Space Exploration Robot

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ABSTRACT

Robots in space have different functionalities as they are used for different applications including Planetary Surface Exploration (PSE). Robots that are designed and built for PSE are expected to perform activities such as rover, shovel, and search for life. This paper presents a Space Exploration Robot (SER) that will use sensors, motors and a camera in order to operate in space and in autonomous mode. For the purpose of this work, this robot is envisioned to communicate and be controlled by Wi-Fi. The SER is also envisioned to be a robot able to explore unknown territory in space and communicate its findings to the control center nearby or on earth.

1. INTRODUCTION

The development of Automation and Robotics (A&R) has had a positive effect on space exploration [1]. The implementation of this technology on space missions has enabled the exploration of areas that are beyond human access. A fast evolution of robotic devices is necessary for the development of complex spacecraft and space exploration missions. Autonomous robots allow the exploration of planetary surfaces and serve as a platform for in space activities. Throughout the years, the evolution of this technology has led to great number of achievements and will continue to be a great contributor to space exploration.

Since 1950s humans have been trying to explore outer space. The capability of going beyond Earth, and exploration of planets, moon, comets, asteroid have been an irresistible attraction for humankind. Space exploration began in the late 1950s early 1960s as a result of the space race between the USSR and USA, sending humans into the Earth orbit and the Moon was the main objective. The development space programs were extremely expensive, scientists used cheap robotic proxies to understand the space environments that astronauts would be operating.

Table 1 shows successful robot missions flown on Earth orbit, the moon, and Mars. Each mission developed systems that include surface rover, robotic hands, and subsurface sampler and drills. These systems helped to understand environmental conditions that exist beyond earth.

The first robotic mobility system successfully operated was a manipulation sampling device also known as a scoop. This device was on board of Surveyor 3 launched on 1967 to the Moon. Following that Luna 16 launched the first planetary robotic-arm mounted drill in 1970, and Luna 17 succeed with the first planetary rover called Lunokhod 1 on 1970.

The new generation of planetary exploration robots has travelled farther into the solar system, its technology and autonomous level is increasing with each mission. Future space missions will require a higher autonomous level on each robot, leading to better robotic explorers and robotic assistants.

Table 1. Successful Robots on Earth Orbit, Moon, and Mars [2]

Year	Mission	Country	Target	Rover	Arm	Sampler	Drill
1967	Surveyor 3	USA	Moon			x	
1970/72/76	Luna 16/20/24	USSR	Moon		x	x	x
1970/73	Luna 17/21	USSR	Moon	x			
1975	Viking	USA	Mars		x	x	
1981/2001/08	ISS's Canadarm1/2/Dextre	Canada	Earth orbit		x		
1996	Mars Path Finder	USA	Mars	x			
2003	Hayabusa	Japan	Asteroid			x	
2003	Mars Exploration Rovers	USA	Mars	x	x	x	
2007	ISS's Kibo	Japan	Earth orbit		x		
2008	Phoenix	USA	Mars		x	x	
2011	Mars Science Laboratory	USA	Mars	x	x	x	
2013	Chang'E 3	China	Moon	x			
2004-14	Rosetta	Europe	Comet		x	x	x

2. Conceptual design

This project is based on 4WD Hercules mobile robotic platform. This is a closed-loop control system with four powerful gear motors to provide precise control process.

Figure 1. Hercules platform [3]

2.1 Robot Components

Hercules skeleton is made up of aluminum alloy plate. The platform includes four servo motors, motor controller, and a lithium battery.

Figure 2. Hercules components [3]

Table 2 shows the bill of materials for the assembly. It also shows specifications and material for each part.

