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Prototype of Teleoperated Unmanned Ground Vehicles for Military Applications

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Abstract - Unmanned Ground vehicles have a significant impact on both civil & military forms of life. In this paper a sincere effort has been carried out to design a UGV which can perform multiple operations like reconnaissance, surveillance, mine detection & transportation of essential items in case of conventional & Non- conventional operations. This prototype uses various sensors for determining locations & providing real time video streaming. This system comprises of two subsystem : UGV & Command Post (Transmitter for providing inputs & display system)

INTRODUCTION

Mobile Robots differs from the conventional form of Robot by moving in an unconstrained environment using various devices like sensors, actuators, and controllers. Unmanned Ground vehicles are a form of mobile Robots which proceed out of their dexterous space & it does not have a human presence in the moving device. Primarily, it can be controlled and directed in two forms: Autonomous or Teleoperation. In its Autonomous form, UGV can decide based on intelligence imparted to the system by employing various programs and algorithms. However, in Teleoperated form of UGV, users provide input and fully control the device. Currently, it is working on 5D's of Robotics in the modern world: Dull, Dirty, Dangerous, Domestic & Dexterous. There are various applications of UGV in different fields such as space, industries, agriculture, mining, construction, hazardous tasks etc. However, in this project, a teleoperated prototype has been developed for military applications that can benefit Armed Forces. In today's world, Armed Forces have multiple challenges to handle, including conventional and Counter-Terrorism operations. UGV is a boon for Armed Forces because it can assist during conventional operations through surveillance, reconnaissance, mine-detection etc. Similarly, during counterinsurgency & counter-terrorism operations, it can assist forces by providing actionable and vital intelligence. Armed Forces personnel gets deployed in multiple roles like Counterterrorism (CT), Counterinsurgency (CI), Conventional operations & Humanity Assistance Disaster Relief (HADR) operations. These operations involve reconnaissance, surveillance & operations like mining, demining, detection & clearance of Improvised Explosive Device (IED) & transportation of ammunition, explosives, or vital stores to combatant during the conflict. These operations are high-risk operations for the Armed Forces personnel, which sometimes also lead to the unfortunate casualty of troops while performing their call of duty. Nowadays, due to the extensive usage of UAVs in all the services of Armed Forces, the commander of Armed Forces gets the real-time picture of the operational zone or area of interest. Still, sometimes an operation requirement necessitates close level real-time surveillance & monitoring of the tactical area, which is impossible by any UAV or quadcopter. Some examples are house clearing in Counter-Terrorism operations, clearance of IED, reconnaissance & surveillance of enemy posts for getting actionable intelligence, replenishment by transporting ammunition, explosives, or other warlike stores to own forces. To have a tactical advantage by gaining vital information about the enemy, UGV is the best solution. It is an autonomous or semi-autonomous vehicle that remains on the ground & performs tasks like surveillance, reconnaissance, detection & removal of mines instructed by the Commander. In today's scenario, operations are fast & swift, which require the highest degree of precision in surveillance; therefore, the requirement of UGV is imminent.

To achieve success in covert operations, there is an inescapable requirement of UGV for Armed Forces, which can perform multiple operations depending on input provided by the Commander based on operational requirement. UGV, which exists for Armed Forces, is designed to perform specific tasks. However, during conventional operations or CI/CT operations requirements of the Commander are vast depending on different scenarios. Battlefield is very dynamic these days & requirements of intelligence based on electronic surveillance is mandatory. To overcome these requirements, UGV will play a vital role in performing reconnaissance by its surveillance technique and assisting in tasks like performing operations such as Demining & transportation.

One of the fundamental points that differ UGV from conventional Robots is that it must localize, know the point of destination, & path towards the destination. The primary goal of this paper is to create a UGV that can perform multiple operations like surveillance, reconnaissance, mine detection & transportation. It differs from other UGV as most UGV can perform only one operation, whereas this UGV is designed to perform multiple operations. Today's battlefield is dynamic & therefore, the requirement of Commanders of the Armed Forces also varies according to different situations & this prototype can provide solutions to the Commanders.

OBJECTIVES

To design a prototype of UGV which can perform multiple operations i.e., surveillance, reconnaissance, mining & transportation of vital equipment. This device will also real time streaming to Command Post which will provide vital information to our troops.

