IOT-ENHANCED MULTI-TERRAIN ROVER FOR URBAN SEARCH AND RESCUE: ADVANCING EMERGENCY RESPONSE CAPABILITIES

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ABSTRACT: Thispaperpresentsthedevelopmentofa 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 capableof 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. Theobjectiveoftherobotistomaneuverwithinthenarrow-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.

1.INTRODUCTION

The robotic innovations have a large impact in today's world in developing mechanisms that perform tasks with greaterprecision.Improvising the sensors and mechanical capability,havemadetheserobotstofunctionmorelike human beings . Theways in which robots fill the gapsareelucidatedbelow.Robotsarenowsenttoplacesthat were unreachable ortoodangerousforhumansto explore which in turn brings back relevant data of that place. It has alsoenhancedour understandingregarding our surroundings that would otherwise deter humans to explore on their own. Theyarebuilttofunction with accuracy. With thespeed and accuracy of robots, the cost of productionand services has significantlyreduced, Automated robots are programmed in such a way that they do not require human interventionto carryouttheirdesignatedtasks.Theyhelpperformingredundant tasks with precision which in turn increases theproductivityofthecompany. [8Theuseofrobotshasbecome verypronounced in thehealth careindustrywhereit is being usedforsurgicalproceduresandseveralbiomedicalequipments. The use of robots in warfare hassubstantially help reducethenumber of lives lost, Robots are equipped to functionaccuratelyinadverseclimaticsituation ofa placeor region and produce optimal results. even the space technology robotsareextensively usedto getustheright data.

Complete task humans are unwilling to carry out: some robotsaresenttoouterspacetocarryoutinvestigations 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. To address this problem a multi-terrain Urban Search and Rescue (USAR) robots are introduced toaid 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. Byusing 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. Thisstudyallowedunderstandingthebehavioroftherobotin theunknownenvironment[2].Amobilerescuerobot usinga hydraulicactuator wasdeveloped 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 to33kN load [3].

Fig.1.(a)Mobile Jack RobotforRescueOperations[3]. (b)Multi-Linkrescuerobot[5]

Amicrorescuerobotwasdevelopedusingsimplelocomotionmechanismand IRsensormodulestodetectthe presenceofa human under the collapsed structures. In order to generate lift and thrust forces for the micro bot a micro eccentric motors are incorporated intothe bot. 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),whichareusedtocutandlifttheobstaclesinthepathto move forward

2.PROPOSED SYSTEM

A conceptual design of the 2-Degrees of Freedom (DOF) multi-terrain rover isshown in thefigure3which is made to suit its requirements of being a portable rescue rover. The roverconsistsofa2RRend-effectordrivenbyaservomotor for open and close operation, which aids in clasping the objectsandremovetheobstruction fromtheterrain.Aworm gearmechanismisusedforopeningandclosingofthe end-effector. The 2-DOF manipulator is mounted on the chassis which is driven by DC motors, which can lift the objectstoaheightupto45cmwithpayloadcapacityof10kg using 2 motors of 50 rpm to control the arm function.

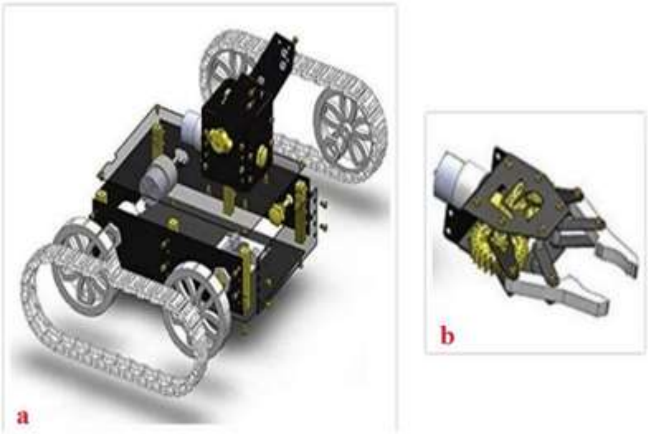

Fig.2. (a)CADmodel of the rover (b) 2-DoFRRend- effector

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.

