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RAKSHAK- An All-Terrain Rescue Robot

[1]Shubhendu Ojas Tewary, [1]Deepesh Acharya, [1]Gaurav Sharma, [1]Drishtant Dhole, [1]Ramnik Singh Walia, [1]Aditi Raghav
[1]SRM Institute Of Science and Technology

Abstract:

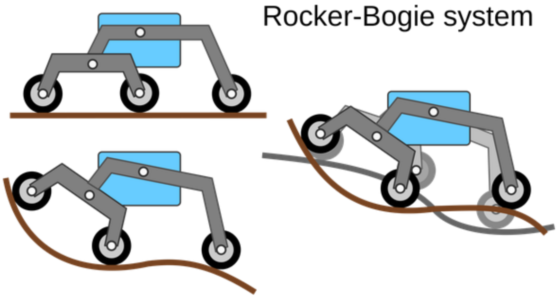
With this project we intend to build an all-terrain mobile robot for environmental observation, surveillance and human assistance. This is a robot that is designed and configured to drive over just about any terrain for use with surveillance and most practical applications. It works on any indoor surface and most outdoor surfaces. This mobile robot is Radio Controlled and upgraded with numerous sensors for better functioning.

Keywords

All-terrain, Thermal Camera, CMU cam, Image Processing, L298n, Obstacle Avoidance, Disaster Affected Area, Arduino UNO, Bluetooth Module, ESP8266, Rocker-Bogie Mechanism, Robotic Arm, Terrain Mapping, V-Python, GPS System

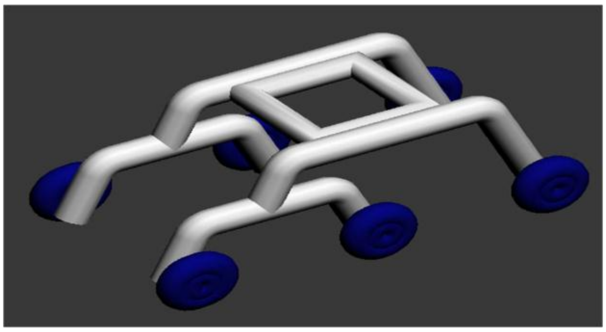
1. Introduction

The All-Terrain Mobile Robot has driven various application and research based developments. This robot is designed to work on almost all indoor and outdoor surfaces. It is designed to drive over any terrain for surveillance, and all terrain locomotion and other related domains. The goal was to develop a versatile robot which derives it's features from CMU Cam, thermal camera and terrain mapping. The arm controller is an added advantage which offers the ability to pick and place the object lying ahead. Since the bot has an inbuilt terrain mapping system it provides with the graphical representation of the terrain. To foster the ability of the robot, the thermal camera feature is used to characterize thermal objects in outdoor environment and objects that extend beyond the thermal camera's field of view such as hedges, wall and other compact objects which are in camera's field of view.



Recent disaster relief programs have shown that there exists a large discrepancy between robotic technology which is developed in science labs and the use of such technology on the terrain. The rough outside world poses several constraints on the mechanical structure of the robotic system, on the electronics and the control architecture and on the robustness of the autonomous components, and with this project we propose an all-terrain robot with a robotic arm which could carry out ‘n’ number of tasks on its own.

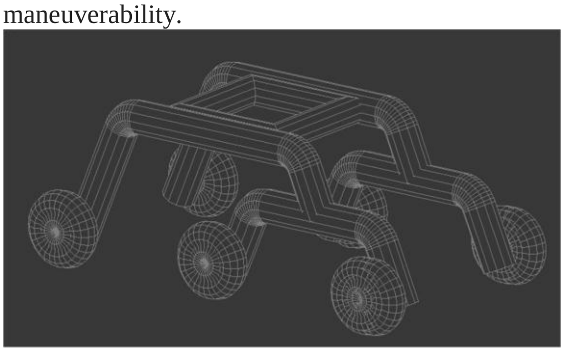
The proposed robot is to be fabricated with 6 wheels which are controlled by BLDC (Brushless DC) motors and coded using Arduino UNO. The installed Cameras, CMUcam and FLIR Thermal Camera are used to serve the sole purpose of surveillance in different manners. The CMUcam is installed on the robotic arm. And thermal camera on the main chassis. CMUcam carries out vision image processing and signature detection whereas Thermal Camera could be used for night vision and life detection. These cameras’ live feed could be seen by a web server. Apart from these there’s an array of Ultrasonic Sensor on the bottom of the chassis for terrain mapping and directly uploading it to the web server made. By uploading data like video feed and terrain mapping on the server we accomplish IoT. The electronic arm made up from 4 servo motors is incorporated to carry out some fundamental tasks.



