A GIS ROBOTICS (SLAM) PLATFORM FOR LAND MINE DETECTION AND MAPPING

FINAL YEAR PROJECT UG 2016

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This is to certify that

Final Year Project Titled

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ABSTARCT

Landmines clearance have always remained a crucial task in peace support operations. In Pakistan that is going through tough peace conflicts, this task has gained importance to save the lives of the military personnel as well as general civilian who might get injured or even die because of these uncleared mines. Currently techniques being used for efficient detection and removal of mines are based on the use of UAVs that search the complete area for detection of mines and then either mark them or detonate them. With the diffusion of geospatial technologies with the existing infrastructure, the induction of geographical information is ever increasing. To overcome the discrepancies in the existing systems such a solution is required that is able to detect the mines and map them accurately in real time so as to save time and also is cost efficient. This project aims at providing an infrastructure that incorporates geospatial technologies in land mines detection procedure. This project suggests an alternative technique to replace the primitive methods of mine detection i.e. instead of traversing the complete contaminated area as was done in conventional methods, the rover, as suggested, is capable of finding the spatial pattern among the mines and then deciphering the pattern and move only to mine positions of higher probability, hence confirming the pattern while moving autonomously in the field avoiding the obstructions in its path. Moreover the project aims at increasing the efficiency of mine detection and mapping by keeping a check on the physical parameters of the mine detector.

ACKNOWLEDGEMENT

In the Name of ALLAH the most beneficent, the most merciful!

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Fatima Afzal

Tooba Shahzad

Syed Abdullah Biz Zubair

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LIST OF ABBREVIATIONS

GIS	Geographical Information Systems
UAV	Unmanned Aerial Vehicles
SLAM	Simultaneous Localization and Mapping
SPADO	Sustainable Peace & Development Organization
EKF	Extended Kalman Filter
LMS	Least Mean Square
GPR	Ground Penetrating Radar
UXO	Unexploded ordnance
GPS	Global Positioning System
PSD	Positive Sensitive Detector
IRED	Infra-red Emitting Diode
SDB	Spatial Database
GIS	Geographical Information System
API	Application Programming Interface

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

1.1.1 Landmines

Mines used in landmine warfare is defined as an explosive or other material, normally encased, designed or damaged ground vehicle or designed to wound, kill or otherwise incapacitate personnel. Mines are significant combat weapon. Its purpose is simple – become a shield to slow down an invasion temporarily, direct attackers to kill zones, otherwise obstruct the enemies from defenseless areas. Enemy targets range from combatants to tanks and vehicles for logistics. Landmines are mostly detonated automatically as the pressure increase on them. This pressure changes occur when a target steps on the mines or drive over them. This pressure changes occur when a target steps on the mines or drive over them. The damage caused by the landmines can either be by direct blast due to explosives or by the fragments that are thrown by pressure to outwards or by combination of these two. Mines are the best artificial obstacles. Mines are mainly divide into two categories:

- **Anti-personnel mines**

Antipersonnel mines are explosive devices that contain small explosive charge and are designed to cause wound or kill people. Anti-personnel mines are designed in such a way that pressure applied by even casually stepping over it can detonate the mine. They can lie dormant for years under, on, or near the ground until an animal or person triggers the detonation. It is set off by a weight of 4kg or more.

- **Anti-tank mines**

These mines are aimed to stop tanks or other vehicles. These are used to damage and destroy belly of vehicle or track of tank. They require higher pressure to trigger detention and contains more explosive as compared to anti-personnel mines.

Anti-personnel mines that are originally designed to destroy military targets are affecting civilians and military personnel daily worldwide. Anti-personnel mines that were deployed in the war zone remains buried in the ground. Due to geological changes such as soil creep, wind or rain factors, these are dislocated from their original position and when the deminers go into the field and search for the mines to remove them, locating them is difficult. And even if by mistake any deminer steps on the mine during search operation then either he dies or gets injured badly, leaving him disable for the rest of life. On stepping over an anti-personnel mine, the blast can often rip off the legs or else with debris of soil, metal, plastic of mine casting, grass, shoes fragments, shattered bones piercing into the body wounding deeply. Similarly, if the explosion takes while handling, then the affected ligaments are fingers, hands, abdomen, spine, face and also might leave the victims blind. Apart from these damaging effects of the landmines, other effects are broadly categorized into four classes in Fig 1 (Ahmed, 2014, p.06).

- Access denial
- Loss of biodiversity
- Micro-Relief disruption
- Chemical contamination

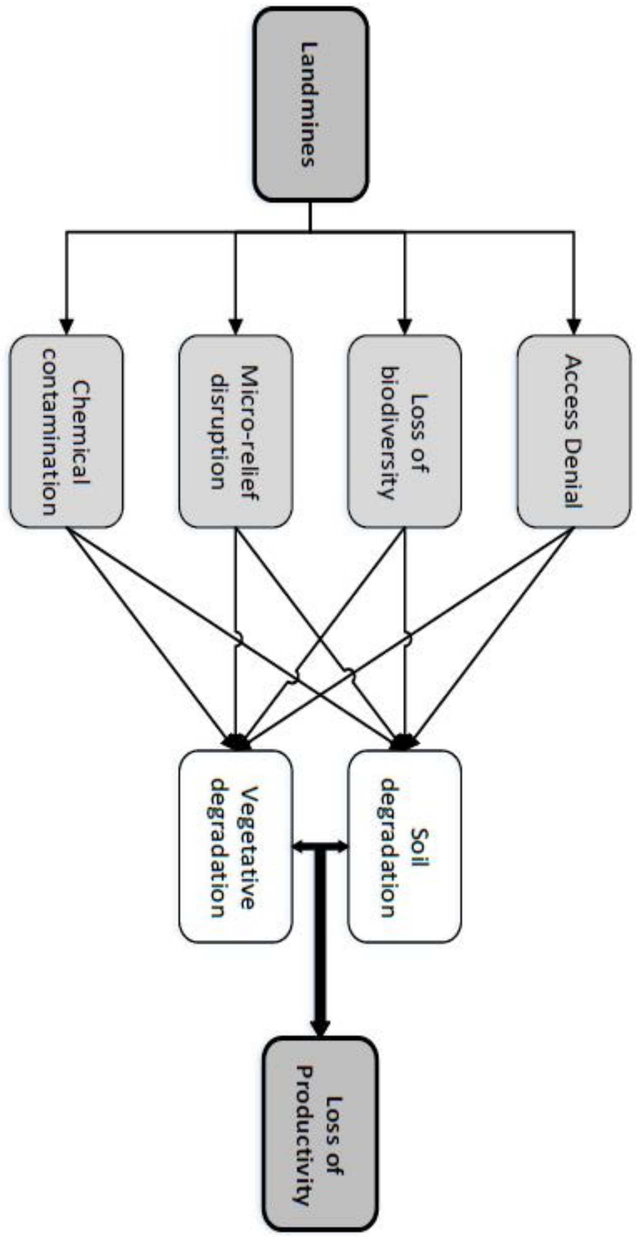

Fig1: Effects of Landmines (Source: Ahmed, 2014, p.06)

1.1.2 Existing Mine Clearing Methods

The process of anti-personnel landmine detection and removal is referred to as ’mine-clearance’ or ’demining’. Many techniques are available for the demining task. There are three main methods for the mine clearance:

Manual clearance where humans are the deminers and carry metal detectors or mine detectors and search for the mines in the field manually by moving detecting equipment over each patch of ground. The process is highly risky as the life of the deminer is constantly at stake. Clearance using animals is another method where rodents are used to detonate the mines so that the region becomes safer for the humanitarian use. Mechanical Clearance is the process where remotely controlled unmanned mechanical platforms are used for the detection as well as removal of the mines.

Conventionally humanitarian approach was used to clear the mines. Later that was replaced by the mechanical platforms. In the recent years, employment of autonomous robots have become an immense trend for the detection and mapping purpose. But time consumption is still too much.

1.1.3 Simultaneous Localization and Mapping (SLAM)

The Simultaneous Localization and Mapping (SLAM) problem asks if it is possible for a mobile robot to be placed at an unknown location in an unknown environment and for the robot to incrementally build a consistent map of this environment while simultaneously determining its location within this map and then updating the map to be more accurate and efficient. SLAM is just similar to a person trying to find his or her way around an unknown place. It forms the basis for robotic mapping of environment.

The SLAM process comprises of multiple smaller parts that need to be solved in order to get the whole working algorithm. It includes Landmark extraction, data association, and state estimation, state update and landmark update etc. In this project SLAM is used to guide the robotic platform about its path in the unknown environment and the platform determines its position with respect to the data it’s been sending to the backend to get mapped on the client side.

1.2 RATIONALE

When it comes to the landmine detection, there are some major perspectives that need to be incorporated for developing an efficient system for landmine detection and mapping which leads to further removal procedure of the landmines with lower risk to health as well as the life of the deminer. Following are the three major perspectives that need to be incorporated

- Detecting Landmines to update own maps
- Landmine Breaching to clear path to move the convoy
- Keeping a check on the Accuracy of Mine Detection procedure

For the purpose of securing own land, authorities lay landmine according to Geneva convention which states that landmine can only be laid in a specific pattern that is repeated over the entire area. Once landmines are laid, at the same time the pattern and position of those laid mines is recorded. Contaminated area is isolated with barbed wires to prevent accidents in case of crossing into the contaminated area. In such a situation, a system is required which is capable of going in the contaminated area all by itself and detect mines as well as map them on the go to confirm the already provided pattern before demining procedures to ensure least risk to human life.

When entering in the enemy territory that is protected by the landmines, anti-personnel as well as anti-tank landmines, army personnel need to clear a path as quick as possible to allow their artillery and heavy vehicles to move into the enemy territory without blasting up due to the landmines in the enemy area. For this purpose a robust and time efficient system is required that is capable of detecting mines and map them dynamically to facilitate the army personnel to move forward for demining as soon as possible.

Third and most important perspective is keeping a check on the efficiency and accuracy of the land mine detection procedure. In the contaminated area when any deminer enters and use handheld demining instrument, small human error may cost many human lives and if not then disabling the humans for rest of the lives. For this purpose such a system is required that keep a check whether the demining instrument is properly adjusted or not and if the sweep speed and coverage is well maintained or not. If not then the deminer as well as the personnel heading the procedure is notified that which region is missed due to deminer's human error so that he can repeat the procedure to ensure the safety of human lives.

1.2.1 Present Situation of Pakistan

In the present state of art of Pakistan, for the past decade the incidents of being injured or slaying own life during demining has increased. The number of causalities due to landmines in Pakistan is high. In 2001, 92 causalities were identified by media whereas this number jumped to 636 in 2011. The actual number of causalities may be higher but few are reported as such incidents occur in remote areas. Sustainable Peace & Development Organization (SPADO) Executive Director Raza Shah Khan explaining reasons for the increase in incidents of landmine blasts affecting army personnel as well as civilians, said in his report on 22nd February 2013.

"*This was due to the increasing use of such devices by non-state actors in the tribal areas and in Baluchistan and due to activity along its borders with India and Afghanistan*".

While clearing mines, first step in the mine clearance task is the precise detection of the position of mine. The whole process involves field surveys, mapping the region and marking the pinpoint location of the mine and then removing the mine. This process is painstakingly time consuming and is a constant threat to the life of deminer. Although there has been significant effort aimed at the detection and removal of land mines, such a methodology and system implementation is required to get safe and rapid delineation of the areas contaminated with landmines. In order to speed up the process, to enhance the efficiency and to save human lives, deployment of UAV has greatly increased in past few years. Keeping in view the recent trend all around the world, robots capable of Land Mine Detection are the need that can be employed in Peace Support Operations as well as for the clearance of the Land Mine contaminated areas.

1.3 OBJECTIVES

The objective of this project was to utilize geospatial technologies in land mines detection procedure and to get the reliable maps on the fly. In order to achieve this, our sub-objectives were:

- Designing a fused sensor network for mine field surveyor, capable of recording the seaming routine to get the area which was not searched properly or missed.
- Designing a rover which is capable of performing the land mine field detection missions thus decreasing the man power needed.
- Creating a spatial database which is capable of storing all the information associated with the mine detection process.
- A mapping engine to show the archived missions as well as ongoing missions using live data transmission.

1.4 SCOPE

This project has been developed with the intent to provide landmine clearance authorities with an efficient, robust and time saving mechanism to get the precise mine locations from the field survey that is based on the probabilistic algorithm approach to get the pattern of the mines instead of searching whole area that is painstakingly time consuming and to get updated mines map in real time. Also the project is intended to enable the deminer to get clear idea in real time that whether the manual searching of the contaminated area is accurate or not i.e. if during the search procedure the mine detector is raised above a specific height or is not balanced or the speed of side to side sweep is high then user is prompted to repeat the procedure.

CHAPTER 2

LITERATURE REVIEW

Before heading to the main topic of this thesis, we first present the reader with a brief summary of information that we collected from various sources including research papers, articles, books and other thesis for refining our knowledge about the idea. Presented first is information relating to mine detection robots, path planning algorithms and Inertial Navigation System. Then we summarize work related to the fusion of GPS and INS sensor in particular and mapping of detected mines.

GIS IN LANDMINES DETECTION

According to Chaminda Saman (2010) it is quite a difficult task to detect and remove landmines manually and people are exposed to a high risk when they are using hand bomb detecting devices to detect landmines. Using a remotely controlled platform, which carries the bomb detector, can reduce the risk. Mine clearance project can be done in an efficient way if we can implement a GIS System to locate the exact positions of the detected landmines on a local map of the area. Then the GIS database also can be used to educate the community about the landmine contamination of their environment. Main purpose of this project is to detect landmines by using a GPS enabled remotely controlled robot and inserting the positions of the detected landmines to a GIS database. Positions of landmines are displayed on a GIS map.

Jim Baumann (2003) says the European Commission (EC) prepared and proposed a geographic information system (GIS) project called the "Geographical Information System for Mine Action in South-East Europe" (GISMASE), which was jointly funded by European Commission and the U.S.State. The goal of the project is the creation of high definition maps that will include the identification of mined areas and their socio-economic and security implications, as well as the development of GIS training capabilities so that the project can be locally supported.

According to Helmut Kraenzle (2000) The Centre for Geographic Information Science (CGIS) at James Madison University supports the Mine Action Information Centre

(MAIC) with a team of faculty, staff and advanced students. The GIS team has developed customized Geographic Information Systems (GIS) for specific needs of humanitarian demining organizations and operators. It has evaluated GIS software for a Humanitarian Demining Support System, and hosted an international conference on mapping and GIS for humanitarian demining. Currently the CGIS is focusing on plans for a clearinghouse for humanitarian demining spatial data. The database clearinghouse will enable the demining community to access information about spatial data sources over the World Wide Web and will provide digital maps.

MAPPING LANDMINES

According to Davison,A.J ; Reid,I.D (2007) the core of the approach is the online creation of a sparse but persistent map of natural landmarks within a probabilistic framework. It includes an active approach to mapping and measurement of features on ground.

H.Zafrir, Y. Bregman, D. Wolf and S. Hershler (1998) demonstrated a prototype (Dempro) of super sensitive magnetic and GPR all-terrain ground robotic system and its outgrowth designed and developed, for real-time and wide coverage mine & UXO detection and mapping.

MINE DETECTION ROBOTS

Prof. R.M. Sahu, Mamata .S. Sawant, Komal .S. Salve and Mangesh .N. Nakade (2016) of College of Engineering, Manjari (Bk), Pune utilized Global Positioning System (GPS) tracking technology and Global System for Mobile (GSM) technology integrated with a robotic vehicle that can be used to detect the exact location of metal in the field. The GSM module transmits the received data to the authorized Mobile user. Main purpose of the project was to detect landmines by using a GPS enabled remotely controlled robot.

Ahmed Ismail, Mohammed Elmogy, Hazem ElBakry (2014) discussed the strategies that can enable the robot to detect mines by means of sensors. They discussed different methods of landmines detection, such as metal detector method, electromagnetic method, acoustic method, that can be implemented by using the autonomous robots which are capable of exploring and detecting buried landmines and marking their locations.

