TACTICAL UNMANNED GROUND VEHICLE FOR CLOSE-QUARTERS SURVEILLANCE & COMBAT

MACHINE DESIGN

7 DISRUPT

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Motivation

During the 2nd Counter-Terrorism week, India's representative, Mr. T. S. Tirumurti, quoted to the United Nations that India has been a victim of terrorism, especially from across the border, over the last several decades[1]. Two of the most deadliest attacks on Indian State Security Personnel in the past two decades were the 2016 URI Attacks, where four terrorists attacked an Indian Army brigade headquarters in Uri, near the Line of Control, and 2019 Pulwama Attacks, where a convoy of vehicles carrying Indian security personnel on the Jammu–Srinagar National Highway was attacked by a vehicle-borne suicide bomber. In the 2016 Uri Line of Control Attacks, 17 army personnel were killed and an additional 19-30 soldiers were reported to have been injured, where 2 more succumbed to death. The Pulwama Attack killed 40 Central Reserve Police Force (CRPF) personnel.

Different regiments of Indian Army include armoured corps, infantry, gunners, army aviation and corps of engineer. Despite all the mechanization and fighter jets, missile systems infantry is considered the most important part of the arm, reason being they drag the last enemies from their bunker to mark their defeat and win the war[2]. Despite of the Line of Control barrier, which consists of double-row of fencing and concertina electrified wire 8–12 ft in height which is also connected to a network of motion sensors, thermal imaging devices, lighting systems and alarms with thousands of landmines, the incidents of infiltrators trying to sneak in are not uncommon. During the conduct of Counter-Insurgency (CI)/ Counter-Terrorist (CT) operations, accurate and real time inputs are critical for success and to ensure minimal collateral damage. During the conduct of CI/ CT operations for the desired high degree of situational awareness and effect on targets, manual methods of surveillance and combat are being employed as of now in India. Present manual methods of surveillance and combat in CI/ CT operations result in collateral damage as well as casualties of our own soldiers. Over the past 30 years, over 6,500 were martyred in terrorist attacks [3].

Figure 1: Indian Soldiers employed for surveillance of India-Pakistan (left) and India-China Borders (right), day in - day out.

[1] https://www.indiatoday.in/world/story/cross-border-terrorism-countries-safe-havens-india-un-1819660-2021-06-26

[2] https://indianarmy.nic.in/

[3] https://www.satp.org/satporgtp/countries/india/states/jandk/data_sheets/annual_casualties.htm

Vision & Necessity

We aim at developing a tactical Unmanned Ground Vehicle (UGV) for **surveillance** for accurate and real time inputs and obviating the inherent risks to soldiers during the conduct of Counter-Insurgency (CI)/Counter Terrorist (CT) operations. The solution to this problem statement will be an extremely useful case for Infantry, RR and Special Forces Battalions employed in the conduct of CI/CT operations. Increased technological threshold has manifested in more precise targeting, a very high degree of situational awareness and intense operations with minimal collateral damage. Tactical UGV can be employed to provide accurate, real time inputs and engage the enemy/terrorists during Hostage Rescue, Close Quarter Combat, etc., during the conduct of CI/CT operations. It will also obviate the inherent risks to the soldiers during these operations.

As was quoted in an executive summary, dismounted ground combat troops carry 40 to 65 kg or more in combat. Heavy loads reduce mobility, increase fatigue, and reduce mission performance[4]. Heavy loads not only affect the mobility, but also decrements the situational awareness, leading to a measurable decrease in shooting response time. The development of improvised armours, usually make the job of soldiers more difficult due to increased payload. The need to optimize the equipment to improvise the probability of survival has grown exponentially over the years. As an engineer, we find it our moral responsibility to come up with a **compact design solution** which is optimised for both, the tasks at hand and payload for soldiers. We aim to achieve an **optimized payload** of ~ 40 kg.

