

Design and Development of Android Guided Rover for Earth's Surface

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Abstract

The Mobile Rover is a modular mobility platform, designed for operation on rough terrain to facilitate Earth based exploration missions and space research. Still now, there are no low-cost rovers available to the researchers for surface exploration. In this paper, a simple Android Phone is used as remote device to control the rover. A standard mechanical and electrical interface is used in this process. A passive kinematic averaging suspension provides excellent mobility over obstacles in addition to improve stability and even weight distribution.

Keywords

Passive Averaging Rocker Arm, Android, Arduino, MATLAB, Accelerometer

1. Introduction

A robot is nothing but an electro-mechanical system with the capability of sensing its environment, manipulating it and acting according to the pre-programmed sequence. It is basically a machine that appears intelligent due to the instructions it receives from a computer inside it which handles multiple tasks. Mobile robots are becoming more widely used in daily life as their level of autonomy and intelligence are being improved. The high costs and dangers associated with space exploration have led NASA and other private enterprises to pursue planetary research through the use of unmanned robotic systems. NASA has continued to develop autonomous navigation to make it easier and quicker to control their rovers. To do this, on-board stereo vision processing was used to develop an image of the environment, which identified positive and negative obstacles relative to the ground plane [1-10]. In lunar surface, Google used Red Rover which has 4 wheel rocker differencing suspension system. This type of passive suspension is based on the rocker-bogie design but is simplified by reducing the number of wheels and free-pivoting axles. It drives the two wheels on each side of the rover together, and thus relies on skid-steering to rotate the rover. For vision, Red Rover has a stereo camera and flash LIDAR which will allow it to make high-resolution terrain maps [11].

In this paper the design, develop, and test of a rover to serve as a robust platform, suitable for testing planetary surface exploration technologies in harsh earth's environments has been discussed. For designing the rover the main features which are essential for most planetary exploration missions are included like :Mobility and basic navigation, Tele-operation and intuitive user controls, Low mass and small form-factor. Besides the entire above requirement it is also our challenge to design the rover with very low cost and less complexity and modular to allow for easy additions of custom or Commercial-Off-The-Shelf (COTS) hardware components.

II. Design Requirements and Specifications

Our main goal is to design, develop, and test a rover to serve as a mobility platform, suitable for testing planetary surface exploration. The design will focus on incorporating features that are believed to be essential for most planetary exploration missions based on research of past and current rovers.

Though our rover is not suitable in space but our main goal to make a robust platform that will be suitable for testing in the earth's environments. Like space bound vehicles this rover also has to accommodate payload capability and also face the same constraints like size & weight. The proposed designed rover must also traverse a wide variety of harsh Earth's environments.

The rover must be able to overcome high obstacles which is a major constraint that prohibited us from designing a space-ready rover. This rover should be designed in such a way that the design specifications may be changed depending upon the obstacle size.



Fig. 1: Front View, Top View and Side View of the Rover

Usually in all autonomy rover's when faced the crucial condition for planetary navigation, the mobility and decision making signals come from the user's end. In this novel designed rover this control is done via an Android based Phone which sends the accelerometer remotely through WIFI to a MATLAB environment running in a PC. The PC then sends serial data to Arduino Microcontroller via Serial Port Link, which in turn drives the motor driver circuit to provide power supply to drive the motors.

Table 1: Summary of Technical Specification

Design Requirements	Value
Maximum speed	35cm/sec 13.8 inch/sec
Maximum obstacle size	7 cm 2.76 inch
Payload	1 kg 2.2 lbs
Available power	5V(>20Amps) 12V(>10Amps)
Maximum total mass	1.5 kg 3.3 lbs
Dimensions (L x W x H)	38cm x 27cm x 17cm 14.96in x 10.63in x 6.7in
On Board Computer	Arduino Duemilanove / ATmega 328
Available I/O ports	Arduino Serial USB Port
Interface	Serial Port Link with PC
Controller	Android Phone
Software	MATLAB, Arduino IDE

III. Design and Analysis

Our design and related analysis is divided into three main sections (A) Mobility (B) Hardware (C) Software Architecture. Each one of these main categories is related to meet fundamental requirements, and combined they provide a comprehensive overview of the design rover.

A. Mobility

Mobility relates to the rover's capacity to traverse varying terrains, slopes, and obstacles. The mechanical design including the chassis, wheel components, drive systems are discussed in this section.