PATH PLANNING ALGORITHM

Pradipta Kumar Das, Amit Konar and Romesh Laishram (2010) studied the online path planning for khepera II mobile robot in an unknown environment. They implemented the well-known heuristic A* algorithm to make the mobile robot navigate through static obstacles and find the shortest path from an initial position to a target position by avoiding the obstacles. The proposed path finding strategy was designed in a grid-map form of an unknown environment with static unknown obstacles. When the mission was executed, mobile robot was able to plan an optimal or feasible path for itself avoiding obstructions in its way and minimizing a cost such as time, energy, and distance.

In one of our study Nyein Chann(2007) of Mechanical Engineering Department of University of Singapore attempted to create a robot that was able to detect buried mines and mark the accurate location of the mines, and it was also capable of self-control from going over the buried Land mines and detonating the Land Mines. For the purpose of detecting buried Land Mines, metal detectors were used since most land mines contain metal components. The marking of the location of the possible buried mine area was done by spraying different color paint onto the location of mine.

INERTIAL NAVIGATION

Kirill Mostov (1996) utilized a half and half minimum mean-squares (LMS)/Kalman filter with the end goal of keeping up security in a framework where mistakes in the model would somehow or another cause unsteadiness. This was finished by utilizing the Kalman filter to expel noise from the framework and utilizing the LMS to figure the weight capacities, which could be interpreted into the Kalman pick up qualities in an iterative design.

Billur Barshan and Hugh F. Durrant-Whyte (1995) use a framework comprising of three gyroscopes, a tri-axis accelerometer and two plan angle sensors to perform inertial route. They concentrate on watchful and point by point mistake displaying to get a position float rate of 1-8 cm/s, relying on the recurrence of speeding up changes. This, like any framework requires extra data from some supreme position-detecting instrument to beat long haul mistakes. In any case, they demonstrate that an ease inertial detecting framework can be utilized to give profitable introduction and position data especially for open air portable robot applications.

A. Svensson and J. Holst (1995) have simulated a variety of filter configurations for the purpose of submarine navigation based on several inertial sensors. They had the most success with a complex fourteen state Extended Kalman Filter (EKF), which used eight states to describe the motion of the submarine and six to describe the measurement system.

GPS AND INS FUSION

Allison N. Ramjattan and Paul A. Cross (1995) utilize just a gyroscope and an odometer encoder, alongside a GPS collector, to create an intertwined yield. They have utilized this framework as a part of the avenues on focal London, and have shown the enhanced position gauge acquired from melding information from just a couple sensor inputs. They assessed the viability of their framework taking into account the framework yield's deviation from the "genuine" way, which was acquired by digitizing the way from an overhead guide.

Ren Da and Ching-Fang Lin (1995) utilize the State Chi-Square Test and the ARTMAP Neural Network to perform disappointment finding in a GPS/INS incorporated route framework. They tried their framework by method for PC reproduction and exhibited the discovery of delicate disappointments by the tests.

The reliability on a landmine searching robot is highly dependent upon the performance of the detector with respect to the landmines, whereas, the purpose of the carrying vehicle is to provide the require pattern of movement in such a way that the detector can do its job. The work of Chaminda Saman (2010) is actually very similar to the work that has been done for this project, a GIS system was implemented using GPS to track the position of landmines and spatial database was used to store the position which were displayed on a GIS map. However, this thesis goes further than to provide information only about how to fuse inertial and GPS data to produce an enhanced output. Furthermore it also provides the information related to the Kalman filter, which was applied to the raw data in order to expel noise from it.

CHAPTER 3

METHODOLOGY

3.1 HAND HELD TRAINER'S EQUIPMENT

Metal detectors are the fundamental and chief parts that are used for mine detection and they have been utilized following the World War II because of their straightforward structure and moderateness. This generic hardware for the most part comprises of an inquiry head, including one or more curls conveying a period shifting electric current. The current created by the curl further produces a comparing attractive field that progressions with time, which spreads towards the metallic focus to actuate swirl streams in it, which thusly create a noticeable attractive field. The expansive measure of metal substance of prior era mines made their identification entirely simple. Be that as it may, with the progression of time landmine outlines has developed accordingly. Presently cutting edge landmines are worked with plastic bodies and miniscule measures of metal or no metal by any stretch of the imagination, enormously expanding the trouble of location for metal locators.

Keeping in mind the end goal to provide food this issue, various new hand-held mine locators are creating as other options to the old customary ones. A portion of the hand-held mine indicator are accessible which are fit for identifying metallic and additionally non-metallic hostile to tank and people killing mines by joining an electromagnetic affectation sensor, ground entering radar (GPR) and some refined calculations. Nonetheless, GPR still displays a few restrictions as it confounds the landmine signal with signs returned by characteristic subsurface, elements, for example, shakes and roots, and this turns into a wellspring of false alert.

Preparing is a standout amongst the most troublesome and basic assignment keeping in mind the end goal to enhance the wellbeing and expansion the viability of the mine recognition errands performed by the human administrators. It is required for new administrators as well as when new identification innovations are presented. For instance the correct utilization of sensors based indicators requires all the more preparing and practice contrasted with metal locators. What's more, further retraining is likewise essential for proceeding with an abnormal state of productivity. As per a few studies poor administrator abilities is a typical issue that dangers the accomplishment of the countermine operations and imperils the work force included.

So the aim is to present a preparation device which enhances the administrator strategy and aptitudes amid mine recognition exercises. It should be possible by using a tangible following framework to contemplate the aptitudes of hand-held finder administrator. The preparation instrument will have the capacity to evaluate the handheld administrator productivity amid the filtering assignments and will give essential input to enhancing their skills. The tangible framework methodology of the preparation instrument depends on a hand-held which will be mounted with an inertial estimation unit to record the scope of the finder, a GPS to record its area and a closeness sensor which will record the separation of the indicator over the ground. These sensors will give data, for example, if a handheld is not covering the territory then breadth separation will educate that specific region is missed by the administrator. In the event that the stature of the handheld locator is more than the edge quality and it is feeling the loss of the territory, which will be shown by the proximity sensor.

It will use the concept of inertial navigation refers to assessing a framework's position taking into account measured changes to the movement of a framework. To achieve this, a mix of increasing speed and precise rate estimation is utilized to process straight movement and demeanor (yaw, pitch, and roll). Accelerometers and whirligigs are utilized to perform this assignment.

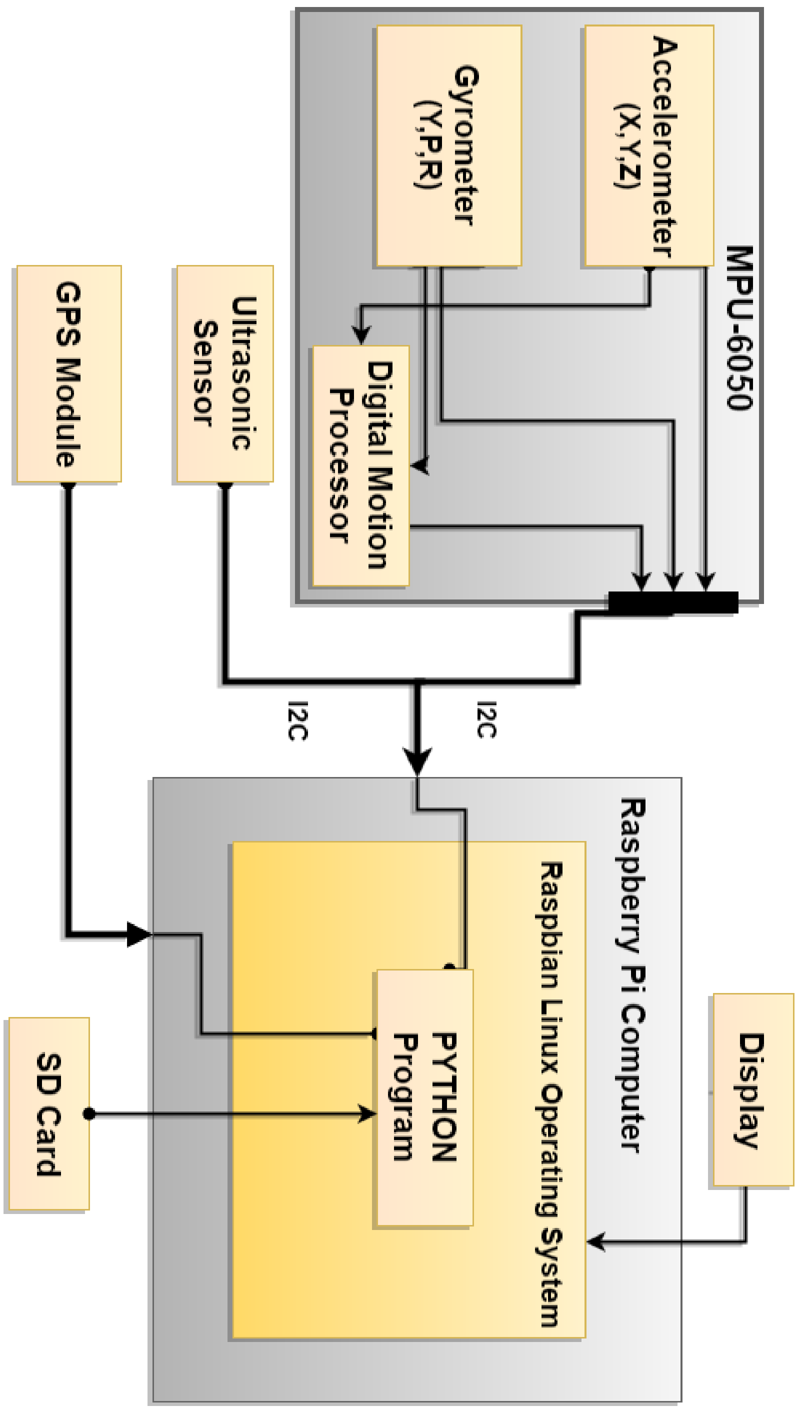

Fig2. Block diagram of work flow (Source: Lykov et al, 2013, p.08)

METHODS AND PROCEDURES (HAND HELD)

3.1.1 Sensor Fusion

Sensor fusion is a process in which different sensors and data are combined in order to produce something that cannot be determined by using any one of them alone. Combining different sensors to produce an improved output is not a new concept. Data from GPS, proximity sensor and mpu6050 will be fused in order to scan the area perfectly.

Data from different sensors is fused using multithreading concept in Python which starts three threads, which are of GPS, MPU6050 and proximity sensor, which read and timestamp data from the external sensors, a fourth thread which further processes and saves the data into a file.

3.1.2 Kalman Filter

The data that we get from accelerometer is raw data which consist of gravity component. It sense static and dynamic forces of acceleration. Static forces include gravity component whereas dynamic forces include vibrations and movement. Linear acceleration is required in order to track two dimensional movement of handheld detector in x and y axis and to get linear acceleration gravity component should be removed.

The raw acceleration data also contains noise and inaccuracies as it is not calibrated data. To remove those inaccuracies and gravity component from raw acceleration data, kalman filter was applied to the raw data.

Kalman filtering, according to Swarnim Naik, is an algorithm that incorporates a series of measurements observed with respect to time, consisting inaccuracies and noise, and as an output it produces estimates of unidentified variables that are more precise than those variables which are based on a single measurement alone.

The Kalman filter basically comprises of two steps. In the first step a mathematical model is used to make a prediction about the system state. In the next step this state prediction is compared to measured values. The difference between the predicted and measured values is the estimated noise and error in the measurements, and an estimated value is output.

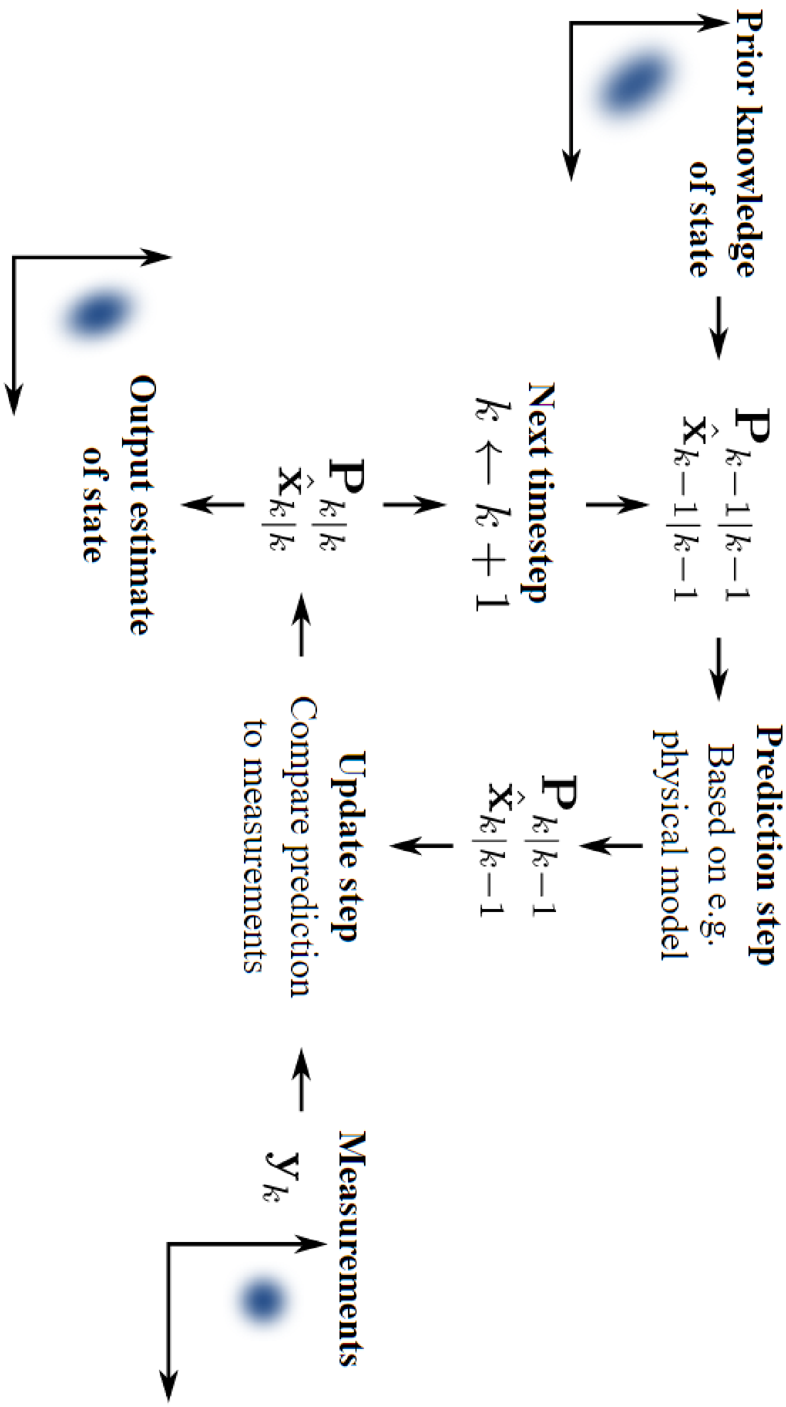

Fig3. Kalman Filter Concept (Source: Granzio, 2016)

3.1.3 Double Integraion

Given a position versus time of an object, x(t), the velocity, v(t), can be found by taking the first derivative.

$$v(t) = \frac{dx}{dt}$$

Acceleration, a(t), can be found by taking the second derivative of position or first derivative of velocity.

$$a(t) = \frac{d^2x}{dt^2} = \frac{dv}{dt}$$

In any case, it is important to turn around this procedure and discover the position signal given a speeding up sign. To do that, coordination must be performed twice on the increasing speed signal.