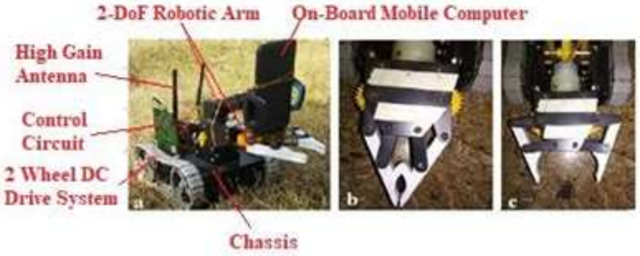

Fig.3.(a).Multi-Purposeroversystem.(b). End-effector clampingmechanism(Closed). (c). End-effector clamping mechanism (Open).

The communication between the rover and user is performedbytheon-boardcomputerwithbuilt-in microphone module with a mono-chrome speaker coupled with 8MPcamerawith aLEDflash 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 onboardcamerawhichisattachedtotherover. Onceaviable 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 versionofLinuxandusingopen-sourcesoftwareisconverted intoalocal-hostedserverwhichcantransmitaudioandvideo feed.

3.HARDWARE IMPLEMENTATION

Abatterysourceof12Vpowersavoltageregulatorandthe 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 tothe mobile computer. Two Antennas of 433 Khz and311Khzisreceivedbymeansofa high gain antenna via a decoder for remote control circuitry which is then connected to a 2 DC motor driver connected to 2 Relay modulewhichdrivesthemotorstorunforboththemaneuver function and arm control which constitute the 2 DOF robot.

4.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 bymeansofaweb-pageon hostednetworkwhich allowsthe 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 interfacewheretheusercanperformthefollowingfunctions.

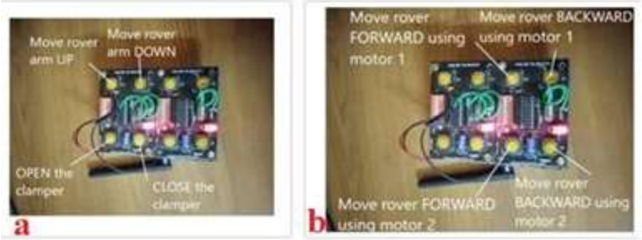

Fig.4.RFcontroller(remote)modesofoperationfor (a) End-Effector,(b) WheelDC Motors.

RF controllers are used for operating the rover wirelessly asshowninfig4.Thefigureontheleftshowshowtocontrol therover'sarmfunctions.Sothiscan beused individuallyor synchronizedwiththeother buttons,sothatboth thearmand 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

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(roughterrain)

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 andtherotation vector with averagemean deviation tobein the 3% mark which is calculated via a graph-measure tool . Othersensorforthemagneticfieldwhichincludesthe 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 themost significant with their averagemean deviation to be over 75%. Notable changes were noticed in magnetic field sensorswithwallsofrockinstimulatedconditionsshowinga difference from normal values to be in the 10 % mark, indicatingsuchkindofterrainisdangerousforotherwiseuse in normal condition.

Thedata from the gyroscope is used to stabilize the rover shoulddittopplewhentheprogrammablethresholdlimitisoff limits.

Anon-boardsignalboosterismadeuseofwhenthegainis decreased. The point to be observed here is that this kind of metadata helps us to gauge the condition which otherwise canprovehazardousfor humanstoexploreon 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 serverhostedbythemobilecomputeroverWi-Fi.Optionsto toggle the video feed resolution are presented with latency factor taken in consideration over the host network’s capabilities.Moreoverthe abilitytostreamtheserverover HTTPSisalsopresented.

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.

5.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 frequencybands to the receiver modulepresent in the rover in fig 6.Nowthe use of Wi-Fi is presented for real-time audio and video feedback.

METHOD OF OPERATION

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

a) Open Server connection as a local host from client device
b) 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.

6.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 showninfig6.Inurbanterrain,testedconditionsweresmall 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 rockyterrain 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.

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

Table1:Physical attributes of therover.

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

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