Table 2. Hercules Platform Parts List [3]

No.	Part	Material	Quantity (pcs)
1	Bracket-1	L Aluminum extrusion 6061	2
2	Bracket-2	L Aluminum extrusion 6061	2
3	Reducing motor	310 rpm DC6V torque: 70 Kg	2
4	Reducing motor w/ encoder	310 rpm DC6V torque: 27 Kg*cm	2
5	Bracket adapter Plate	Cold rolled plate	4
6	Screws (3*10mm)	Metal	30
7	Nut	Metal	4
8	Motor connector	Metal	4
9	Wheel	Plastic-rubber	4
10	Spring shim	Metal	4
11	Screw (M4*10mm)	metal	4
12	Under-Plate	Tea black Acrylic	1
13	Washer	PA	4
14	Power switch	-	1
15	Hercules dual 15A 6-20V motor controller	-	1
16	Screw (M3*23mm)	Metal	4
17	Acrylic-plate	Transparent acrylic	2
18	Cover-plate	Tea black acrylic	1
19	Cu pillar	Signal stud	4
20	Top-plate	Aluminum	1
21	Screw (3*21mm)	Metal	4

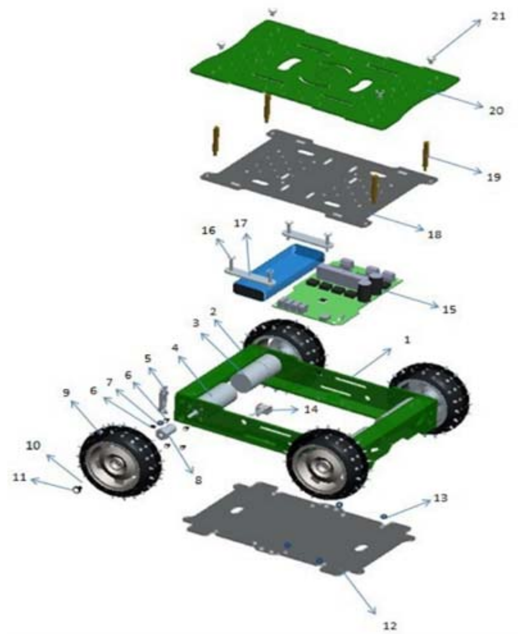

Figure 3. Assembly diagram [3]

2.2 Servo Motors

Hercules platform uses four 25GA-370 servo motors.

Figure 4. 25GA-370 motor [3]

The motors are horizontally placed on the output shaft. They work with a nominal voltage of DC 6.0V. Motors have a CCW rotation (CW, from the direction of the shaft).

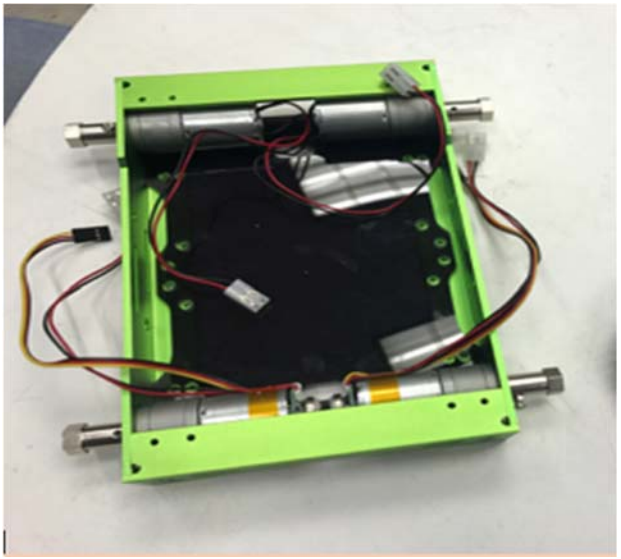

Figure 5. Servo motors installation

Full connection diagram was obtained from Seed Studio and it can be seen in Figure 6.

