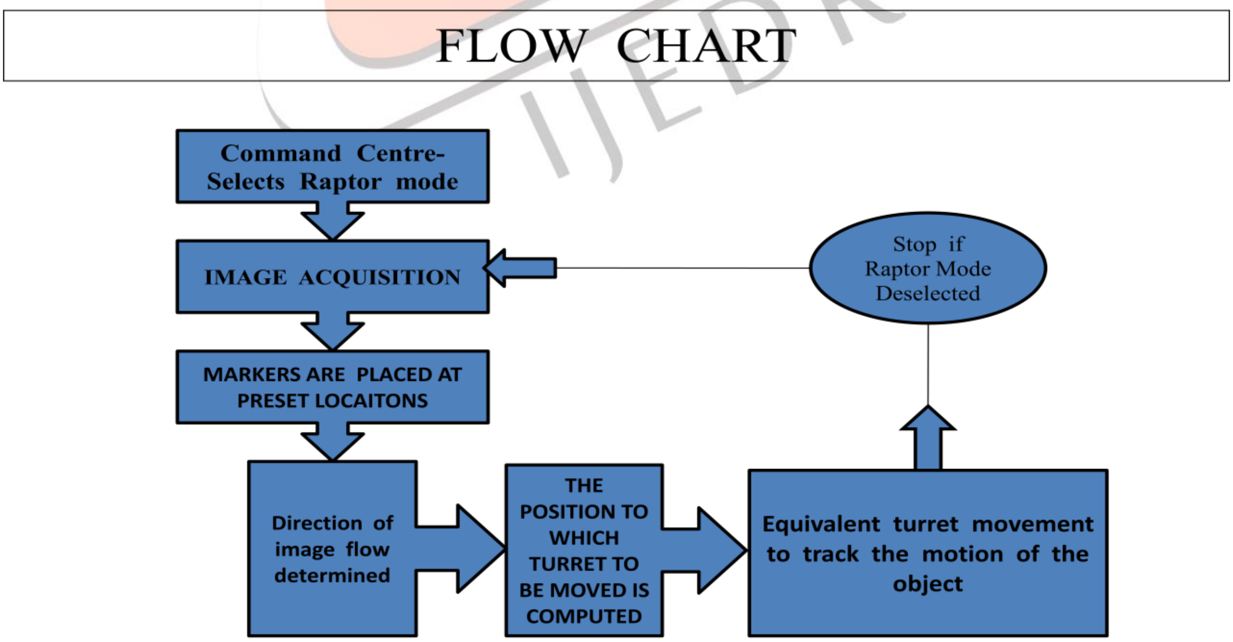

Fig 11: Flow chart for the raptor control mode

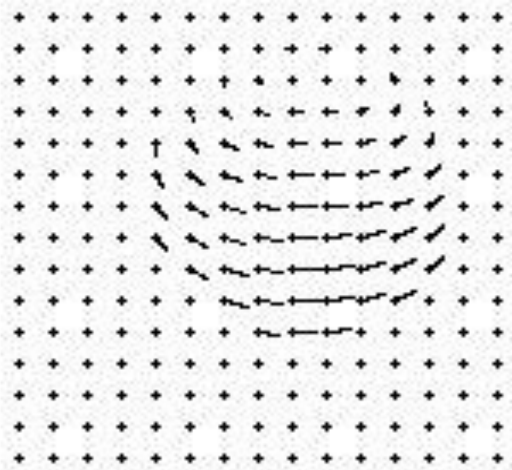

Fig 12: Vector flow diagram of rotating object

III. Applications of UGV

1. Before RECONNAISSANCE- Also known as Scouting, is the military term for performing a preliminary survey, especially an exploratory military survey, to gain or collect information.
2. BOMB DISPOSAL- Used in defusing and deactivating Explosives as a result of which an added feature a robotic arm can be added.
3. SEARCH AND RESCUE-In times of Natural calamities or man based disasters, it proves to be a reliable machine to locate people or objects with ease where it renders human effort futile.
4. BORDER PATROL AND SURVEILLANCE- In times of military warfare or border encroachment, it is used to monitor alien force entering into the territory.
5. ACTIVE COMBAT SITUATIONS- Widely used on the battlefield, UGVs equipped with Explosives, Weaponry and shields have proven to be handy expendables assets without the cost of human life
6. STEALTH COMBAT OPERATIONS- Spying purpose without coming into the radar of the enemy is effective in war strategies.
7. NEW EXPLORATIONS – Deep cave searches, underwater explorations and the currently executing Mars and outer planets exploration can be performed.
8. To undertake dangerous missions which involves loss of human life.