1. Chassis Design and Rocker Suspension

This Rover uses differencing suspension with four wheels and two rocker arms allowing the rover to turn in place and avoid skid-steering. This method boasts some benefits of the rocker-bogie system by providing a level of ground compliance; however, its main advantage is in its comparatively simple design, as it requires fewer wheels, axles, linkages, and motors.

This novel design is less complex and very much cost effective with all other methods of designing a rover. In this design one motor dedicated to drive directly the corresponding wheel. This technique reduces the need for a complex power transfer system, which is often done with belts, gears, or drive shafts. In this selected design velocities of each wheel is controlled individually to optimize trajectories over rough terrain. The main requirements pertaining to mobility are the slopes that can be traversed, the maximum size of obstacles, and speeds. These design criteria drove constraints for the wheel size, wheelbase, and rocker configuration, which led to the design shown in fig. 2.

Overcoming obstacles is an essential aspect of rovers. For this design criteria the rover being able to traverse obstacles up to 7cm in height or depth from the ideal ground plane. This is mostly achieved by selecting a wheel diameter slightly greater than the maximum obstacle height. By selecting a wheel diameter of 10cm the rover should be able to easily surmount obstacles up to about 7cm. Additionally the chassis has a ground clearance of about 9cm, which means the rover can easily go over obstacles that tall, if such obstacles are within the wheel base.

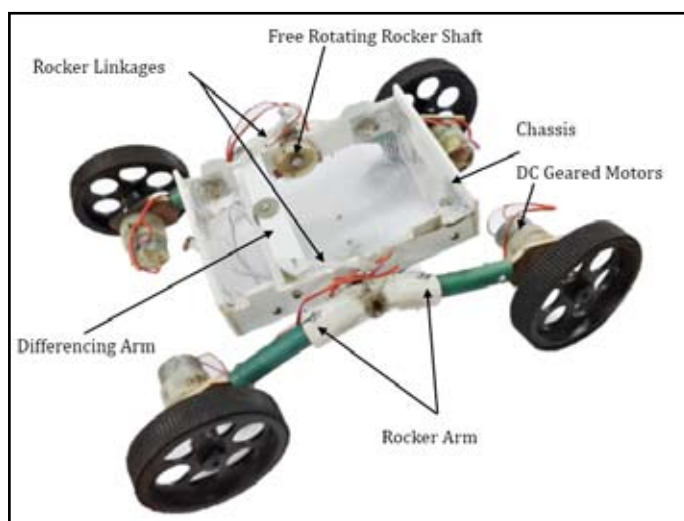


Fig. 2: Chassis and Rocker Suspension Design

Though this design suggests that 7cm obstacles can be traversed, the rocker differencing suspension provides the ability to traverse obstacles much larger, and it is up to one wheel diameter in height. One advantage of the rocker differencing suspension is its resulting

ground compliance. This means that over rough terrain all four wheels can remain in contact with the ground, increasing stability and traction. This is due to a similar effect that is achieved with the rocker-bogie design, where the force required to lift a wheel vertically is reduced by the passive suspension.

The main body of the rover is made from three rails of 137x45x4 mm³ width rectangular plastic plates and two 190x45x4 mm³ is shown in fig. 2. Four of these rails are clamped together, and fixed with glue to form a box, 38cm long by 27cm wide by 17cm high. The last chassis rail is fixed across the width of the rectangular frame to add support, and is also used to secure a pivoting location for the differencing arm. Besides bearing all structural loads associated with driving and the rocker differencing suspension, the chassis is able to securely store all electrical components.

2. Wheel Design

An important design goal is for the rover to be ruggedized and capable of operating in harsh environments. As previously discussed, a wheel diameter of about 10cm was selected based on mobility requirements. The wheel needs to be lightweight and should sustain the loads of the rover. Small Gripping Wheels are used for their light-weight. Heavy gripping rubber material is used for the grip in rugged terrains. While our wheel design may not be optimized in terms of strength and weight reduction, it resulted in a cost effective solution with minimal manufacturing time, and a wheel that should meet all design goals.

3. Drive Motor Selection

The process of selecting motors began with reviewing power criteria of similar sized rovers and eventually considering the power requirements needed by our rover to meet mobility objectives. Space bound rovers are slow, on the order of 3cm/sec, and generally do not allocate large amounts of power for driving.

