

IoT Based Multi-Terrain Rover for Urban Search and Rescue Application



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Abstract: This paper presents the development of a semi-autonomous exploration perspective (approach) for Urban search and rescue environments (USAR). The developed rescue robot consists of a 2-wheel drive with a traction system capable of traversing in various terrain within a 47-degree inclination. A 2-DOF articulated end-effector is attached to robot, which can reach to a height of 45 cm from the ground, hold and lift the object up to 20 Kg. The robot movement is controlled by RFID and Wi-Fi for low latency audio and video feed by a mobile unit. The rover has a night mode with less noise capabilities to aid rescue in dark among various sensors for topography mapping. The objective of the robot is to maneuver with in the narrow-spaces where there is zero-visibility and create space by removing the possible obstacles in the path using the arm. The rover was tested in places with strong EM interference and was found to be viable.

Keywords: IoT, Rover, RFID, Rescue, Vision, Wi-Fi.

I. INTRODUCTION

The robotic innovations have a large impact in today's world in developing mechanisms that perform tasks with greater precision. Improvising the sensors and mechanical capability, have made these robots to function more like human beings [6][11][12]. The ways in which robots fill the gaps are elucidated below. Robots are now sent to places that were unreachable or too dangerous for humans to explore which in turn brings back relevant data of that place. It has also enhanced our understanding regarding our surroundings that would otherwise deter humans to explore on their own. They are built to function with accuracy. With the speed and accuracy of robots, the cost of production and services has significantly reduced, Automated robots are programmed in such a way that they do not require human intervention to carry out their designated tasks. They help performing redundant tasks with precision which in turn increases the productivity of the company. [8]The use of robots has become very pronounced in the health care industry where it is being used for surgical procedures and several biomedical equipments. The use of robots in warfare has substantially help reduce the number of lives lost, Robots are equipped to function accurately in adverse climatic situation of a place or region and produce optimal results. [9][10], even the space technology robots are extensively used to get us the right data.

Complete task humans are unwilling to carry out: some

robots are sent to outer space to carry out investigations never to return. Robots come in different sizes to suit the specific needs. This is reduced when there is an integration of robot and human. In the recent years, robots are aiding humans in the areas where the action needs to be precise and accurate. Precision and accuracy are required in a very sensible life risk situations like performing an operation on the patient, similarly search and rescue events in case of a natural disaster or collapsing of a building. Search and rescue is really difficult and hazardous for the humans to perform because of the unclear environment, existence of poisonous in the area and in-accessibility to the area [7]. To address this problem a multi-terrain Urban Search and Rescue (USAR) robots are introduced to aid the humans. As in case of the search and rescue operations the robot needs to approach unfamiliar areas where there is a need for human supervision to guide the robot to the specified area. To explore the unknown environment a frontier-based exploration is implemented in two cooperating mobile robots. By using this method, an overlap between the robots is minimized in the exploration time [1]. A test study was conducted on mobile robots in urban search and rescue applications by creating an arena which replicates the unstructured environments and challenging environment. This study allowed understanding the behavior of the robot in the unknown environment [2]. A mobile rescue robot using a hydraulic actuator was developed for applications where the heavy weights structures are required to be lifted in case of natural disasters as shown in fig 1(a). The bot integrated actuator acts as a mechanical jack which can lift up to 33kN load [3].



Fig.1. (a) Mobile Jack Robot for Rescue Operations [3]. (b) Multi-Link rescue robot [5].

A micro rescue robot was developed using simple locomotion mechanism and IR sensor modules to detect the presence of a human under the collapsed structures. In order to generate lift and thrust forces for the micro bot a micro eccentric motors are incorporated into the bot [4].

Manuscript published on 30 December 2019.

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A two multi-linked rescue robots were designed, as these robots are equipped with a cutting tool and a mechanical jack as shown in fig 1(b), which are used to cut and lift the obstacles in the path to move forward [5].

II. PROPOSED SYSTEM

A conceptual design of the 2-Degrees of Freedom (DOF) multi-terrain rover is shown in the figure 3 which is made to suit its requirements of being a portable rescue rover. The rover consists of a 2 RR end-effector driven by a servo motor for open and close operation, which aids in clamping the objects and remove the obstruction from the terrain. A worm gear mechanism is used for opening and closing of the end-effector. The 2-DOF manipulator is mounted on the chassis which is driven by DC motors, which can lift the objects to a height up to 45 cm with payload capacity of 10 kg using 2 motors of 50 rpm to control the arm function.

