Title # TOPOGRAPHY - a LIDAR Simulation

Grade Level(s): 9 - 12

Estimated Time: 1.5 hours

Discussion of Technology: Appendix A

Construction Details: Appendix B

MSDE Indicator(s)

Goal 1: Skills and Processes

1.8.6 use appropriate instruments and metric units when making measurements and collecting data

1.8.7 collect, organize, and display data in ways others can verify (i.e. numbers, statistics, tables, graphs, drawings, charts, diagrams) using appropriate instruments (e.g., calculators, spreadsheets, databases, and graphing programs)

1.8.9 interpret and communicate findings (i.e., speaking, writing, and drawing) in a form suited to the purpose and audience, using developmentally appropriate methods including technology tools and telecommunications

1.8.22 explain that a model has advantages and disadvantages and may need to be changed for different purposes

1.8.23 demonstrate and explain that tools are essential to scientific investigation for such purposes as to observe, estimate, measure, compute, collect, and communicate scientific data and information (i.e., size, distance, motion)

Goal 2: Geometry, Measurement, and Reasoning

2 The student will demonstrate the ability to solve mathematical and real-world problems using measurement and geometric models and will justify solutions and explain processes used.

2.1 The student will represent and analyze two- and three-dimensional figures using tools and technology where appropriate.

Goal 3: Mathematics – Data Analysis and Probability

3.2.1 make informed decisions and predictions based upon the results of simulations and data from research

Goal 4: Geography

4.1.12.1 use a variety of geographic tools to collect, synthesize, interpret, analyze, and evaluate information to answer geographic questions in the context of other social sciences

4.2.1.4 construct and/or draw and/or validate properties of geometric figures using appropriate tools and technology.

Science Core Learning Goal 2 – Earth and Space Science

1.2 The student will describe current efforts and technologies used to study the universe (optical telescopes, radio telescopes, spectroscopes, satellites, space probes, manned missions)

Brief Description:

Outcomes:

- Simulate the LIDAR-based topographic mapping techniques used by satellites in remotely acquiring surface data.
- Use a computer-interfaced motion detector to acquire vertical distance (elevation) data from a constructed model surface on the Earth (in a lab situation).
- Understand how elevation data are obtained using an ultra-sound motion detector (a technical discussion of the data acquisition process using an ultra sound motion detector may be found in Appendix-A).
- Export data acquired with the motion detector to an Excel spreadsheet producing a topographic map of the surface.
- Analyze the topographic map to understand general surface features and possibly identify the location of specific features of the model surface.
- Possibly use the Excel-generated topographic map in a related robotic exercise requiring a map drawn to scale of a surface to be traveled by the robot.
- Possibly use the Excel-generated topographic map itself as an object of analysis for the purpose of understanding the limits of measurement precision and representation.

Anticipated Student Errors and/or Pre-Conceptions:

- Students believe that all “data” are accurate representations of reality.
- Students do not understand that satellite altitude data is measured relative to the observational platform (e.g. the satellite) instead of from ground level.
- Students misinterpret color scales indicating relative altitudes.
- Students make errors in proportional reasoning when “scaling up” maps.

Prerequisite Skills/Concepts/Vocabulary Needed by Students for Meeting the Objective(s):

- Understanding simple algebraic formulas of the type: A = B / C
- Understanding scaled measurements
- Use the concept of proportion to produce a scaled representation
- Use Excel software to import data and create graphic representation
- Vocabulary
    - topography scale LIDAR altitude contour
    - ultra sound SONAR speed of light speed of sound
    - satellite coordinate system proportional representation

Background knowledge / teacher notes:

Equipment Needed:

- A constructed surface with varying vertical relief features. The surface should occupy a square area not to exceed approximately 150 cm on a side. The range of vertical relief of the surface can vary depending on the PVC frame holding the motion detector: relatively small vertical heights of 5 cm - 30 cm simulating craters, or larger-scale objects such as tables, chairs, and trash cans can also be easily accommodated.
- A Vernier motion detector was used for this activity: either a standard motion detector interfaced to a computer through Vernier's Lab Pro (an analog-to-digital converter) with Logger Pro software, or a simpler Vernier "Go Motion" motion detector directly connected to a computer with supplied software was used in the activity; but a motion detector from another company could also be used if the digital data were easily accessible for exporting to Excel.
- A computer (Windows or Mac) with MS Excel software.
- A three-section vertical PVC framework to align and hold the motion detector during experimental measurements (see Figure-1). A list of the materials required to assemble the PVC framework shown in the photograph can be found in Appendix-B.

