Assembly and Testing of a Robotic Arm for a Mars Analog Mission

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Abstract - *The Mars Desert Research Station is a low to medium fidelity planetary habitat that hosts six-person crews for fourteen-day human analog missions. The National Society of Black Engineers (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 commercial off-the shelf (COTS) robotic arm and conducted a series of assembly and check out operations to determine its suitability as an analog device. This testing revealed minor issues with the COTS device and some desired enhancements that should be implemented prior to field use, but in general the system is viable for use in a Mars analog experiment.*

Keywords: Remote manipulator, robot arm, Mars Desert Research Station, MDRS.

1 Introduction

The Space Special Interest Group 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. [1] 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

NSBE is planning an expedition to MDRS that will explore the productivity of local telerobotics (direct control of a robot by a human operator) in a planetary outpost. When robotic assistants are working in conjunction with Extravehicular Activity (EVA) crew it may be more efficient to control these robots with local crew as opposed to by mission control on Earth. The time delay may make real-time Earth-based control impractical in such cases.

The experiment will use two COTS robots to explore basic tasks. Test subjects will use four distinct operating modes [2] for operation of the robots:

1. EVA Direct Observation – teleoperated control of a robot by an EVA astronaut in immediate proximity (e.g. at the same work site) 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 Lynxmotion AL5D 4 Degrees of Freedom Robotic Arm [3] for use in conjunction with a four-wheel drive robot. The arm is used to load and unload payloads from the four-wheel drive robot.

1.2 STS-2013 Assembly and Test 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 robotic arm

The robot kit was shipped disassembled, requiring complete assembly of the arm. This included both physical assembly and electrical connections. Additionally, a camera was to be mated to the robot assembly.

1.2.2 Establish communications between robot and the commanding interfaces

Commanding software was to be loaded onto a control laptop. The laptop was also connected to a hand controller via USB port and to the robot via serial port.

1.2.3 Command robot to perform certain operations and observe behavior

This step enabled determination of whether the robot arm could be controlled with sufficient precision for use as part of the NSBE MDRS expedition. It included maneuvering of the arm as would be needed to load and unload test objects from the four-wheel drive robot.

1.2.4 Test robotic arm efficacy with grasping and manipulating various objects

The strength of the robot arm was not clear in the product literature, therefore testing was required to determine a range of objects that could be used in the NSBE MDRS expedition. Several test objects of varying dimensions and masses were lifted by the robot arm. This was not intended to fully characterize the strength of the arm, only to establish "proof of concept" demonstrations that potentially useful objects exist that can be manipulated by the robot.

2 Robot Configuration and Assembly

2.1 Physical configuration and assembly

Significant assembly was required for the robot arm. As shown in Figure 1, the robot shipped in many small pieces. As a first step, these components were inventoried and matched to online instructions. [3]

Figure 1. NSBE team members arrange robot arm components

The robot base was not designed to be free standing, but contained screw holes for mounting it to a fixed platform. As a manner of improvisation, the team procured a plywood sheet and screwed the robot arm to the sheet, shown in Figure 2, providing a stable operating platform.

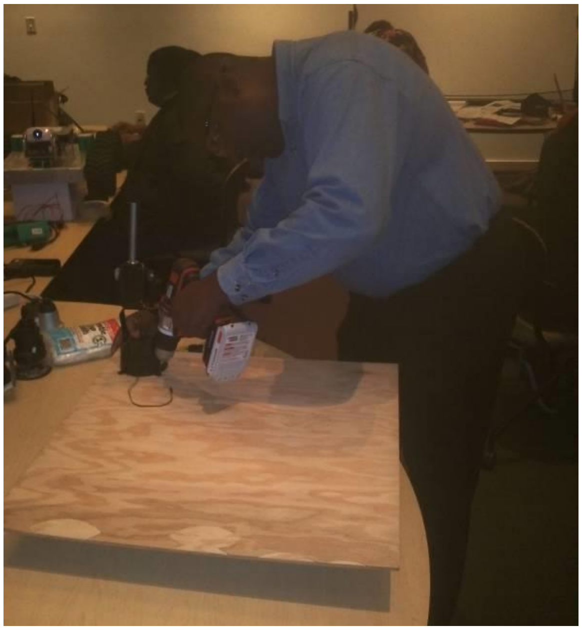

Figure 2. Integration of Robot Arm with Base Platform

2.2 Calibration

The angular velocity for the arm's joints was never altered from the factory default settings. If desired, it can be varied along with other arm properties through the RIOS program. [4]