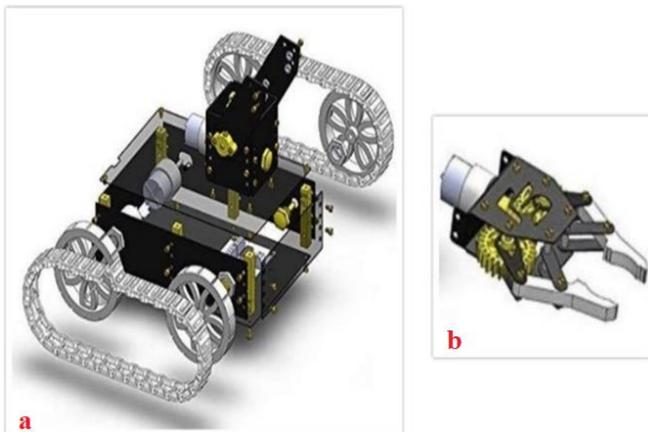


Fig.2. (a) CAD model of the rover (b) 2-DoF RR end-effector

The rover has a pair of traction belts for locomotion in varied terrains with 2 motors for maneuverability. The proposed system uses a portable computer by means of a mobile for image processing techniques and a custom programmable controller for controlling the robotic arm.

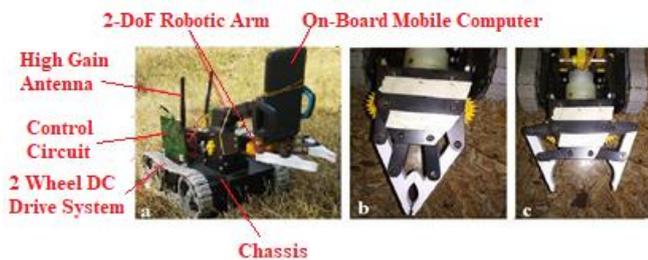


Fig.3. (a). Multi-Purpose rover system. (b). End-effector clamping mechanism (Closed). (c). End-effector clamping mechanism (Open).

The communication between the rover and user is performed by the on-board computer with built-in microphone module with a mono-chrome speaker coupled with 8MP camera with a LED flash with 10 lumens capacity alongside sensors like accelerometer, magnetic-field, gyroscope, light sensor, proximity sensor, gravity sensor, linear acceleration, rotation vector and a GPS (Global Positioning system) sensor as shown in fig 3. The target object in reference from the video feed is captured by the

onboard camera which is attached to the rover. Once a viable obstacle is identified, a metadata is generated and a manual trigger is given to the custom controller to maneuver and control the robotic arm atop the rover. This runs a custom version of Linux and using open-source software is converted into a local-hosted server which can transmit audio and video feed.

III. HARDWARE IMPLEMENTATION

A battery source of 12 V powers a voltage regulator and the mobile computer. An on-board camera coupled with sensor to generate a metadata chart along with a communication module which happens to be a 802.11 n Wi-Fi antenna is attached to the mobile computer. Two Antennas of 433 Khz and 311 Khz is received by means of a high gain antenna via a decoder for remote control circuitry which is then connected to a 2 DC motor driver connected to 2 Relay module which drives the motors to run for both the maneuver function and arm control which constitute the 2 DOF robot.

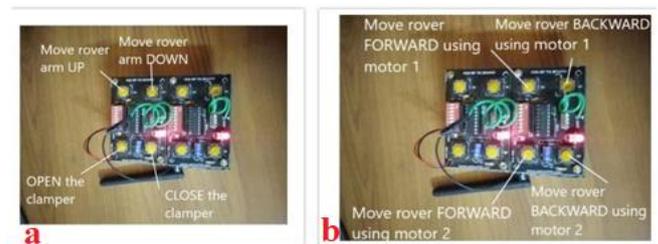


Fig.4. RF controller (remote) modes of operation for (a) End-Effector, (b) Wheel DC Motors.

RF controllers are used for operating the rover wirelessly as shown in fig 4. The figure on the left shows how to control the rover's arm functions. So this can be used individually or synchronized with the other buttons, so that both the arm and the clamp can be controlled in real-time. The figure on the right depicts the rover's motion in a 2D plane, i.e. moving forward, backward, left and right. Since the rover has 2 motors, changing the polarity can be used to reverse the direction in which they rotate.