On a fundamental level, utilizing twofold coordination on a speeding up sign to get a position flag, the underlying position and starting speed must be known. After the primary combination, the underlying speed ought to be added to the outcome, as the underlying position ought to be included after the second joining. These operations are illustrated in the following equations:

$$v(t) = v(t_0) + \int_{t_0}^{t} a(\tau)d\tau ,$$

Where t0 is the initial time and v (t0) is the initial velocity, which is a constant. To get the position signal from velocity, a similar formula is used:

$$x(t) = x(t_0) + \int_{t_0}^{t} v(\tau)d\tau$$

Therefore, for a double integration to be performed on acceleration, the two initial conditions (velocity and position) must be known to avoid integration errors. Doing integration on noise will cause cumulative error. So the filtered data from Kalman filter was linear acceleration in x, y and z axis, which was integrated to get linear velocity in all three axis. The linear velocity was further integrated to get position in x-axis, y-axis and z-axis using Python script.

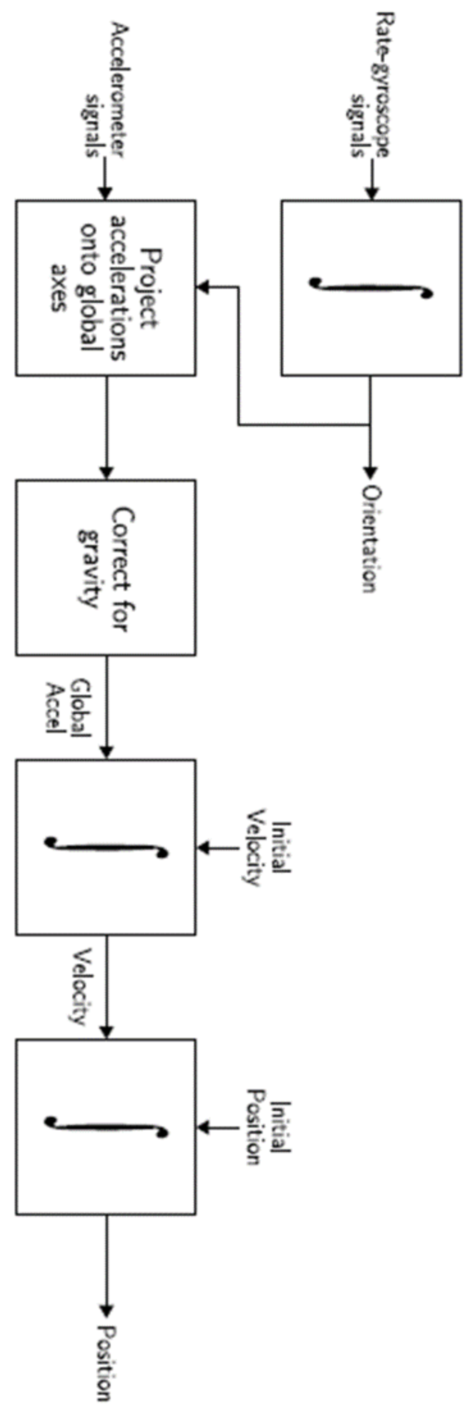

Fig4. Double integration using kalman filter

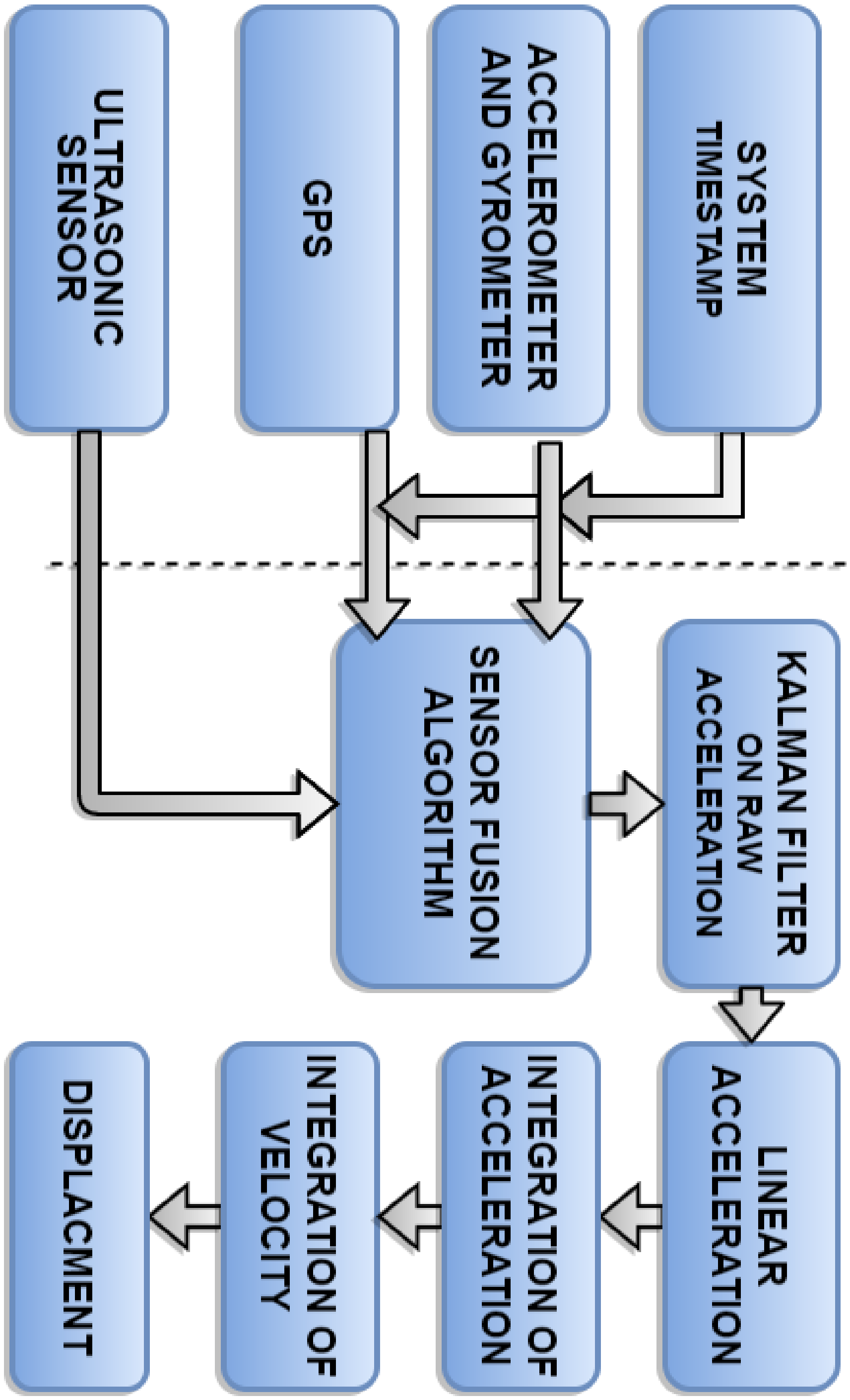

Fig5. Kalman filter workflow

3.1.4 Step Length and Stride Length

The position values in x, y and z direction are used to compute the distance walked over a step, with handheld detector. The displacement calculated from position data further calculates the step detection, stride length, and heading length that how much handheld detector is moving in the horizontal axis (stride length) and how much it is moving in the forward direction (head length). The calculation of these lengths will provide the area covered by the handheld detector. The area covered by the handheld detector was compared to the scanning area which informs about the coverage of area and produces a false alarm on the map in case of not proper coverage and sweep on the end of handheld operator.

3.1.5 Mapping Information

The information provided by the handheld device on the field was mapped in real time on the back end application so that the trainer of the mission can see the skills and efficiency of the handheld operator in real time. The green signal will turn red if a certain scanning area is missed and will provide information that if this happened because of the improper sweep or height of the handheld detector. The trainer will be able to inform the handheld operator through remote communication modes that he is missing certain area. The location of area will be provided with the help of GPS. The operator will be able to go back and rescan that area properly, thus increasing his skills and efficiency in the mine detection activities.

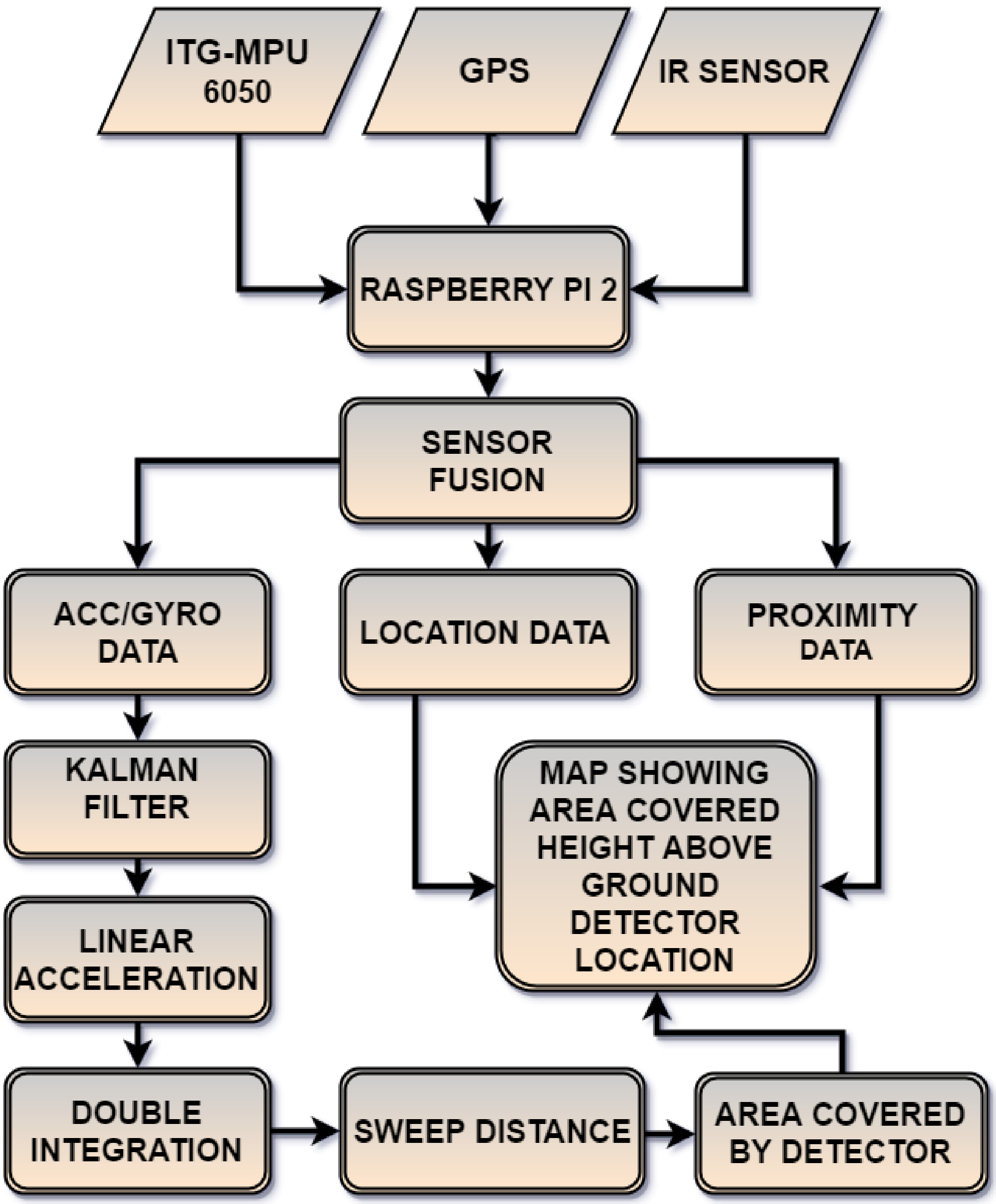

Fig6. Workflow for the Handheld Trainer's Equipment

3.2 MECHANICAL PLATFORM

Robotics is a branch of technology that involves designing and construction of autonomous machines, operating them and their application in various fields where they can sense their environment and perform functions to modify that very environment. This field is rapidly growing among the researchers to find its application in various fields.

However most of the practical robotic platforms and sensors, with an exception of a few, are capable of working indoors. Although there has been developments focusing on robotic platforms that are capable of working outdoors in various applications but a large proportion of these have been focused on large platforms with highly budgeted applications in the field of military and many such fields as the authorities in such fields are able to fulfill the need of high cost in the outdoor environment.

When the high cost required to develop large efficient robot platform as well as applications is countered by reducing the size of the platform to small platform many other problems are encountered. Such small platform have low power and are not able to move on highly rough terrain, terrain with steep slopes or terrain with vegetation on it. In short those downsized platforms are not all terrain. if the platform is not all terrain then many factors from the environment such as mud, gravel, water, vegetation, dust etc. damages the electronics onboard and affects the readings being logged on to the platform. So such a robotic platform is required that is all terrain, robust, but requires least cost to develop and maintain. The chassis should be modular enough to impart new changes when required and to test it in the field every now and then.

3.2.1 Rover Design

The design of rover is suggested by keeping in view the functionalities it needs to perform and the efficiency required throughout the process. The size and dimensions are such that the resulting weight of the rover is minimum and is capable of moving around uneven field while keeping itself stable and reduces the chances of being overturned by the rough terrain.

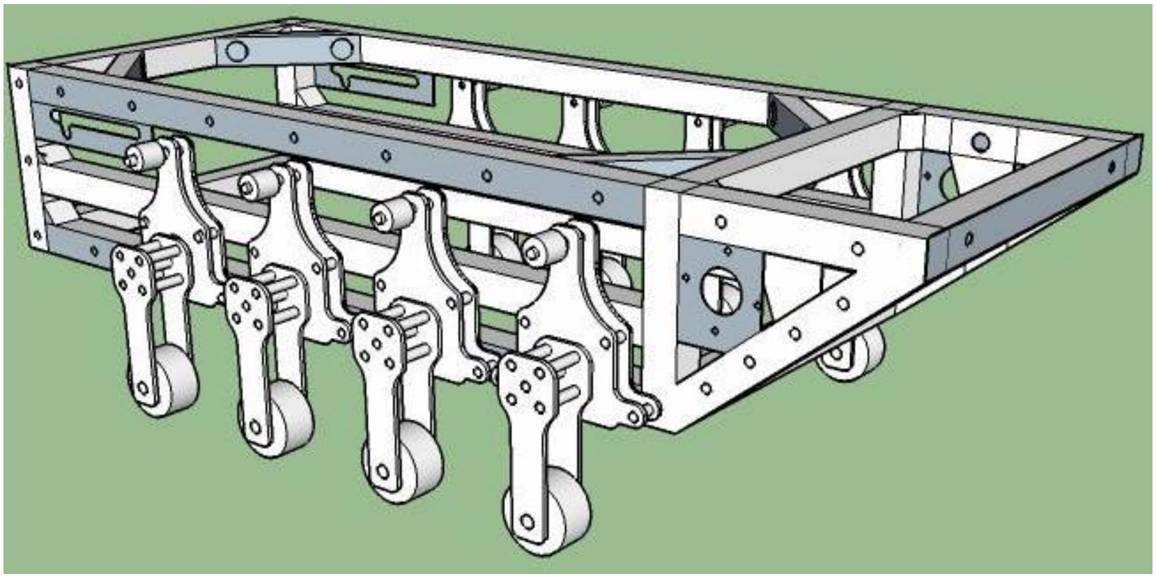

Fig7. Chassis without tracks (ISO view)

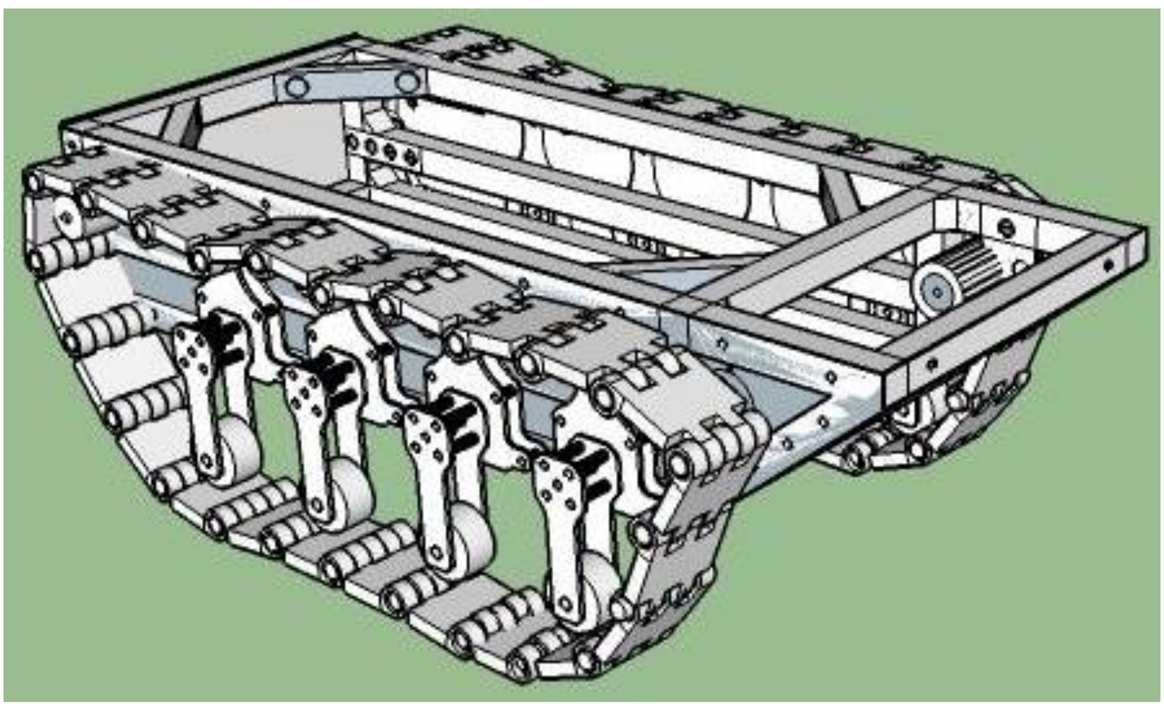

Fig8. Chassis with complete tracks (ISO view)

3.2.2 Fabrication Material

For outdoor robotic platform, material to be chosen is one big task. Although these days many different types of materials are available commercially, but where their properties are concerned with respect to their use in the field only a few matches the requirement. There are four basic type of metals that are well suited to robot combat in the outdoors i.e. aluminum (Al), magnesium (Mg), titanium (Ti) and steel.

