Tele-operated Ground Vehicle: A Surveillance to War Field

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Abstract One of the most vital problems the world is facing right now is the Terrorism. Government of every nation is spending billions of dollars just to keep safe their citizens and soldiers from the terrorist attacks. Scientists are keeping their research work going on for new defence systems. We have made great strides in the area of defence vehicles. Autonomous robots are now used for various purposes, ranging from delivering food to serving the nation for defence. A robotic system can be manned or unmanned. Our project "Tele-operated Ground Vehicle" (TGV) is built to take care of injured soldiers or persons during an attack. The robot is equipped with advanced defence system. The robot is tele-operated from control station using advanced communication in a very secured way.

Keywords Defence system · Tele-operated ground vehicle · Terrorist attack and autonomous robot · Secured communication

1 Introduction

Day by day the use of robotics is increasing in our life. Robots are now able to perform task on behalf of humans too. Table 1 illustrates the significant types of robotic research start times. An tele-operated ground vehicle (TGV) is a vehicle that runs on the ground without the presence of a human on board. We can use TGVs at places where human interpretation can be dangerous or hardly possible.

TGVs can be actively used in both the civilian and military sectors to conduct critical operations [1]. We have already seen explosive and bomb disabling vehicles. This TGVs can easily go to places where a human cannot reach. In case of earthquakes, we can use TGVs for searching purpose in the debris. Currently, governments are supporting this type of research work to members of the armed forces and civilians.

In this work, we have tried to use the TGVs for rescuing injured soldiers. Technically, the vehicle will observe the environment with the help of its pre-installed sensors, and will make a decision autonomously or it will pass the information to its nearest base station. Then it will work according the instruction of the human controller. The TGV will take the injured soldier to the nearest army base station where the treatment of the soldier will take place.

1.1 Related Works

The authors in [2] propose the concept Pibot model, which refers to the local network and can be controlled by anyone, anytime, anywhere. They also claim that the local network can be any place, e.g., home, office, prisons, or anywhere temporary or permanent monitoring is required - just connect the network and the robot is ready for use.

A new approach for precision indoor tracking of tele-operated robots is proposed in [4], called "Heuristics-Enhanced Dead-reckoning" (HEDR) shown in Figure 1. HEDR uses odometry and a low expense MEMS-

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Table 1: The Ongoing Development of Robotics Research Involving Mobile-robots, Nature-inspired Robots, and Robotic Arms [3]

Type of Robot	Sub-Class	Year
Mobile Robot	Mobile Robot and Multi-Robot	1968 and 1990
Nature Imposed Robot	Walking Robot and Humanoid Robot	1968 and 1972
Robot Manipulation	Industrial Robot and Flexible automation	1960 and 1990

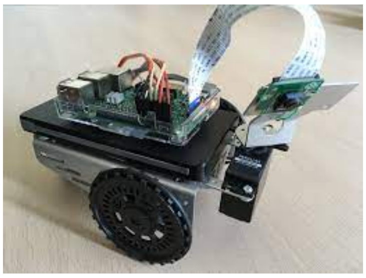

Fig. 1: Pibot

Fig. 2: Remote controlled Robot for surveillance

Fig. 3: iRobot PackBot

based gyro for navigation ambition. The aim of this study is to provide the map view of the robot's current location to the user. In [3], a new method for robot surveillance with tracking and obstacle avoidance for general purpose indoor robots is presented in Figure 2. Algorithms are implemented in the robot for receiving commands from the remote controller and avoiding obstacles while manoeuvring. The work done in [5] introduces a communication system which has a variety of features optimized for the UGV used. The communication system does not fully comply with the Joint Architecture for Unmanned Systems (JAUS) specification, which leads to compatibility problems when communicating with other UGVs. However, the system focuses on communication inside a UGV and resolves performance issues and improves stabilities by applying different techniques to implement communication inside of a node and between nodes.