Figure 1 - Scanning with an ultra sound motion detector

- Basic familiarity with ultra sound motion detector

- Basic familiarity with analog-to-digital computer interfaced data acquisition
- Basic familiarity with Excel software

Procedure:

- Construct a rectangular PVC framework required to hold the motion detector, enabling the motion detector to be slid along the top piece of frame, parallel with the model surface, while maintaining a constant downward pointing position. In the described activity, PVC pipe of 1.25 inch (inside diameter) was used for the support structure. The vertical height of the side pieces of the PVC structure have no particular fixed length – the length of these pieces (which determines the maximum elevation of the motion detector from the surface) will be chosen to be appropriate to the height of the objects on the model surface. Motion detectors have a vertical position precision of 1-2 mm, so generally the detector should be placed within 25 to 50 cm of the top of the highest structure on the model surface for best results.
- A motion detector clamp (supplied with the motion detector) is used to hold a slightly larger diameter section of PVC (1.5 inch inside diameter) enabling the motion detector to be easily slid across the top frame of the structure.
- A model surface grid can be constructed by placing tape on a floor in a large square of appropriate size, and making marks on the tape that will correspond to the number of "runs" or data scans that will be used in the process.
- Assemble an array of objects of varying height and width that will be used as the model surface to be topographically analyzed.
    1. If the exploration is designed only to produce a two-dimensional height vs. position representation (one "run" or scan of the motion detector) the only considerations are that the surface objects fit within the width of the vertical PVC frame pieces, and that the objects have sufficient separation to show their shape when scanned by the motion detector.
    2. If the exploration is designed to produce a two or three dimensional topographic representation of a surface area then there are several additional considerations:
        - The scanned data is most easily displayed in Excel if the surface area is a square. The motion detector has both a sample rate setting and an overall duration setting. For the sample lab we used a fifteen second scan duration combined with a sample rate of 2 samples per second, resulting in 30 pieces of position data for every "run". The model surface was designed as a square grid of 150 cm on each, each line being separated by 5 cm. This results in a "data cube" of 30 by 30 points: a fixed x-y coordinate plus a variable vertical position.
        - Improved precision is obtained by increasing the sampling rate. However this requires a commensurately greater number of grid lines that will have to be scanned in order to produce a square map. Thus there is a practical trade-off of precision and time required to produce a map.

    - Selecting the size of objects that will be included in the model surface is an important factor since a relatively limited number of data points are available to resolve the features of the objects. Separation distance between the objects is also a factor.
    - Using the sample lab we found that it took a team almost 30 minutes to make 30 “runs” of 15 seconds each. Some factors affecting the time required to acquire a complete set of data are:
        - Practice sliding the motion detector across the top bar at a constant rate in a fixed time period is sometimes required.
        - After each “run” the entire PVC frame must be moved to the next grid position and properly aligned.
        - Care must be taken to position one’s feet to avoid touching surface features and yet be able to reach across the distance to be scanned while moving the motion detector at a constant rate.
        - Rotating “jobs” gives everyone on the team complete experiences, but slows down the process of collecting the data, and introduces additional uncertainty in the accumulated measurements.
- Assign specific “jobs” to each member of the team (the team members may change jobs during the acquisition of an entire set of data). These jobs include holding the PVC frame rigidly on either side; scanning the surface by moving the motion detector across the top bar; noting and calling out the time (to the scanner) during each “run”; and managing the computer which records the data returned by the motion detector.
- Holding the motion detector so that the ultra-sound signal is directly downward, the detector is slid at a constant speed across the top of the PVC frame. The beginning of a “run” is coordinated with a team member starting the computer software program that collects the data. If, for example, the “run” was to be 15 seconds in duration, the team member moving the motion detector must pace its motion so that the distance along the frame is covered completely and at a constant rate. This can be accomplished by having evenly spaced marks on the top crossbar that match the number of seconds of the “run”. Another team member can also call out the time to help coordinate the pacing.
- After each “run” the PVC frame is moved one grid line, and the scanning process is repeated. Each “run” of data is easily stored in the software program for exporting at the end of the process.
- When the process has been completed, the data from the motion detector software are exported to an Excel spreadsheet for the construction of the topographic map.

Construction of the topographic map in Excel

- At the present time the process of selecting and exporting data acquired by the motion detector to an Excel spreadsheet must be done manually (see Appendix A). We are working on automating this process to simplify final construction of the topographic maps.
- See Figure-2 for a sample topographic map associated with a model of lunar craters.