India shares its Land Borders with Bangladesh, Bhutan, China, Myanmar, Nepal, Pakistan and Sri Lanka. India-Pakistan border includes the following terrains:
- Rajasthan: Desert which have a shifting land pattern with air and sand, 100m sand dune can shift itself! Barmer desert region is also muddy and marsh. Near the Rann of Kutch, salt dissolved in air can burn and damage skin on long exposure.
- Gujarat: Rann of Kutch has salt dissolved hot air and marshy-muddy land. Special all terrain vehicle is designed for this terrain for army.
- Jammu and Kashmir: Rivers running between India and Pakistan, valleys, snowy mountains, rocky mountains, glaciers and wild grassfield.

We aim at targetting a variety of terrains, comprising valleys, spiky-rocky terrain, rain-forest and dry dusty sharp rocky terrain.

Figure 2: Terrains of India Borders: rocky mountains, glaciers and snowy mountains and dessert.

[4] https://www.cnas.org/publications/reports/the-soldiers-heavy-load-1

Existing Solution

Contemporary Solutions by Other Countries/Organizations include DOGO (Mark II) by General Robotics. On the mechanical front, DOGO robot is capable of weaponized shooting, handling tough terrains and climbing stairs. The robot is bag-pack-able light-weight ($\sim$ 10 kg) and compact in size ($49 \times 14 \times 38$ cm^3). The robot is also proficient in audio transmission for 2-way audio negotiations, 360 degree monitoring for situational awareness, enemy detection and auto video motion detection. The robot is also equipped with point and shoot technology and is integrated with standard 9 mm pistols. It is also equipped with non-lethal pepper spray and dazzling light module which generates intense flickering light to dazzle the target and create a diversion from a distance of up to 10 meters. The faster point and shoot interface enables accurate designation of lethal or non-lethal means.

Figure 3: DOGO (Mark II) working prototype by General Robotics.

Goals

- Maneuver in difficult terrains
- Navigation using existing mapping of the region, to work in coherence with existing technology and knowledge
- Origami design to make the parts come into multiple use
- Surveillance of the region for 360 degree monitoring
- Rescue aid in case of hostages
- Ability for 2-way communication for negotiations
- Origami inspired design to make it easy to transport, store and deploy
- Grenades and land-mine detection with self-protection ability
- Bullet-proof origami jacket
- Point and Shoot with Friend and Foe distinction
- Ability to recoil from ammunition

Usage Scenarios

Terrain

India shares its land borders with seven other countries. Given that the length of our land borders is large, it is accompanied by various geographical features and variations. The terrains of our borders vary from marshy mussy land with salt dissolved hot air to damp wild grass fields and rain-forests with rivers and drainage.

A significant part of our heavily militarized border comprises the mountains and valley with terrains having spiky rocks, an abundance of loose dust and dry air. Many of the hills are steep, with inclinations lying in the range of 60-80 degrees. This makes it difficult and tiring for soldiers to carry a load of 40-50 kgs uphill to reach their posts or vantage points.

Military operations are also targeted towards hostages/terrorist activity. This terrain could be like an apartment with multiple levels.

Element of Surprise

In any military operation the information of the troop position being secret is very critical to the success of the mission. In addition to this, knowing what's ahead in their path help them plan the next move wisely. This increases the chance of success of their mission and decrease chance of harm to the soldiers.

Destroying Enemy Bunkers

Bunkers and hiding zones are the one which help soldiers survive a war. These help soldiers stay stay while attacking at the ones who approach them from open. Hence it often get difficult to recapture an area in-case enemies have set up their bunkers. Most of the causalities occurs when our soldiers try to advance in open to destroy enemies bunker.

Navigation

Global localization is very important for the bot to work in the autonomous mode. The localization will serve 2 important needs. The localization would serve as feedback to the controller when commanded to move from position A to position B (in military operations these location are often provided in form of latitude and longitude) by giving real-time feedback of its measured position. The Mapping of the environment would help the soldiers to know the environment ahead of them even at night because of mapping. The main goal of global localization would be to create an approximate map of the environment as well as sending the continuous position of the device to the base.