The research is conducted by *Cubber et al.* in [6], in this field likely focuses on developing algorithms and techniques for efficient multi-modal data fusion, robust terrain classification, obstacle detection, and adaptive path planning specifically tailored for all-terrain crisis management robots. Their work contributes to enhancing the capabilities of such robots in navigating and operating in challenging environments during crisis situations. The robot is called iRobot PackBot shown in Figure 3.

The paper [7] presents the Integrated Components for Assisted Rescue and Unmanned Search Operations (ICARUS) project, which aims to develop advanced robotic systems for assisting in search and rescue operations. The project focuses on the integration of different robotic components and technologies to enhance the capabilities of rescue teams. The authors emphasize the importance of effective command, control, and intelligence capabilities in rescue robotics. The C2I aspect involves the development of software systems and algorithms for coordinating multiple robots, managing mission plans, processing sensor data, and enabling intelligent decision-making in dynamic and unpredictable rescue scenarios.

1.2 Contributions

We have reached a solution to solve the problem of rescuing wounded soldier from the battle field. We have developed an unmanned rescue ground vehicle which has its inbuilt defence system like gun, missile launcher and bullet protective shield. To rescue the soldier, it tracked the soldier and rescue them safely back to camp. Every vehicle has different controller and controlled by different people. This vehicle can be manually assembled the required parts for multi-purpose usage in different

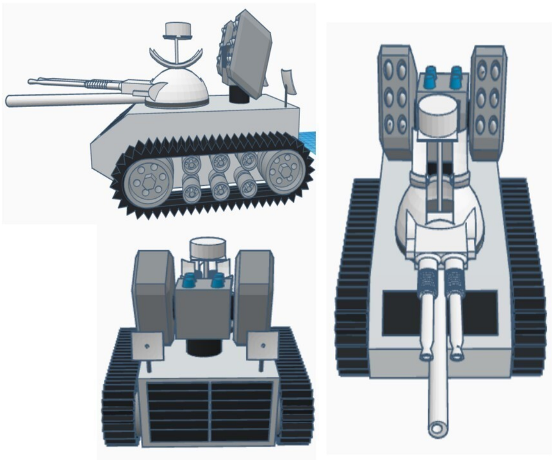

Fig. 4: Diagram of the Proposed Model

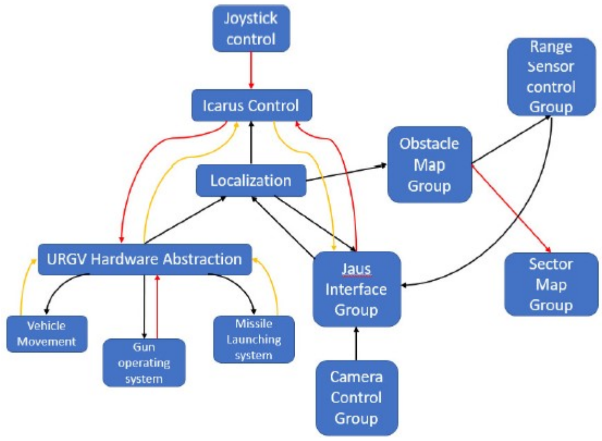

Fig. 5: Block diagram of Control Structure of the Proposed System

functionality. The capabilities available to accomplish the UGV mission are as follows:

- Automatic victim detection.
- Creation of material map based on Light Detection and Ranging (LIDAR).
- Multi-modal human-robot interaction.
- Bullet resistance vehicle body.

2 Mechatronics of the Tele-Operated Ground Vehicle (TGV)

2.1 Design Concept

The major source of power is a diesel engine, which drives a hydraulic piston. The latter is responsible for injecting oil into the pistons that power the two tracks. The oil flow also powers a turbine connected to a generator, which produces 220 volts alternating current.

Because of its large caterpillars, which allow in-place rotation, TGV has considerable mobility on rough terrain, as shown in Figure 4. The end-effectors can be outfitted with a variety of tools, including a gripper, a rifle, and missiles. Running on a computer connected to a PLC, which works directly with the low-level hardware, is the control application. The manipulator has its own controls that are connected to the main computer.