For the purpose of a rover that goes in the minefield and simultaneously maps the field, such material is required that has high strength so the rover is not damaged with sudden drops but at the same time the material should be light enough so the landmine does not go off merely by the weight of the robotic platform. For this purpose choice was to be made between steel, alloy of iron and carbon, and aluminum. Steel has highest hardness which is well suited for the outdoor environment but at the same time it is heaviest. Whereas aluminum has relatively lower hardness when compared to steel and titanium but it is also the lightest. Due to lower density of the aluminum, it is possible to manufacture strong, stiff plates that can be bolted together to get a rover chassis that is light weight but have higher strength to weight ratio and also provide resistance to corrosion and impact, which is required by the rover that needs to work in the mine field.

3.2.3 Dimensions

Chassis of the rover is designed in such a way that it imparts least weight on the ground while at the same time it is able to carry all the sensors as well as motors and batteries.

The clearance below the main hull above the ground is kept at such a height that enables the rover to avoid small rocks or rugged vegetation on its path. The height of hull above the ground is around 2.5 inches which provides acceptable clearance below the hull.

The total height of the rover is around 5.5 inches in all (including the suspension system). Such low height of the rover ensures that the center of gravity is closer to the ground and reduces the chances of turning over of the rover in the rough terrain.

Length of the rover is 1.4125 feet approx. whereas width of the rover is about 6.125 inches approx. This ratio of length to width makes the body elongated and provides stability against roll dynamics on the ground.

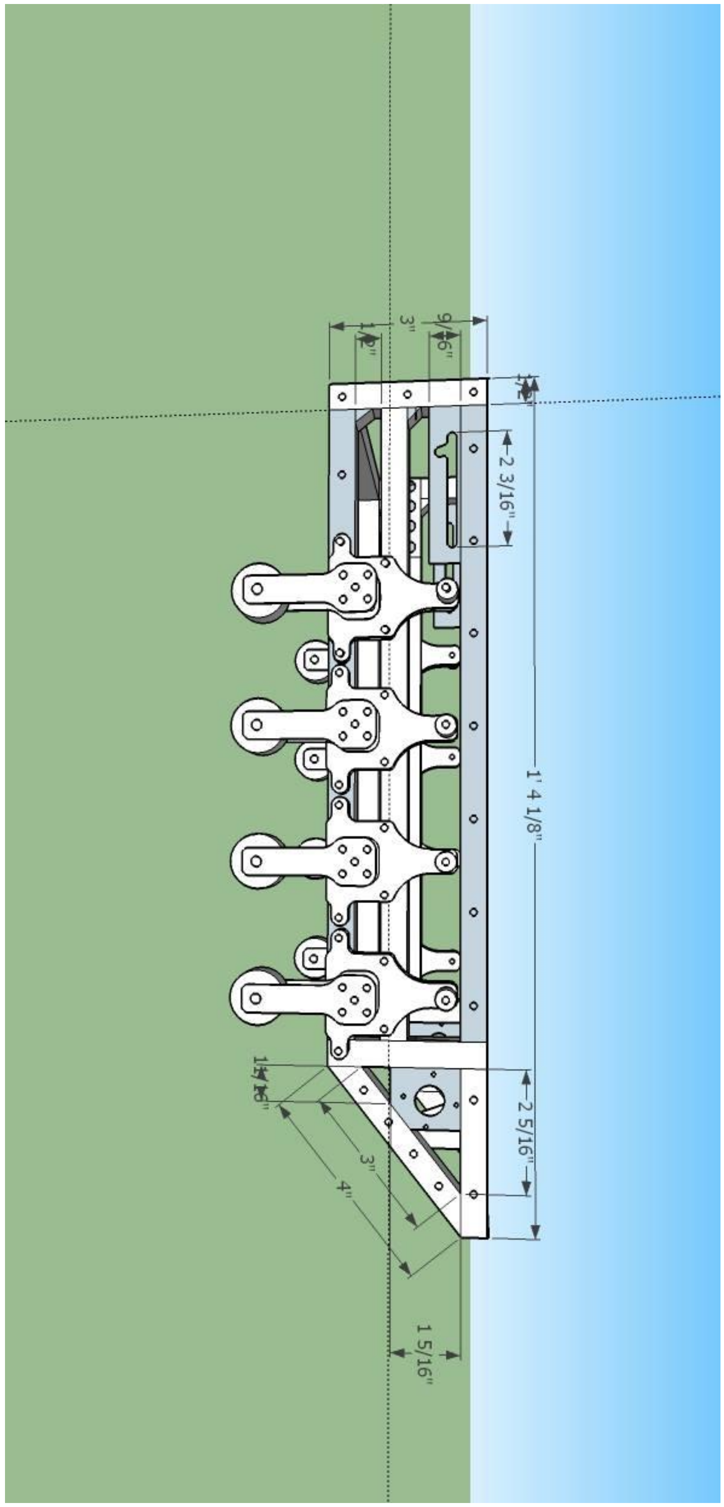

Fig9. Chassis with dimensions (lateral view)

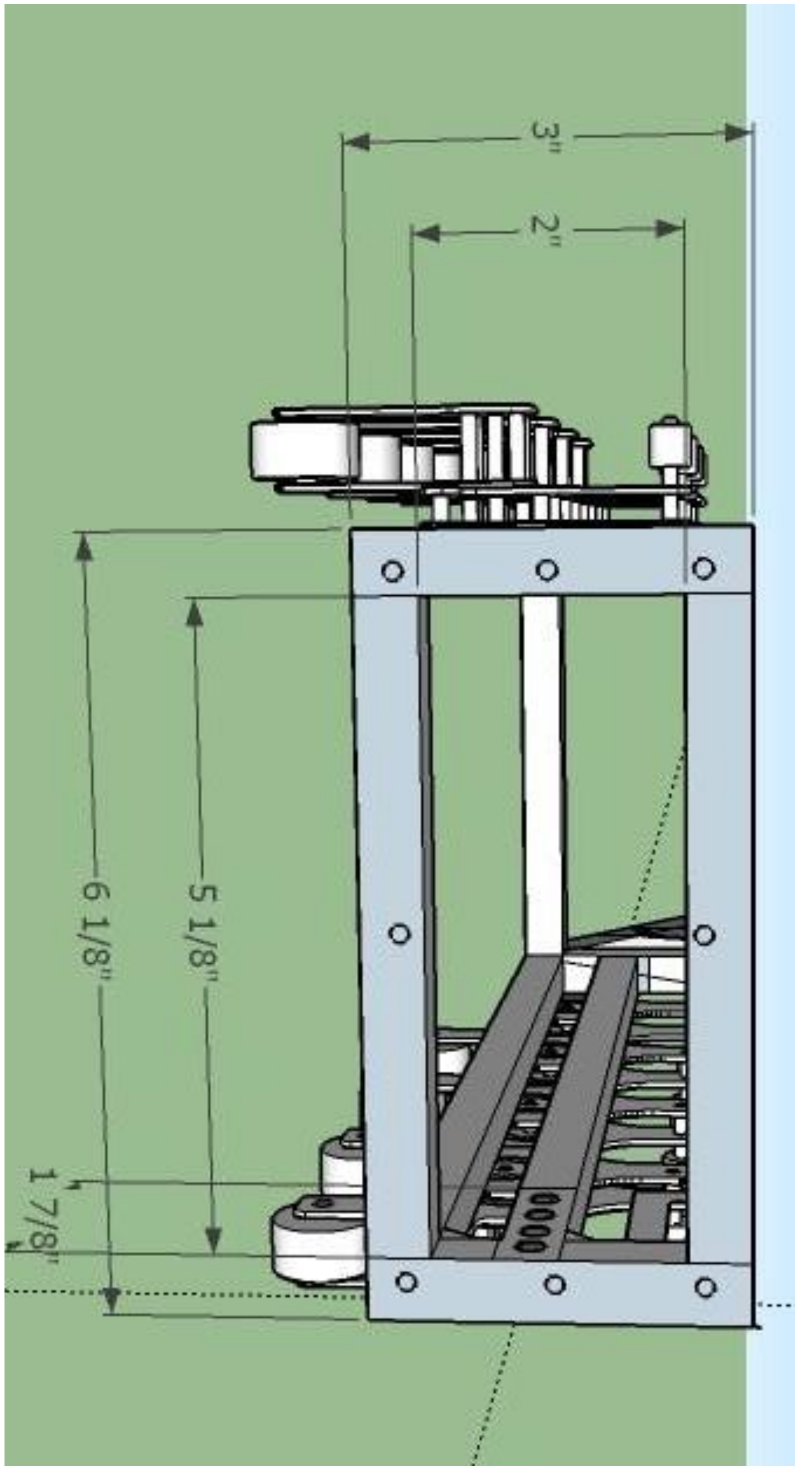

Fig10. Chassis with dimensions (Rear View)

3.2.4 Hull

The basic framework of the hull is composed of aluminum rods made out of aluminum sheets. Each aluminum rod is 0.5 x 0.5 inch. These aluminum rods are bolted together. Front end of the hull is slanted upwards and provides enough space for metal detector to be mounted below it. The streamlined front end enables the rover to move with least air resistance. Four corners of the main body of the hull are provided with slanted supports so as to protect the body from collapsing against external pressure. The overall framework of the hull is modular and can easily be replaced or repaired. Every system in the chassis is bolted to these 0.5 x 0.5 inch rods.

3.2.5 Suspension System

The suspension system in the chassis is the part that is most susceptible to impacts. Suspension system is the most critical part of the rover. The suspension system enables the rover to attain the maximum achievable speed in the real world and reduces the effects of frictional vibrations produced when the rover moves over the rough terrain. These frictional vibrations reduce the lifetime of electrical components.

In main body of the suspension system, one bolt at the top is connected to one of the bolts on central mass through a spring connection. Such assembly has many advantages over conventional single pivot designs or torsion bar. It protects the main hull from the damaging effects of environment like electronics affected from the mud, water or dust in the environment. It also allows smooth dropping or climbing on undulated terrain without much effects on the system on board.

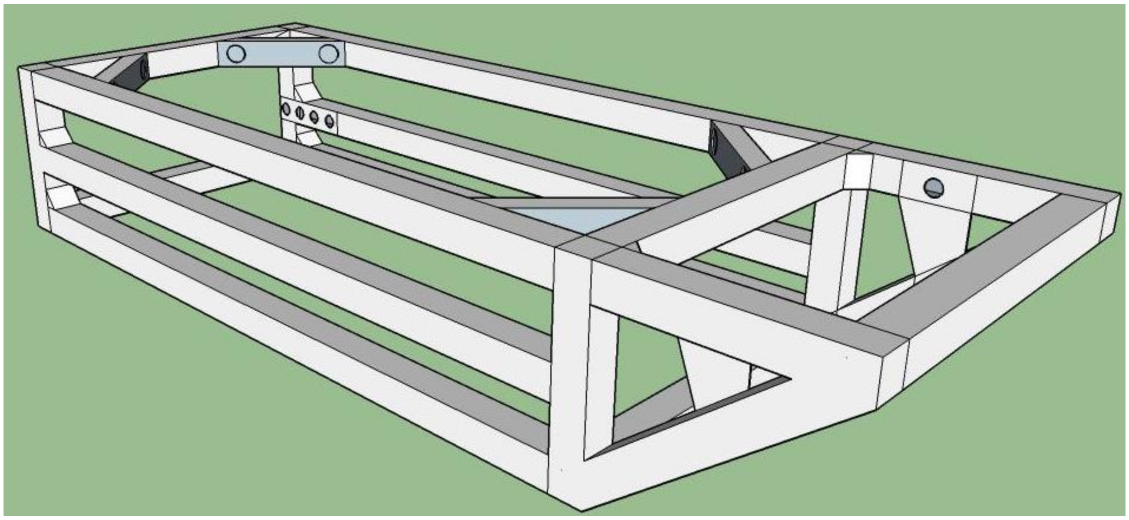

Fig11. Hull (ISO view)

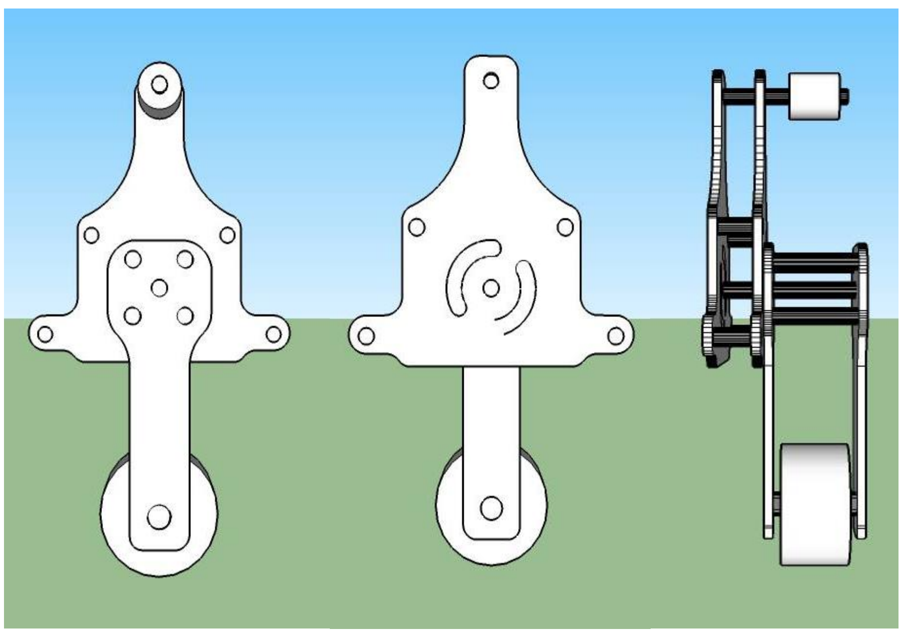

Fig12.a) Suspension body (Front view) b) Suspension body (Rear view)
c) Suspension body (Side view)

3.2.6 Caterpillar Treads

Caterpillar treads are continuous tracks that are large and heavy with armored cubes and have better traction as compared to the wheels. Wheels on the other hand are easy to control and manipulate but result in higher point load. This higher point load is to be avoided when application of robotic platform in the mine field is concerned. So to cater for such problems caterpillar treads are used that provide larger area of contact as compared to wheels and result in lower point load as the weight distribution is higher in treads as compared to in wheels. Moreover such continuous tracks acts as conveyor belt and results in lower impact when sudden drops are considered.

