Full Throttle STEM™ Rover

Implementation Guide

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Gaming Research Integration for Learning Laboratory™ (GRILL™)
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1. CHALLENGE PROBLEMS: ROVER

Modeling and simulation (M&S) professionals often utilize commercial off-the-shelf (COTS) games to provide a basis for the virtual environment training and simulation. Utilizing existing games reduces the economic investment required to provide a customized training environment and therefore moves the business or industry forward without a large investment in the development of the simulation. These challenge problems provide students with the opportunity to create a virtual model similar to those used by industry professionals. A simulation of a real environment depends on data collected about that real environment. Students working through these challenges build progressively more complex tools towards the ability to collect data that would inform modeling and simulation applications. The rover is the platform for this data collection, and these challenge problems work towards increasing autonomy of the rover.

Autonomy is a measure of how much a system makes its own decisions. For example, a system has a small amount of autonomy if the user defines a path but the system decides how to turn that path into a specific sequence of movements. There is more autonomy involved if the user picks a destination but the system chooses how to navigate around obstacles in order to reach that destination. Autonomy has exciting military, transportation, or robotic applications. One important area of robotics research is to enable a robot to cope with its environment whether it is on land, underwater, in the air, underground, or in space. Autonomous robots are robots that can perform desired tasks in unstructured environments without continuous human guidance. Many kinds of robots have some degree of autonomy. Different robots can be autonomous in different ways. A high degree of autonomy is particularly desirable in fields such as space exploration, cleaning floors, mowing lawns, and search and rescue.

Live, virtual, and constructive (LVC) sensor data are essential to implementing high fidelity M&S. M&S systems can interpret large amounts of data to help humans understand and effectively use the data. The deployment of robots into the field to collect data for interpretation aids LVC. The deployment of robots into the real world is a special subset of robotics, called field robotics. Outside of the Air Force Research Lab, Carnegie Mellon Field Robotics Center and NASA have also researched the challenges found in field robotics. Carnegie Mellon University has built robots that can explore flooded mines and roam the desert in search of life, while NASA has built rovers that explore the surface of Mars. Students completing these rover challenge problems will face some of the same the challenges of autonomous movement, sensor data collection, and wireless communication faced in similar real world projects.

These challenge problems tend to build on each other. You may choose to have all students work through all challenge problems sequentially. If you want to divide your students into different teams working in parallel, you may want to divide the projects into hardware and software components. Additionally, you should also consider the following sequence options (Figure 1).

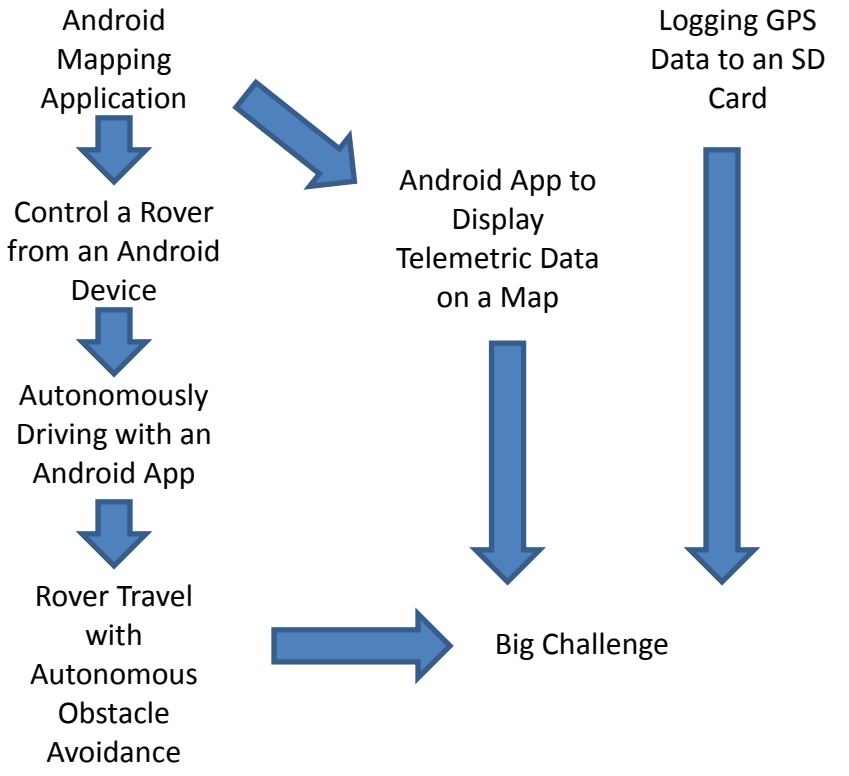

Figure 1: Recommended Order of Challenge Problem Implementation

2. IMPLEMENTATION GUIDE AND INSTRUCTIONAL RESOURCES

This implementation guide provides an overview of the tools and tutorials available for each challenge problem. Students developed the associated tutorials during summer internships at the GRILL™ at Wright-Patterson Air Force Base in Dayton, OH. Consistent with the philosophy of challenge problems, teachers should not give these resources and tutorials directly to students; this will help ensure students actively engage in the learning and problem-solving process. The

resources and tutorials are a tool for teachers to help foster these processes and skills in students.