LITERATURE SURVEY

Bouhraoua, Abdelhafid, et al. "Design and implementation of an unmanned ground vehicle for security applications. [1] In this research paper, a UGV has been designed can perform security operations like surveillance, firing etc. The developed vehicle is based on a Quad motorbike with a one-cylinder gasoline engine, which can either be fully automated or teleoperated. It is controlled through a wireless connection by Command & Control Centre, which activates actuators, sensors and motors for locomotion, firing, braking etc.

Aakash Dogra, Ashiwni Gohokar, Nachiket Sonar, Gauri Khapre, 2014, MILITARY SURVEILLANCE AND DEPLOYMENT ROBOT [2] In this paper, a methodology has been elaborated for designing UGV, which primarily can perform surveillance operations but can also drop explosives at a designated place. The author believes this model can be beneficial for security forces. It is a teleoperated control and provides a camera feed to the operator.

Kaur, Tarunpreet, and Dilip Kumar. "Wireless multifunctional robot for military applications' [3] In this paper, a prototype has been developed which can work in autonomous & manual mode & works on 3G technology. It provides surveillance & also detects bombs, fire & harmful gases. It has a solar panel for power consumption & it can be tilted for maximum efficiency.

Budiharto, Widodo, et al. 'Development of Tank-Based Military Robot and Object Tracker' [4] In this paper, a Military Robot has been designed to work on vision-based technology. This robot is designed for security forces to conduct anti-terrorist operations in Indonesia. This robot is a tank-based prototype with object detection & tracking for the simulation of shooting down the enemy.

Man, Christopher Kwet Young Lam Loong, Yogesh Koonjul, and Leckraj Nagowah. 'A low-cost autonomous unmanned ground vehicle [5] This project designs an Autonomous UGV which can navigate autonomously avoiding obstacles in its path by reading QR codes. Raspberry Pi3 acts as a brain in this system. It also uses DC & servo motors, Ultrasonic & IR based sensors, batteries, power bank, smartphones etc.

Kopuletý, Michal, and Tibor Palasiewicz. 'Advanced military robots supporting engineer

reconnaissance in military operations '[6] This paper focuses on designing a military robot that can perform Engineering Reconnaissance in Military operations. This prototype emphasizes military engineering tasks like demolition, breaching, bridging etc. It also gives impetus to future trends of engineering reconnaissance.

Wang, Ziyang. 'Robot obstacle avoidance and navigation control algorithm research based on multi-sensor information fusion'. [7] This project emphasizes on navigation of UGV by performing obstacle avoidance algorithm which works on TSS based FNN multi sensor fusion. It also combines neural network & fuzzy logic.

Dawid, Wojciech, and Krzysztof Pokonieczny. 'Methodology of Using Terrain Passability Maps for Planning the Movement of Troops and Navigation of Unmanned Ground Vehicles.'[8] This paper focuses on the navigation of UGV by selecting the optimal route between two points using the graph generation technique. This paper compares two methods of graph generation: A star & Dijkstra. Index of passability (IoP) is defined as a function that determines the route of UGV to the destination.

Matthies, Larry, et al. 'Obstacle detection for unmanned ground vehicles: A progress report.' [9] In this paper, obstacle avoidance is carried out through Autonomous UGV by evaluating terrain geometry. A real-time stereo vision-based system comprising multiple sensors is used in UGV so that correct image interpretation is carried out for obstacle detection and avoidance.

Shimoda, Shingo, Yoji Kuroda, and Karl Iagnemma. 'Potential field navigation of high-speed unmanned ground vehicles on uneven terrain' [10] This paper proposes a Potential field method to navigate UGV to the destination at high speeds avoiding obstacles. Potential field planning is conducted in two dimensions: path curvature & longitudinal velocity. UGV and obstacles are chosen with the same polarity in this method, whereas UGV and goal are opposite polarities.

Jabbarpour, Mohammad Rzea, et al. "A green ant-based method for path planning of unmanned ground vehicles [11] Green ant based methodology is used for path planning of UGV that also integrates power/ energy consumption prediction model. Simulation tools are also used for evaluation & validation of G-ant.