2.2 Sensor System

The TGV's location and orientation are provided via a global navigation satellite system (GNSS) and an inertial measurement unit (IMU). Because of the enormous amount of space available on the TGV, two GNSS antennae may be installed, allowing for more precise location measurement.

A stereo camera system is mounted on the front part of the web tower to create a dense 3D point cloud for mapping and obstacle detection. Live streaming is performed using an MJPEG streamer. It collects photos at regular intervals and then overwrites them to create the illusion of a continuous video stream. Since the range is greater than a time-of-flight camera, the stereo camera system was chosen. The MJPEG Steamer streams video based on the principle of time-lapse photography. For direct visual feedback, the remote operator uses one of the stereo camera systems.

3 Control System

The first step towards autonomous vehicles is for the vehicles to travel about their environment on their own. This necessitates the cars sense their environment, create models, and then plan paths. The vehicle is controlled at a range from a tele-operation centre via a radio frequency link, the image is transferred through wireless medium, and the tele-operation station is created in C++ software, that standardizes the cameras and transmitting commands, and manages mobile control via a joystick [8].

It is well documented that externally imposed hierarchical structures can be used to reduce the complexity of a learning control system shown in Figure 5. Courses of action are abstracted (by hand) into capabilities within this given hierarchy, and the robot is limited to fine-tuning the given capabilities [9]. It is apparent that allowing the computer to learn the hierarchical structure independently is a critical step towards adopting more generally relevant behaviours.

Geometric knowledge is critical but not sufficient to ensure successful navigation in foreign contexts. Many navigational obstacles cannot be described by a geo-

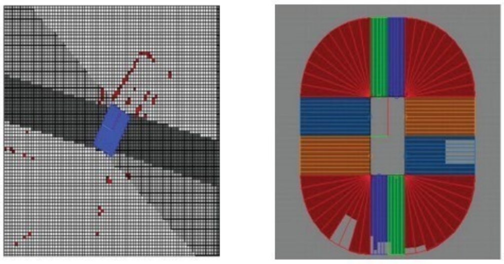

Fig. 6: Grid Map and Sector Map [7]

metric model alone [10]. Geometric models do not include obstacles such as soft ground, snow, ice, mud, loose sand, trash hidden in foliage, and nuisances such as small ruts and washboard effects [9]. Sensors such as colour vision, texture, infra-red imagery, and instrumented bumpers are used to detect these features and circumstances. In addition, many of these landscape features change from place to place, season to season, and even hour to hour. For this, we use the Learned Traficability System (LTS), which helps the vehicle learn, adapt, and take the necessary actions in any situation.

4 Mapping Navigation of TGV

Both robots have a suitable mapping system. It analyses the information about the environment collected by the sensors and translates it into a format that the collision avoidance system and the human operator can use. This system is composed of the following components [11]:

• Laser range finders (LRF) combined with a stereo camera (LUGV only).

• Sector map and Grid map, as depicted in Figure 6.

The LUGV is equipped with two LRFs, one in the forward and one in the rear. Both are linked to a section bar construction that is joined directly to the bumpers. A SICK LMS511, a weatherproof and dust-resistant planar laser scanner, is used as the sensor. The scan features an 80 m scan range, a 180° horizontal FOV, and a 1/6° minimum angular resolution. As the sensor frequency is set to 10 Hz, each device must do 10 scans every second, producing 1080 planar points for each scan. Both of the vehicle's laser scanners are partially enclosed by its bumpers, so if obstacle detection is unsuccessful and an object is struck, the bumper will be the first to be damaged rather than the more expensive and sensitive laser scanner.