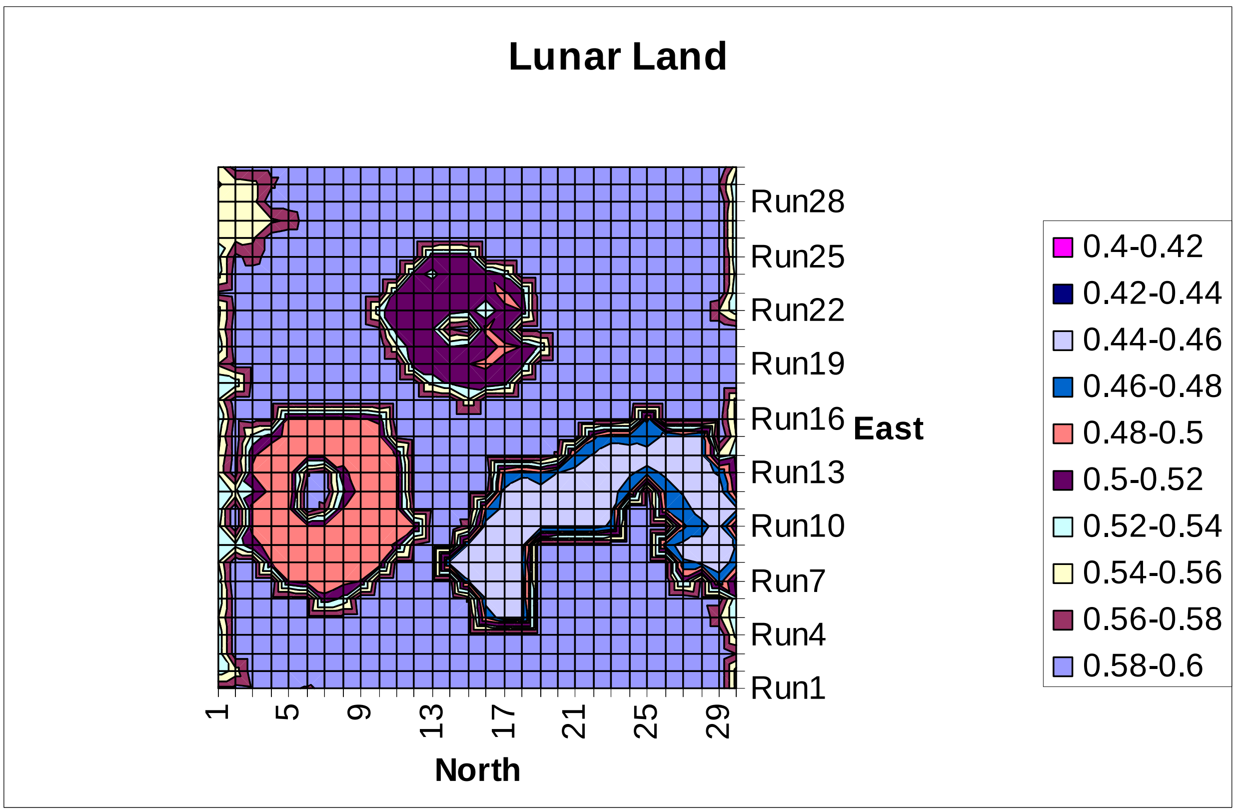

Figure 2 Upper frame - photograph of “Lunarland”
Lower frame - topographic map of “Lunarland”

5-E's Lesson Plan :

ENGAGE	A simulated space mission is the object of the laboratory activity. The specific purpose of the simulated exploration (searching for water or some mineral on the Moon for example) is described. Given certain constraints, such as the need to acquire surface data remotely, and the need to limit expenses through prior preparation, issues involving remote data acquisition will be elicited from the students. The necessity for making a scaled representation of the simulated area of exploration is described in terms of the particular robotic vehicle that will be used for exploration (e.g. "humanoid" or BOE-Bot). The use of a computer-interfaced motion detector is described, detailing how a measurement of elevation will be derived from its use.
EXPLORE	The students will use the motion detector to gather data related to the selected surface area. That data will be exported into an Excel spreadsheet and used to produce a 2-dimensional topographic map of the surface.
EXPLAIN	The students will analyze the topographic map produced from the data and decide upon an appropriate scale that relates to the real surface explored. The scale chosen in this part of the activity must be appropriate to the particular robotic vehicle that will be used in the actual remote exploration of the surface.
EXTEND	The students will analyze the topographic map produced from the data and decide upon an appropriate scale that relates to the real surface explored. The scale chosen in this part of the activity must be appropriate to the particular robotic vehicle that will be used in the actual remote exploration of the surface.

Appendix – A: Technical Discussion:

The key technical processes in this activity, assuming a basic knowledge of computer interfaced probeware, are (1) the exporting of motion detector acquired data into an Excel spreadsheet, and (2) the construction of the topographic map within the Excel software. This discussion is based on using a motion detector manufactured by Vernier Software. A similar discussion will be forthcoming using a Pasco motion detector and Pasco's Data Studio software.

(1) Vernier motion detector data is returned in the following example format:

Vernier Format 2
Untitled.cmbl 3/11/2007 10:41:12 .
Latest

Time	Position	Velocity	Acceleration
t	x	v	acc
s	m	m/s	m/s²
0.5	1.471215	0.0351624444444	-0.032288617284
1	1.494588	0.0202753888889	-0.0363974475309
1.5	1.501709	0.001859	-0.0497382333333
2	1.485838	-0.0215412777778	-0.0616292067901
2.5	1.492561	-0.0505763333333	-0.0695017160494

Appendix – B: Construction Materials for the PVC Frame:

- All frame pieces are constructed with 1.25 inch (inside diameter) PVC pipe.
    - (2) Vertical sides: 1.5 m (more or less, depending on height of surface objects)
    - (1) Horizontal top bar: 1.7 m
    - (6) 90^{o} Elbows
    - (2) T – connectors
    - (4) Horizontal bottom pieces: Approx 0.25 m

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