Assembly and Testing of a Four-Wheel Drive Robot for a Mars Analog Mission

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Abstract - *The Mars Desert Research Station is a low to medium fidelity planetary habitat analog that hosts six-person crews for fourteen-day analog missions. NSBE is developing a suite of scientific and engineering experiments to conduct during an expedition to MDRS. As part of the development of an experiment to evaluate local Mars robotic teleoperations, NSBE has assembled a COTS robotic rover prototype and conducted a series of assembly and check out operations to determine its suitability for use on an analog mission. This testing revealed both equipment failures and design flaws with the COTS device that must be corrected before it can be usable in a Mars analog experiment.*

Keywords: Mars Desert Research Station, MDRS, robotics, teleoperations.

1 Introduction

The Space Special Interest Group (SIG) of the National Society of Black Engineers conducts engineering projects to investigate technical challenges surrounding human and robotic space flight. Research conducted by Space SIG members and documented in this paper represents volunteer labor executed on behalf of NSBE, a 501(c)3 nonprofit organization headquartered in Alexandria, VA. NSBE coordinates the inputs of aerospace industry experts to propose innovative solutions to complex technical challenges facing the United States. Recommendations, results, and conclusions in this paper do not reflect NASA policy or programmatic decisions.

The Mars Desert Research Station (MDRS) is a low to medium fidelity analog planetary habitat owned and operated by the Mars Society and located in the Utah desert. The Mars Society uses MDRS and three sister facilities to help advance knowledge needed to prepare for eventual human missions to Mars. This includes the development of science research protocols, engineering design and testing, and development of operations protocols.

The Mars Society facilitates analog missions using these habitats, typically with six-person crews for fourteen-day missions. Crews may be internal from the Mars Society or from any other organization, including non-profits, government agencies, and corporations.

NSBE is organizing a series of experiments for a NSBE expedition to MDRS. The NSBE expedition will conduct a nominal MDRS expedition, including a crew of six NSBE members who will conduct a fourteen-day simulation of a Mars surface mission.

1.1 MDRS Teleoperations Experiment

In addition to other locations, NASA has conducted analog mission tests with small robotic assets at Moses Lake, Washington. [1] Many of these tests focused more on the capability of these robots than on their controllability.

One of the experiments being planned for the NSBE expedition to MDRS is a teleoperations experiment to explore robot controllability. This research study will explore the productivity of local telerobotics in a planetary outpost. Local telerobotics assumes that the robot is being operated by a crew member on Mars as opposed to by flight control teams on Earth. It is expected that some robotic assets will operate alongside human crews and it will be both safer and more efficient to control these robots from Mars, rather than from Earth, primarily due to the time delays associated with communication between Earth and Mars. The study will explore four operating modes [2] for local crews to control robotic assets:

1. Extravehicular Activity (EVA) Direct Observation – teleoperated control of a robot by an EVA astronaut in immediate proximity to the robot with direct view;

2. Support Vehicle Direct Observation – teleoperated control of a robot in a shirt sleeve environment from a support vehicle in immediate proximity to the robot with direct view;

3. Third Person Camera View – teleoperated control of a robot in a shirt sleeve environment from a remote workstation using a third person camera view;

4. Onboard Camera View – teleoperated control of a robot in a shirt sleeve environment from a remote workstation using a camera mounted onboard the robot.

In order to perform these investigations, NSBE acquired a four-wheel drive robot for use in this study, shown in Figure 1. The robot is the SuperDroids 4WD WiFi Controlled (ATR) All Terrain Robot. [3] It is intended to serve as an analog for an unmanned rover that would be used in support of crew tasks. Such a rover may carry equipment for crew, prepare equipment for crew, perform hazardous operations, or carry out other tasks in support of a human Mars expedition. Assembly and initial check-out testing of this robot was conducted at the 2013 NSBE Space Technology Session (STS-2013). The Space Technology Sessions are hands-on engineering sessions held over the Martin Luther King, Jr. holiday weekend of odd-numbered years to provide a forum for NSBE Professionals to gather from across the country to collaborate on space-related NSBE science and engineering projects requiring co-location for design, fabrication, assembly, testing, or operations.

Figure 1. Four-Wheel Drive Robot

1.2 STS-2013 Assembly and Check-Out Objectives

This paper serves to document work performed during this assembly and testing activity and to make a recommendation regarding the use of this robot during MDRS NSBE expeditions.

1.2.1 Assemble Rover

The rover was shipped largely assembled, but required some power and data connections to be performed. Also, physical assembly of the camera interface and structural integration of the battery, WiFi bridge, and camera were required.

1.2.2 Establish communications between robot and the commanding interfaces

This step involved installing and configuring control software for both the robot and its onboard IP camera on a laptop designated for control of the unit. It also required physical connection of the remote control device to the laptop. A LAN cable was then required to make a physical data connection between the robot and laptop to allow for initial system configuration, required before activation of the WiFi bridge for wireless communication.