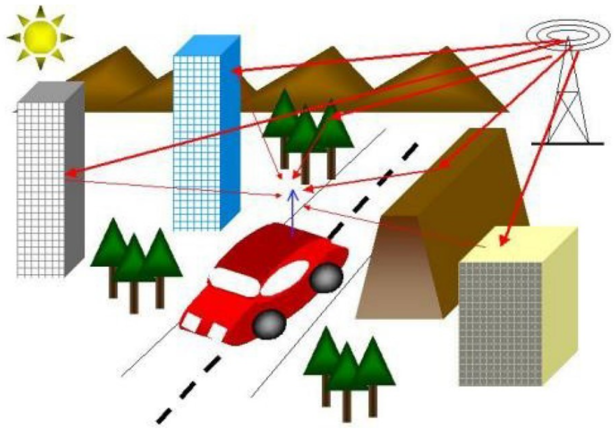

Fig. 7: Multi-path effect on a rover receiver

5 Communication System Used

In this project work we are using the non-line of sight communication system as the vehicle is going to operate in the region which is partially obstructed the route between the signal's emitter and its reception location. Barriers include trees, buildings, mountains, as well as other man-made or natural barriers or items.

To modulate the signal, we use the coded orthogonal frequency division multiplexing system. It is a telecommunications system which accepts frames of k bytes as input, modulates data based on bandwidth, and transmits information at high speeds across communication channels using coding and error correction procedures in the receiver. COFDM combines modulation and coding blocks to form a digital data compression technique. The major characteristics of COFDM are as follows:

• Coding against error.

• Interleaving of data carriers in terms of frequency or time.

• Channel status information paired with flexible split decoding to improve Viterbi decoder performance.

By varying the effective response in the channel frequency, COFDM receivers in motion (shown in Figure 7) generate a selective fading in time and frequency in each carrier signal. In order to establish the maximum number of carriers that the Orthogonal Frequency Division Modulation (OFDM) symbol will have, this impact is regulated by predicting the spacing between two carrier signals based on the Doppler frequency which is a function of the fastest speed at which the receiver would travel and repair of receiver faults.

5.1 COFDM Transmitter

The Viterbi decoder in the COFDM demodulator performs better when the data bits are distributed evenly among the carriers within an OFDM symbol, which

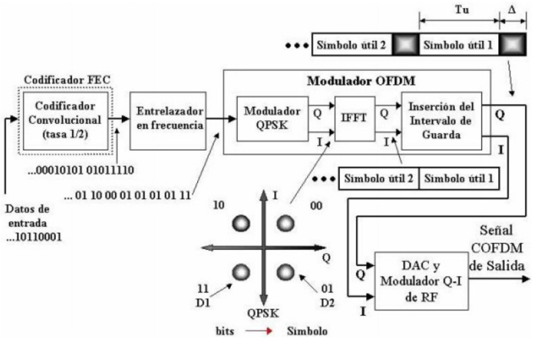

Fig. 8: Diagram of the COFDM Transmitter

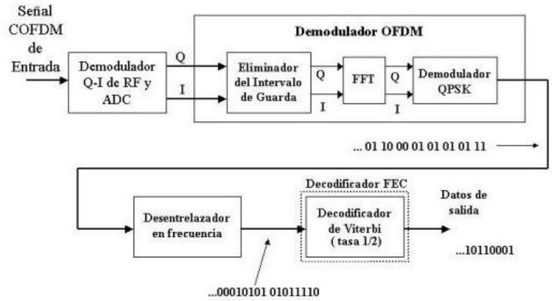

Fig. 9: Diagram of the COFDM Receiver

is achieved by the COFDM transmitter, allowing it to transmit a string of bits that enter the convolution encoder, giving redundancy to the transmitted bits by correcting errors in the demodulator, and then several are grouped of bits in the frequency interleave to randomize it. The diagram of COFDM transmitter is shown in Figure 8.

The calculation of the bandwidth (BW) in Hz is defined as the ratio of the number of carriers, denoted by N_p, and the useful symbol duration, denoted by T_u. Mathematically the BW may be represented as

$$BW = \frac{N_p}{T_u} \tag{1}$$

The transmitted bit rate in bits/seg, denoted by T_b, is defined as

$$T_b = \frac{N_p}{T_u + T_c\triangle} \times N_{bm} \tag{2}$$

The number of bits per symbol in the schema modulation used by data carriers is denoted by N_{bm}. The FEC encoder rate is represented by T_c, and $\triangle$ is the guard interval duration.