3.3 SENSOR NETWORKING

The overall structure of the sensor network can be seen in figure 13. How the sensors are connected and how the information is flowing between different parts of the fused sensor system. Motor shield used for the wheels of the rover connects to arduino. Also the infra-red sensor used for distance measurements is operating on arduino. This arduino serves as the bridge between sensors and the raspberry pi, the brain of the system. Some sensors are working by connecting directly to the raspberry pi. GPS sensor and the sensor for measuring the inertial motion against gravity are among those sensors.

3.3.1 Hardware Components

Sensory tracking system that is mounted on the mechanical platform is basically a fusion of different sensors which will keep track of the scanned area and will provide information if a certain area is missed from scanning. These sensors are ITG-MPU6050, GPS module, Proximity sensor and Raspberry Pi minicomputer.

InvenSense MPU-6050 Inertial Measurement Unit

The primary sensor utilized for the project is the InvenSense MPU-6050 IMU (Inertial Measurement Unit) with breakout board. This chip conveys six axes of data: x-acceleration, y-acceleration, z-acceleration and data related to attitude which is yaw-rate, pitch-rate and roll-rate.

SKM53 GPS Module

The SkyNav SKM53 GPS module consist of a GPS antenna which enables high performance navigation in the most strict and harsh environmental conditions. It is based on the high performance features of the MediaTek 3329 single-chip architecture. GPS module is used to send out the position data of handheld detector that currently where it is located.

Sharp GP2Y0A21YK0F IR Sensor (Proximity Sensor)

It is a distance measuring sensor unit that can be used as proximity sensor. Because of its triangulation method, distance detection is not easily affected by environmental conditions. This device outputs the voltage corresponding to the detection distance.

Raspberry Pi 2 Single-Board Computer

The heart of the framework is the Raspberry Pi single-board PC. It's Linux based OS is utilized to run the multi-threaded Python code which interfaces with sensors and recoveries handled sensor information to record. The IMU, GPS, and proximity sensors were attached to the I/O pins of the Raspberry Pi through I2C, UART, and I2C, separately.

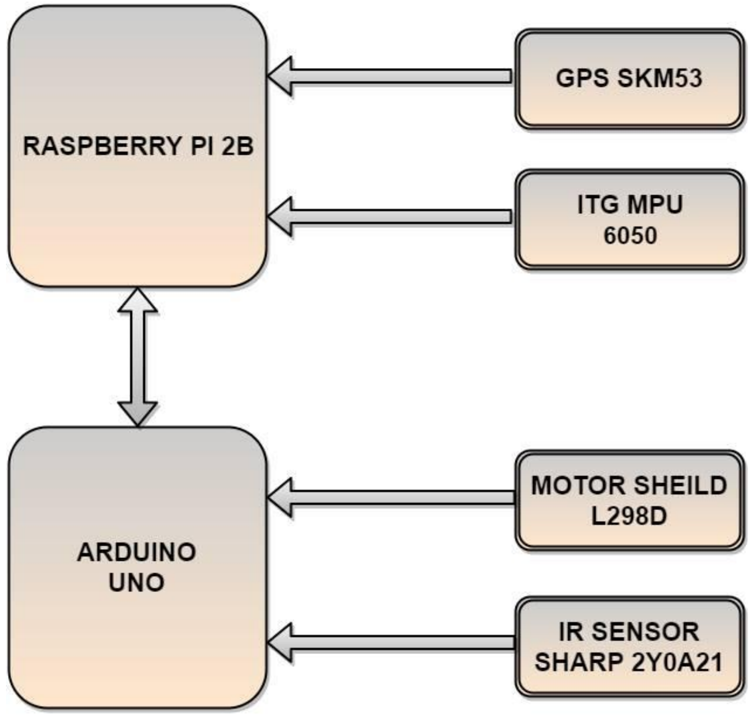

Fig13. Sensor Network Diagram

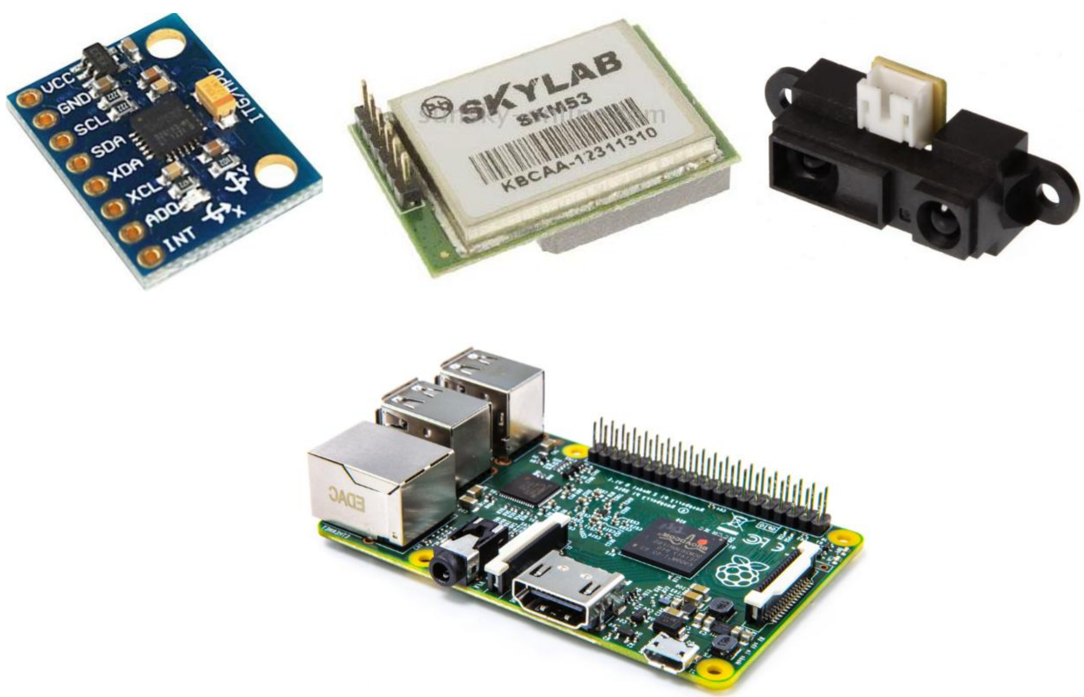

Fig14.a) ITG-MPU 6050   b) Skylab GPS SKM53

c) Proximity Sensor   d) Raspberry pi computer

3.4 ROVER WORKING PRINCIPLE

Initially before starting the mission the rover gets the search area as input. It has few pre-stored paths. Rover starts moving forward. After 3 feet it first turn left and move forward again 1 feet and then it searches the mine in area of radius 1 feet. After that takes a 180^0 turn and moves back to the main path where it moves again 3 feet in the forward direction. After that it turns left in the area and then moves forward 1 feet. This process goes on until it finds any obstacle or mine. In case of mine detection it simply sends the coordinates of the mine to the backend whereas in case of obstacle detection it changes its path and so that it can avoid the obstacle. The following is the path diagram and it is with the best case scenario. In which the rover didn't find any obstacle.

3.4.1 Algorithm Flow

Figure16 showing the detailed flow of algorithm from the starting point till the contaminated area is cleared and the real time data display on the maps. When the mission is initialized the user is prompted to select bounds of the contaminated area to limit the rover so that much time is saved and the rover battery is not drained out. Once the area is selected and fed to the system the rover uses the already fed pattern according to Geneva Convention and then moves in the field to confirm the pattern. If during the traverse it faces any obstacle then it sense it and avoids the obstacle and then return to the original path. When the rover moves in the contaminated area, it keeps on searching for the landmines using the mine detector. When any mine is sensed, the detector generates a beep. This beep is recorded and sent to the backend along with the gps coordinates to get mapped dynamically.