2. Mechanical Structure

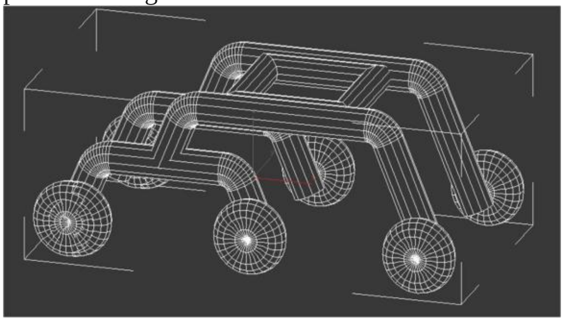
2.1. Rocker-Bogie Mechanism

The mechanical structure of the Scorpion was designed keeping in mind mobility and maneuverability over any and all types of surfaces and weather conditions. Inspiration was taken by Martian rover Curiosity, which establishes the 'rocker-bogie suspension system. The primary mechanical feature of the robot is its true-blue all-wheel-drive capability, which is achieved by 6 motors powering the six wheels of the robot. Usually while building a robot, the suspension system is usually not required, but depending on the circumstances, there will be instances when the suspension cannot be avoided. The "bogie" in the rocker-bogie design refers to the system of linkages that have a drive wheel at each end. There are no springs or axles at any of the wheels, which allows the robot to climb over multiple obstacles, such as rocks, while at the same time ensuring that all the six wheels of the systems are in contact with the ground. Thus ensuring proper traction as well as maneuverability.

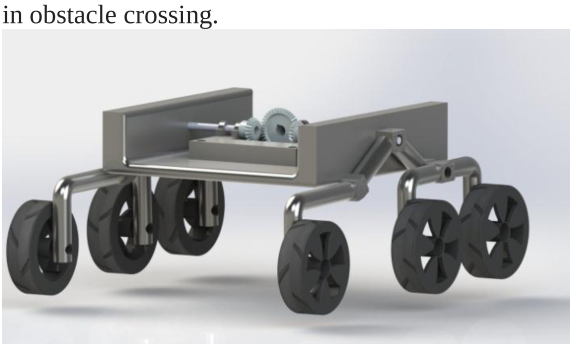


2.2. Design of Rocker-Bogie

The key element in employing the rocker-bogie suspension system in the mobile robot has the correct dimensions of the rocker and bogie linkages that are deployed and the angles subtended between them. The precision in the design will ultimately adjudge the capability of the proposed robot in scaling uneven surfaces, as well as surfaces that will be at a particular height.



Taking the example of stair climbing for an instance. To climb the stairs with stability, the chassis deploys only one pair of wheels in rising position at one instance of time. Thus, in order to find the dimension of the bogie linkages, the first pair of wheels is placed right at the very end of the point where it is supposed to commence climbing, and the second pair at some horizontal distance from the vertical height of the stair. At this instant, the third pair of wheels has nearly completed their climbing before the first pair starts its rise. The design of the wheel, as well as the selection, was done keeping in mind that it was to provide maximum traction possible across all types of terrains that was served to it but at the same time not be too heavy to create a strain on the motors. Thus six lightweight rubber wheels were chosen, with a diameter of 125 mm, the width of 60 mm and a shaft diameter of 6mm. the wheels proved to be ideal for providing support to the overall frame as well as decent maneuverability in obstacle crossing.



The locomotive duties were handled by six motors incorporated in the legs of the vehicle. the motors are 12V, with 6 mm shaft diameter, brushless DC motor capable of churning out 30 rpm maximum output. Analysis over multiple terrains, like marshy land, rocks, sand, depicted this motor and wheel combination to be suitable concerning the sustainability of the chassis and the frame, consisting of the arm, the Arduino microcontroller and all its peripherals acting as payload.

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2.3. Design of Motor Arm

The robotic arm incorporated in the proposed robot is fully automated and design keeping in mind that no 3D printed components is to be used to keep the cost in check. The basic components involved an Arduino and 4 servos, one for each motor action of the arm. Breaking down each movement of the arm, starting from the claws, were designed by glueing to clips on two gears and rotating them using one servo motor. the jib or the 'elbow' of the arm is motorized using vertical servo motor and the 3 part, that is the bottom arm is connected to the second vertical servo motor. This entire system is attached to a base and provided with a 360^0 rotation using the horizontal servo motor. The servo motor was chosen to be lightweight but at the same time provide some amount of structural rigidity in the entire system. A coreless motor proved to be suitable for the proposed

3. Hardware Architecture

All terrain, six-wheeled robot with a robotic arm is designed so as to traverse on all kinds of surfaces. The all-terrain traversing is achieved with the rocker-bogie mechanism which is also used in NASA's rover Curiosity. The six wheels connected to the DC motor are controlled using L293D which are further connected to Arduino UNO.

