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Design and Implementation of Unmanned Space Exploration Vehicle for Martian Terrain

Gokulavasan. M[1], Rahul Kanuganti[2], Shyam R Nair[3]
[1]*(Student, Department of Computer Science Engineering, Hindustan University, Chennai)*
[2]*(Student, Department of Mechanical Engineering, Hindustan University, Chennai)*
[3]*(Assistant Professor, Centre for Automation and Robotics, Hindustan University, Chennai)*

Abstract: - In this paper, we present the design for a unmanned space exploration vehcle for using in Martian terrain. The main focus will be on the basic building blocks of the system from mechanical to software and various applications in the Martian terrain. We also discuss a little bit of future expansion of the system.

Keywords: - *Astronaut Assistance, Autonomous, Kinematics, Rover, Space Exploration, Terrain Traversing, Trajectory, Unmanned Ground Vehicle.*

I. INTRODUCTION

Space robots are general purpose machines which are capable of surviving space environment and exploring, assembling, construction, maintanance, servicing or any other task assigned by humans. Space robots are generally designed to do multiple tasks depending upon the applications.

There is a growing international interest in global exploration of Mars and other distant planets and planetary moons. There are many robotic options for Mars like gravity deployed pnetrators, shallow and deep drilling platforms, semi-autonomous mobile robots.

In this paper we are proposing a design for semi-autonomous mobile robot or rover for exploring Martian terrain with some specific capabilities.

II. TERRAIN TRAVERSING

Terrain traversing is the most important functiionality of a mobile robot and if the robot is to traverse in complex terrain like the Martian, the design is of great importance.

To build an effective and efficient locomotive system for the rover. Aluminum T6-6063 is the preferred material. An Omni directional steering mechanism has been implemented. The motors used are Duratrax 550 series with Banebot planetary gearbox assembly. When calculated, each motor gives a torque of 85.37 N-m. Wheels are made out of Polyurethane. The reason for choosing them being that when filled with the right amount of Nitrogen, give an unparalleled performance. This entire frame is supported by High Carbon Steel shafts that have very high yield strength.

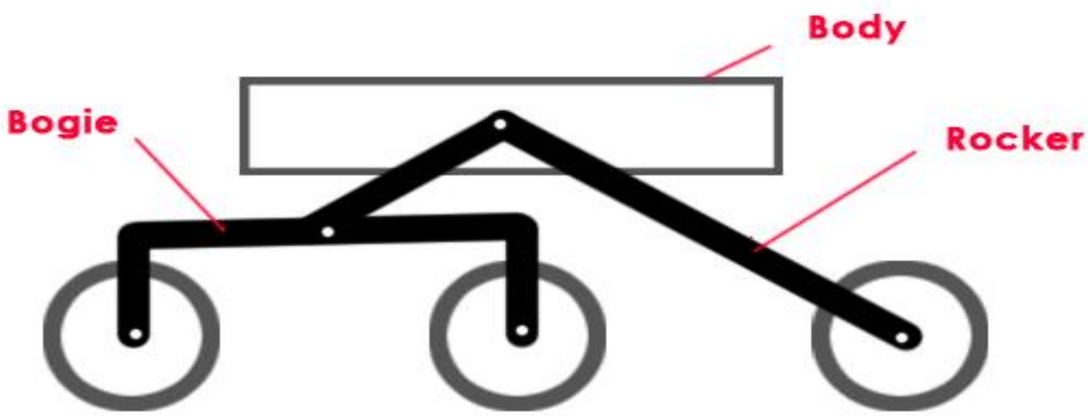

Fig.1. Rocker Bogie Suspension

The rocker-bogie design has no springs and stub axles for each wheel, allowing the rover to climb over obstacles, such as rocks, that are up to twice the wheel's diameter in size while keeping all six wheels on the ground.

In order to go over a vertical obstacle face, the front wheels are forced against the obstacle by the center and rear wheels. The rotation of the front wheel then lifts the front of the vehicle up and over the obstacle. The middle wheel is then pressed against the obstacle by the rear wheels and pulled against the obstacle by the front until it is lifted up and over. Finally, the rear wheel is pulled over the obstacle by the front two wheels. During each wheel's traversal of the obstacle, forward progress of the vehicle is slowed or completely halted.