2.1. ENGINEERING LOGBOOKS

Students should use engineering logbooks as a personal reference about project learning and results. Logbooks help monitor and control where students have invested their time, knowledge learned, resources, and problem solving. Teachers can also use logbooks as a resource for grades.

Teachers should have the following general expectations for logbook entries:

- Date for each entry
- Log of personal activity, communications, and team activity
- Research and engineering analysis
- Review of individual/team performance
- Sketches
- Class notes
- Meeting notes
- Math calculations
- Design process
- Project reflections
- Rationale for decisions
- Decision criteria
- Design alternatives
- Project requirements
- Links to helpful resources

Note: Include everything contributed towards the solution the good, the bad, and the ugly.

2.2. HARDWARE AND SOFTWARE

Each challenge problem requires some combination of hardware and/or software. Table 1 illustrates possible application of various tools to each of the problems. Do not use this list as the sole solution to the challenge problem, but as an example of a solution students may implement.

Table 1 Hardware and Software Tool Options for each Challenge Problem

Challenge Problem	Tools
1 – Android Mapping Application	Android device, and Android development software
2– Control a Rover from an Android Device	Rover, Android device, two Arduino boards, XBee dongles, XBee shields, Arduino and Android development software
3 – Logging GPS Data to an SD Card	Arduino board, GPS shield, SD shield, SD card, and Arduino development software
4 – Autonomously Driving with an Android App	Rover, Android device, two Arduino boards, radio transmitter/receiver shields, GPS shield, Arduino and Android development software
5 – Rover Travel with Autonomous Obstacle Avoidance	Rover, Arduino board, ping sensors, and Arduino development software
6 – Android App to Display Telemetric Data on a Map	Android device and Android development software
7 – The Big Challenge	Rover, Android device, two Arduino boards, radio transmitter/receiver shields, GPS shield, Arduino sensors, Arduino and Android development software

Table 2 summarizes the approximate costs and provides links to information regarding each of the potential tools. We collected these estimates at the time we prepared this content. Accordingly, teachers implementing this content should verify the costs with the makers of each tool for planning purposes.

Table 2: Tools and Approximate Costs

Name	Type of Tool	Link	Cost
Nexus 7 Tablet	Android Tablet	http://www.bestbuy.com/site/Nexus+7+7+inch+Tablet+with+16GB+Memory/1484847.p	$230
Arduino Uno	Microcontroller	http://www.seeedstudio.com/depot/arduino-uno-rev3-p-694.html	$25
Arduino Mega	Microcontroller	https://www.sparkfun.com/products/11061	$59
Robot Rover for Arduino	Rover	http://www.robotshop.com/robotshop-robot-rover-arduino-tank-kit-rubber-tracks.html	$86
Rover V2	Rover	http://www.robotshop.com/dfrobotshop-rover-tracked-robot-basic-kit-3.html	$95
XBee S1	Radio Transmitter and Receiver	https://www.sparkfun.com/products/11215	$25
Arduino Motor Shield V3	Motor Shield	http://www.robotshop.com/productinfo.aspx?pc=RB-Ard-35&lang=en-US	$30
XBee Explorer Dongle	XBee-computer connector	https://www.sparkfun.com/products/9819	$25
XBee Shield	Shield for the Radio Transmitter and Receiver	https://www.sparkfun.com/products/10854	$25
Adafruit Ultimate GPS Logger Shield	GPS Shield	http://www.adafruit.com/products/1272	$50
SD Card Shield V4.0	SD Shield	http://www.seeedstudio.com/depot/sd-card-shield-v40-p-1381.html	$14
SD Card	SD Card	most electronics stores	varies