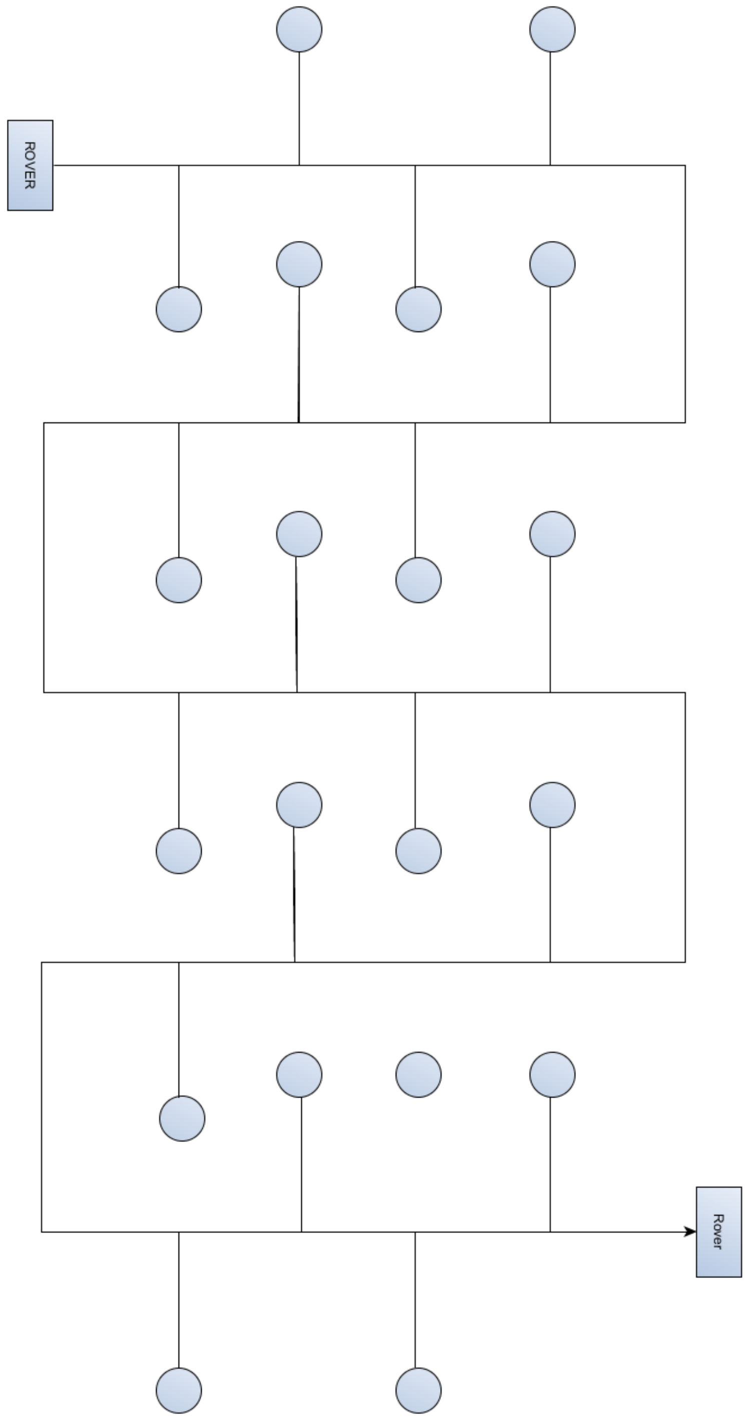

Fig15. Basic Rover Algorithm

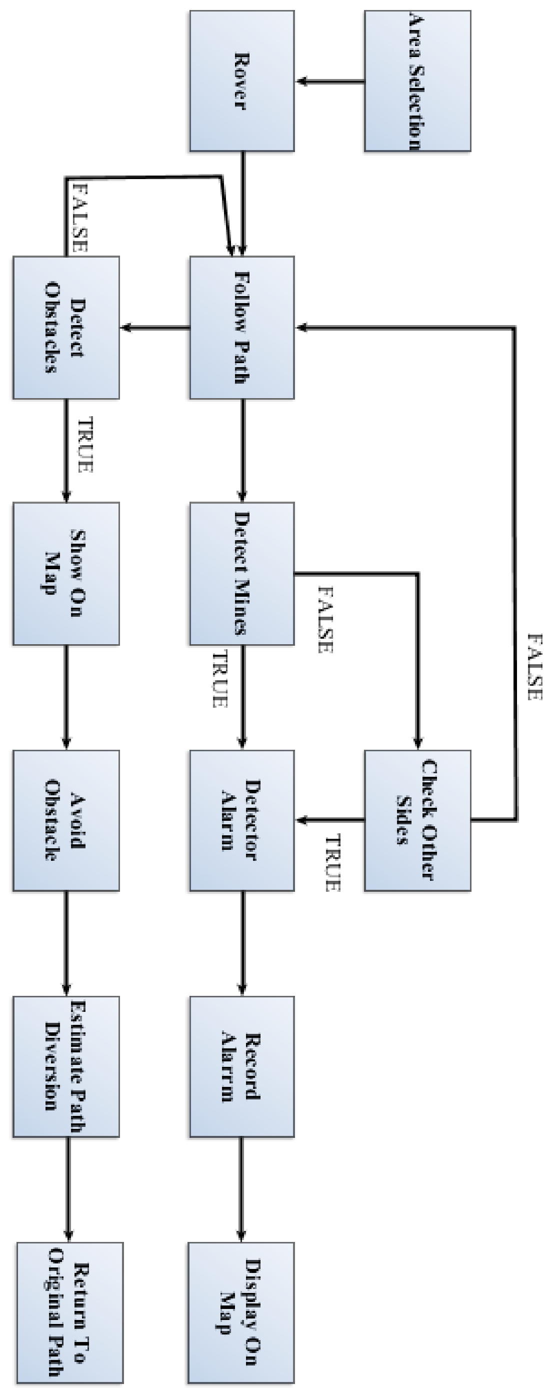

Fig16. Algorithm Flow

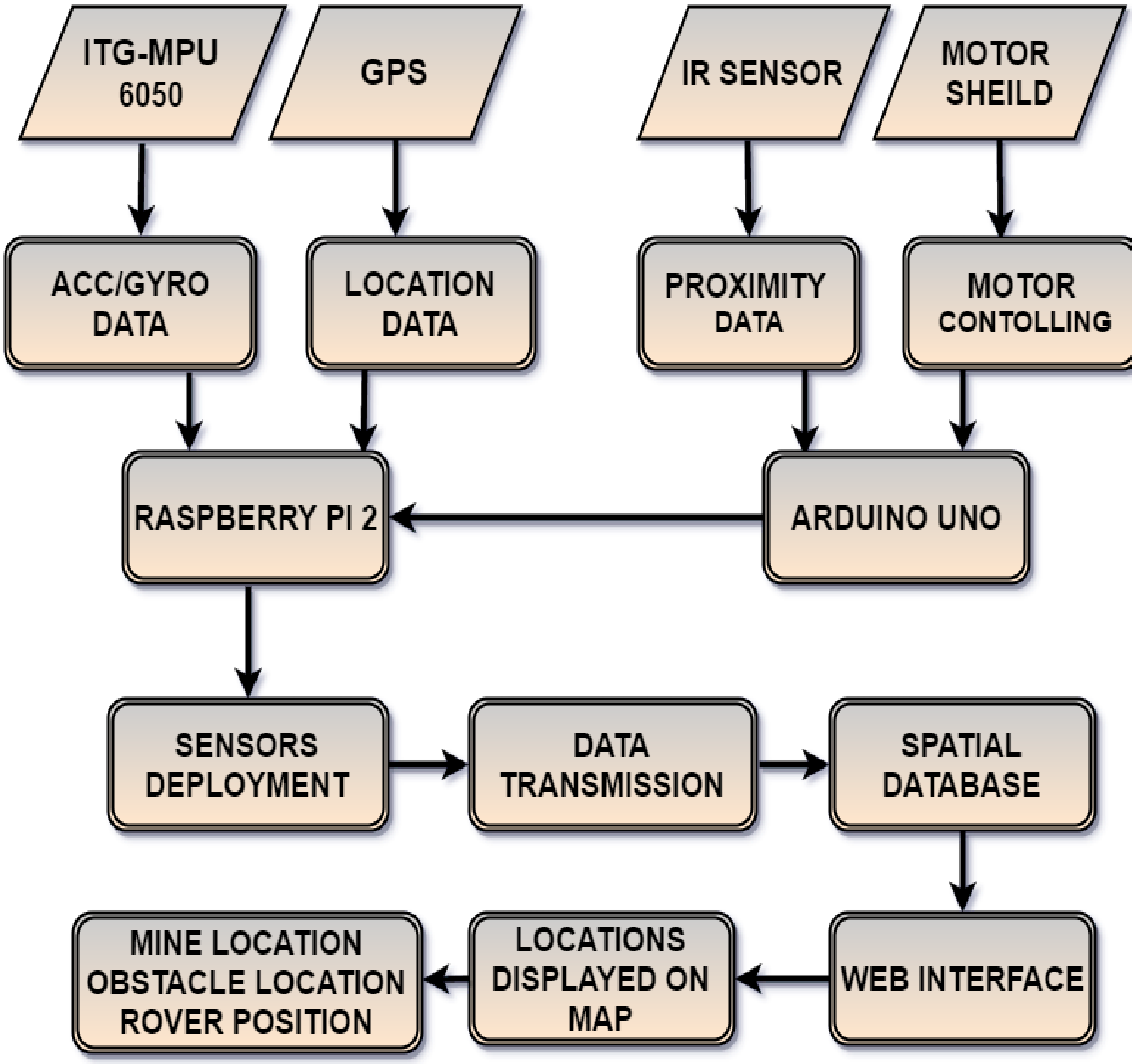

Fig17. Workflow for the mechanical platform

3.5 DATABASE SELECTION

As the project is aimed at a rover going in the field that is not manually controlled but is capable of moving autonomously in the field. While in the field now the rover has to find its path by detecting the obstacles. These obstacles will be avoided using the obstacle avoiding algorithm. At the same time these obstacles will be displayed on the map in real time. Once the obstacle is avoided then the robotics platform has to return to original path and continue moving on its path. At same time it is searching for the mines according to the probabilistic approach algorithm and if a mine is detected at a point that position of mine needs to be displayed on the front end map. If no mine is detected then it returns to previous path and checks the other leg of the path. For this purpose such a storage mechanism is required to that is capable of keeping track of the position of the rover at regular intervals. Storage mechanism should also be capable of storing all the data coming from the sensory network either from raspberry pi or arduino. Moreover data is being processed on the go so that processed data is stored in the database and the database is regularly updated at regular interval.

As the data to be stored also comprises of spatial data such as polygons for the search area, path of the rover as line geometry and mine location as point geometry, so a spatial database was required that was capable of supporting these multiple geometry types and that is not volatile and is reliable. The methodological approach and software architecture for managing the data have to meet the specific requirements of spatiotemporal data series which are the result of the data coming from the rover in the real time. Following are the requirements that are required to be met for database selection:

Scalability

System incorporating sensors especially GPS sensors can record thousands of locations for a single mine detection mission over short intervals (seconds, minutes, hours). Data collected by additional sensors such as IR sensor, ITG-MPU can increase the total amount of data collected by immense amount so data management technique must be able to incorporate this perspective, continuously growing amount of data.

Regular and automatic data acquisition

As the data acquisition is in real time so such a procedure is required that is automated and is able to require, process and store data in database in real time.

Management of Spatial data

Data regarding the field as well as sensor data sent over by the rover is spatio-temporal data as the data has been collected while the platform is on the move. Retrieval of the data, its manipulation and management should be in compliance to the spatio-temporal data domain.

Long-term Data storage

For data to be available in the archive for further usage beyond the scope of the project data was stored in such a system which allows easy retrieval of data even after thousands of records have been added to the database and stays there unless the administrator deletes that on purpose.

Efficient data retrieval

As data is being sent to the backend continuously so its size is increasing as the platform works in the field. Efficient data retrieval tools are required for the efficient data analysis without missing any data.

Global spatial and timestamps

When datasets are being received at multiple scales and from different regions, the use of spatial reference systems and global time stamping enables the user for comparison of such data.

Multi-User support

Multiple users at different levels need to access the data simultaneously with different access privileges and either locally or remotely. If one user is working on the data then other users should be able to access the data regardless of one already accessing the data in the database.

Integration of additional data sources

The scope of the project can be enhanced in the future by incorporating data, either spatial or non-spatial, as well as data from additional sensors such as video camera etc. So a storage mechanism is required that is capable of managing data correctly and integrating efficiently into a complete data structure.

Cost effectiveness

Data storage mechanism should be such that it requires least cost to manage the data so funding for the project can be focused on the data collection and analyzing the data.

For the criteria mentioned above data base selected was postgresql. This database system is open source. And is capable of supporting spatial as well as non- spatial data efficiently. Spatial tools were integrated with the database system that can accommodate spatial data types e.g. point, lines, polygons, rasters etc. for the integration of spatial tools with postgresql spatial extension of SQL i.e. Post GIS was enabled with the database. This enabling of spatial extension transform simple database into spatial database or SDB. Spatial databases are easy to incorporate with the Geographical information systems or GIS, which can be used for analysis or as client applications.

3.6 LOGICAL DATA MODEL

As the platform proceeds in the field it is continuously sending data to the database that is residing on the server. Data needs to be stored in such a manner that data makes sense and can be managed properly and efficiently.so a data model is required that tells what types of data are stored and how they are organized.

The logical representation of the real world in the databases can be viewed using the data objects i.e. tables or relations and their mutual relationships.

The logical model of the data comprises of following data objects (tables):

Mine Detection Mission

This table contains all the information regarding the mission that is required for the successful execution of the mission and for keeping a record of the mission. Each mine detection mission has attributes including mission ID, mission name, and mission description so one will get an idea why and where the mission has been initiated, starting data, mission status whether it has been completed or still on going and lastly the user id that keeps track that who has supervised the mission for mine detection. The primary key is “ID” which is the identifier number of the mission. This relation serves as central table that connects all the other relations.

Rover Path

Information related to the rover’s path will be kept in this table. Path followed by the robotic platform is extracted in real time using the continuous GPS receiver data being sent to the database. A time stamp field has also been added to the table to keep a track when the last changes has been made to the path. Furthermore it will also store the geometry of the path as poly line feature. “Path ID” is primary key of the table and “ID” from the mine detection mission table serves as the foreign key connecting this table with mine detection mission table so that each mission can have exactly one path stored against the mission ID. The relationship of platform path and mine detection mission is one to one.

Path obstacles

This table contains data about the obstacles which are faced by the rover on its path. When the rover moves in the field and finds any obstruction on its path, it senses that obstacle and sends flag to the backend where gps data corresponding to the time, when flag appeared is stored in the table as the obstacle location. The geometry of an obstacle will be a point which will be represent the obstacle on the map. It is a weak entity as it doesn’t have its own primary key. So to get the primary key of the table a combination is created of three keys i.e. Obstacle_ID, Path_ID and Mine detection mission “ID”. This is because the obstacles are directly related to the path and one path can have many obstacles so the relationship here is one to many. Obstacle_ID alone cannot be selected as the primary key because obstacles from another path can have same ID as that of already existing. Further mission ID is also present in the table as mission is related to obstacles through path relation and their relationship is one to many i.e. one mission can have many obstacles related to it.

Area

This area table contains area ID as well as the area geometry and the mission ID. Area ID serves as the primary key of the table. The relation is connected to mine detection mission relation through foreign key ID that is mission ID. The relationship between mine detection mission and the area is one to one i.e. no mission can take place at more than one locations at a time.

Mines Detected

This table contains all the information regarding location of the mines. When a mine is detected the signal is sent to the backend that triggers the flag on gps data corresponding to the timestamp of the beep so that a mine record is added to the mine table. The geometry of the mine is point type and it is stored in the geometry column of the table. The primary key of this table will be Mine_ID which is associated with each mine record found on the path. This table is also connected to the mine detection mission table through foreign key ID that is the primary key of the mine detection mission table. The relationship among two is one to many i.e. one mission can have various mines detected records associated to it.

User profile

All the information related to user is stored in this table. Attributes of the user such as User name, user ID assigned to him, user first name and last name, user level and password are kept in this table. User level depicts the type of user and user is granted privileges based on the user level assigned. In the present case, we have considered only two roles or user levels i.e. operator and viewer. This user level is depicted in the table as 0 or 1. Mine detection mission is connected to user profile through foreign key User_ID which is the primary key for user profile relation. The relationship among these two tables is one to many as one user can perform multiple missions.

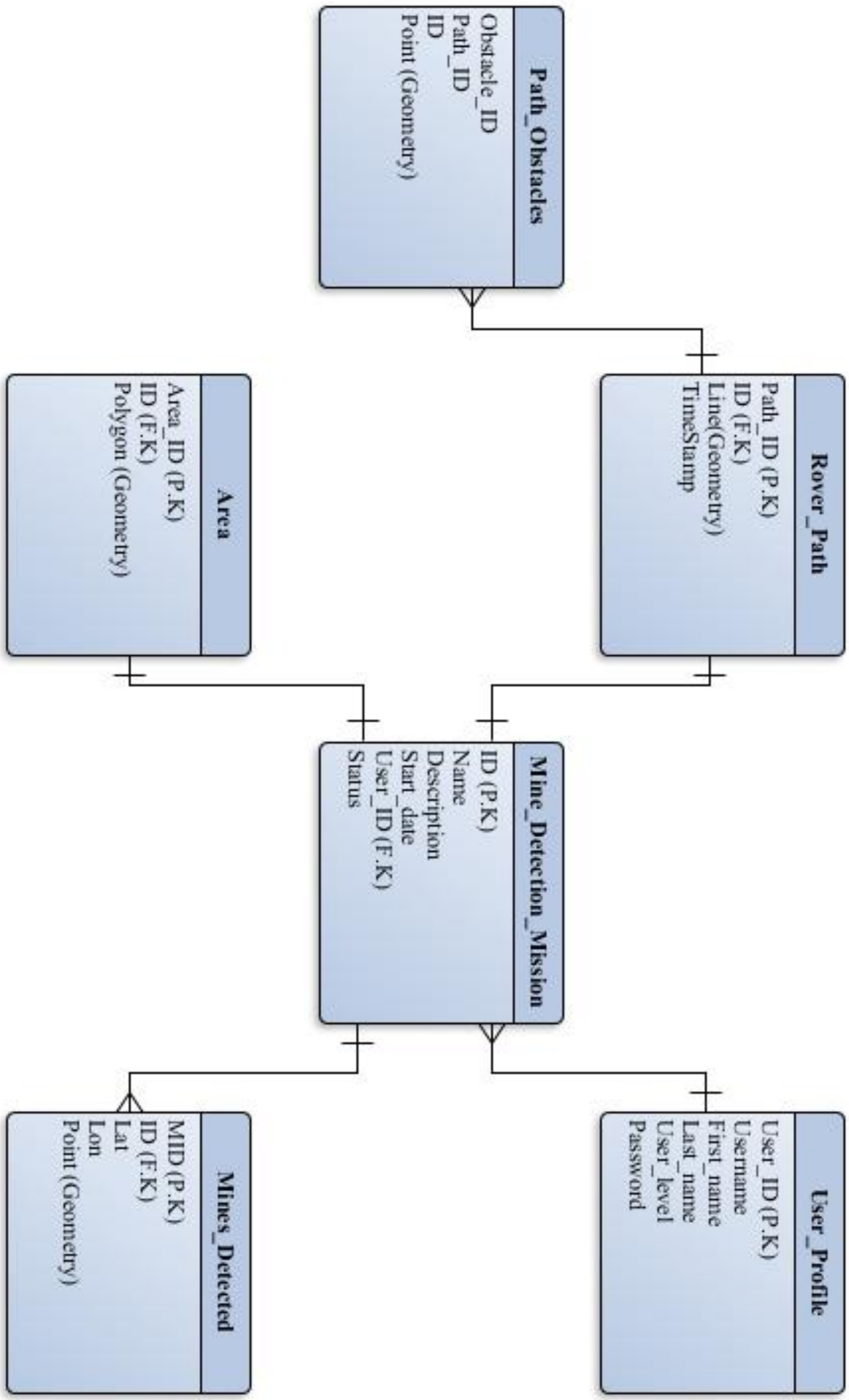

Fig18. Entity relationship diagram

3.7 DATA FLOW

User login

When any user assigned a user name and password logs into the system, an authentication is done based on the data for authorized users in the User_Profile table so as prevent any irrelevant user from logging into the system.

Area selection

At the start of new mission the user is prompted to select area for the execution of mission. The user draws a polygon which gets stored in the database in the Area table.

Path Extraction

As the rover moves in the field, it is continuously recording GPS data and sending it back to the database residing over the server through Wi-Fi module. This gps data is being processed at the backend and path being followed by the rover for certain mission gets updated in the Rover Path table.

Obstacle detection

On its path, rover also encounters some obstacles that need to be avoided. For this purpose obstacle are stored in the database. As soon any obstruction comes in the path of the rover that it cannot move over, then a signal is sent to the backend where that signal triggers the extraction of GPS data for the obstacle and send it to the Path Obstacle table.

Mine Detection

When the rover is on the move and it detects any mine the signal is sent back to the database that triggers the data from the gps corresponding to the time of detection to get stored in the database in Mine_Location table. From here data is displayed on the map at the client end.

3.8 CLIENT SIDE

As the rover moves in the field, it goes on sending data to the database server in real time. Now this data in the database requires to be analyzed and visualized by the user at the front end. Major part of this component is intended to provide user interaction with the database as well as the robotic platform in the real time. Client side has been categorized into two categories:

- Land rover sensory system
- Hand held trainers equipment

3.8.1 Land Rover Sensory System

For the land based robotic platform, the client side comprise of a web based interface to incorporate geospatial technologies with the users consent. For this purpose the web based platform is designed in such a way that user can access it anywhere in the network and there is no inconvenience of installing the system and dynamic linking libraries (dll) associated to it. The interface has following features:

Log in page

That allows the user to get authenticated from the database as this system is not open for public. User requires valid username and password to log into the system. Signup mode is not enabled and only those users can get access who are already been authorized by the system administrator.

Mission selection

Once the user log in is successful, he is redirected to the mission selection form. Here two options are available i.e. selection of existing mission and new mission creation. In existing mission selection, user is to fill the requirement that on basis of what attribute he wants to select the mission. In new mission creation, user is asked to fill details for new mission such as mission name, description and starting date.

Main page

Once the form is completely filled the user is redirected to the main page of the site which comprises of the map to display the information regarding the mission from the archive as well as in real time and a menu bar that allows multiple user functionalities based on the user level.

Existing mission viewing

In existing mission selection, user is provided with options to view the previously recorded data of any mission with status as completed. He can get the contaminated area, the path followed by the rover, obstacles detected in path of the rover and the mines detected. He can also view the description for the mine detection mission.

New mission execution

In new mission execution, user is provided with the capability to select or limit the area for search and the bounds of this search area does not allow the rover to move beyond the bounds. Moreover user can view the instantaneous position of the rover and the path being followed by the rover, obstacles in its path and the mine detected.

3.8.2 Hand Held Trainer's Equipment

Hand held trainer's equipment is provided with the ability to view the sweep area of the mine detector and to keep a check whether the sweep performed by the mine detector is accurate or not. Basically it's a system that allows the training of people in using the mine detector for manual clearance of the mines and at front end displays the sweep properties, efficiency and accuracy to the user conducting the training as well as prompting the trainers to get to know when the accuracy of detection gets disturbed.

3.8.3 Technologies

For the purpose of developing the above mentioned capabilities, following technologies have been used at client side:

HTML

Hyper Text Markup Language is a language for web development that allows to create hypertext documents which can be viewed as a webpage in any browser. Data in HTML is encapsulated in markup tags. It was used for the development of the front end of the interface in the project.