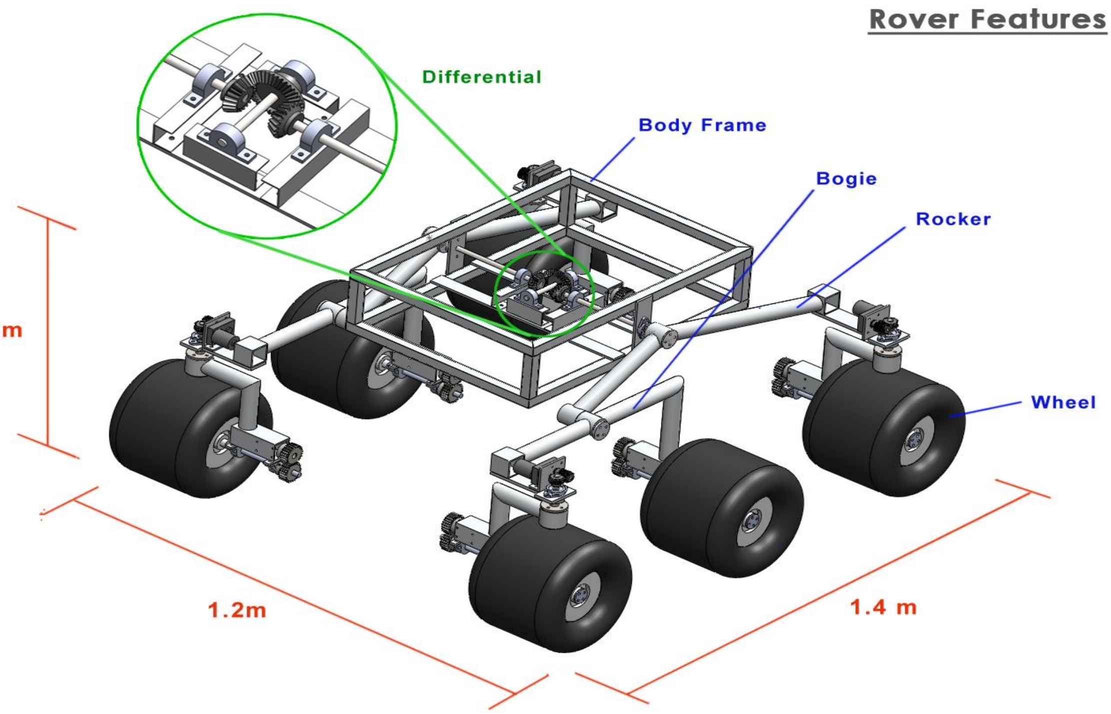

Fig. 2. Mechanical Design of Rover

The major terrain traversing features are:

- Navigation on harshy analogus Martian surface to climb and steep traversing of 50^{o}.
- Position and Orientation monitoring based on coordinates of rover using gyro.
- Condition monitoring for wheel spin and free rotation.
- Guidance through remote view.
- Sensor based navigation assistance system.
- GUI based image processing with incline guidance.
- Obstacle avoidance using
- Camera fixed in the front of rover.
- OpenCV based threshold classification.
- Fuzzy based control algorithm to take decision.

There are two modes of traversing:
1. Semi-autonomous traversing.
2. Fully-autonomous traversing.

The major features in semi-autonomous traversing are:
- Closed loop control based arcitecture.
- Onboard kinematic and dynamic analysis.
- Trajectory planning is carried out by onboard controller, but base station takes decision on final trajectory to be followed.

- For complex profiles, rover is controlled from base station.
- Complex process like equipment servicing and picking of irregular objects are controlled from base station.

The major features in semi-autonomous traversing are:

- Closed loop control based architecture.
- Onboard kinematic and dynamic analysis.
- Autonomous trajectory planning.
- Obstacle avoidance using onborad sensors.
- Real time data transferred to base station.