The distance which the troop covers on foot is about a few kilometers with the time of operation being a few hours. This includes stand-by time when the troop waits for command from base or for a perfect time of attack.

Yet another challenge and problem in navigation is landmines and bombs. The soldiers needs to be careful of landmines and bombs while moving towards the enemies. As the use of robots in war zones has increased, the application of these robots has also diversified.

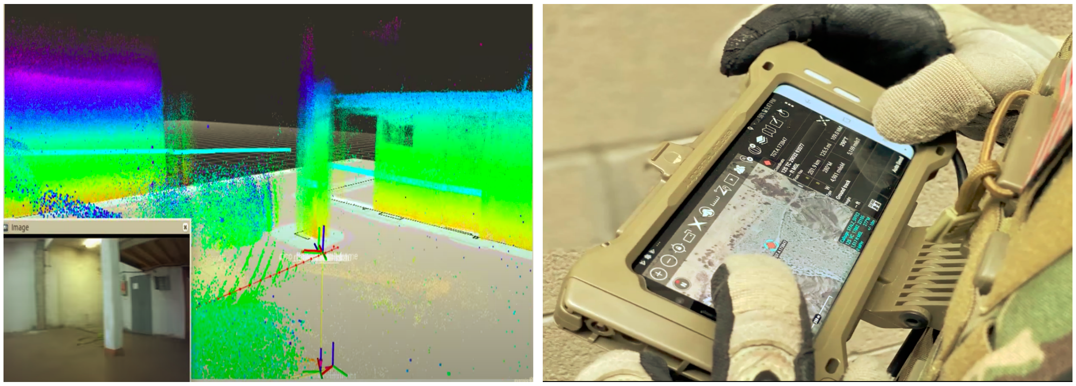

Figure 4: Device mapping the surrounding as well as sending its live location at receiver end

Roadside bombs have been detected by robots such as Fido. Soldiers can use these robots to search caves-buildings for insurgents, detect mines and ferret out roadside and car bombs.

Automatic Enemy Detection

In the war zone or surveillance mission, one of the most important task is to identify enemy location, who are either hidden or out of field of view of the soldiers. The robot should be capable of automatically detecting enemies using machine learning based **human detection**.

To discover the hidden enemies in bushes or land we would use **camouflage detection**. These task would be done using the high resolution cameras and it would show the enemy view to the receiver end giving them ability to directly shoot the enemy .

Figure 5: Enemies using camouflage technique to hide in bushes and rocks

We plan on incorporating a **point and shoot technology** in the robot with the capability of **friend and foe detection**. The robot will allow **two-way communication**, thus enabling the receivers to make the decision of shooting. We don't aim at making the decision of shooting autonomous due to ethical issues.

Functional Requirements

Terrain

As stated above the soldiers already carry a lot of weight with them , so adding onto the same would solve no problem. Hence we instead want to design something which can march alongside soldiers carrying their equipment and arms. The robotic solution which we build should be capable of maneuvering through above discussed terrains.

Figure 6: *Left*: A robot carrying the load, which can march along with the army. *Right*: A drone carrying explosives, which ultimately destroy the enemy bunker.

Destroying enemy Bunker/Attacking

As we want our bot to carry heavy equipment, the size of the bot will be big, meaning it can't move without being spotted for surveillance. Hence, we need to have a detachable part of the product which can maneuver on a similar terrain and can move without being spotted when needed and survey an area or carry explosives to an enemy's bunker.

In addition we also want to have a point and shoot mechanism on our bot. For this the bot has to be able to effectively transfer the recoil energy to the ground without losing its stability. A mechanism for pointing the gun in required direction with ability to differentiate between friends and enemies needs to be developed.

Element of Surprise

We need to minimize noise while travelling. In addition it should be electronically invisible, meaning it must not make use of any such signal or sensor which can compromise its location.