1.2.3 Command robot to perform certain operations and observe behavior

This testing determines whether or not the robot has the controllability required to exercise tasks planned for the MDRS experiment. Thus, it was important to verify that the robot could drive forward and backward, and to determine how well it can execute turns in different terrain. The IP camera is steerable and as such it was also important to test the ability of the camera to be pointed at an object of interest. During the MDRS experiment, the operator will use the camera to aid in robot navigation and to provide visibility for manipulation tasks conducted by a separate robot arm.

1.2.4 Perform range testing between Rover and commanding interface

Range testing determines how far the robot can operate from its control laptop. This is important in designing the MDRS experiment because the desire is to compare the effectiveness of controlling the robot when it is beyond line of sight. The range test involved simply driving the robot until the wireless connection is lost.

1.2.5 Design payload bay and attachment mechanism for 4WD robot

The MDRS teleoperations experiment involves using the robot to navigate a course and use a separate robotic arm to load and unload a payload from the four-wheel drive robot. Because the robot does not come with a payload bay, it is necessary to design some capability for the robot to carry the payload.

2 Robot Physical Configuration and Assembly

The mobile robot base is comprised of the base (sheet metal chassis and major electronics underneath in an unshielded frame). Attached to the top of the base are two platforms, a steerable one for the IP camera that provides pan and tilt capability, and a second for the Ethernet bridge which is used for all communication with the mobile base. The bridge (should be) attached to the top of the rear platform with Velcro, while the camera is firmly secured. Also attached to the top of the robot base are two bays for the robot's batteries. This configuration is shown in Figure 2.

Beneath the platform for the network bridge, the serial to Ethernet adapter is loosely stored. This adapter converts the control request received over the network into serial (RS-232) commands that control the motors and camera (4 analog outputs) and four (4) digital outputs. Two of these input-output pairs are used to control the pan-tilt of the IP camera, while the other two control the motors. This serial adapter also facilitates analog and digital data to be sent back to the controller, including the current state of the IP camera servos.

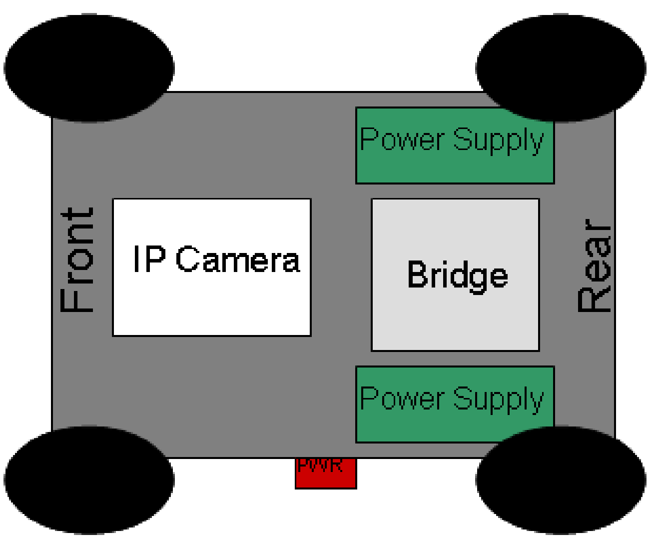

Figure 2. Robot Chassis Orientation (Top View)

3 WiFi Network Configuration

The wireless bridge supplied by the vendor is the Cisco WET200 Wireless-G Business Ethernet Bridge, shown in Figure 3. This device creates a wireless network, thus enabling the robot able to operate without a data tether connecting it to the controlling laptop.

The bridge capability of this device also allows the devices connected to the bridge to be accessible over another network. An example of this use case could be connecting the bridge to a campus wireless network as a client (just as a laptop on the campus network), then all the devices (the mobile base, and the IP camera) are then bridged to the campus network. This is the advantage of a bridge over a wireless router.

Figure 3. Cisco WET200 Ethernet Bridge

The IP addresses of all network devices can be changed, but for this robot it is more convenient to maintain the settings in Table 1, which were provided by the vendor.

Table 1. Robot IP Addresses

Device	IP Address	Ethernet Port
Wireless Bridge	192.168.10.226	N/A
IP camera	192.168.10.241	1
Serial Ethernet Adapter	192.168.10.240	5

The WET200 has four physical Ethernet ports. Of these, three are used in the current configuration – one for the camera, a second for the Serial Ethernet Adapter, and a third must be available for LAN connectivity for testing. The fourth port is available for any additional peripherals to expand the robot's capabilities.

The networking is active as soon as power is turned on for the mobile base. All the components tend to become network accessible within 1-2 minutes of power-on.

Networking can be disabled by either detaching the power cable from the back of the WiFi bridge or by complete power down of the robot base.