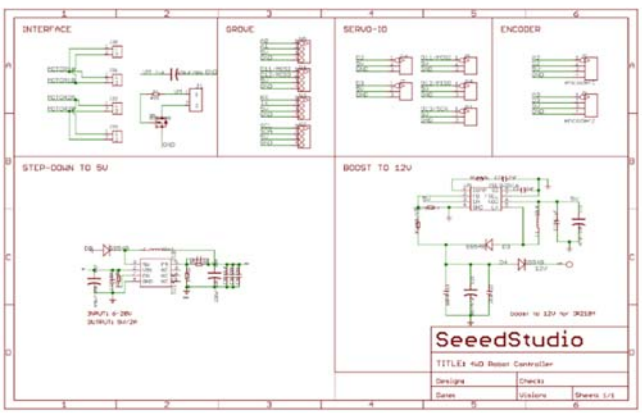

Figure 6. Servo motor connection diagram [3]

2.3 Motor Controller

Hercules uses a 15A 6-20V Motor Controller. This control board is Arduino compatible and includes a microcontroller processor, motor drive circuit, a charging unit, and two fuse to protect the board from overloading. Figure 7 illustrates the controller used.

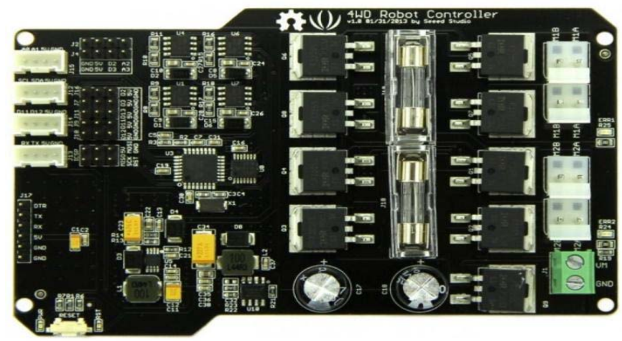

Figure 7. Robot Controller [3]

Figure 8 shows output wiring connections from servo motors to motor controller.

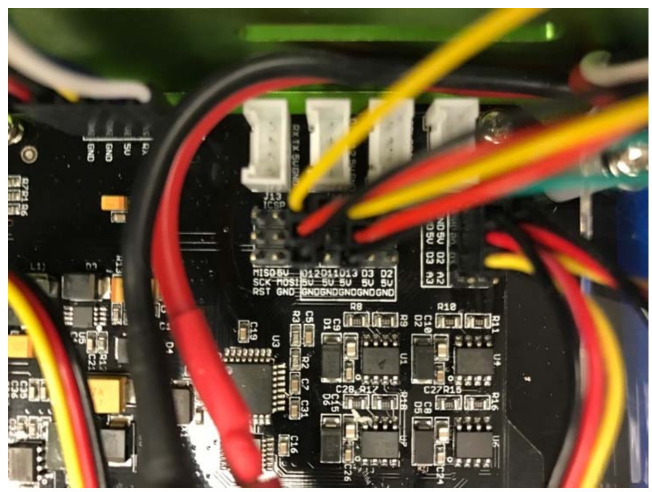

Figure 8. Output wiring connection

Battery

Hercules uses a two cell Lithium Battery with outputs 7.4V storing 2200mAh of charge, since this is a two-cell battery, a special charger is needed.

Figure 9. Platform battery [3]

The battery is soldered to a power switch and is located right next to motor controller. Soldering and installation process can be seen in Figure 10 and Figure 11, respectively.