Simultaneous Localization and Mapping (SLAM)

The localization of the device which is passing through uneven terrain or for whose sensors are highly unstable or performing fast maneuvers is a challenging problem in the SLAM domain. The primary requirement of the SLAM system would be to send accurate feedback with errors less than 5 cm on plain terrain(housing operations) and less than 12 cm on the uneven environment (forest operation) in the run of up to 500 m.

Energy

It is crucial to discuss the energy requirements of the bot since battery life often turns out to be a bottleneck in robots and other electrically powered devices. In our case, the energy requirements of the bot would be quite high since it has to perform a variety of functions like mobility, mapping, point-and-shoot and two-way communication. The energy requirement is also affected by parameters such as type of motion, weight of the bot etc. Increased energy requirement means that a battery of higher capacity will be required. This would cause an increase in the weight of the battery, which in turn increases the weight of the bot. This produces a vicious cycle wherein the weight of the bot and its energy requirement keep increasing. There may be a number of engineering problems that we will have to solve to build a lightweight and energy efficient battery. Some of them are:

- Target range (distance)
- Target life (standby time)
- Cell configuration (determined by the ratings of the components used)
- Charging considerations

Landmine and Bomb Sniffing Technology

The integrated sensor module can sniff bombs and at the same time use the on-board camera to send images to the ground station. A manipulator arm can be used to move the sensor along the underside of the vehicles and difficult the access areas.

Understanding ambiguous situations usually help prevent casualties. It is also one of the safer ways to detect landmines in war-zones.

Engineering Requirements

- Payload Capacity : 40kgs
- Volumetric Payload Capacity : 1.2m*0.5m*0.3m
- Noise level less than : 30 dB
- Climb slope of upto 60 degrees
- Climb stairs of height upto 25cm
- Range of the bot : 3km
- Smaller detachable bot of size: 50cm*50cm*20cm
- Smaller bot payload capacity : 1kg
- Send and receive signal from base upto distance of 5km
- Position error of less than 5cm on plain terrain over the run of 500m
- Position error of less than 12cm on uneven terrain over the run of 500m

Team Roles

Designing Multi-Terrain Bot

First and most important challenge of the team would be to design a optimal sized bot which can move on rocky terrain with slope of upto 60 degrees. This bot is supposed to carry a payload of 40kg and the noise level of the bot is also restricted. For all these requirement we will have to be wise in selecting our actuator.

The three challenges identified here are terrain, payload and noise level. We shall start studying the existing design under these three parameters. The knowledge acquired from the same along with our own understanding of mechatronics shall help us find an optimal solution for the same.

Optimize Design based on Upcoming Technology

We shall focus on creating solution to our problem using newer techniques of origami or soft robotics to the extent possible. We plan to reduce redundant parts to reduce the energy requirement as well as cost of the product. The smaller bot which we planned to include in our product shall include all the sensors and processing unit. Such that when detached it acts as an autonomous unit in itself. While when the two are attached the same sensor and processor comes in use of the whole bot.

Algorithmic Development

We intend to make the product autonomous to the extent possible. This would require us to work on computer vision, SLAM, path planning and controls. In the process we would make sure that our bot can make use of information available with the army (map, location to navigate to etc). In addition we will make our code modular such that the same piece of code could be used at different places with similar actions. This requires building independent packages for different actions/measurement and stitching them together with some robotic framework.

Electrical

To make our bot capable of carrying out the tasks mentioned we would need to mount various sensors and actuators. This would require us to build a proper circuit to interface these with the processor. This also calls for effective battery management and packing to optimise the range and time of working of bot.

Subsystem Leads	Tasks	Engineers
Mechanical	Material Selection/ Failure analysis	Kratik Bhadoriya and Barath Krishna
Design	Optimization/Origami designs	Mitalee Oza and Shubham Agrawal
Computer Vision	Enemy Detection/Perception	Rishab Khantwal and Kritti Sharma
Controls	Dynamic Simulations	Aman Malekar