In calculating drive speeds we assumed a nominal motor speed of 100rpm. Since the only power source on the rover is a 12V we are not able to achieve full speeds because the L293D motor driver can only deliver up to 95% of the that voltage to drive the motor; meaning the motor will run slightly below its rated voltage and thus slightly below its nominal speed. Due to the frictions and the added weight of the rover the motor speed again reduces by a fraction. The estimated motor speed is nearly about 70rpm.

The velocity of the rover can be calculated using the following equation

B. Hardware

The hardware design for the rover includes an Android Phone connected to a Laptop running MATLAB via a WIFI link. The Android sends the Accelerometer data to MATLAB which then processes the data and generate the control signals. It is then sent to the Arduino board which drives the Motor Driver which in turn drives the 12V DC Motors. The Circuit Diagram is shown below:

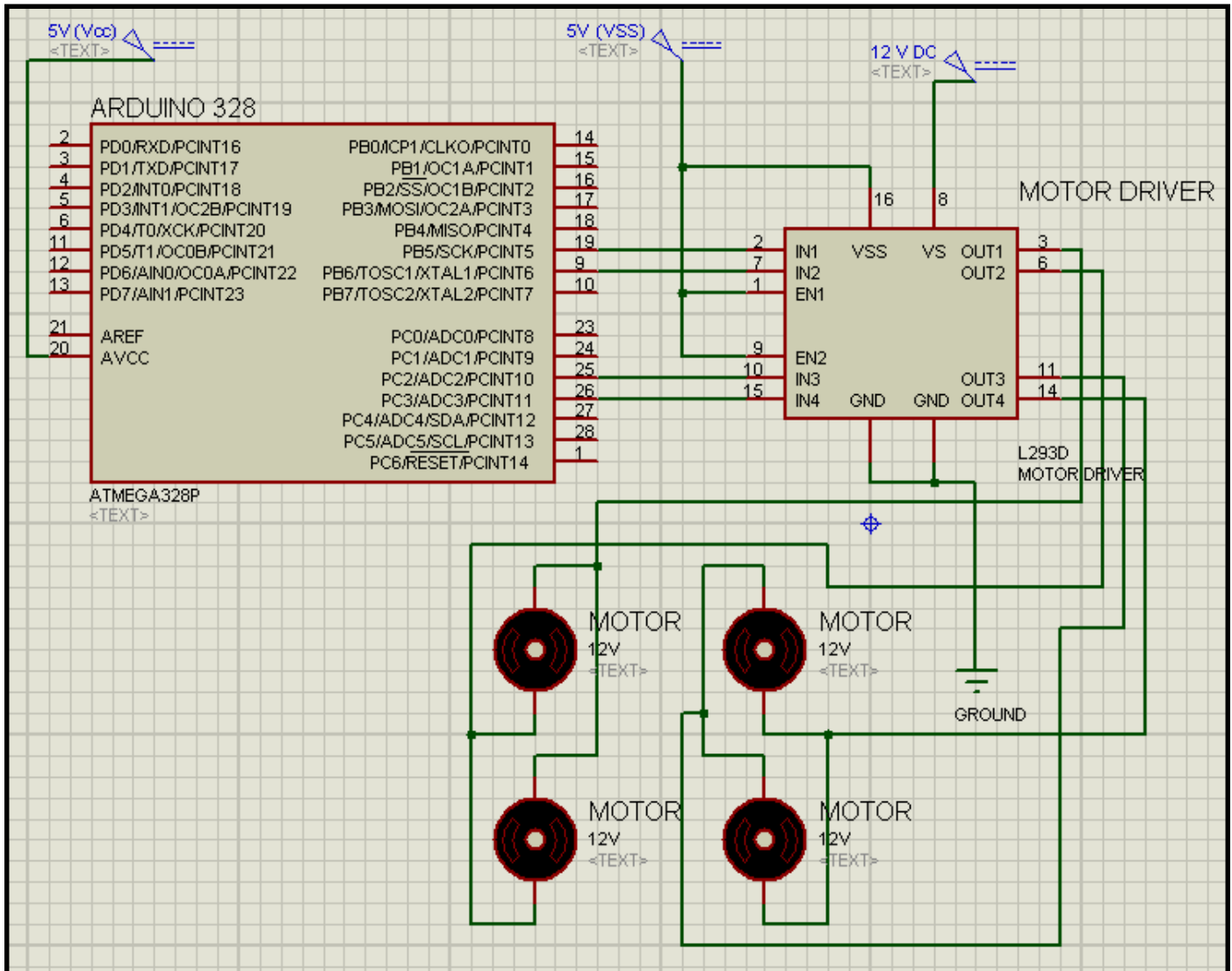


Fig. 3: Complete Circuit Diagram for the Rover

A. Software Architecture

This subsection describes the software architecture selected for use on the mobile rover. The Arduino and the MATLAB are commonly used programming and automation framework and has several advantages for our application. A design diagram of the software architecture is presented in Figure 4. It describes how each software “node” integrates with the rover. In this subsection, activities of each node and the necessity of designing this software architecture are discussed.

1. The Controller-Android Mobile with ML-Connect

The controller is chosen to be an Android Phone, equipped with ML-Connect which is the MATLAB version for Android Phones. The ML-Connect is connected to a Laptop or Desktop running MATLAB via a WIFI link. It then picks up the accelerometer data from the smart-phone and sends the data to MATLAB where the data is processed to generate the control signals to connect to the ARDUINO Microcontroller. The WIFI server is generated from the MATLAB code whereas the Android connects to this server as a client and sends the data. The accelerometer takes the X, Y and Z axis data and sends to the MATLAB for processing.