- To move forward->Press forward motor 1 + forward motor 2
- To move backward->Press backward motor 1 + backward motor 2
- In order to change direction, pressing buttons diagonally will make 1 motor to spin in clockwise while the other in anti-clockwise.
- To turn left->Press forward motor 1 + backward motor 2
To turn right->Press forward motor 2 + backward motor1

IV. SOFTWARE IMPLEMENTATION

The software used in the image processing and rover sensor functionality is IP-Webcam; an open-source application having a client module for Linux Kernel based mobile devices.

The central access server which is accessed by means of a web-page on hosted network which allows the user to see the environment. Based on the motion, of the rover and the on-board computer generates the metadata of the terrain using the sensor incorporated in the on-board computer as shown in fig 5.

In this setup, the local-host server would provide an interface where the user can perform the following functions.

- A 2 way Audio-Communication: In disaster prone areas, critical communication is vital. A ‘walkie-talkie’ setup is done wherein encoded audio is transcoded over the Wi-Fi to the central server which as a browser generates a secure HTTPS certificate over which user can communicate in the typical format of HTML5 Wav, HTML5 Opus and a convenient flash format.
- Motion-Detection module: Here a custom detection algorithm can be specified based on the sensitivity of detection. Object detection is done via a Python script where parameters like line intensity and object acuity can be defined.
- Night-Vision: To aid rescue in poorly lit areas, the control for triggering LED on the communication module alongside the ability to switch to backup stereo camera is presented.
- Sensor Metadata: Just gauging the terrain using visual and audio information won’t be enough if the terrain has an irregular topography which otherwise can’t be interpreted without gyroscope data and altitude.

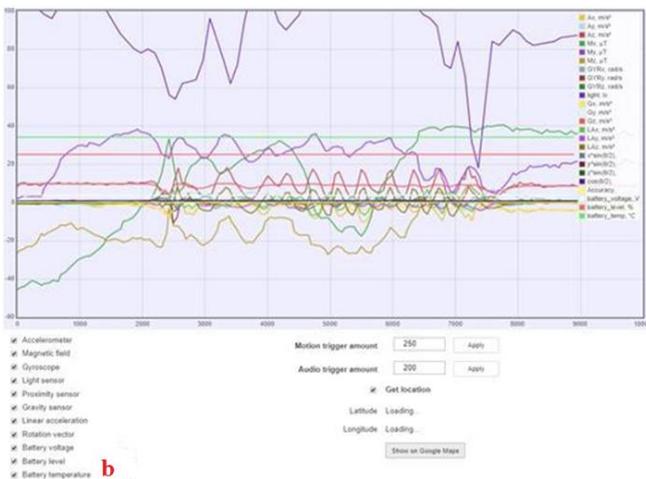


Fig. 5. (a). Sensor metadata (normal terrain). (b). Sensor Metadata (rough terrain)

Each color in the graph corresponds to a different sensor value in the following order:

Violet-> Accelerometer, Red-> Magnetic field, Yellow-> Gyroscope, Light-Green-> Proximity, and Blue -> Gravity sensors.

The graph on the left (Fig 5.a) is from a typical grassy terrain with negligible amounts of topography sensor fluctuation wherein a observed change was noticed in accelerometer, gyroscope, gravity-sensor, linear-acceleration and the rotation vector with average mean deviation to be in the 3% mark which is calculated via a graph-measure tool . Other sensor for the magnetic field which includes the hall-effect sensor was found to be in norms, indicating the terrain to be safe for EM transmission and reception.

The graph on the right (Fig 5.b) is from a rocky terrain with notable changes in topography with medium to deep sized pot-holes with a remarkable change notices in the sensor metadata graph. Sensors like accelerometer, gyroscope, linear-acceleration and the rotation vector were the most significant with their average mean deviation to be over 75%. Notable changes were noticed in magnetic field sensors with walls of rock in stimulated conditions showing a difference from normal values to be in the 10 % mark, indicating such kind of terrain is dangerous for otherwise use in normal condition.

The data from the gyroscope is used to stabilize the rover should it topple when the programmable threshold limit is off limits.

An on-board signal booster is made use of when the gain is decreased. The point to be observed here is that this kind of metadata helps us to gauge the condition which otherwise can prove hazardous for humans to explore on their own and check for feasibility conditions to mark a USAR mission more successful on its own. Information sent from the communication module is presented by means of a web server hosted by the mobile computer over Wi-Fi. Options to toggle the video feed resolution are presented with latency factor taken in consideration over the host network’s capabilities. Moreover the ability to stream the server over HTTPS is also presented. Considering the need for multi-user (approach), the channel in this aspect can be streamed simultaneously to multiple users in real time with negligible attenuation.

