Team 11 – Robo-Ops
Operation Manual

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1.0 Introduction

The objective of this project is to build an innovative rover design capable of competing in the 2014 Robo-Ops competition. The robot must be capable of traversing environments similar to those on Mars, it must be teleoperated using wireless communications, and it must be able to selectively pick up brightly colored rocks using an extraction unit.

2.0 System Diagram

Figure 1 - High-level system diagram.
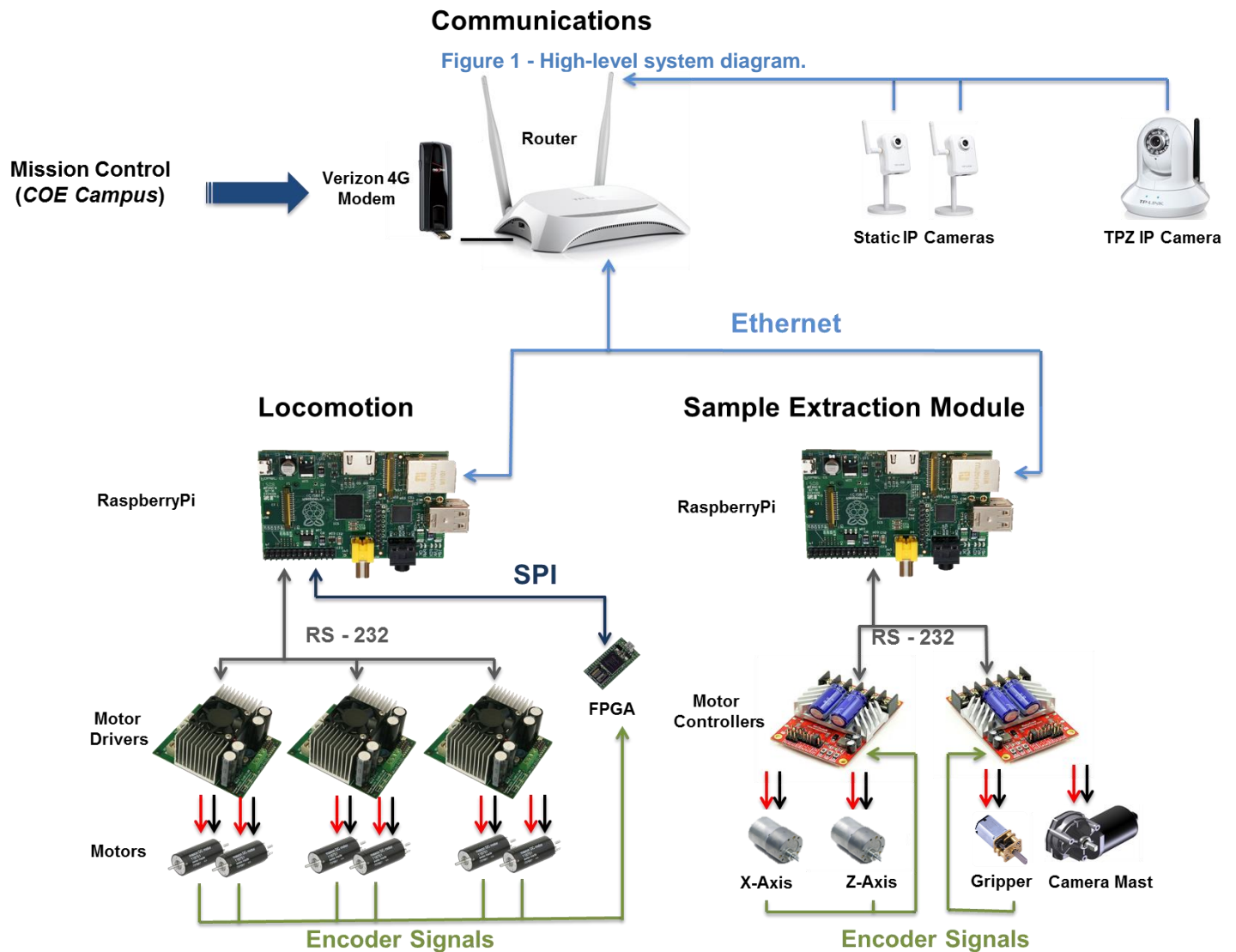
3.0 Rover Control