The all-terrain traversing is achieved using two modes of operation: Autonomous Mode of Operation and Radio Controlled. The obstacle avoidance system incorporated in the robot with the help of Ultra Sonic Sensor (HC-SR04) makes the Robot autonomous and collision-proof (in cases where moving over the obstacle is not an option).

The Radio Controllability could be provided by three possible mediums-

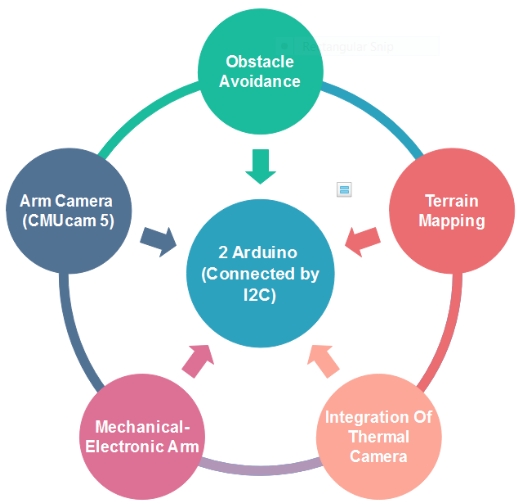
- Bluetooth Module (HC - 05): It is interfaced with the Arduino and the mobile phone app.

- Wifi Module (ESP8266): It uses Arduino as an interface to the controller and creates an AP (access point) and transfers the data to the browser.

- Transmitter- Receiver: It uses RF module that sends and receive the radio signals.

Further, the robotic system includes a surveillance monitoring unit which remotely surveils the extreme environments and sends the data to the web server. The surveillance monitoring unit consists of a CMUcam and FLIR(Forward Looking Infrared Radiometer) thermal cam. These cameras are interfaced to the Arduino. However, the CMUcam is used to track and monitor colours, does motion detection and is used to follow the lines. The FLIR Thermal cam is used to translate the heat into the light to analyze a particular object and displays it onto the screen using a specialized software Arduino IDE. It is further used to detect the human life by sensing heat from the human body by using heat sensors. The robot performs terrain mapping which is an application of IOT with the help of GPS module, an ultrasonic sensor(HC-SR04), a colour sensor and with the help of obstacle avoidance the all-terrain robot reaches the GPS location which maps the terrain surface. The mapped terrain surface is then uploaded onto the web server.

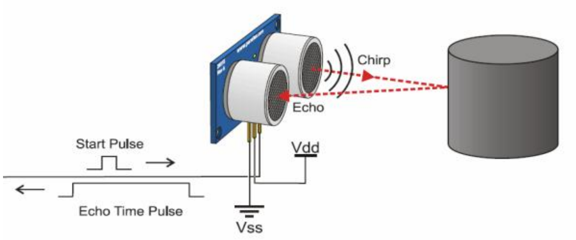
The four levels of the electronic arm are controlled by four servomotors on which the CMUcam of surveillance unit is installed which is used for pick and place mechanism. However, the arm system consists of an image processing feature which uses a set of inductive, capacitive and optical sensors to differentiate object colour. The image processing senses the objects in an image captured in real time by a CMUcam and then identifies colour and information of it. Based on the detection the robotic arm moves to the specified location releases the object and comes back to the original position.