5.2 COFDM Receiver

The COFDM receiver, shown in Figure 9, receives the signal going into the RF demodulator and the analog Q-I output is converted to digital Q-I digital using two converters. Feed the QI baseband signal into the OFDM demodulator. The function of this OFDM demodulator is to remove the stored intervals and thus remove the first sample containing the guard interval. An FFT is then performed in which the 8 samples to be processed are grouped to give 8 symbols each to be demodulated by the demodulator.

5.3 Antenna Used

For transmitting the signal from operation center to vehicle and vehicle to center using Omni-directional antenna shown in Figure 10. This antenna was chosen

Fig. 10: Omni directional Antenna 480-520 MHz

Fig. 11: Transmission port of SG-T5000s

Fig. 12: HD Digital Video Recorder

because it has the potential to broadcast a signal in all angles, characterizing its shape as a flat oval; its major application is in open spaces; it is generally used with a voltage jump filter to minimize electrical storm difficulties; and its gain ranges from 15 to 20 dBi.

This antenna was used:

- One to send footage from the vehicle's PTZ camera to the receiver.
- One for sending data from the wireless module to the receiver.
- One for data transfer from the computer to the vehicle.

The necessary calculations for the installation of an antenna are as follows:

1. Antenna range:

$$D = 3.6\left(\sqrt{A_1} + \sqrt{A_2}\right) \tag{3}$$

Fig. 13: Wireless data module

where, A_1 and A_2 are the transmitting and receiving antenna height in meters. The maximum emission distance in kilometres is denoted by D.

2. Wavelength calculation: The wavelength λ in meter is defined as,

$$\lambda = \frac{\delta}{f} = \frac{3 * 10^8}{490 * 10^6} = 0.6122m \quad (4)$$

where, f and δ represents frequency (Hz) and Speed of light $3 * 10^8$ m/s.

3. Antenna length: The antenna length L in meter is defined as,

$$L = \frac{\lambda}{f} = \frac{0.6122}{2} = 0.31m \quad (5)$$

6 Components Used in Transmission System

6.1 SG-T5000S

The SG-T5000S transmitter was chosen for the development of this project, in charge of transmitting video from the analogue cameras found in the vehicle. The 2 MHz bandwidth is the one that determines the transmission speed. For transmitting we are using the Portable Audio Video Transmitter in security systems SG-T5000S shown in Figure 11 and for receiving HD digital video receiver is used, shown in Figure 12.

6.2 Wireless data module

Figure 13 depicts a module with high stability and reliability in VCO structure, data transmission with fault systems, and rectification software design using sophisticated mathematics that uses a double phase-locked loop. The transmission capacity provides transparent protocol, data gathering, command interpretation, addressing, and other operations that can relieve CPU burden.

6.3 Quad multiplexer video server

The QUAD, shown in Figure 14, enables you to watch multiple analogue video feeds on a single monitor. It may display four quadrants on the screen that correspond to the four cameras you want to view. Its image compressor digitises the video signal, compresses it into the appropriate quadrants (each Quad is built for 4, 8

Fig. 14: Quad and multiplexer SP − 460B

Fig. 15: PTZ camera

or 16 cameras), and then conducts time correction by synchronising all the signals so that when the final video signal is produced, it plays back at the correct time.

7 Electronics Devices

This section will discuss everything relevant to the electronic component, including cameras, motors, and power circuits used in this project.

7.1 Surveillance camera

The PTZ camera shown in Figure 15 will be in charge of tracking the environment where it is mobilised and will offer great quality indeed when utilizing the zoom. PTZ cameras offer recording capacity, high resolution, remote control, and the ability to track moving objects thanks to the camera's mobility. For setting the variation of the zoom level, the position is specified as the relationship between the needed zoom and the default zoom limits.

$$position = \frac{(desired\ \ zoom\ \ position)}{(zoom\ \ limit)} \times 65535 \quad (6)$$

7.2 Choice of Engines

For the advancement of vehicle motion systems which create and direct the motion of the mobile we are using Ebike MY1016DC motor as depicted in Figure 16. The installation, operating mode, and required maintenance must all be considered, followed by the power