Ordonez, Camilo, et al. "The virtual wall approach to limit cycle avoidance for unmanned ground vehicles." ***Robotics and Autonomous Systems*** **56.8 (2008): 645-657. [12]** In this methodology of the virtual wall, three stages are identified for navigation. In the first stage, UGV is navigated to the destination towards the goal. In the second stage, obstacles are identified using the labelling operator, whereas, in the final stage, the path is determined using waypoints outside the deadlock area.

GAP IN LITERATURE.

After studying various Journals of UGV, the following gaps are noticed in the existing Literature: -

a) Various studies have been conducted for designing UGV, which can perform an explicit function like Surveillance, Reconnaissance, Simulation of shooting, Obstacle avoidance, Mining & Demining operations. However, the requirement of Commander in Armed Forces is not limited to a single task & it keeps on varying according to different situations.

b) Logistics operations on the battlefield are critical operations that replenish ammunition, warlike stores, & any specific store to troops on the battlefield. UGV deployment in logistic operations can boost the Armed Forces in need of the hour. Unfortunately, not many studies or journals have been worked in this direction.

c) Live streaming in operations provide ease in decision making

SYSTEM ARCHITECTURE

CONCEPT

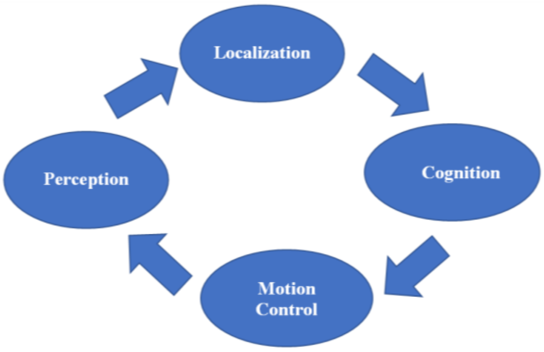

Figure 1

The Control scheme of UGV comprises four procedures: Perception, Localization, Cognition & Motion Control. These procedures are interconnected with each other. Perception includes extracting, collecting & collating information from various sensors. The complete Perception procedure involves feature extraction, matching of extracted feature with the predicted model, updating feature in the system, model integration & comparing the model produced with the new feature. During the localization process, UGV predicts its present position with the help of various types of sensors. Generally, UGV has two types of sensors: exteroceptive & proprioceptive. Exteroceptive sensors acquire external environment information like distance and sound, e.g., ultrasonic sensors. Proprioceptive sensors measure internal information like RPM, wheel velocity, e.g., Odometry. For localization of UGV, two filters work on probability models, i.e. Markov & Kalman filter. After localization next step is Cognition; UGV moves towards the destination either in autonomous mode or teleoperated. Therefore, the controller provides Mission Commands for various actuators of UGV after selecting the path. The final step in UGV is Motion Control, where the navigation process executes through path planning & obstacle avoidance. Path planning is carried out either through graph search or potential field planning. Obstacle avoidance is carried out through various types of Bug algorithms. The above procedure is for navigation of UGV to a selected point of destination. Additionally, UGV will also be subjected to various other types of commands by users according to the requirement, which will work in addition to the procedure mentioned above.