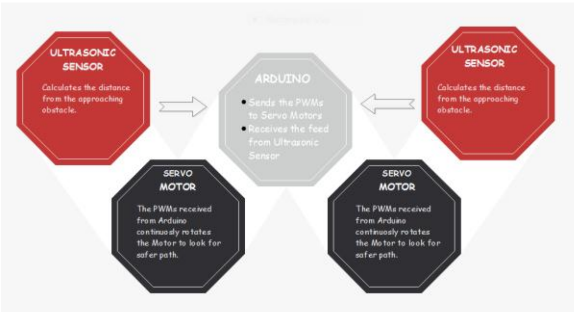


4. Software Architecture

4.1. Obstacle Avoidance

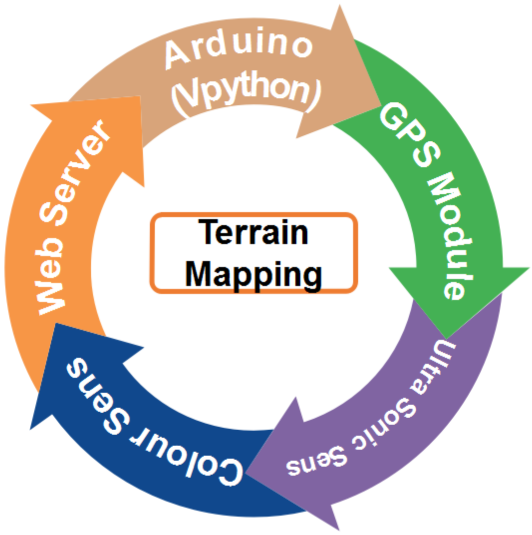
The robot will be equipped with ultrasonic sensor in front which will be rotated by servo motors in both the direction covering a range of 180 degrees in front. Whenever the robot is going on the desired path the ultrasonic sensor transmits the ultrasonic waves continuously from its sensor head. Whenever an obstacle comes ahead of it the ultrasonic waves are reflected back from an object and that information is passed to the microcontroller. The microcontroller controls the motors left, right, back based on ultrasonic signals. In order to control the speed of each motor, pulse width modulation is used. (PWM).





4.2. Terrain Mapping (IOT Integrated)

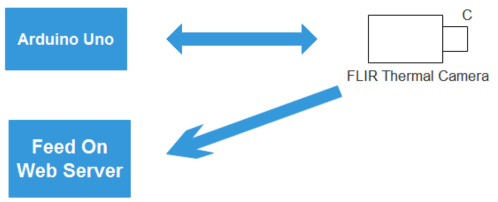
Terrain Mapping is one of the IOT application of the robot. This particular system uses a GPS Module, Ultrasonic Sensor (HC-SR04) and a Color Sensor to achieve terrain mapping. The all-terrain robot is fed with particular GPS coordinates, and with the help Obstacle Avoidance and all-terrain traversing the robot reaches the GPS location. The array of Ultrasonic sensor installed on the lower side of robot helps to graphically map the terrain of the surface on which the robot is traversing. The integration of Arduino and Python is done and Vpython library is used to display the feed received from the Ultrasonic Sensor and Colour Sensor on the screen. The distance measurement received from Ultrasonic Sensor is received by the serial port.



The so received terrain map of the location is uploaded to the web server, which receives such maps from numerous robots sending from different locations, all these information is integrated to generate a complete map of the area. Terrain Mapping is one of the IOT application of the robot.

4.3. Integration Of Thermal Camera

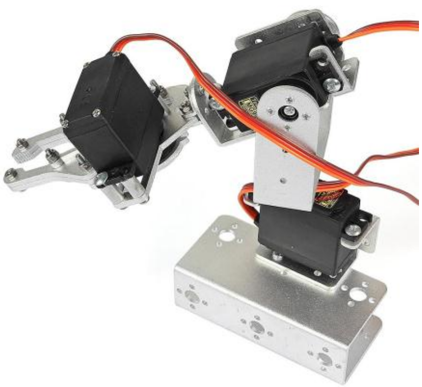
FLIR (Forward Looking Infrared Radiometer) Thermal camera or thermography is a type of infrared visualization. The robot will be equipped with the thermal camera that forms an image using infrared radiation, similar to common cameras that forms an image with visible light.



They will do so by detecting the heat signatures from the body coming across the robot which will take only one-thirteenth of a second for infrared detectors present inside the camera to make the thermal image of the object. It facilitates the robot with night vision and heat detection. Thermal Camera can also be used to detect radioactive leakage.

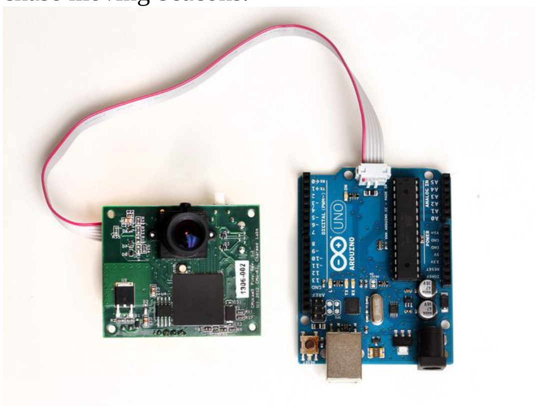
4.4. Mechanical-electronic Arm

An arm made up using servo motors at 4 level is positioned on the chassis. The four levels of Servos are 1 each at elbow, wrist, claw and base. This gives an all-direction free motion to the arm. The servo motors are controlled by Pulse Width Modulation (PWM) sent from the microcontroller to complete basic mechanical tasks. It is designed as such to pick and place objects.