Control of all rover sub-systems has been integrated into a single Graphical User Interface (GUI), which can be installed on any Windows-based PC. In this section, a detailed description of each control and feature of the user interface will be provided.
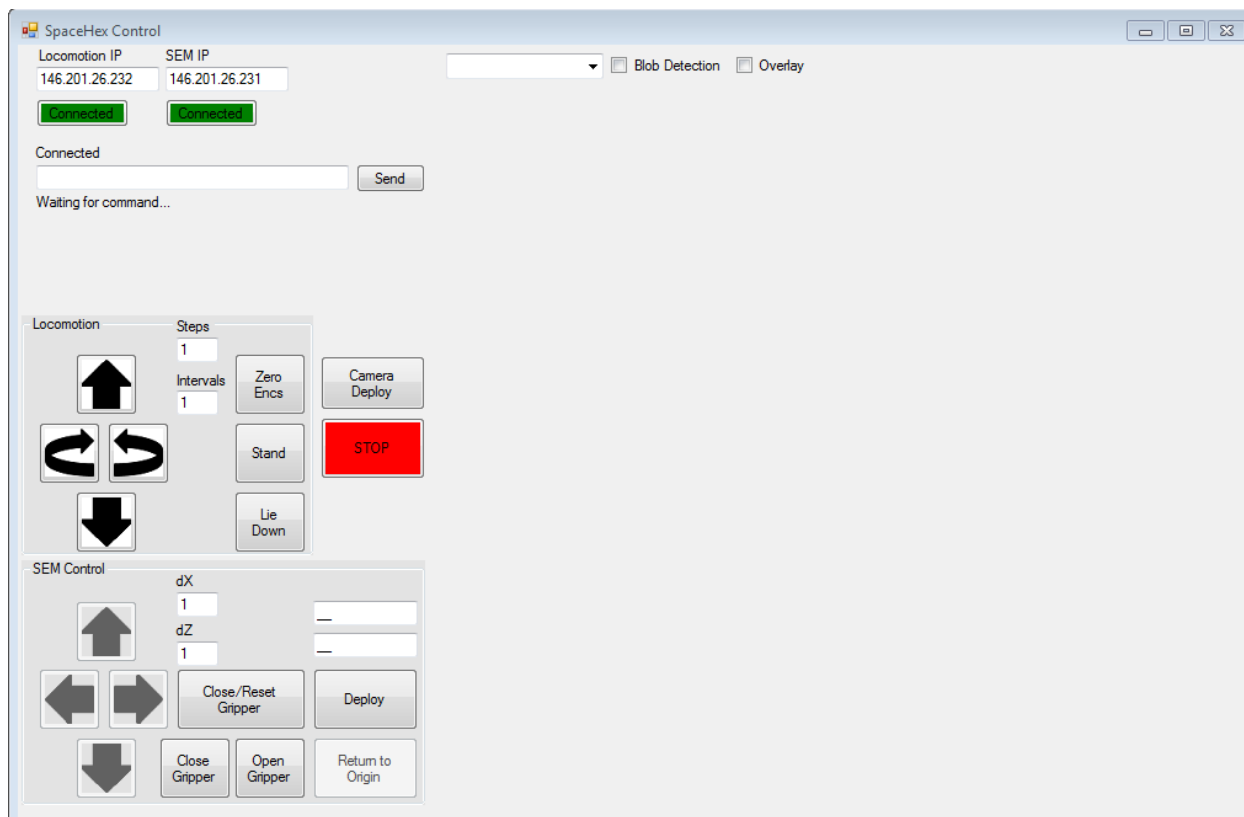

Figure 2 - User interface used to control the rover's sub-systems.