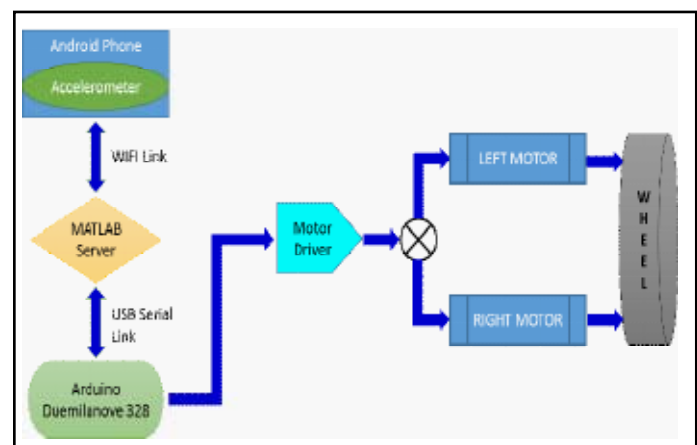


Fig. 4: Software Design Architecture for the Rover

2. Data Processing-MATLAB

A WIFI server is created by MATLAB; it then waits for the Android Phone to log in to the MATLAB server. Once the client logs in the program starts running which then accepts the accelerometer data and starts processing. The processing and corresponding accelerometer values are shown in the table below.

Table 2: Summary of Technical Specification

Motion of Android	Range of Accelerometer Data (m/s ²)	Motion of Rover
Without Tilting	$-2 < X < 2$ $-2.5 < Y < 4$	STOP
Right Tilting	$X < -5$	RIGHT TURN
Left Tilting	$X > 5$	LEFT TURN
Forward Tilting	$-2 < X < 2$ $Y < -2.5$	MOVE FORWARD
Backward Tilting	$-2 < X < 2$ $Y > 4$	MOVE BACKWARD

3. The On-Board Processor – ArduinoDuemilanove 328

Arduino is ideal for our application because it provides a framework that allows multiple programs across multiple computers but realizes as a single program i.e., multitasking. This allows for intuitive compartmentalization of code; rather than having a single program controlling every aspect of our rover. For the Arduino Code we are using Analog and Digital Input and Output Server for MATLAB. MATLAB Support Package for Arduino enables to use MATLAB to connect with the Arduino board over a USB cable. This package is based on a server program running on the board, which listens to commands arriving via serial port, executes the commands, and, if needed, returns a result.

IV. Sub-System Testing and Validation

A. Testing the Accelerometer with ML-Connect & Android

For testing the Accelerometer data, the ML-Connect is connected with MATLAB and the data sent is plotted using MATLAB. The three axis accelerometer is used to plot the graph. Three separate colors are used for the three axes shown in figure-5 below. The graph shows four distinct regions: Rotation of X-axis i.e. the left and right rotations, Y-axis i.e. the forward and backward rotations, a region of no rotation that is the stop condition and an extreme jerking of the phone.