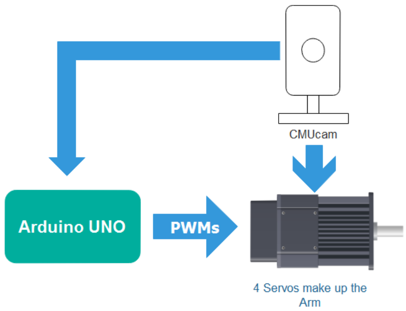


4.5. The ARM Camera

The robotic arm constructed with the help of 4 servo motors is also equipped with a camera (CMUcam). CMUcam (CMUcam 1) is a low cost, low-power sensor for a mobile robot. It is used for real-time vision processing tasks. It is serially connected to Arduino UNO. It tracks or monitor colours, does motion detection and so is used to localize landmarks, target acquisition, and follow lines and to chase moving beacons.



The CMUcam1 is fed with few templates according to which it detects any object of that template and colour. It can find hundreds of objects at the same instant with a processing speed of 50 frames a second. The object which has to be detected its template is fed into the processor of CMUcam1 and then any object with that template and colour is detected and the cam moves towards it, this free motion is accomplished by 4 levels of servo motors in the arm.



5. Data Extraction

The systems are designed to collect information from the Rakshak's hardware and software modules for the purpose of analysis, troubleshooting, and this system is fully supported by ROS, as it provides a standard tool chain for collecting, publishing, analyzing and viewing data.

CMU Cam vision system uses a low-cost microcontroller for high-speed processing of camera data and contains software to perform simple vision tasks. The user can choose to output only low bandwidth high-level information from the vision system. CMU Cam's fastest frame rate is 16.7 frames/sec. Using serial software protocol, the frame rate can be slowed down as desired. CMU Cam can communicate at baud rates of 9600, 19200, 38400,115200. The baud rate can be selected via jumper settings on the CMU board. The CMU Cam has been used in the project for target acquisition and template matching.

A 4 level arm has been instilled in the project so as to diversify its applications. To control the arm, four servo motors are used. Arduino has been coded such that it sends PWM signals to the servo motors thereby giving the motors the necessary commands. The arm is used for pick and place i.e. with the help of the arm, the bot can pick things up and place them at the desired location. The arm also provides a base to the CMU cam.

FLIR Thermal Camera has been used in the project to infuse night vision capabilities in the bot. The camera detects infrared energy (heat) and converts it into an electronic signal, which is then processed to produce a thermal image on a video monitor and perform temperature calculations. The bot uses this feature for night vision, leaked radiation detection and life detection in the disaster affected areas.

In Terrain Mapping, ultrasonic sensors rotating on the bot measure the horizontal and vertical distance of the bot from the ground thereby mapping the terrain. The read data is uploaded on the server thereby providing the user real time access.

6. Diagnostic And Recovery

The fundamental systems and modules of the robot are supported by a diagnostic system which is supported by ROS as it provides standard diagnostic toolchain for collecting, publishing analyzing and viewing diagnostic data. The diagnostic system involves the use of camera for continuous feed to server and GPS system. The diagnostic system alerts the server when the battery goes below a threshold value. When the server is alerted it acquires the GPS location of robot and prepares the shortest return path depending on the terrain map designed earlier, the robot goes into a power saving mode where all functionalities except the traversing turns off unless manually overwritten. This is done to recover the robot safely.

7. Conclusion and Future Prospects

Robots have the capacity to shape the world in ways we can't even predict. It is important for a broad range of people to have access to the fundamentals of robotics so that they can bring diverse perspectives to problems we will encounter in the future. Rakshak which is an all-terrain robot is a step taking this legacy forward. Rakshak is equipped with some of the most advanced applications which makes it an important tool in disaster prone areas.

The robot serves the following applications such as-

1. Obstacle avoidance with the help of ultrasonic sensors.
2. Can be used as night vision camera with the help of thermal cam.
3. Cmu cam will give the robot an object following application which will guide the robot to reach to its predefined target on its own. Cmu cam will also be used a surveillance camera in robot
4. The robot is also equipped with a mechanical arm which allows the robot to pick and place things in the specified position.

Robots have revolutionized the way humans used to work, perceive things and react to real time events and they will continue to do so in the near future. One such possible application which can be added to the robot in the near future is swarm robotics. Swarm robotics is an approach to the coordination of multirobot systems which consist of large numbers of mostly simple physical robots. One of the most promising uses of swarm robotics is in disaster rescue missions. Swarms of robots of different sizes could be sent to places rescue workers can't reach safely, to detect the presence of life via infra-red sensors.

Swarm robotics in Rakshak will further enhance its usability and will give a wider dimension to its application

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