IV. Limitations of UGV

1. IR sensors used on board for obstacle avoidance are extremely directional; it works inefficiently in sunlight and fails to detect black bodies.
2. Current capacities of the batteries i.e. (Li-PO and Ni-Cd). These batteries can power up the system only for a particular duration defined by their current capacities, elapsing which the batteries would drain out leaving the system powerless.
3. It is required for the system to have high data rates of 3G internet services for the communication between the base station and UGV. Failure in providing such high data rates would lead to inefficient processing and thus an unreliable system.
4. It is required that the computers that are used on board and the one used in the base station need to have high computational capabilities and high processing speeds.
5. GPS used on board to get the current location of the UGV will not lock onto a value unless and until there is direct line of sight between the UGV and at least 4 satellites.
6. Magnetic compass used on board to acquire the current heading of the UGV is subject to interferences from other on board components and outer atmosphere which results in unreliable readings.

V. Results

- Successfully built a stand-alone rover capable of both manual and autonomous modes of control. In general, implemented four modes: command mode, self mode, gesture mode and raptor mode as shown in fig 13 and fig 14.
- Added a rotating camera platform that can target the enemy with/without human control.
- Successfully implemented features including motion tracking, obstacle detection, path planning , gesture control and GPS.
- We have made use of Modern communication advancement such as 3G services to provide ease of access and portability to our UGV.

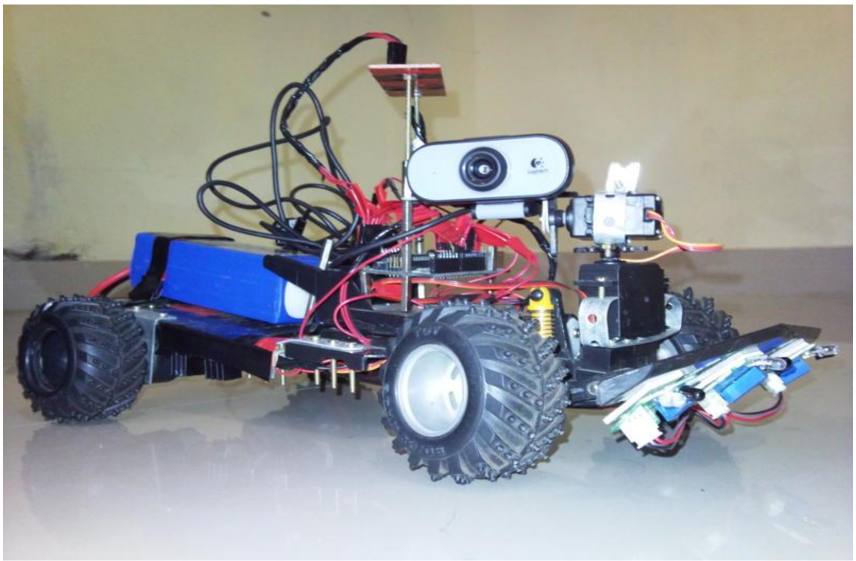

Fig 13: Prototype Unmanned ground vehicle (side view)

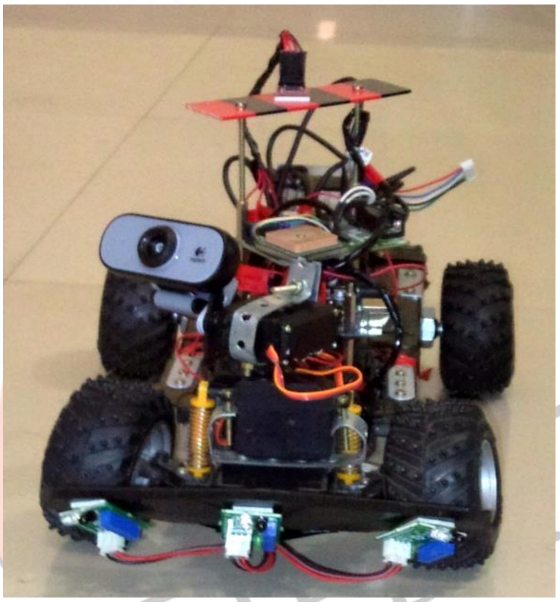

Fig 14: Prototype Unmanned ground vehicle (front view)

VI. Conclusions

- The incorporation of various technologies under one roof has given us the path to achieve goals which have never been realized in such an efficient manner in the past.
- These technologies bring about a self relying and able machine to tackle situations on its own and ease a human's job in the present day scenarios.

VII. Future Works

- Additional sensors such as Passive infrared sensors, thermal imaging, Gas sensor, can be added to enhance the capabilities of the UGV.
- Optical flow augmented with other image processing algorithms such as frame differencing, edge detection to accomplish more reliable motion tracking.
- High end technology with higher resolving capabilities can be added to enhance the present functionality of the UGV.
- Secure satellite links for communication increases the security of UGV operation.

VIII. Acknowledgment

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