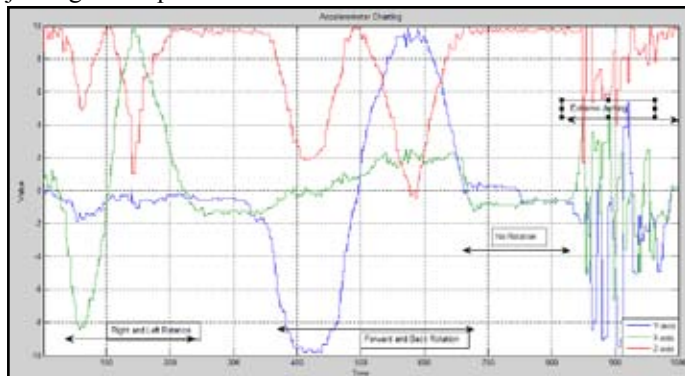


Fig. 5: Charting for Android 3-axis Accelerometer from MATLAB

B. Field Testing of the Rover

To test the mobility of the rover rough terrain (i.e., fields, rocky terrain, small gravel etc) is chosen and found very good stability and traction. The wheel gripped rocks and traversed vertical obstacles very well, without skidding. The passive averaging suspension is also performed very well with full satisfaction. At the time of movement of the rover all four wheels remained in contact with the ground. This rover can cross an obstacle up to 7cm high or deep very easily. Fig. 6 shows some snap shots of the movement of the rover.

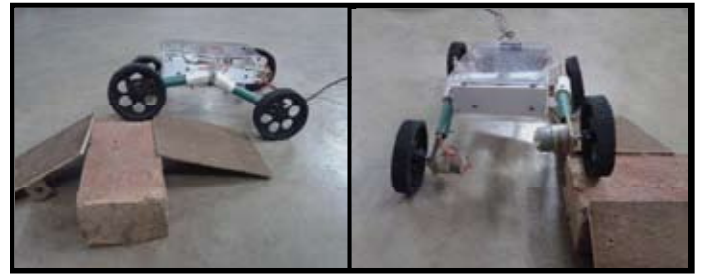


Fig. 6: Different Views of the Rover Climbing Over Obstacle of Height 7cms

V. Conclusion

The proposed method of designing a rover successfully overcomes all the design constraints. This rover can move very well in varying terrains, slopes, and obstacles without skidding. This rover not only overcomes the obstacle of 7cm height or deep but can also ride on a straight wall up to 15cm. This novel method is very much encouraging for the new designer due to its low cost and less complexity. This rover is tested on the earth's surface only but modification obviously needed for working in space.

References

- [1] "Mars Pathfinder Engineering Team. (1997)", Mars pathfinder frequently asked questions. Retrieved October 9, 2011.
- [2] Goldberg, S. B., Maimone, M. W., Matthies, L., "Stereo vision and rover navigation software for planetary exploration", 2002.
- [3] Wilcox, B. H., Nasif, A. K., "In California Institute of Technology (Ed.)", High mobility vehicle (180/345 ed.). United States: B60K 17/36, 2000.
- [4] Lind, R., "NASA - About analog missions and field tests. Retrieved 10/11, 2011.
- [5] Miller, D. P., Lee, T., "High-speed traversal of rough terrain using a rocker-bogie mobility system. Proceedings of Robotics 2002: The 5th International Conference and Exposition on Robotics for Challenging Situations and Environments, Albuquerque, New Mexico, 2002.
- [6] Bickler D. "A New Family of JPL Planetary Surface Vehicles", Missions, Technologies, and Design of Planetary Mobile Vehicles, pp. 301-306, Toulouse, France, September 28-30, 1992.
- [7] Volpe R, et al., "The Rocky 7 Mars Rover Prototype", Workshop on Rovers, IEEE Robotics and Automation Conference, Minneapolis, Minnesota, April 22-28, 1996.
- [8] Gat E, et al., "Behavior Control for Robotic Exploration of Planetary Surfaces", IEEE Transactions on Robotics and Automation, Vol. 10, pps. 490-503, 1994.
- [9] Weisbin C., "Rovers and Telerobotics Technology Program", Robotics and Mars Exploration Program Office Publication, JPL.
- [10] K. Tanie "A Position Sensor Based Torque Control Method for a DC Motor with Reduction Gears", Proc. IEEE Int. Conference. Robotics and Automation, Vol. 3, pp. 1867, 1988.
- [11] Astrobotic, "Scouting rovers", Retrieved 10/10, 2011.