V. CONTROL MECHANISM

The user is able to control the rover by means of a RF (radio frequency) controller as shown in fig 4, wherein the control signals are sent in 2 separate frequency bands to the receiver module present in the rover in fig 6. Now the use of Wi-Fi is presented for real-time audio and video feedback.

5.1. METHOD OF OPERATION

The steps followed using the proposed robotic system is as follows,

- Open Server connection as a local host from client device
- Establish connection to host IP network.

- c. Note the port number for device and open it in browser.
- d. Check video feed latency, audio communication and start the real-time audio and video feed.
- e. Using the RF controller navigate the rover to the terrain using the feed.
- f. Use the sensor metadata profile to gauge in-depth information about the terrain.
- g. Identify the obstacle in the terrain and navigate towards it.
- h. Use the 2DOF arm to interact with it and make corrective actions.
- i. With the live feed, observe and check for any repercussions in the vicinity.
- j. Use the transmitted data to compile a profile of the vicinity to the control room.
- k. Return back to base station.

VI. RESULT AND DISCUSSION

Field results were obtained with various terrains as mentioned above with the rover being able to traverse inclines of up to 47 degrees without any perturbation as shown in fig 6. In urban terrain, tested conditions were small staircases with a height of 5 cm with the surface to be variable, metal speed-breaker roads and in gravel. A muddy terrain is then used with 1 cm of water with the rover maintaining good traction control while traversing. In order to stimulate rocky terrain rocks and rubble were placed and rover was able to traverse them without any problem. Following which is the mountain terrain with rover being able to traverse alongside keeping arm functions steady. Table 1 shows the overall dimensions and parameters of the rover.

Table1: Physical attributes of the rover.

Function	Parameter
Size	25 cm*38 cm*22(30) cm
Weight	5 Kg
Max velocity	0.6 m/s
Max payload	25 Kg
Design expansion payload (in co-ordination)	1500 kg
Min inserting height	1 cm
Max lifting Height	50 cm
Max Range in normal terrain	220 m
Max Range in varied rocky terrain	158 m
Battery endurance (normal terrain)	Around 90 minutes
Battery endurance (abnormal terrain)	43 minutes.
Operating Range of mobile computer	300 m
Rover tolerance	2°C to 57°C

VII. SUMMARY

A novel design of a multi-terrain multi-purpose rover is fabricated and implemented for rescue and surveillance application suitable for rocky and muddy environment due to its modular drive systems. The rover has an empirical range of incline to be up to 47 degree owing due to optimized chassis design which supports the rover to achieve this result. The maximum operable range is 300m with an external high gain antenna in general conditions with an endurance rating of around 2 hours with a charge time of 4 hours over regular 12V DC power supply. The arm supports a payload of 25 Kg which can be lifted over a height of 50 cm. Transmitted feed can be adjusted based on its variable resolution it has minimum latency while transmitting at 1280*720 resolutions with video quality set to medium. Higher FPS is observed at QVGA (320*240) resolution. The feed can be modified extensively with ability to stream in Flash, native Browser, Java and JavaScript respectively, with ability to control exposure and gain alongside manual routine trigger for focus. Modification of ISO sensitivity is possible with anti-banding, white balance and lock-exposure being an addition. A combination of rovers acting in a co-bot system helped to rescue a test object weighing 75 KG in stimulated conditions.

The rover has limitations that require some further development. Firstly, the operating range was low, which could be fixed by investing in high gain transceiver system with a frequency hopping mechanism. Secondly, this is a semi-autonomous rover where-in some parts like real-time feature extraction, automatic scheduler based on defined parameters, image processing, auto-backup option to cloud servers are mainly software based and being able for the rover to guide autonomously is something which can be worked on.



Fig.6. (a). Muddy terrain with ankle-depth water, (b). Mountain terrain, (c). Rocky terrain, (d). Urban terrain (e). Semi-Rocky terrain, (f) .Grassy terrain.

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AUTHORS PROFILE



Mr. S Shankar Narayanan is an extremely passionate and astute person in the field of science having completed his undergraduate in Electronics and Communication Engineering at Vellore Institute of Technology, Chennai in 2019. He has done exceptional projects in his domain having addressed critical problems prevalent in the society with diligence. He has involved in intense research with his patent being published in the National Patent Journal of India.



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