3 Robot Webcam

3.1 Physical configuration and assembly

A Microsoft LifeCam Studio™ Webcam will be mounted to the robot arm. This was not part of the supplied robot arm kit and is a modification being made in support of NSBE test objectives.

The functional intent for the robot arm camera is to provide a view of the gripper in order to guide an operator's use of the arm and gripper to approach, grasp, and lift objects as well as place grasped objects in desired locations. The camera is shown in Figure 3 in its as-purchased configuration, which includes a flexible mounting bracket that also can serve as a stand. This stand/bracket is designed for optional mounting to a standard camera tripod via the threaded hole in its flange. The small size and light weight (2.4 in x 1.8 in x 4.5 in; 4.5 oz) of the camera is not expected to severely impact the lift capacity or performance of the robot arm, although this remains to be confirmed during physical integration.

Figure 3. Microsoft LifeCam Studio™ Webcam with flexible bracket and swivel axes

The flexible stand/mounting bracket is attached to a swivel base on the bottom of the camera that allows for the camera to be pointed in almost any desired direction (see Figure 3). Three small screws fasten the flexible stand/mounting bracket to the swivel base. Options for mounting the camera to the robot arm may be chosen that make use of the stand/bracket or the 3-screw connection. Partially shown in Figure 3 is one end of the 6-foot cable attached to the camera; the other end terminates with a high speed USB connector for simple interfacing to a PC serving as the operator control station that would receive camera images (and control any configurable camera features).

3.2 Display configuration

The Microsoft LifeCam Studio™ Webcam comes with a CD-ROM including drive software to be installed on the control laptop, a standard Windows 7 PC. This software provides an interface for viewing webcam video. Alternately, the camera feed can be incorporated into a custom user interface.

3.3 Integration with robot arm

There are a couple of places on the robot arm at which to mount the camera that allow use of existing arm hardware mounting points or brackets while also providing a view of the gripper workspace. One location is on the link shared by the elbow motor and wrist pitch motor, using hardware mounting points on the elbow joint assembly; a second location is on the wrist pitch bracket. In both cases, the camera would be mounted with its aperture aligned perpendicular to the joint axis of rotation. The first location would provide a good view of the gripper when the gripper is in its nominal (zero pitch) position and when the gripper is pitched up, but not when the gripper is pitched down. The second location does not have this issue since the center of the camera viewing fulcrum would be aligned with the gripper approach axis; however, some views will be partially obscured by the gripper when it is rotated away from horizontal.

Feasible options for mounting the camera to the wrist pitch bracket range from using cable ties to fabricating a custom bracket. While fixing the camera to the wrist pitch bracket may offer the best tradeoff of operational views of the gripper, a rigid attachment to that bracket may require fabricating a custom bracket that uses available screw holes (see Figure y) and includes a bolt-on interface for the camera itself (with or without the flexible stand/bracket). Modifying the wrist pitch bracket by drilling mount holes for a custom camera bracket is yet another option. A mounting option that is simple, yet sufficiently rigid will be chosen in the future.