ARCHITECTURE

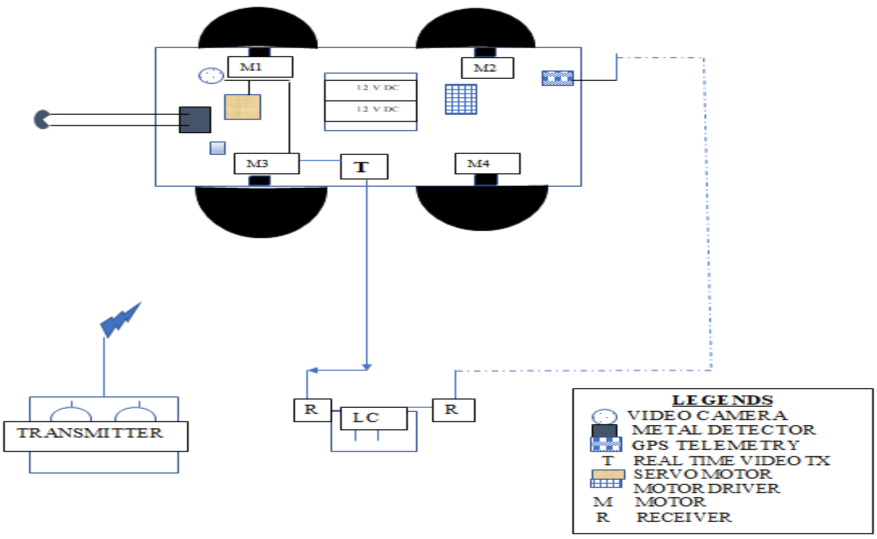

Figure 2

PARTS DESCRIPTION

A. RADIO TELEMETRY & GPS It is a device with two radio modules with antenna that sends radio signals to determine the location of an object. The real-time location of UGV will be determined by GPS. The Radio Telemetry transmits real-time location to receiving station. In the receiving station there is a display system which displays location as shown below. It also displays speed & altitude. Radio Telemetry has mainly three components: Transmitter, Antenna & radio receiver. The transmitter is attached to the body of UGV, whose location is to be determined. In contrast, Antenna & radio receiver are attached to receiving station in Command Post & the same is displayed on the LCD/ LED.

Figure 3

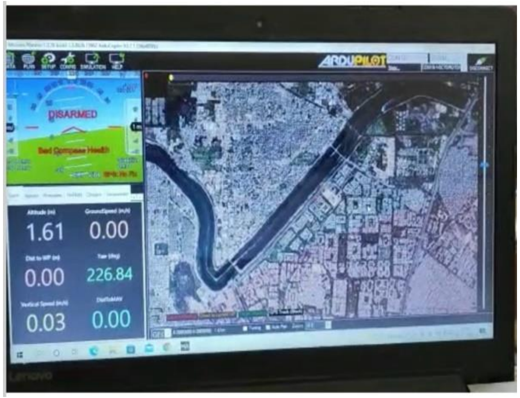

Figure 4

B. ULTRASONIC SENSOR This sensor determines the distance of an obstacle from UGV with the help of Ultrasonic waves. This sensor transmits waves at regular intervals & when there is an obstacle in proximity to the UGV, it alerts the system with a beep. It has a transducer that receives & transmits ultrasonic waves & determines the object's proximity.

Figure 5

C. METAL DETECTOR This device (LM-324) provides safe passage to troops, vehicles & equipment when moving inside an enemy territory or any hostile area. It can detect dangerous explosives & mines. It can search mines & metals hidden inside any surface. In this project, LM 324 metal detector is being used, which works on the Pulse Induction technique. It comprises an Oscillator producing AC at regular intervals that pass through the coil & has an alternative magnetic field. It transmits an electromagnetic field at regular intervals; whenever any metal is hidden inside, it gets energized by EM & retransmits the area, which is detected by the detector. In this manner, metal detector used in UGV detects hidden minefield inside surface & alerts Commanders for possible danger area.

Figure 6 **Figure 7**

D. VIDEO TRANSMITTER CAMERA Video transmitter camera works on wireless communication. Along with the camera, wireless transmitter is used which sends real time video to receiver. During the receiver procedure signal gets amplified, demodulated & passed at low pass filter & thereafter signal gets displayed in LCD/ LED screen. In this project we have used 2 MP camera mini camera which can also be tilted according to user requirement.

Figure 8

E. DC MOTOR Brushed DC motors are used in this UGV so that high torque to inertia ratio can be generated. Locomotion of UGV is carried out through this DC motor. The brushed motor has the advantage of providing almost three to four times greater than rated torque. It consists of two pieces : stator which includes permanent magnets, brushes, housing etc & rotor which consists of output shafts, windings, commutator etc. In this project 12 V DC geared motor has RPM of 300 & 1.5 amp current has been used.

Figure 9

F. SERVOMOTOR It is a closed-loop device that produces torque & velocity based on the current & voltage supplied. Servomotors are controlled by a controller which sends input voltage to the amplifier. Stator gets amplified signal from amplifier & after that, it rotates windings according to the input voltage. The system receives a constant feedback for accurately turning & positioning windings. The servomotors are small, accurate & easily executable. They are used in devices where precision is required. In this project, the steering system & tilting of the camera for capturing images in different directions will be performed through servomotor. In this project, we have used Tower pro micro servo SG90. The Operating Voltage of servomotor is 4.8 V & stall toque is 1.8 kg/cm.