CSS

It is the style sheet language that is used for the styling of HTML at the front end. In our project CSS was used to style element rendering on the interface.

BOOTSTRAP

Bootstrap was used to develop responsive webpages.

JAVASCRIPT

JavaScript is popular high-level, dynamic programing language of web and HTML. JavaScript is the scripting language that is used for deciding the behavior of the elements on the webpage.

JQUERY

Jquery is the programming library of java script.

AJAX

Ajax is used to load data on the webpage without refreshing of the page. It is also used to connect the client end with the server end by requesting data to the server, receiving response from the server and sending data to the server in the background. Ajax was used in the interfacing for fetching data from the server and also for showing data in real time.

Google Maps API

Google Maps API is the java script mapping library that allows the incorporation of maps on the front end as well as customizing the maps in the application. Google maps are used in the interfacing for visualizing the real time data with reference to Google base map. Also feature edition is allowed on the Google maps added to the front end.

CHAPTER 4

RESULTS AND DISCUSSIONS

The results for this project have been very promising. We have shown that with a system using only a few inexpensive inertial sensors along with a common GPS module and IR sensor, we are able to produce a much better estimate of location of mines and mapping those location. This is also true for detection of obstacles on rover's path, we have detected the obstacles on rover's path and mapped them so that the operator can see that an obstacle came in the path that's why it changed its path and came back to its original path. Sensor fusion was done perfectly.

To determine the progress of the complete project we had four parameters to cross check the project. One being the hardware design, second being the removal of noise from the sensor data, third being the algorithm designing for landmine detection and time efficient autonomous movement of robot in the field and last being the mine reporting on the map in real time.

4.1 HARDWARE DESIGN

The design proposed was checked for the point weight distribution so that the point weight does not exceed the threshold required to detonate the mine. All the other parameters were simulated to get the idea how the platform will react in real world scenarios. The results of the simulation were positive.

However due to many factors such as time constraints, fabrication facilities limitation and the financial restrictions, the manufacturing of the original design has to be done at later stages in the deployment phase when the robot platform will be deployed in the field. Instead for the testing purpose a prototype is fabricated to serve as the representative of the actual robot. In this view of prototype selection, care should be taken to ensure that the prototype manufactured closely resembles the original design of the intended robotic platform. Therefore the prototype used is of the same size as that of the intended robot and the number of the components is the same as they are to be in the actual robot. The components in the prototype are designed or made as their functioning is as such that resembles the functioning of the real robot.

4.2 REDUCING ABNORMALITIES

As the sensors in the network are not working in ideal conditions so environmental factors has affected the data stream coming from those sensors to the database server. So before sending the data to the database, data values are passed through the kalman filter in order to reduce the noise and to extract the displacement using ITG-MPU sensor.

4.3 ALGORITHM DEVELOPMENT

In algorithm development phase, the rover has been made capable to follow a fixed path where starting from the initial point it moves 3 paces forward and 1 pace sideward. This process continues until the robotic platform finds mine. This is the point where comes the probability for each path stored in the database. As the rover goes on and detects two to four mines the, comes the part of algorithm where subtraction of multiple events occurs and rover starts deciding its path according to the spatial pattern of the mines.

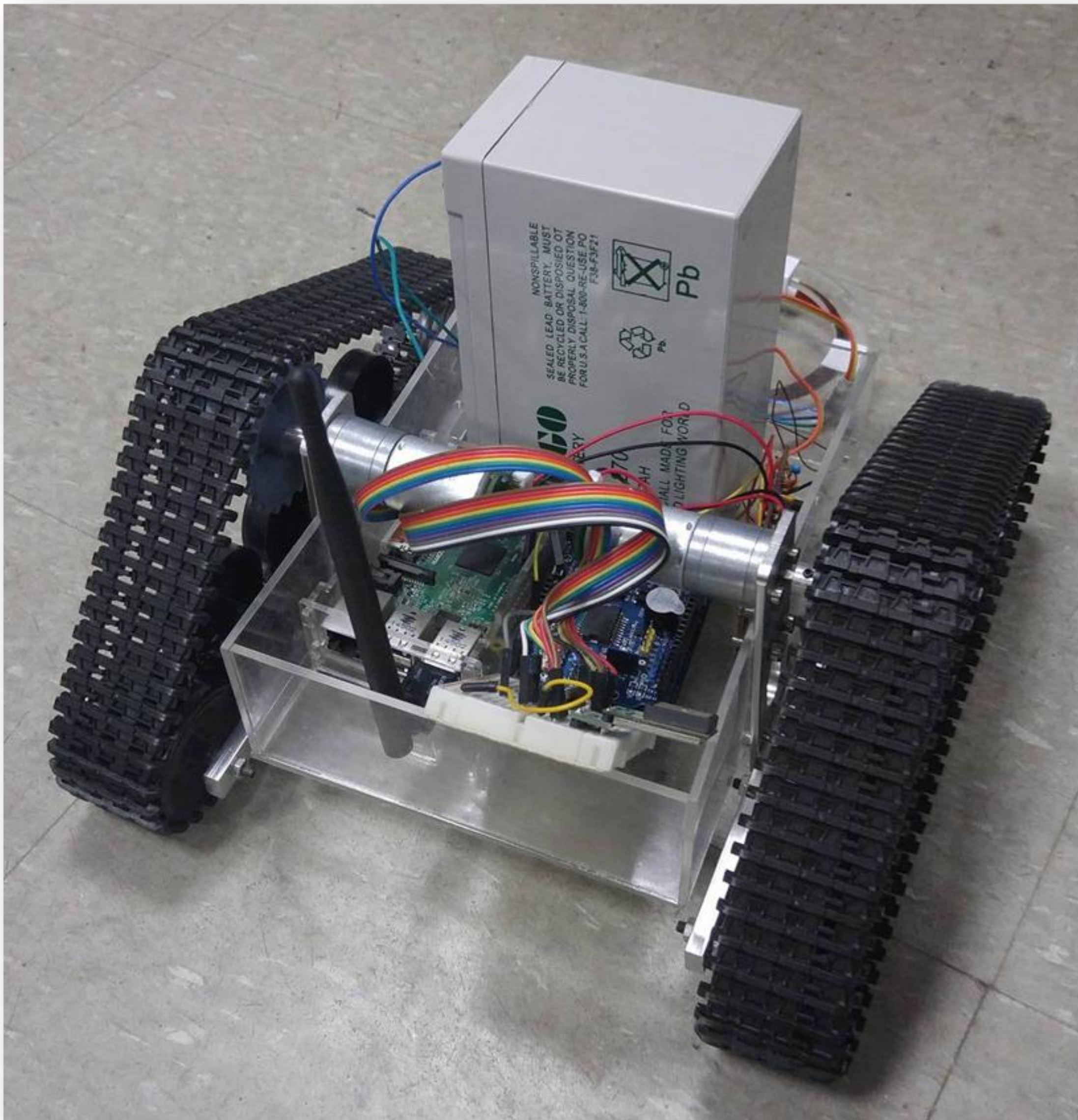

Fig 19. Mechanical Platform Prototype (I)

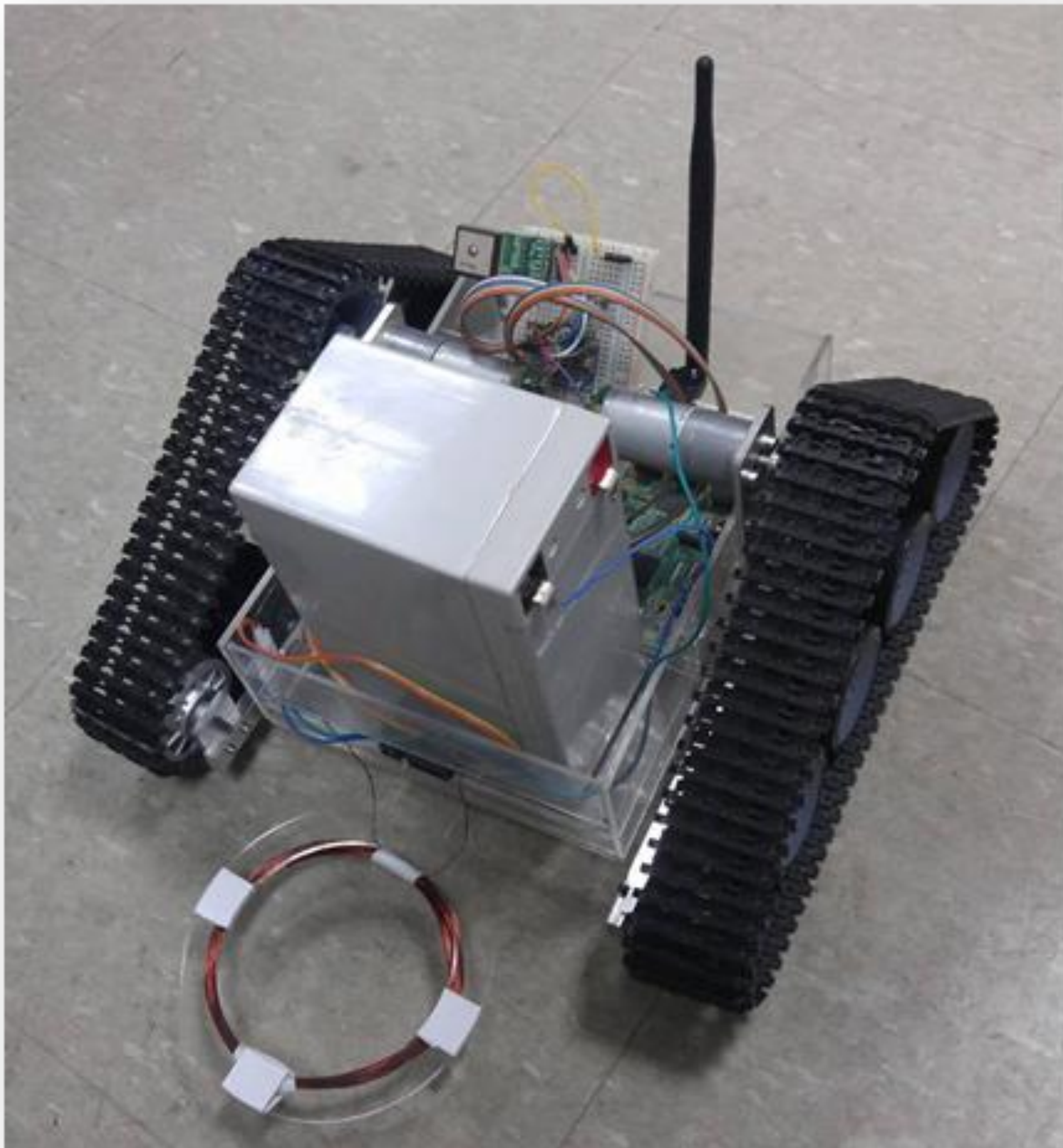

Fig 20. Mechanical Platform Prototype (II)