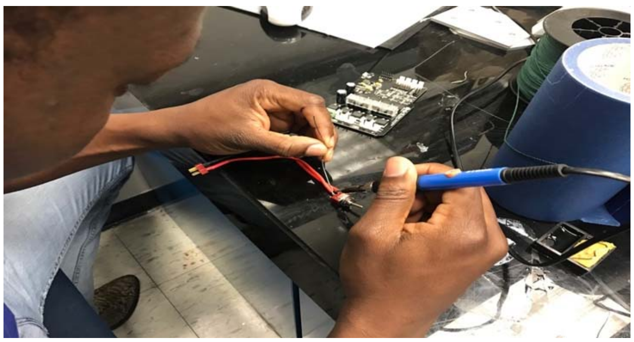

Figure 10. Switch soldering

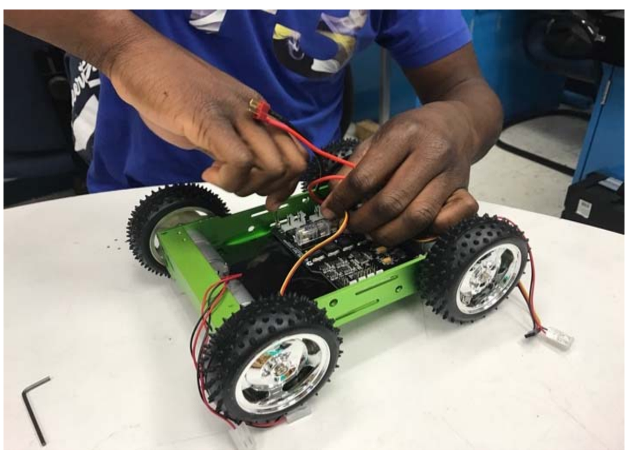

Figure 11. Battery installation

2.4 Object detection sensor

SER uses five SF-SR02 ultrasonic distance sensors. These sensors have a detection range between 0.79 to 275.6 inches. They have a power indicator LED to tell when the sensor is powered. Sensors work with 5V and 16mA current.

Figure 12. SF-SR02 Ultrasonic distance sensor [4]

2.5 Camera

Platform will use a DZDL HD mini super small portable camera to record videos. This camera has a video resolution of 1080P, and can be controlled with smartphones or PC. The camera has 90-degree lens view angle, support 32GB Micro SD Card, works with 3000mAh, and has 5-hour battery operating life.

Figure 13. Mini camera

2.6 Base for Sensors and Camera

A base will be created to mount object detection sensors and camera mentioned before. This base will be first designed in 3D using SolidWorks, and then will be printed in 3D using ABS material.

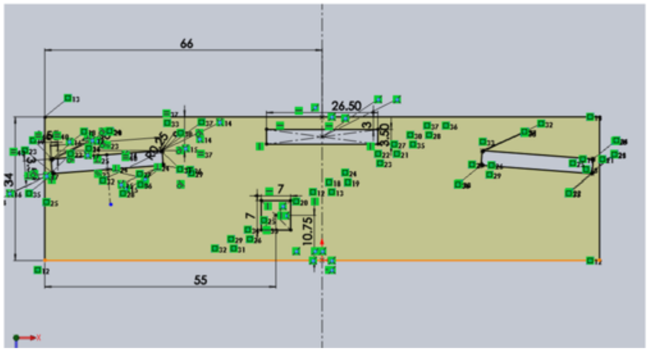

Figure 14. Solid Works 3D base contraction

The ABS base must have enough spaces to install five sensors. A sensor on the middle will detect how far an object is from the front of the platform. Sensor on the top right-left will detect objects near front wheels, avoiding collisions against walls. Platform has also two sensors on the side to determine how far objects are. If platform has to make 90 degrees turn, these sensors will turn platform toward farthest object avoiding collision on back wheels.

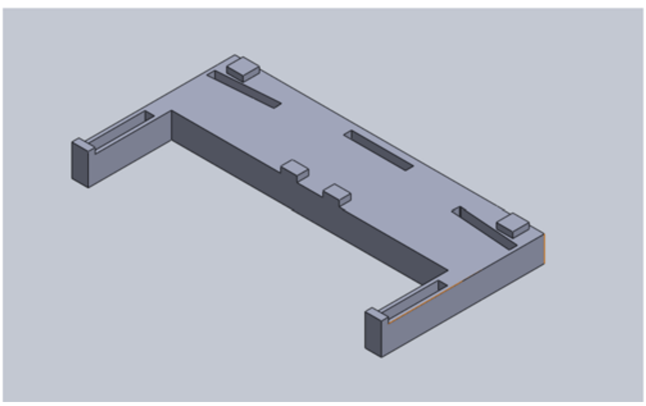

Figure 15. Solidworks 3D base

3. Programming

For programming, C++ language is used. Since, Arduino boards are being used, the use of C++ is the most reasonable choice. The programming of the Bot is as simple as possible, sensors are used so that the bot continues traveling and exploring forward until an object is detected.