Name	Type of Tool	Link	Cost
SainSmart Ultrasonic Module HC-SR04 Distance Sensor	Ping Sensor	http://www.amazon.com/Ultrasonic-Module-HC-SR04-Distance-Arduino/dp/B004U8TOE6/ref=sr_1_1?s=electronics&ie=UTF8&qid=1368735225&sr=1-1&keywords=arduino+ping	$5
Barometric Pressure/Temperature/Altitude Sensor	Arduino Sensor	http://www.adafruit.com/products/391	$30
Moisture sensor	Arduino Sensor	http://www.dfrobot.com/index.php?route=product/product&product_id=599	$5
Cube3D	3D printer	http://www.cubify.com	$1300
Eclipse	Integrated development environment	http://www.eclipse.org/downloads/	$0
Android SDK	Android software development kit	http://developer.android.com/sdk/index.html	$0
Android Studio	Integrated development environment	http://developer.android.com/sdk/installing/studio.html	$0
Arduino IDE	Integrated development environment	http://arduino.cc/en/Main/Software	$0
Solder Iron	Hand tool for soldering	--	$10
Solder	Electrical solder	--	$10
SparkFun	Electronics Distributor (sensors, etc.)	http://www.sparkfun.com/	varies
SketchUp	3D modeling Software	http://www.sketchup.com/	$0

Name	Type of Tool	Link	Cost
Hacrocam	Camera	http://hacromatic.com/products/184 or http://hacromatic.com/products/188	$21 or $40
FTDI friend	Serial to USB adaptor	http://www.adafruit.com/products/284	$15
A to mini-B cable	Cable	http://www.parallax.com/Store/Microcontrollers/PropellerDevelopmentBoards/tabid/514/ProductID/33/List/0/Default.aspx?SortField=ProductName,ProductName	$4
Jumper wires	Electrical wire	http://www.adafruit.com/products/758	$8
Female wires	Electrical wire	http://www.adafruit.com/products/266	$7
Hobbywing Switch Mode UBEC-3A	Voltage regulator	http://www.valuehobby.com/hobbywing-switch-mode-ubec-3a-ultimate-bec-for-2-6s-lipo.html	$8
Slide Switch	Switch	http://www.radioshack.com/product/index.jsp?productId=19964156	$4
Breadboard	Universal component board	http://www.radioshack.com/product/index.jsp?productId=2102844	$3
1800mAh 7.2v NiMH Sport Stick Batter	Battery	http://www.stormerhobbies.com/cgi-bin/seekpart.pl?pn=RCESP1800	$12
Ultrasonic Distance Sensors	Arduino Sensors	http://www.amazon.com/SainSmart-Ultrasonic-Distance-Mega2560-Duemilanove/dp/B004U8TOE6	$6
Sketchup STL Exporter	Plugin for 3D printing	http://sketchupdate.blogspot.com/2013/01/stls-for-3d-printing-in-and-out-of.html	$0
SketchUp	3D Modeling software	http://www.sketchup.com/	$0
Servo motor	Motor	https://www.sparkfun.com/categories/178	varies

2.3. RESOURCES TO GUIDE AND SCAFFOLD INSTRUCTION

Users and participants have used the resources listed in this section to help solve the Rover STEM Challenge problems. These resources are neither exhaustive nor comprehensive and should not be treated as complete tutorials. Teachers should use these resources to help familiarize themselves with the relevant tools and to guide and scaffold instruction. Table 3 includes supplemental resources for the Rover STEM. Table 4 includes resources focused on modeling. Coding and programming resources are included in Table 5 and Aurdino resources are included in Table 6. Android resources and XBee are included in Table 7 and Table 8, respectively. Sensor and Servo resources are included in Table 9.

Table 3: Supplemental Resources for Rover and STEM.

Title	URL	Brief Description
Reverse Engineer the Brain	http://www.engineeringchallenges.org/cms/8996/9109.aspx	Article on using computers to emulate human intelligence
Design Thinking for Educators Toolkit	http://designthinkingforeducators.com/	This toolkit has been adapted to meet the context of K-12 education. These processes, methods, and tools help tackle complex challenges.
Artificially Intelligent Autonomous Robots	https://www.youtube.com/watch?v=cdFTOyDmQhA	TED talk describing algorithms, methods, and AI employed to make quadcopters autonomous.
A Primer of Modeling and Simulation	http://www.corporatepress.com/clientfiles/ntsa/	Primer includes definitions, history, applications, value, and future of modeling and simulation.
Seed Spreading Robot	http://www.instructables.com/id/Seed-Spreading-Robot/step21/Seed-Spreader-Brackets/	Instructions to create a seed spreading robot, including similar sensors and technology utilized in the tutorials.