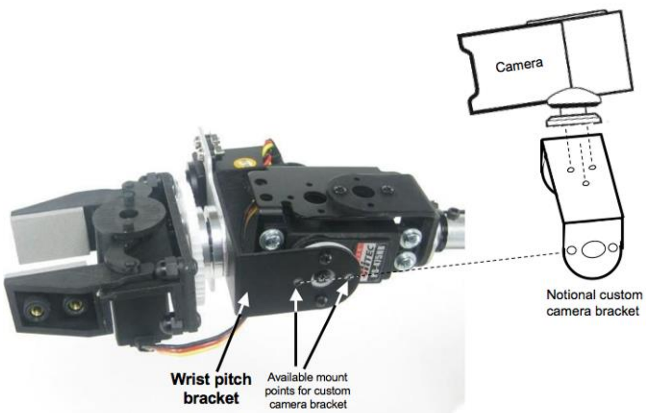

Figure y. Available screw holes on the wrist pitch bracket for one custom camera bracket mounting option, and a corresponding notional bracket design.

Further evaluation of the camera mounting location on the wrist pitch bracket is needed to ensure that the depth of focus (several inches minimum focus range) on the gripper and vicinity remains adequate (even though the camera has an auto focus capability) throughout the gripper rotational range of motion.

4 Communications between Robot and Commanding Interface

Both the robot arm and the camera use cabled connections to the control laptop, the robot arm using a serial port and the camera using a USB port. This interface experienced no communications dropouts during STS-2013 testing, but obviously limits the operator to being in the immediate vicinity of the robot, which could potentially interfere with test objectives.

5 Robot performance

Testing of the robot arm revealed no problems with the arm's software and servomotors. There were also no problems in the use of a game controller to operate the robot. The lifting capacity of the arm was not rigorously tested. In testing the arm was used several times to pick up and reposition two masses. The first mass was a 9-volt DC battery. Figure 5 shows the robot arm moving into position to pick up the battery. The robot experienced no difficulties in manipulating or lifting the battery.

Figure 5. Robot Arm Positioned to Lift 9V Battery

The second mass tested was a pocket Allen wrench set. The size of the wrench set approached the limits of the jaw opening of the robot arm's end effector, making it difficult for the operator to grasp the Allen wrench set. However, once grasped, as shown in Figure 6, the robot arm had sufficient power to maneuver the wrench set.

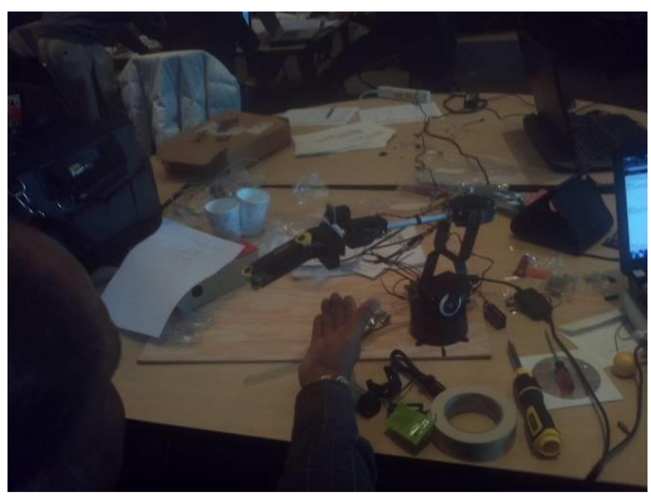

Figure 6. Robot Arm Manipulating Allen Wrench Set

6 Conclusions

The NSBE team was able to successfully operate the robot arm. Connectivity was uninterrupted over the serial port connection. Additionally, camera video was obtained over the USB connection. However, the camera was not permanently mounted on the robot.

Forward work includes permanent installation of the webcam on the robot arm. Additional testing is also needed to determine the limits of arm operability and to determine maximum weights and dimensions of payload objects that can be manipulated by the arm. Also, the reach envelope of the arm must be determined, as it will have implications for the payload bay of the four-wheel drive robot. Finally, WiFi connectivity will be needed to effectively use the robot in the field. A viable WiFi connection will need to be developed.

While some additional work is warranted for this robot arm, preliminary testing indicates that it is generally a viable option for use during MDRS NSBE expeditions.

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