3.1 Networking

For full control of the rover, network connections to the locomotion computer, Sample Extraction Module (SEM) computer and cameras are established over the Verizon 4G Network.

Connection to Rover

To connect to the rover router over the 4G network, simply open up a web browser and type in the static IP address of the Verizon 4G Modem.
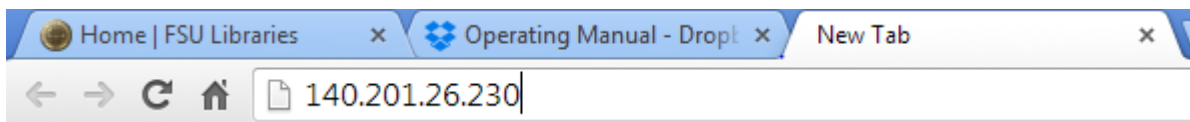

Figure 3 – Connecting over the Verizon Network

The user can also connect to the rover locally by connecting to the router using the Windows Network and Sharing Center. This does not provide the range of the 4G Network.

Locomotion and SEM Computer Network Linking

To connect to the two computers on the rover to the router, simply enter their IP addresses into the 'Locomotion IP" and "SEM IP" fields at the top left and click "Connect". The colors of the "Connect" buttons indicate whether the connection has been successfully established.
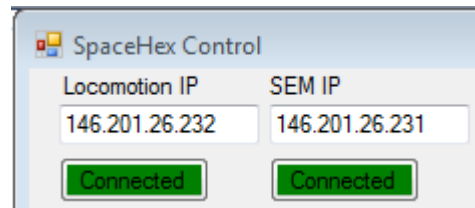

Figure 4 - IP address fields and connect buttons which serve as status indicators.

Connection to both of the Rover's computers is required before the locomotion and SEM controls are enabled.

Camera Networking

Connections the various cameras on the rover are made automatically by the interface upon selection of the desired camera from the drop down menu as shown below. If credentials are required to access the camera, a prompt will appear upon selection of the camera. Default credentials are admin/admin (username/password) for all cameras.
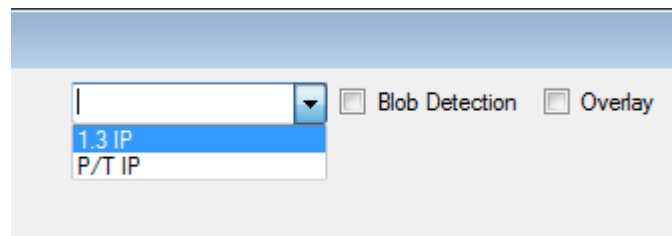

Figure 5 - Camera selection drop-down menu.

The video feed for the selected camera will appear automatically once a connection has been established (5-10 seconds).

Due to the rover containing legs instead of tires, it is important to note that the rover will walk in "steps". The step size and rotation turn interval of the rover vary depending on the surface being traversed (less traction will result in smaller steps and turn intervals). On high-traction surfaces the rover takes steps of approximately **9"** and rotates at **30°** intervals. This is important because if an angle of less than 30° is desired, the "turn while walking" function must be used rather than the "stationary turn" function to reach the desired location. Both of these functions are available with the XBOX controller.

It is also important to note that all sent commands and returned-rover-feedback (messages, camera feeds and sensor data) are subject to a network delay of **3-7 seconds**. This means that the user must release the joystick to stop the rover's motion 3-7 seconds before it is actually desired. Fortunately, if the rover goes too far forward, the rover can simply reverse into position.

XBOX Controls

Shown below is an XBOX controller used to send commands to the computer.

Figure 3 - Rover locomotion controls.

The left joystick will move the rover forward, backwards, stationary left, and stationary right. The right joystick will activate a turn while walking in either the left or right directions. 'Y' will enable calibration, and 'A' will lie the robot down and then stand it up when desired. If a joystick is held in a certain direction, the rover will continue to move in that direction until the joystick is either released or another direction is pressed. If another direction is pressed, the rover will finish its step in the previous direction and immediately begin to move in the new desired direction until that new joystick is released.