When an object is detected in the front, the bot turns right about ninety degrees and continues forward until it is able to get around that object. There are many if statements that set the conditions on how the robot should travel. Following the program developed, the robot should not get stuck and should be able to traverse until its battery power is low.

4. Final Prototype

The prototype that has been created has five ultrasound sensors. Platform itself came with a few pins. The team hardwired another Arduino board to the other to have more pins; so, practically there is no limit on how many accessories that could be placed onto the platform.

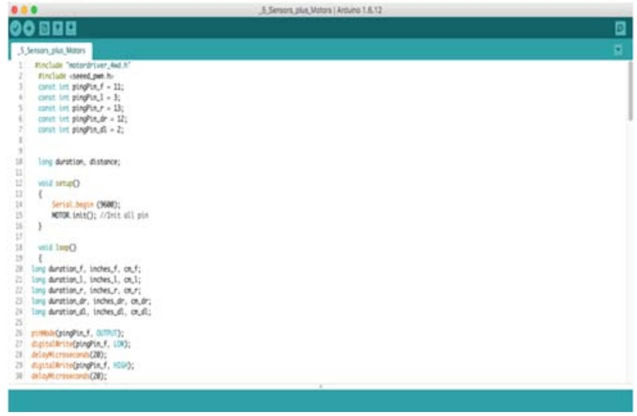

Figure 16. Sensors programming on Arduino

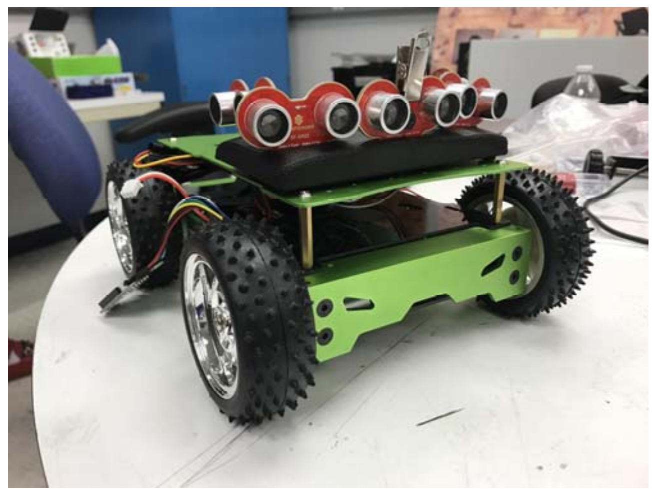

Figure 17. SER side view

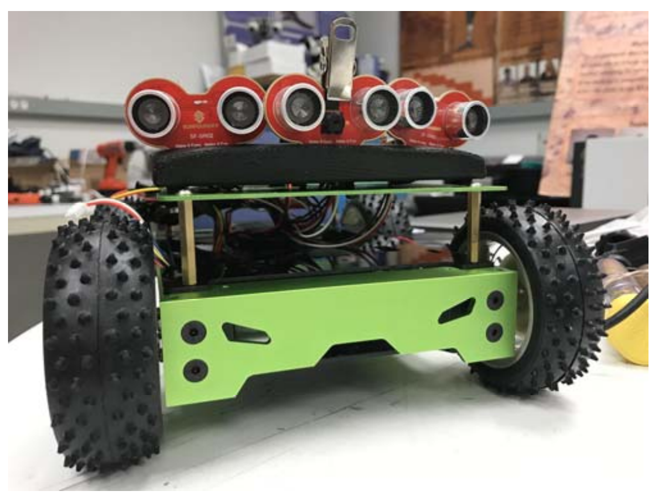

Figure 18. SER front view

For the camera that has been installed onto the platform, there is no coding necessary. The team decided on an option to make the camera wirelessly controlled with its own wireless capability.

Since there is wireless onboard, set user can modify the wireless chip to be able to put in more distance between the user and robot.