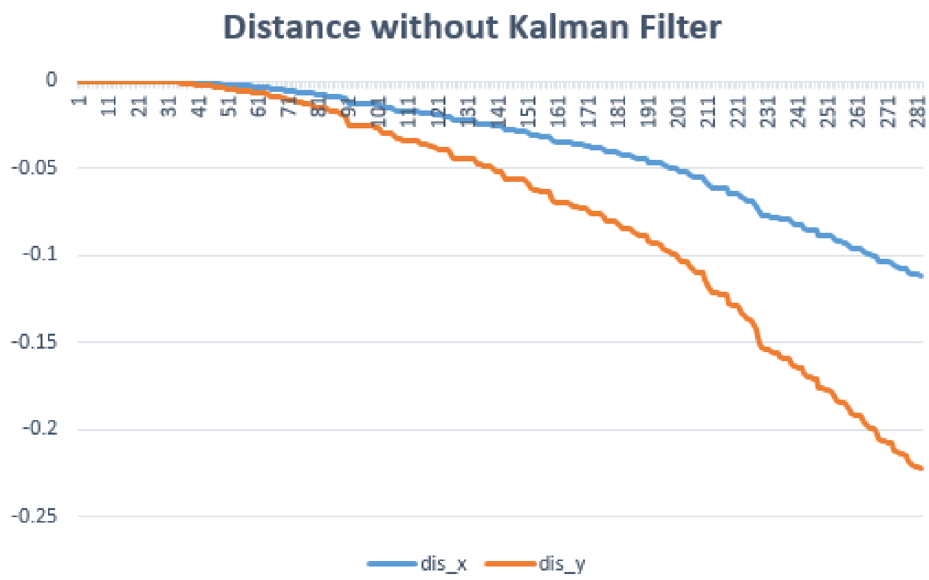

Fig21. Data without kalman filtering

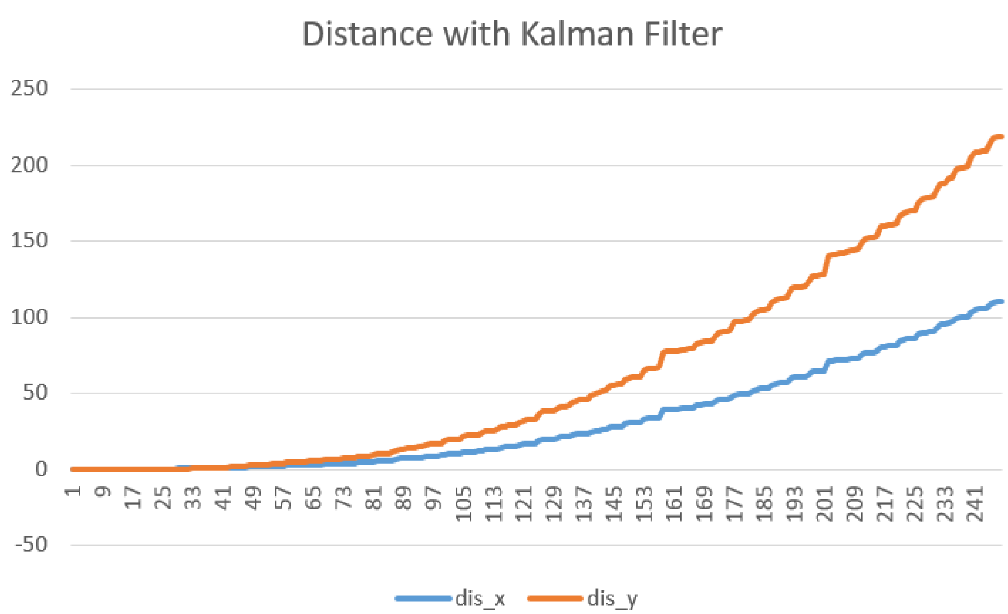

Fig22. Data with Kalman filter

4.4 MINE REPORTING AND GEO SPATIAL DATA ENABLED FRONT END

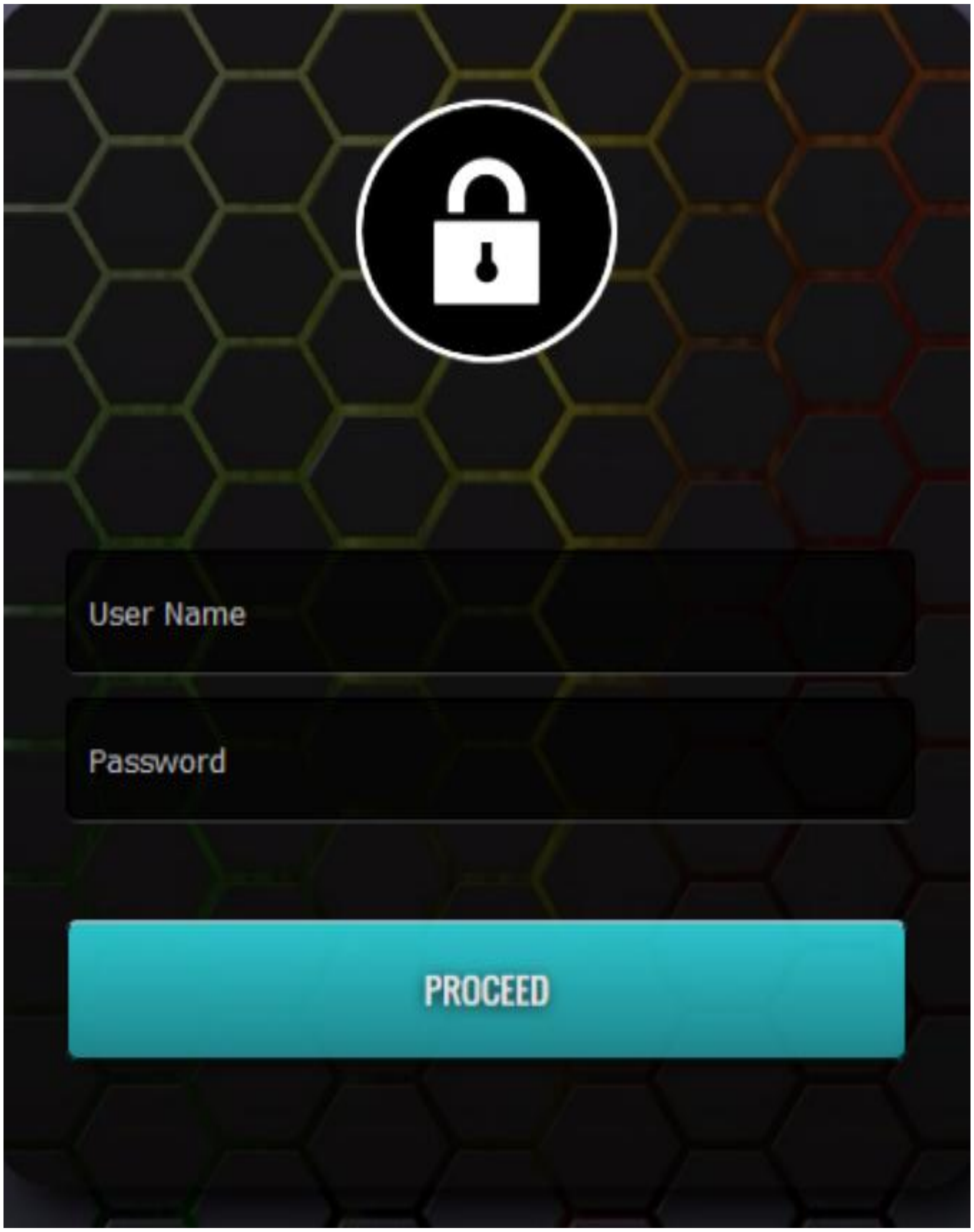

Fig23. Log-In Form

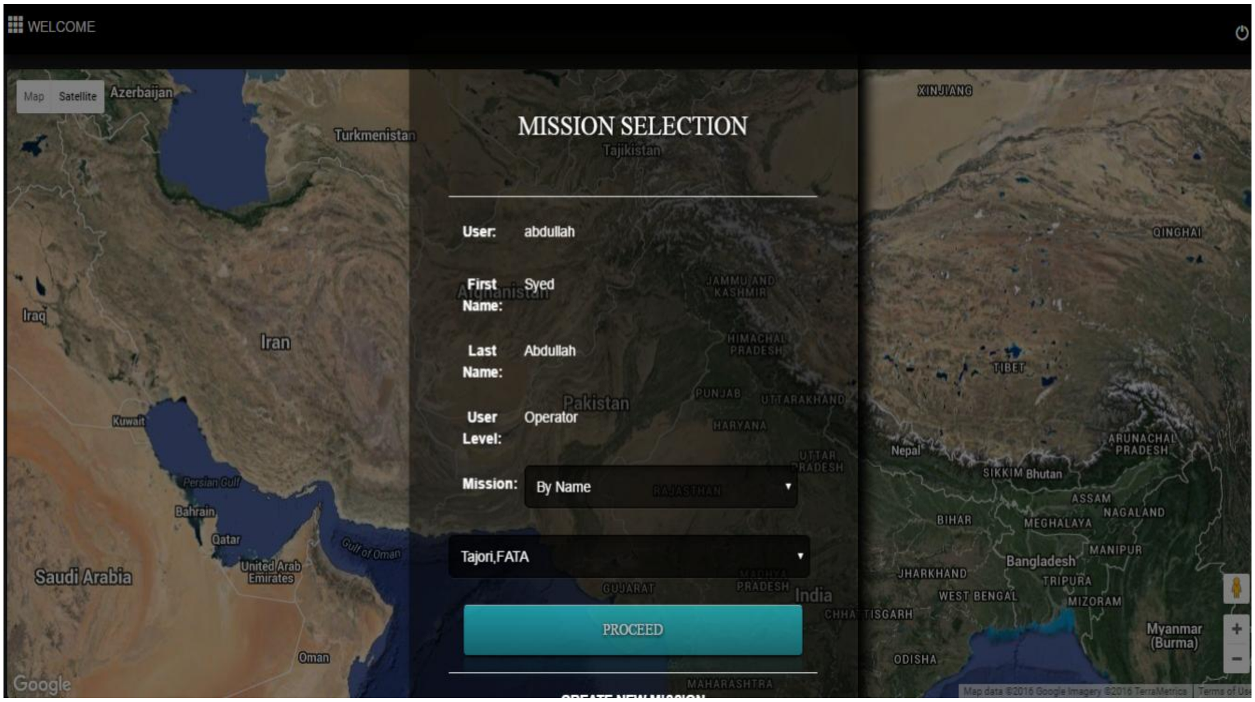

Fig24. Existing Mission Selection:

Prompts the user to select one of the existing missions

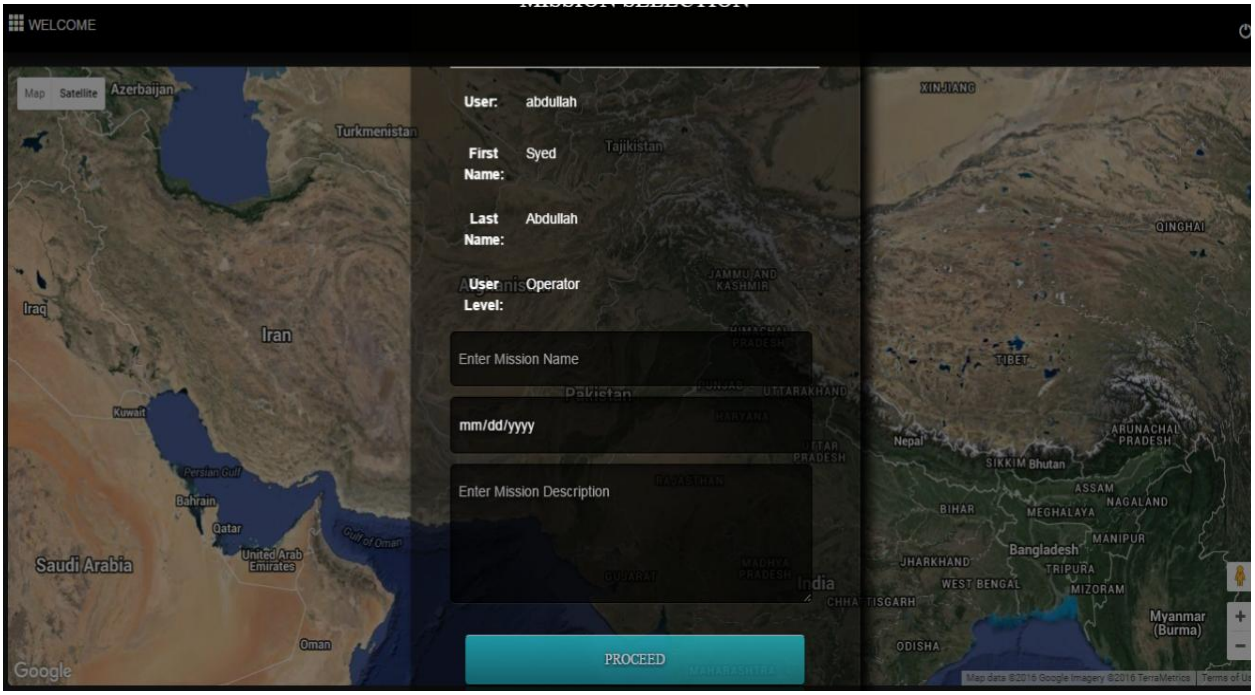

Fig25. New Mission Creation:

Form to prompts user to fill in details to start the mission

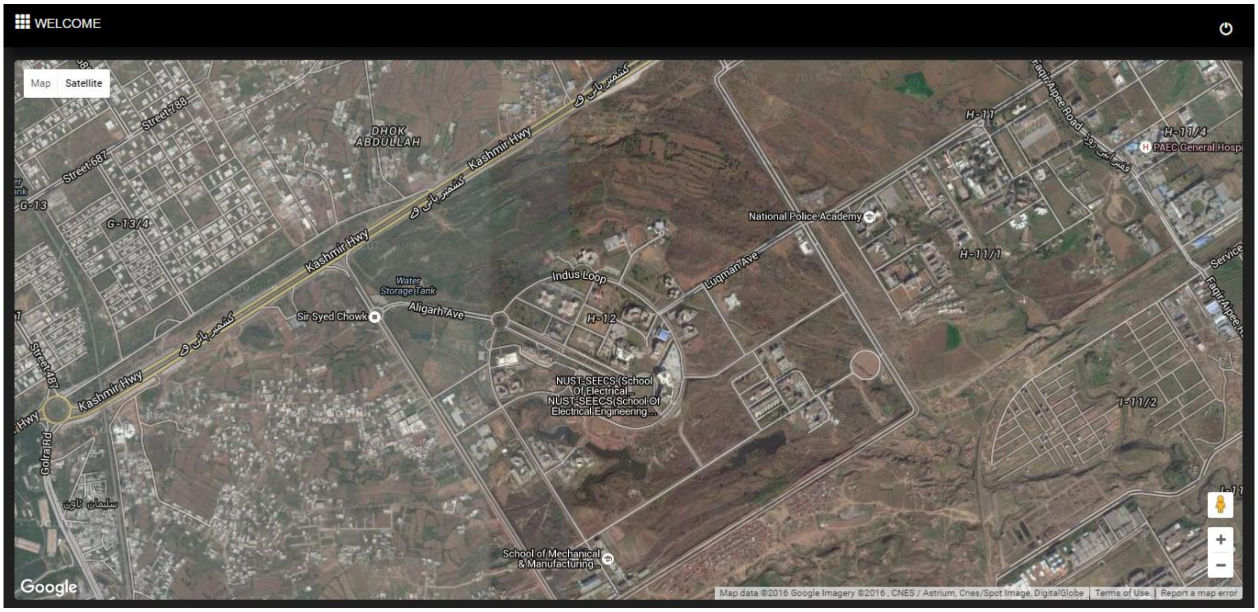

Fig26. Home Page:

Displays the Location live on the map

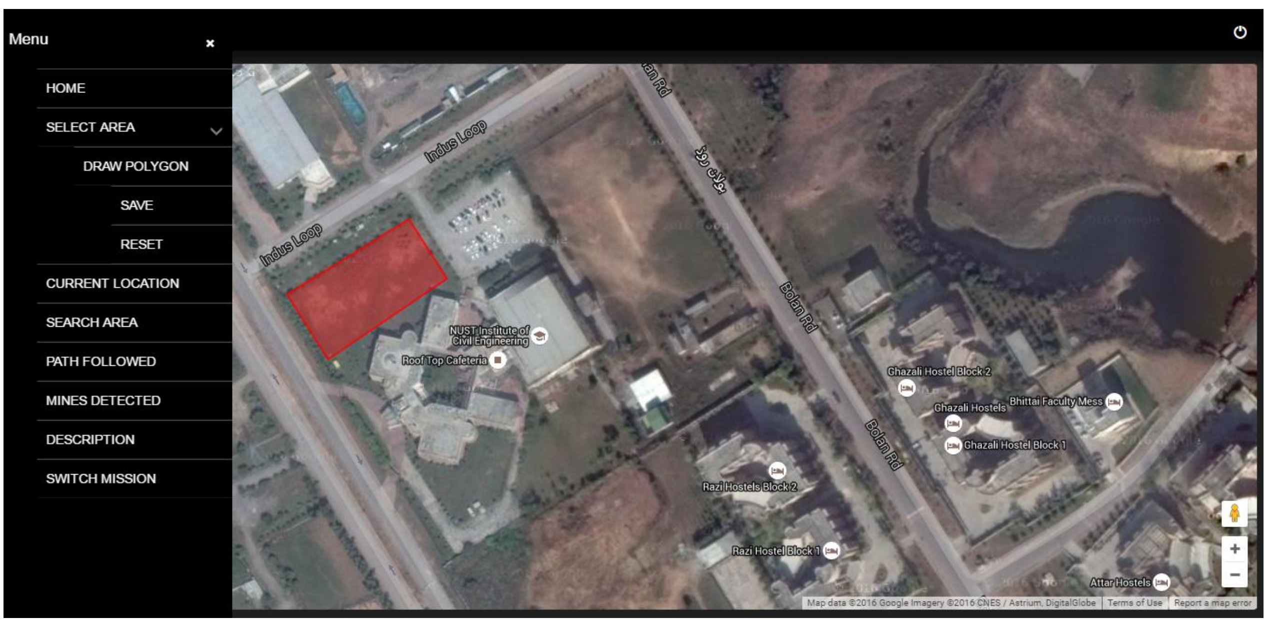

Fig27. Area Selection:

A polygon drawn to mark the bounds of the area under consideration

Fig28. Area display:

Capability of zooming into the area selected

Fig29. Area + Path display:

Live display of the path followed by the rover in the field

Fig30. Mines Detected:

Map displaying all the mines detected up till then (LIVE)

4.5 SHORTCOMINGS

The basic plan of the project was to enhance the efficiency of land mine detection process by using different geospatial techniques and decrease the man power requirement. The accuracy was achieved in measuring distances i.e. mine detector's head height from ground and distances of obstacles from rover front end. The data transmission and visualization of it on the map was also a success story of this project but like other academic projects this project also have some shortcomings.

Major shorts comings came because of cheap sensors. The use of Skylab GPS is one major short coming because its accuracy is around 30m which is very disturbing compared to this type of project where high positional accuracy is required. The other shortcoming was because of cheap and locally made IMU sensor which gives loads of garbage values as well. In rover controlling the major contribution is of motor shield which controls the motors with precision. The motor driver we used is not so accurate because once the motors starts rotating the temperature of the driver starts climbing and after some time it starts malfunctioning. So, to achieve maximum accuracy one should chose the hardware components and sensors of higher precision and accuracy.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

The basic plan of the project was to enhance the efficiency of land mine detection process by using different geospatial techniques and decrease the man power requirement. The accuracy was achieved in measuring distances i.e. mine detector's head height from ground and distances of obstacles from rover front end. The data transmission and visualization of it on the map was also a success story of this project but like other academic projects this project also have some shortcomings. Major shorts comings came because of cheap sensors. The use of Skylab GPS is one major short coming because its accuracy is around 30m which is very disturbing compared to this type of project where high positional accuracy is required. The other shortcoming was because of cheap and locally made IMU sensor which gives loads of garbage values as well. In rover controlling the major contribution is of motor shield which controls the motors with precision. The motor driver we used is not so accurate because once the motors starts rotating the temperature of the driver starts climbing and after some time it starts malfunctioning. So, to achieve maximum accuracy one should chose the hardware components and sensors of higher precision and accuracy.

This project has fulfilled most of its objectives and has even proposed the idea of hand held sensory tracing detector. The requirement whereby it states that the robot must detect 90% of the mines is beyond the limitations that are set by the circumstances of this project. Among all the detectors, metal detectors are the most unfavorable type as most of the mines are made with plastic bodies. The other options which are the use of GPR (ground penetration radar) and thermal imaging cameras are beyond this project's budget. Therefore, the research on the detection of mines and differentiation of false alarm versus real warning was unable to be carried out and that objective was compromised. However, the literature survey has been done on the performance of Infrared Thermal Imaging cameras and its results are promising.

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