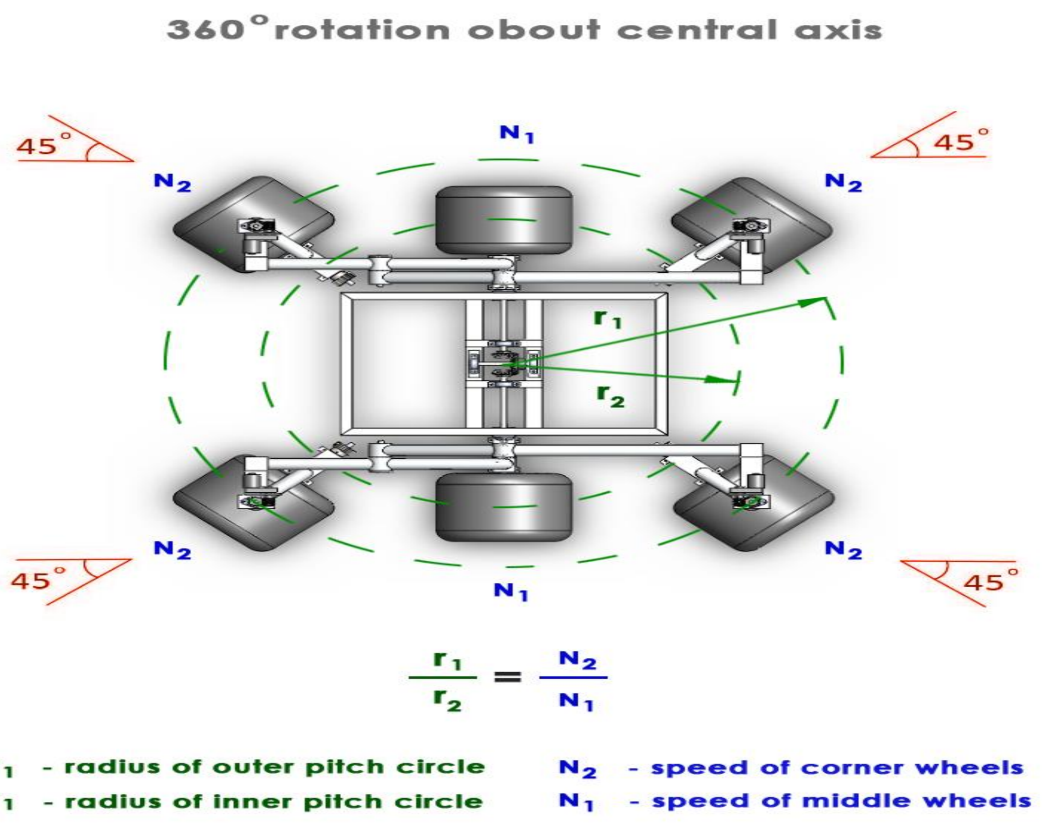

Fig. 3. 360^o rotation about central axis

III. EQUIPMENT SERVICING

In any space explortation operations, humans and robots will have certain equipments for purposes like analysis or communication etc. There will be instances when these equipments need to be serivced. In such situations, the robot should have the capability to service these equipments.

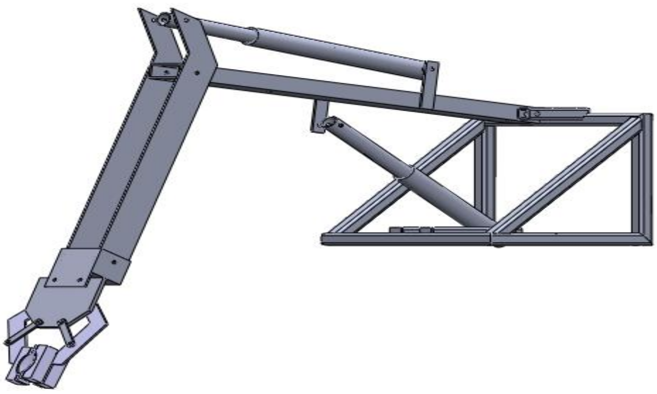

Fig. 4. Robotic gripper for equipment servicing

Aluminum End Effector is designed to hold objects both large and small at the end of the gripper. It is also grooved in a pattern that increases the friction between the object that is being held and the end effector. The motors of the end effector are controlled through the front end using analog inputs. The feedback received from the cameras placed on the robotic arm, and the corresponding encoders are used for the effectual control of the gripper.

The major equipment servicing features are:
- Remote navigation to equipment service panel.
- Identification of panel based on image processing.
- Manual handling of the panel board using cvamera view.
- Autonomous detection of instruments and servicing.
- Variable end effectors based on service panel.
- Delivering the damaged part to base station.

IV. ASTRONAUT ASSISTANCE

The rover is also designed to work with and support astronauts working on the Martian terrain. Basically the rover should be able to pick some device or gadget and deliver it to the astronaut or pick some from the astronauts and deliver to base station or some particular location.

A GPS module is used to locate the packages based on the given coordinates and meanwhile a high resolution camera will also capture panoramic view to guide the rover on its path. An end effector is designed to pick up objects up to a weight of 5 kg. On command, the rover obeys the astronaut from base station or a remote location.

The major Astronaut assistance features are:

- Path planning and GPS navigation.
- Trajectory planning and sensor based obstacle avoidance.
- Localization and package lifting capability.
- Payload stabilization and delivery.
- Adaptive balancing of the vehicle.

V. SAMPLE ANALYSIS/COLLECTION AND RETURN

There is a rising demanding in analysis of the Martian surface globally and hence any robot designed for the purpose of exploring the Martian surface should be able to do certain basic soil analysis, collect some sample and return to base station.