Fig. 16: Ebike MY106 DC motor

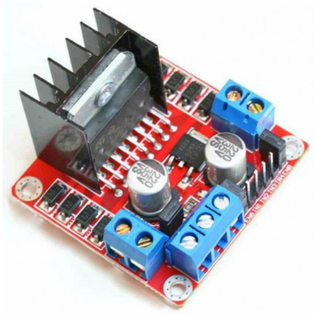

Fig. 17: L298 Motor-Driver

Fig. 18: RS-232 to RS-485 converter

supply, nominal power, rotation speed, duty cycle, load coupling, and motor type.

7.3 Power stage for engines

A power and control stage is required for the chosen motors, with a "H-Bridge" permitting control of the amount and direction of current flow through the motor. The L298 power circuit device, shown in Figure 17, can control the motors' direction of rotation at an output current of up to 2A. The design is unique and minimises interference while operating at an input level of up to 46 V.

7.4 Serial Communication

We are using RS-232 to RS-485 converter shown in Figure 18 is used for converting serial interfaces to intelligent instruments extends connectivity up to 1.2 kilometres and enables for asynchronous data exchange. The PTZ camera's data transmission was converted using this converter into a wireless data transmission module that can handle RS-232 connectivity.

Fig. 19: TK-102B GPS pin configuration

Table 2: Frequency Range

Band	Interior Frequency	Frequency Higher
UHF	300 MHz	3000 MHz

7.5 Selection of GPS/GPRS

A TK-102B GPS Configuration was selected at this stage of the project's development since it will deliver data such position; speed; and time; features that will aid pinpoint the location of the vehicle. It runs on a 3.7 V rechargeable lithium battery that keeps going for around 12 hours, communication with the integrated display system, price, size, and weight. After reviewing the GPS TK102B, shown in Figure 19, it was determined that it was one of the finest solutions available and met all the requirements. The platform is not very large, and all electrical gadgets must be present without generating any sort of interference.

7.6 Lithium Battery

The lithium battery is considerably more environmentally friendly, which is crucial in this era of intense pollution. It also has a significantly shorter recharge time than a normal battery, making it much more profitable for vehicles by reducing downtime. Other crucial elements for the creation of this project's construction include weight and geometry.

8 Frequency Band Selection

Due to the low power of the equipment used, a UHF (Ultra High Frequencies) band of 490 MHz is selected for data transmission and reception. UHF frequencies are handled between 300 and 3000 MHz. The frequency and wavelength characteristics are shown in Table 2 and Table 3 respectively.

Table 3: Wavelength Range

Band	Wavelength Inside	Wavelength Higher
UHF	$\lambda = \frac{3*10^8}{300*10^6} = 1m$	$\lambda = \frac{3*10^8}{3000*10^6} = 0.1m$

The mathematical expression for channel spacing may be expressed as follows [12]:

$$B_n = 2\,(M + DK) \tag{7}$$

where B_n is the nominal band, M is the nominal band with maximum modulation frequency, D is half of the difference between the maximum and minimum values of the frequency and K is the factor that varies according to emission and it depends on the distortion $K = 1$.

The FRESNEL zone is calculated as follows [12]:

$$r_n = 547.723\sqrt{\frac{n * d_1 * d_2}{f * d}} \tag{8}$$

where, r_n is the radius of the $n-$th Fresnel zone $[M]$, d_1 and d_2 is the distance from the transmitter and the receptor to the object $[KM]$, d is the total distance of the link $[KM]$ and f is the frequency in $[MHz]$.

9 Conclusion and Future Scope

This paper introduces a communication system which has a variety of features optimized for the TGV used. To accomplish the TGV mission several availabilities like victim detection, Creation of material map based on LIDAR, Multi- modal human-robot interaction, Bullet resistance vehicle body and MJPEG streaming system are there in our system. For futuristic work it can upgrade the automatic victim detection without any human interference and can be upgraded from diesel engine to electric vehicle engine so to protect the environment from pollution.

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