Leg Calibration

Prior to attempting the stand or move the rover, the positions of the legs must be synchronized and calibrated. The procedure for calibrating the legs is as follows:

1. With the rover on **FLAT** and **LEVEL** ground, click and hold the 'Y'.
2. Wait for the legs to finishing rotating into the synchronized position.
3. Once the rover looks like it does in Figure 6 below, release the 'Y' button and the rover will stand, ready for commands.

Shown below is a photo of the Hexcavator robot at the end of the calibration routine.

Figure 4 - Synchronized legs following calibration routine.

Laying Down/Standing the Rover

The rover can be raised to the standing position or lowered to the laying position using the 'A' button on the XBOX controller. To lay down the rover, simply press the 'A' button once. When the rover reaches the ground, it will stay lying down until the 'A' button is pressed again. When the rover is lying down, the rover will begin to accept inputs for arm control. Once the button is pressed, the rover will stand up and be ready for locomotion inputs.

Emergency Stop

If at any time the user wishes to halt the command currently being executed, the red **STOP** button can be pressed and the rover will immediately cease movement.

4.0 Sample Extraction Module Operation

The goal of the SEM is to quickly locate, extract, and store the colored rock samples strewn throughout the JSC Rock Yard during the competition.

4.1 Sample Extraction and Storage

Once a sample has been located the following procedure can be used to capture it within the gripper:

1. Orient the rover so that the sample is within the extraction zone.
2. Lay down the rover by pressing the **Y** button.
3. Deploy the gripper by pressing the **A** button on the x-box controller
4. Position the gripper using the model arm shown in Figure 7
5. Once the gripper is positioned over the sample press the **B** button to capture the sample.
6. To store the sample simply click "Return Home" and arm will return the gripper to the stored position after dropping the rock in the collection bin.
7. Press the **Y** button again to return to the standing position.

5.0 Troubleshooting

This section will provide a general strategy for diagnosing rover issues. Please keep in mind that the complexity of the rover and the number of components present makes the creation of an exhaustive troubleshooting guide impractical. Because this rover is not a commercial product, it is expected that the operator be thoroughly familiar with the hardware, software, and operating procedure of the rover.

5.1 Network Issues

The most probable issues that a user may encounter when operating the rover involve the rover's networking and communications subsystem. A diagram for this sub-system is shown below to clarity to the troubleshooting discussion. A computer able to access the rover's local network is required to effectively troubleshoot networking problems.
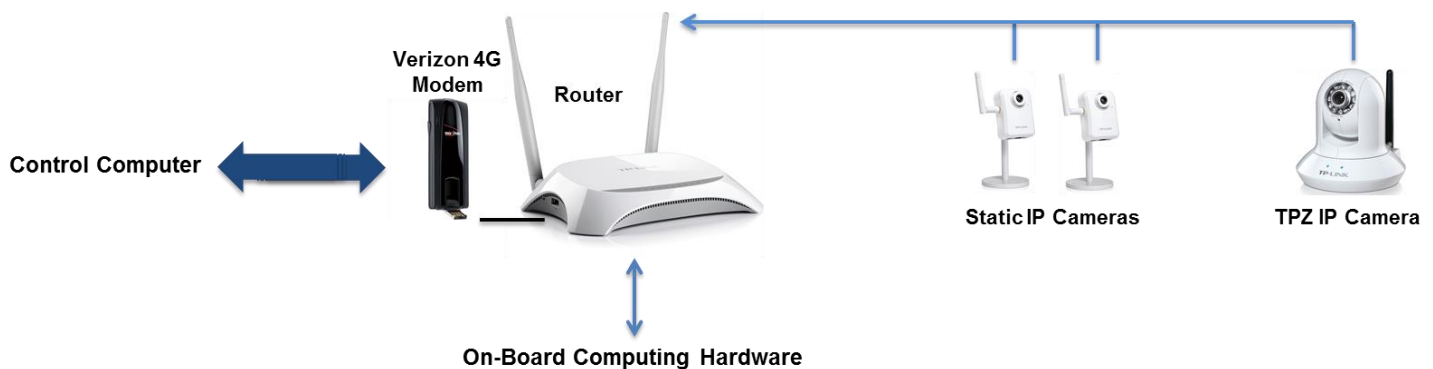

Figure 5 - Communication sub-system diagram.