Figure 10

METHODOLOGY

This system comprises two essential components: Control Station & UGV. The control station has primarily two devices transmitter & display system. Crucial components of UGV are DC motor, Servomotor, Video Transmitter Camera, Metal detector Ultrasonic Sensor, GPS, Radio Telemetry & Motor driver. The Transmitter device of the Control Station provides inputs from the user to UGV for locomotion (forward, backward, steering etc.), activation of the camera & metal detector. In contrast, the Display system of the Control Station provides an output of the location & real-time camera. Whenever Transmitter provides input to the UGV for locomotion, DC motors (along with four wheels) get activated. In case of steering action, Servomotor becomes activated & takes control of steering. Similar action for tilting the camera is also done through Servomotor. For determining real-time location, coordinates are determined from GPS & real-time coordinates are transmitted to the receiver in the display system. During metal detection, Electromagnetic wave gets released at regular intervals. When a hidden metal is inside the surface, it gets energised by EM waves & It retransmit EM waves which gets detected by the detector. For live streaming of UGV to Control Station, Video Camera transmits video to Control Station & same gets displayed in LED/LCD. To detect obstacles, the Ultrasonic detector function by sending an Ultrasonic wave at regular intervals & whenever there is an obstacle ultrasonic wave gets reflected by the obstacle, which is received by the receiver, which calculates the distance of the obstacle from UGV. The calculated distance is sent to Control Station. It also alerts the Control station in case of an obstacle which is in proximity to UGV.

Specifications.

Table No 1

S NO	Description	Specification
1.	Dimension of chassis	30 X 24 X 12 (inches)
2.	DC Motor	Four
3.	One way radio	Interlink between UGV & Command Post
4.	Battery	12V 7.5 amp (two)
5.	Sensors	GPS, Ultrasonic, camera, Metal detector

Technical Specifications.

Table No 2

S NO	Description	Specification
Size and Weight		
1.	External Dimensions	30 X 24 X 12 (inches)
2.	Internal Dimension	12 X 2 (inches)
3.	Weight.	20 kg
Speed & Performance		

4.	Maximum Speed	5 kph
5.	Run Time	4 to 5 hr
6.	User Power	12V DC
7.	Torque.	95 Kg cm sq
Sensors		
8.	Video Transmitter Camera Resolution	2 MP
9.	Radio Telemetry	915 MHz, 100 mW (2 way full duplex communication, 5V DC supply Volt)
10.	Ultrasonic Sensor	Range (2 cm to 400 cm)
11.	LM 324 Metal detector	Dimension - (45 X 10 X 8 cm), Operating Volt – 9 V Battery Detection distance maximum – (160-170 mm dagger)
12.	Wireless Video Transmitter	12 V Dc, Range upto 400m
13.	DC motor	12 V Dc, 300 RPM & 1.5 amp current
14.	Servomotor	Micro Servo SG 90, Op Volt – 4.8 V & Stall Torque – 1.8 kg/cm

Figure 11

Figure 12

Figure 13

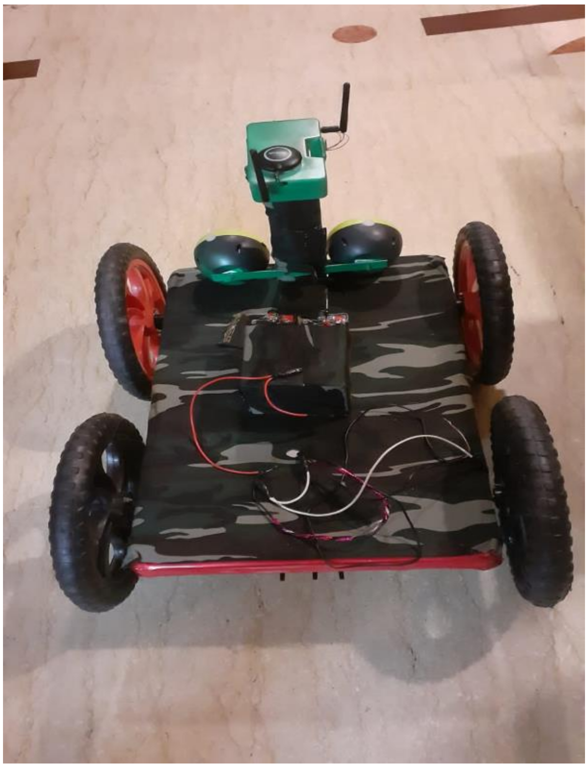

Figure 14

RESULTS

Kinematic simulation has been performed in MATLAB for the developed UGV prototype. As we know the relation between velocity input commands (**ζ**), Jacobian matrix (J(ψ)) and the derivative of coordinates (**η**˙) is given by the following Forward dynamic equation:-