A pH and humidity sensor are attached to the end effector/gripper after calibration. These sensors are inserted into the soil where the analysis is to be done. If instead some sample is to be taken to the base, then the showel connected at the end effector will take some sample and save it in a closed container in the base of the rover.

Fig. 5. Onsite soil analysis

The major Sample analysis/collection and return features are:

- Robotic arm capable of dwelling and minning the soil.
- Sample testing using onboard sensors.
- Instrument handling capability.
- Delivering required amount of sample to base station.

VI. ELECTRONICS

The main controller is programmed to analyze the environment, receive commands and take necessary actions. The 4x HD IP Cameras helps in observing the environment from base station. Sensor Feedback system is integrated with controller using an interface unit to isolate controller from field sensors. Actuat are also connected to the controller using an interface unit to isolate controller from actuators.

The built electronic system is capable of doing the following tasks: Wireless Control, Communication via Wi-Fi and integrating the drive system, robotic arm and its end effectors with a microcontroller (Arduino Mega ATMega2560). It is connected to an Ethernet Controller which is in turn connected to a wireless router. The Planetary Gear Motors are controlled by using motor drivers with a 100A current rating enabling the rover to climb even the steepest slopes with minimal voltage drop and heat generation. The entire system is powered by 40 x 2200 mAh Lithium Polymer Battery Packs closely monitored with an Auto Step down and Step up Regulator and LM 35 temperature sensors. The Wi-Fi Communication system uses Eight Gigabit Ethernet LAN ports for high-speed wired connections on a wireless router, which is operated on a 2.4 GHz channel. It can provide a range up to 2 Km with the help of a high gain Omni-directional antenna. The data transmission rate is 300 Mbps. The control system is developed in a UDP client socket using Python, whose command line interface is sufficient to control the rover using the keyboard keys on a laptop. There are 4x1080p HD resolution and 30fps Cameras integrated on a separate Wi-Fi network to prevent interference and isolate the control system.

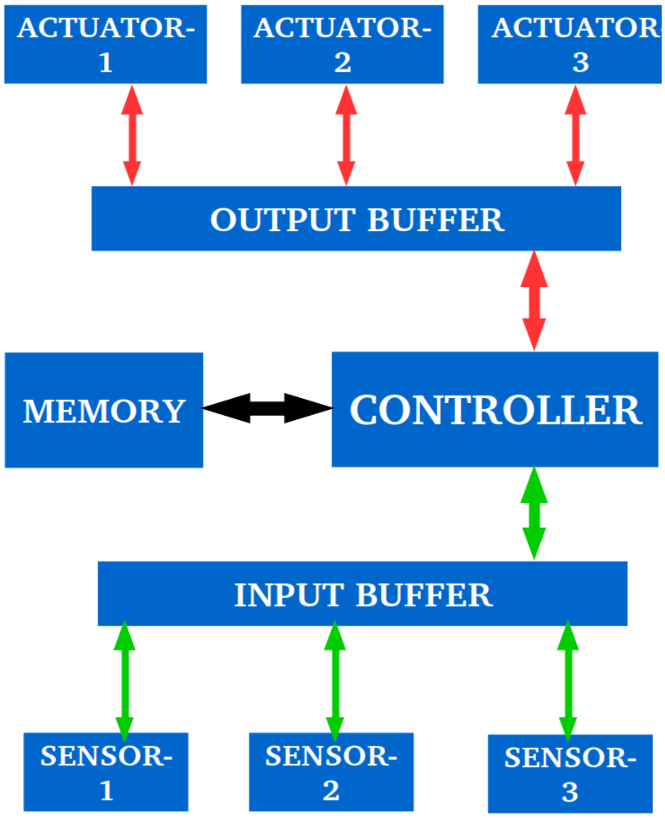

Fig. 6. Electronics architecture

VII. SOFTWARE

To build an interface capable of doing the following tasks: Real-time Feedback Interface System for monitoring the internal conditions of the rover and display feedback of the control system (Wheels, Turning Mechanism, Robotic Arm and End Effectors). Processing is used for the interface development. Integrated with the Arduino, color variables are used to represent the current state of the rover which will work based on the output of KY-040 Rotary Encoders and Hall Effect Current Sensors connected to the Planetary Gear Motors. Arm Control involves different feedback data involving: Linear Actuators, Arm Links and Gripper movement. Linear Actuators functioning will be monitored by Hall Effect Current Sensors. Arm Links are monitored by Potentiometers by analog feedback. The angle of rotation is displayed as a digital output reading. Internal Rover Condition Monitoring System is monitored by LM 35 Temperature Sensors. The temperatures values are plotted on a rolling 100 point graph whose values are taken from the microcontroller using serial communication. It is integrated with a warning system that alerts the controller when a particular system in the rover exceeds a particular temperature threshold.