Router and Modem Troubleshooting

If an SSH connection cannot be established through the user interface, the following message will be displayed in the GUI "Response" text field:
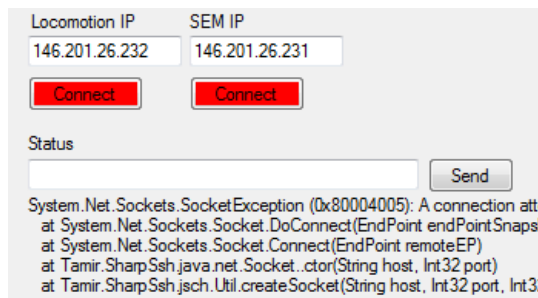
Figure 6 - SSH connection failure message.

The following steps should be followed to troubleshoot connection problems:

1. Ensure that the IP addresses entered are correct by executing the "ifconfig" command on the rover's local computers.
2. Using the diagnostic computer on the rover's local network, access the router's configuration and information program by entering "192.168.0.1" into the web browser.
    a. On the "Home" page of the router, check that a 3G/4G connection has been established. If not, disconnect the modem from the router, wait 10-15 seconds, and reconnect. If the connection is still not working, call the service provider for further troubleshooting.
    b. Check that the connection mode of the router is set to "3G/4G Only" on the connections page.
3. Reboot the router.
4. Check the router user guide for further troubleshooting advice,

5.2 General Rover Non-Responsiveness

If connection to the rover has been established but is partially/fully non-responsive, the following sections suggest the first steps that can be taken to begin the troubleshooting process.

A low charge on the battery can cause any of the issues discussed below and should be eliminated as a possibility before further troubleshooting.

Locomotion AND SEM Systems Non-Responsive

If connections have been established to both of the rover's computers but the rover does not respond to commands to either of the main subsystems, the IP addresses of the two computers are likely switched, meaning the SEM connection has been established to the Locomotion computer and vice versa. Restart the user interface program and switch the IP addresses. If the problem persists, more thorough component-by-component troubleshooting is required locally. Refer to the next sections for individual troubleshooting strategies for the SEM and Locomotion systems.

Locomotion Non-Responsive, SEM Responsive

If a connection has been established to the computer used to control locomotion but no response is observed to sent commands, the most likely issue is related to the wiring of the power system. Check the battery connections to the motor drivers. If some legs are responsive but others are not, check the +/- motor connections between the motor drivers and motors.

SEM Non-Responsive, Locomotion Responsive

Similar to the section above, first check the battery connections to the motor drivers, then check the connections between the drivers and motors.

5.3 Erratic Motor Response (SEM and Locomotion)

Improperly connected or disconnected encoders can cause motors to respond in an erratic manner. The correct motors have a response when a command is sent, but the response is not what was expected, check to make sure the encoder connectors have not become dislodged and that the wires are intact. In the case of erratic locomotion motors, a dislodged or damaged FPGA could also be the cause of erratic motor response.

6.0 Maintenance

This rover is not intended for commercial use and therefore no maintenance schedule shall be provided. The following spare parts will be brought to the competition in the case of malfunction or breakage during the competition:

(1) Carbon fiber or fiberglass leg

(1) Router

(Multiple) Fasteners, miscellaneous physical hardware

(Multiple) Wires, leads, connectors, miscellaneous electrical hardware

(2) Raspberry Pi computers

(1) Sabertooth motor driver (Locomotion motors)

(1) RoboClaw motor driver (SEM motors)

(2) SD cards, one pre-programmed for the locomotion computer, one for the SEM computer

(1) Fully charged battery set

The team is allotted up to 10 minutes (subtracted from roving time) during the competition for troubleshooting or repair of the rover.