4 Robot Electrical Subsystem

Much of the robot's electrical subsystem is visible in Figure 4 and key elements are highlighted in Table 2. The twin 12V batteries provide power for all of the onboard systems, with the voltage stepped up to 24V for the four motors. The voltage is stepped down to 5V to power the RS-232 to Ethernet Converter, WiFi bridge, and onboard video camera.

The rover is controlled via software loaded onto a laptop and a remote controller that is also connected to the laptop via a USB connection that provides both power and data connectivity for the controller.

Figure 4. Robot Electrical Subsystem

Electrical Subsystem	Quantity	Description
Power Source	2	12V NiMH Batteries
Secondary voltages		5V, 24V Regulated
Motors	4	320027-60932R (24V)
Peripheral I/O	4 4	Digital Inputs Digital Outputs
IP Camera	1	TrendNet Internet Camera
Communications Interface	1	RS-232 to Ethernet Converter
WiFi bridge	1	Cisco WET200 Bridge
Remote Controller	1	Logitech Joystick

5 Robot Operability

Test drives of the robot revealed a number of issues which must be corrected before the system can be used at the Mars Desert Research Station.

Most importantly, the robot steering mechanism was utterly ineffective. The robot struggled to make turns on smooth hallway floors or concrete. It could not turn at all on carpet or grassy terrain; it could only drive in forward and reverse. It is possible that modifications to the control software may solve this problem.

Alternately, two hardware modifications may also be employed. The rover is intended to turn by reversing the drive on either side of the vehicle, the same manner in which a tank turns by driving its treads in opposite directions. However, the greater the friction between the wheels and the ground the less effective this means of turning becomes. The rover wheels, as shown in Figure 5, are designed for high traction, which makes this style of turning difficult.

The first modification option is to replace these wheels with smoother wheels, potentially coated with a low friction substance. The vendor's current website shows this robot with lower friction wheels than those sold at the time of purchase, which may reflect customer dissatisfaction with the high friction wheels. [3] However, lower friction wheels may have the effect of reducing the rover's overall traction making maneuvering in rough terrain difficult, particularly climbing over obstacles.

The second hardware approach could be to replace the motors, seen in Figure 4, with higher power units. This will increase battery drain, resulting in either shorter operating times or a need to replace the battery system with one providing greater energy storage.

Figure 5. Robot with High Traction Wheels

Also, communication with the WiFi bridge was highly degraded. The connection frequently dropped and range was extremely limited. Reliable communication was only established when the robot was connected to a laptop via LAN cable. When connected via wireless, the robot tended to lose connection whenever it moved more than approximately twenty to thirty feet away from the laptop. The team believes that the Cisco WET200 bridge supplied with the robot may be defective and recommends swapping out the unit to see if performance improves.

Communication with the robot's steerable camera was also achieved. The camera responded properly to control inputs but did exhibit to return to a default position in the absence of an active control input. This prevented the team from pointing the camera at a particular target. This is likely a software setting that can be changed with more analysis of the code.

Finally, as can also be seen in Figure 4, the electrical components are exposed on the vehicle underside. This can potentially subject the robot to damage when traversing rocky terrain, as can be expected in the Utah desert surrounding the Mars Desert Research Station. The team recommends fabricating a metal closeout for the underside to protect the electronics from liquids, dust, and rock debris. However, cooling will then become a concern as the airflow to the electrical system will then be compromised. This may require the addition of a fan as well as intake and exhaust ports.

6 Conclusions

The NSBE team was able to establish communications between the robot and operating laptop. Connection was reliable when tethered via LAN cable, but unreliable over wireless. The live video feed operated successfully, though there is a desire to rewrite some of the code driving the camera. Driving tests demonstrated the ability of the robot to drive in forward and reverse, but revealed an inability of the robot to make effective left and right turns. Due to issues encountered during robot testing the team did not proceed with the design of a payload bay and attachment mechanism, as it was unclear what changes to the robot configuration might be required to overcome the observed problems.

Forward work includes improvements to the limitations discovered during testing. The Cisco WET200 will need to be replaced with another device to provide wireless communication. Additionally, two software modifications are required. The first is to reconfigure the camera software to permit the camera to remain on target. The second is to reconfigure the controlling algorithm for motors to optimize turning functionality. If this modification fails, the next two options are to replace the wheels or to replace the motors. If successful, it will also be appropriate to create a draft user manual, including any remaining limitations of the robot. Finally, because the robot lacks volume for a payload bay (which will be needed for the MDRS experiment) either a payload bay or a towable trailer must be fabricated.

Ultimately, it is unclear if this robot can be made acceptable for use in the desert environment of the Mars Desert Research Station. This does not, however, mean that the robot has no value. Implementing the suggestions recommended in this paper will provide valuable hands-on engineering activity for participating NSBE members. The required fabrication, programming, assembly, and testing is all useful skills development. If further testing reveals the robot to still be unsuitable for desert testing, it can still be useful as a NSBE engineering testbed. Hands-on opportunities are extremely limited for many engineers and activities to modify the robot's performance and capabilities will provide valuable learning experiences.

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