Having such wireless capability gives more control to the user to be able to look at where the robot is and what is being explored in real time, while capturing the images themselves. A micro-SD slot and card is also installed where the pictures being taken will be stored in, where the user can collect once the robot returns. The camera having its own battery supply ensures further travel and performance of the sensors and motors of the platform.

5. Platform testing

SER was tested on both flat and rough terrain. On rough terrain, sensors tend to slide from their original position and tend to fall from their base indicating malfunction in obstacle detection. To solve this problem, a better base must be created, this base must have a better grip of the five sensors to prevent them falling or moving.

Figure 19. Hard terrain platform testing

The camera was also tested to make sure the platform meets all expectations. The camera is clipped to the middle sensor. This was a quick solution, but obviously not an ideal solution. Ideally, the camera must be separated from the sensor. In case the sensor has to be replaced, the camera position should not be affected.

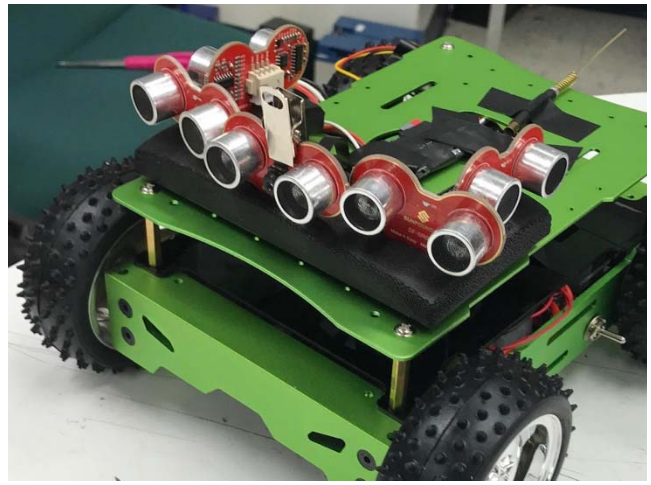

Figure 20. Camera clipped to front sensor

To use the camera, an application named P2PLiveCam must be downloaded. On this application, the user can connect wirelessly with a phone and can record videos, take snapshots as shown in Figure 21 and 22, or set an alarm to record during set time periods.

Figure 21. Platform testing

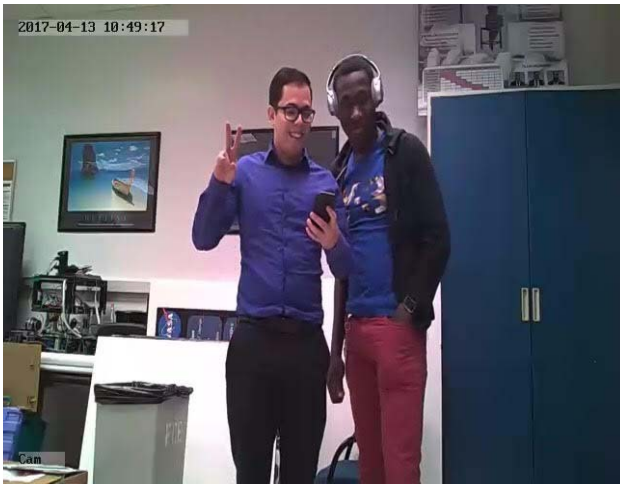

Figure 22. Team members Hanser Castro and Raheem Maliki in the Robotics and Automation Laboratory testing P2PLiveCam

6. Conclusions

The Space Exploration Robot (SER) can be a useful asset for the exploration of unknown territories. This platform can be a tool to preserve the lives of astronauts during dangerous space missions. The robot uses multiple motors and sensors to detect objects and avoid obstacles in autonomous mode. The platform also has a camera with HD resolution. This camera can take photos and record videos making it easy to study the terrain before sending humans. The prototype developed for this project is the first attempt to study the behavior of the proposed platform SER. Further study and development of more realistic platforms will undoubtedly be needed before such a platform can perform successfully on other planets.

7. Acknowledgments

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8. References

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