$$\dot{\eta} = J(\psi)\zeta$$

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{bmatrix} = \begin{bmatrix} \cos\psi & -\sin\psi & 0 \\ \sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u \\ v \\ r \end{bmatrix}$$

Simulation has been performed so that the coordinates of the future position of UGV can be calculated based on the inputs provided below.

Simulation initial parameters for Position Propagation & Motion Animation

Initial coordinates	0,0
Step size	0.1 sec
Total simulation time	10 sec
Initial orientation	π / 4
Velocity input commands (u, v, r)	0.1, 0.05, 0
Method	Position propagation using Euler
Length	0.3
Width	0.24
Coordinates of four vertices of Mobile Robot	(-l/2, -w/2) (-l/2, w/2) (l/2, -w/2) (l/2, w/2)

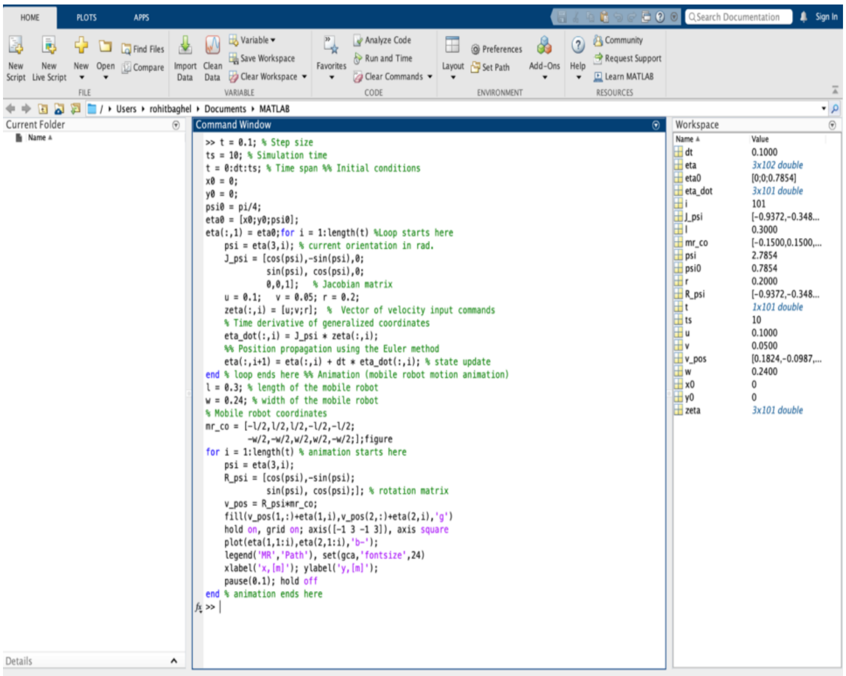

Figure 15

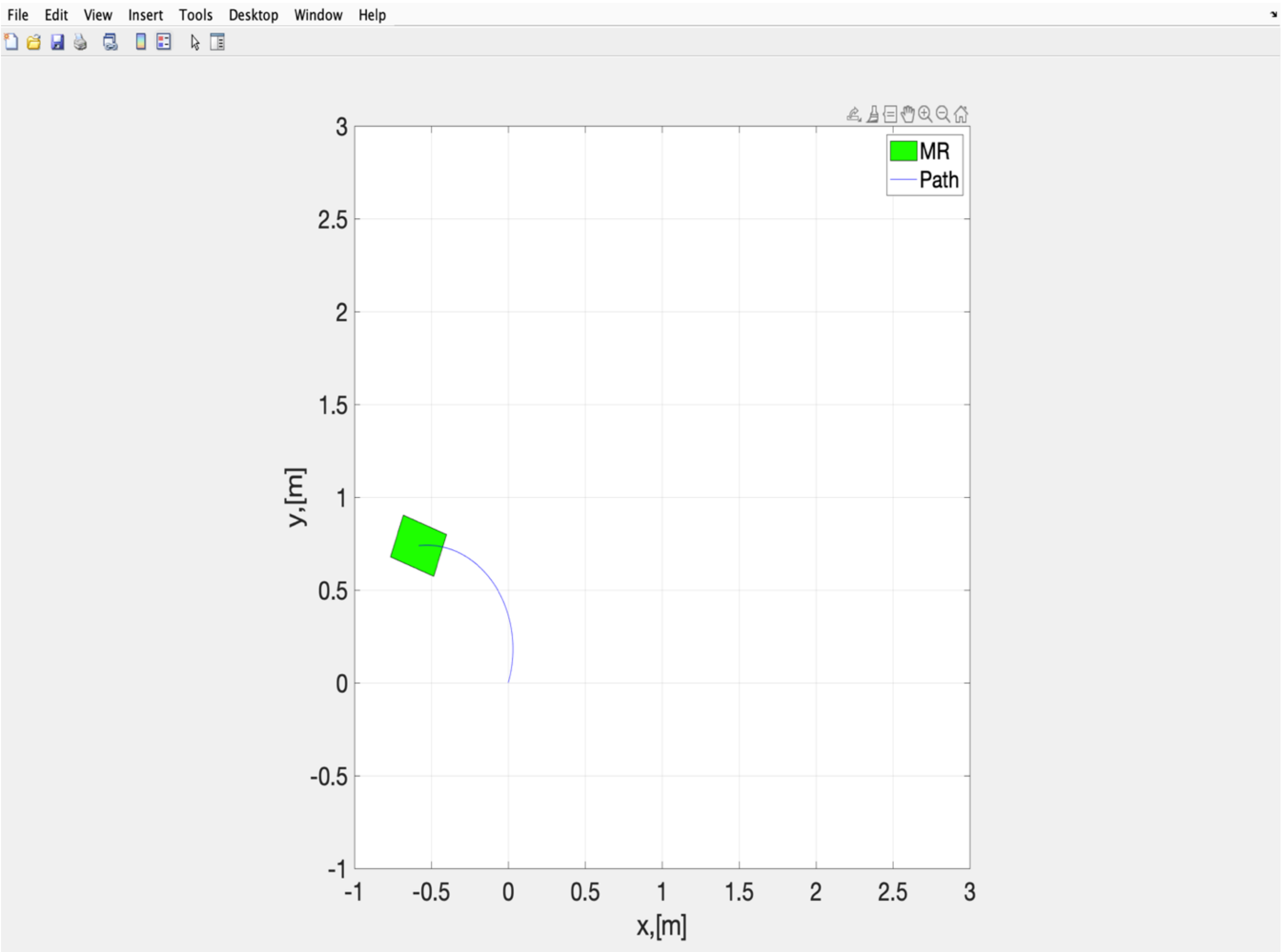

Figure 16

CONCLUSION

The UGV, which has been discussed in this paper, has been successfully developed & demonstrated with full potential. The purpose of the research was to create UGV which can perform multiple operations & does not stick to a single process. It can perform operations like surveillance, reconnaissance, transportation & mine detection. In today's scenario, the battlefield is highly dynamic & requirement of Commanders of Armed Forces changes according to different situations in the conflict. Given this, the prototype has been specifically designed such that Commanders of Armed Forces can suitably deploy it according to specific requirements during conventional or Counter insurgency operations. The design approach has been carried out so that the system is ruggedised & it can be employed in various terrain. The prototype has been deliberately designed for the telerobotic as automation is challenging to achieve on the dynamic battlefield & it provides freedom for Commander to command UGV according to the operational plan. During hostilities, vital information about the enemy can be obtained by deploying this UGV in enemy territory, which will assist the Commander of Armed Forces in securing information like enemy defences, the pattern of the defences & amount of weaponry deployed by the enemy. It will also assist in transporting essential equipment like ammunition, spares, and stores immediately required for replenishment by our forces. It is assumed that conflicts in today's scenario will be swift and dynamic. Therefore, the requirement of the Armed Forces will keep on changing according to various situations & UGV fulfils those requirements because of its functionalities.

LIST OF FIGURES

LIST OF TABLES

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