Table 4: Modeling Resources

Title	URL	Brief Description
SketchUp	http://www.sketchup.com/	3D modeling program with a warehouse that houses downloadable models.
STL Plugin	http://helioslabs.blogspot.com/2013/02/sketchup-8-stl-files-for-3d-printing.html	Instructions for installing the plugin to SketchUp

Table 5: Coding Resources for Rover Challenge Problems

Title	URL	Brief Description
Blue Pelican	http://www.bluepelicanjava.com	Free high school computer science textbook available for download or on-line use complete with exercises and programming projects.
Code Academy	http://www.codeacademy.com	Provides online tutorials for learning various languages including JavaScript, HTML, CSS, Ruby, Python, and APIs
Lynda Tutorials	http://www.lynda.com	Online video-training library with more than 1,400 software and training titles allowing anyone to learn software, design, and business skills. Membership is required.
Greenfoot	http://www.greenfoot.org/	Visual and interactive tool to teach object orientation with Java

Table 6: Arduino Resources for Rover Challenge Problems

Title	URL	Brief Description
Arduino in a Nutshell	http://hci.rwth-aachen.de/arduino	Introduction to Arduino and written for people that have limited exposure to programming and new to electronics.
An Introduction to the Arduino	http://www.youtube.com/watch?feature=player_embedded&v=CqrQmQqpHXc	An overview of what the Arduino is and what its possibilities.

Title	URL	Brief Description
Writing a Library for Arduino	http://arduino.cc/en/Hacking/LibraryTutorial	Explains how to create a library for Arduino, which will allow other people to easily use the code and update it as it improves.
Ping Sensor Resource	http://arduinobasics.blogspot.com/2012/11/arduinobasics-hc-sr04-ultrasonic-sensor.html	Provides a basic diagram of setting up the Ultrasonic sensor and example of code
Ping Sensor Library	http://playground.arduino.cc/Code/NewPing	A library for using ping sensors
User manual for the Robot Rover	http://www.robotshop.com/ca/content/PDF/robotshop-rover-development-manual.pdf	Includes guidance for assembly, wiring, and Arduino coding
Motor Reversing	http://learn.adafruit.com/adafruit-arduino-lesson-15-dc-motor-reversing/arduino-code	Provides Arduino code for reversing a motor
Fritzing	http://fritzing.org/download/	Free software for creating schematic diagrams of Arduino boards wired to different components.

Table 7: Android Resources for Rover Challenge Problems

Title	URL	Brief Description
Install the Google Play Services SDK	http://developer.android.com/google/play-services/setup.html#Install	Instructions on how to install the software development kit (SDK) for building Android apps from within Eclipse
First Steps with Android Studio	http://www.youtube.com/watch?v=ICqUnxAIFGA	This video illustrates the process of creating a new project.
Building Your First App	http://developer.android.com/training/basics/firstapp/index.html	Provides instructions to build an Android app including creating an Android project, debugging, fundamentals of app design, and simple user interface design

Title	URL	Brief Description
Android SDK: Working with Google Maps – Application Setup	http://mobile.tutsplus.com/tutorials/android/android-sdk-working-with-google-maps-application-setup/	Provides instruction to build an Android app using Google Maps that will mark the users current location and nearby places of interest.
Google Maps Android API v2	https://developers.google.com/maps/documentation/android/start#installing_the_google_maps_android_v2_api	Tutorials on developing Android Apps using Google Maps
Map Fragment	https://docs.google.com/document/pub?id=19nQzvKP-CVLd7_VrpwnHfl-AE9fjbJySowONZZtNHzw	Steps to create a Map Fragment

Table 8: XBee Resource for Rover Challenge Problems

Title	URL	Brief Description
XBee S2 Quick Reference Guide	http://www.tunnelsup.com/images/XBee-Quick-Reference-Guide.pdf	Reference guide
XBee Basics – Lesson 1	http://www.youtube.com/watch?v=odekkumB3WQ	General information and initial setup of the XBee
XBee Basics – Lesson 2	http://www.youtube.com/watch?v=mPx3TjzvE9U	Simple chat program between two XBees in AT mode
XBee Basics – Lesson 3	http://www.youtube.com/watch?v=jh-GIaghIjw	API Mode: Digital input from remote sensor
XBee Basics – Lesson 4	http://www.youtube.com/watch?v=rnBx2yqKn_E	API mode: reading analog data from remote XBee
XBee Basics – Lesson 5	http://www.youtube.com/watch?v=3M00K7-nT24	API mode: send digital output to a remote XBee

Table 9: Sensor and Servo Resources for Rover Challenge Problems

Title	URL	Brief Description
Wiki page for the Moisture Sensor	http://www.dfrobot.com/wiki/index.php/Moisture_Sensor_(SKU:SEN0114)	Explains how to wire and use the moisture sensor.
Arduino - Servo	http://arduino.cc/en/reference/servo	Explains how servos function and how to control them with an Arduino.