The graphical user interface for the control system and feedback is developed using the G4P library for Processing. The GUI also displays the feedback from all the sensors and the cameras, needed for effective control and monitoring of the rover.

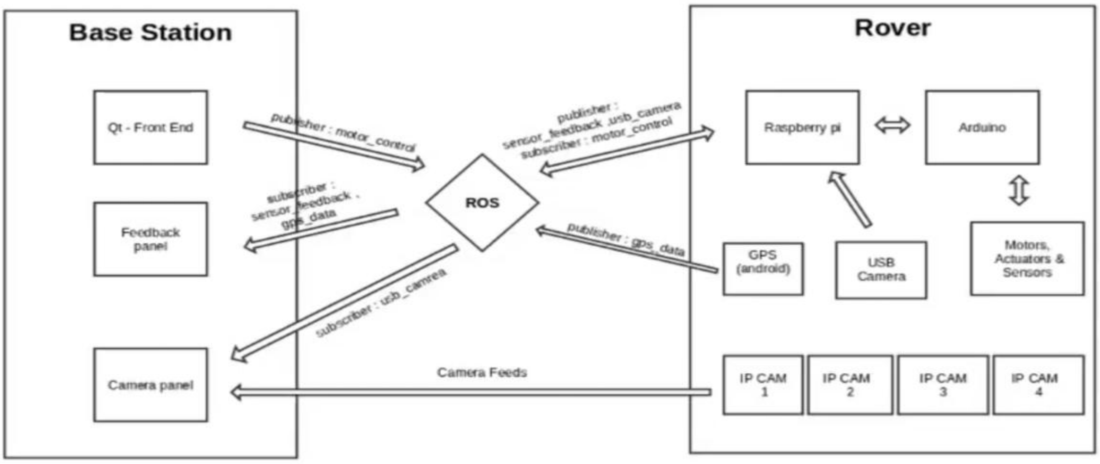

Fig. 7. Software architecture

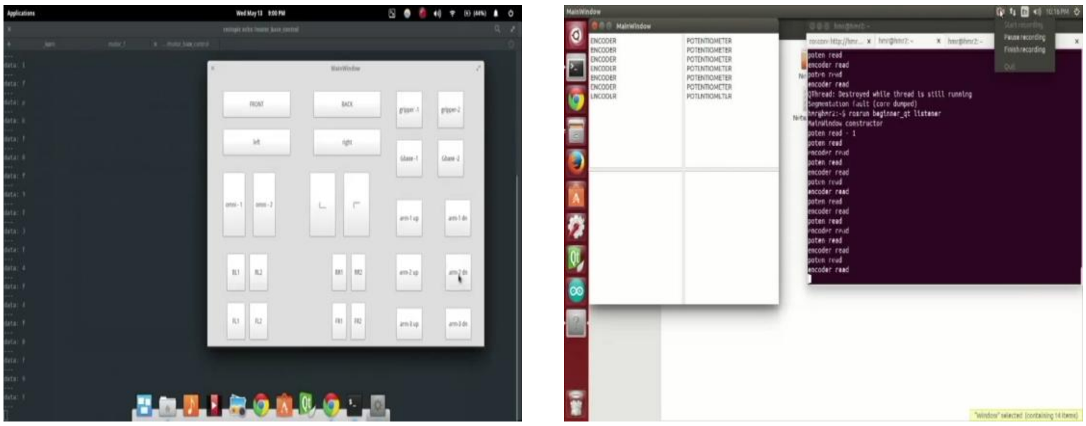

Fig. 8. Software Screenshots

VIII. CONCLUSION

An unmanned space exploration vehicle was designed for exploring Martian terrain. The rover can be made to follow the commands from the base station and it may also take certain decisions in fully autonomous mode. The additional cameras on the base of the rover allows more accurate traversing and also avoids collition. The special design of wheel driving system allows 360^{o} rotation for efficient traversing. Rover uses the 5 DOF arm attached to it for assisting astronaut, panel servicing and for sample collection process.

IX. FUTURE WORKS

With use of stereo vision and advanced image processing techniques, the accuracy in fully autonomous operation may be improved. Also with use of macro mini assistive systems like a combination of drone and rover, the path planning may be processed with better accuracy and reliability.

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