An Astronaut in Motion

Background

This problem is part of a series that applies mathematical principles in NASA's human spaceflight.

Maneuvering around or performing a task while in the reduced microgravity environment of space can be a difficult feat. Doing these things while wearing a bulky space suit may present additional and unique challenges. To better understand how astronauts function in their suits and their environment, researchers at NASA Johnson Space Center's Anthropometry and Biomechanics Facility (ABF) are studying motor control and evaluating human physical measurement, variation, and movement. The results of these studies are helping astronauts to perform tasks more efficiently in space and complete mission goals with optimal performance.

The ABF is one of few facilities in the world that has gathered both suited and unsuited human strength data relevant to Earth, lunar, and Martian gravitational environments. It is uniquely equipped to conduct ground-based biomechanics and ergonomics research studies, including human motion research – which deals with potential movement issues astronauts may encounter while living, working, and exploring in space.

For example, researchers may study how crews perform work procedures while wearing space suits to learn if the suits allow for proper movement while performing tasks related to a spacewalk. Astronauts' movements and their interactions with equipment within a space vehicle might be tested, or even simulated. The data collected and analyzed would be used to evaluate human performance issues. Ultimately, the research conducted at the ABF supports projects for evaluating space suit and human performance data for future exploration missions. This research is used to improve crew living and working conditions in order to enhance productivity and operational efficiency.

Figure 1: Surface Airlock Hatch Opening Evaluation Analysis

Figure 2: Advanced Crew Escape Suit (ACES) Seated Motion Analysis

To study human movement, ABF researchers use motion capture technology. One system is a camera-based or "optical" system called VICON®. Using VICON, a series of cameras track a set of retro-reflective markers attached to a subject. Light-emitting diodes (LEDs) are placed around the perimeter of each camera's lens that produce light, which is reflected off the markers and back into the camera. Each camera can determine where a marker is in its own view, and the cameras are adjusted (or calibrated) in the VICON software, so that cameras know their positions relative to each other. The position of the camera system relative to the floor is also calibrated. This allows a marker to be tracked in three-dimensional (3-D) space whenever it is in view of at least two cameras.

By using the VICON motion capture technology, a segment of the body (e.g. the lower arm) can be tracked in 3-D as it moves. This data is used to determine the range of joint motion required to complete a task. The joint motion data can then be applied to an avatar (a computer model of the astronaut) to identify potential issues that could occur when an astronaut performs a specific task.

The avatar of the astronaut can also be placed into a model of a space vehicle to see if an astronaut would have difficulty moving naturally within the confined space, or to detect potential collision issues. This same avatar can also be scaled up and down in size, to get an idea of what problems a smaller or larger-sized astronaut could have while doing the same task. Conducting ground-based research with this technology is helping NASA designers and engineers develop efficient tools and equipment, non-restrictive space suits, and easily accessible controls on space vehicles.

Instructional Objectives

- You will apply translations in the coordinate plane;
- You will apply reflections across the *y*-axis in the coordinate plane.

Problem
On the TI-Nspire™ handheld, open the document *Astronaut_Motion.tns.* Read through the problem set-up (pages 1.1 – 1.2) and complete the questions embedded within the document.

Embedded Questions
On TI-Nspire page 2.2, you will find a two-dimensional figure representing an astronaut. The ranges of motion for the astronaut's arms have been captured. To move the astronaut's arms, grab the open point and move it around.

2.3 What is moving besides the astronaut's arm?

3.1 On page 3.2, the same two-dimensional figures are shown with the coordinates denoting the location of each right arm movement. Move the astronaut's arm again by grabbing the open point. Record five different positions of the astronaut's right arm along with the corresponding position of the avatar's right arm on page 3.3.

3.3

Position #	Astronaut's Coordinates (pre-image)	Avatar's Coordinates (image)
1		
2		
3		
4		
5		

3.4 What is the relationship between the astronaut's coordinates and the avatar's coordinates?

3.5 What type of transformation could be used to describe the relationship between the two?

3.6 If the astronaut's position is (-4, -2), predict the avatar's position (*x, y*) using the translation used on page 3.3. Explain.

Page 4.2 shows another two-dimensional figure representing an astronaut. This time, the astronaut is in a space suit. The space suit limits the range of motion of the arms. Move the right arm by grabbing the open circle.

4.3 Why does a space suit limit the range of motion in this way?

4.4 Edit the values for both the horizontal translation **(Htranslation)** and the vertical translation (**Vtranslation**) on page 4.2 (by double clicking on the zero and replacing it with a new value) in order to determine what translation is needed to move the astronaut's avatar to the platform, so that the avatar's arm can reach the button on the control panel. Record your answers here.

4.5 On page 4.2, move the hint slider to the yes position. The hint slider shows a point on the astronaut and the corresponding point on the avatar. How do these values help you to predict/verify the translation values for the avatar?

Now let's look at another transformation that involves the limited motion of an astronaut. An astronaut's space suit not only limits the range of motion for the arm, but it also limits the movement of the astronaut's head. Restricted head motion limits the astronaut's ability to read instructions and labels that are placed on the front of the space suit. To assist the astronaut, a mirror (sewn into the astronaut's glove) is used to read the labels. But the labels must be written in such a way that the mirror reflects the instructions in a readable direction.

5.2 How do you think the word "NASA" needs to be written so the mirror reflects the word properly?

5.3 On page 5.4, the words "NASA ROCKS" have been written on the left side of the screen and reflected over the *y*-axis to the right side of the screen. Will the reflection (the words on the right side of the screen) read properly using a mirror?

5.5 On page 5.4 turn on the coordinates of a few of the points by sliding the "Points" switch to ON and complete the table on the next page.

Coordinates of a point (pre-image)	Coordinates of the point reflected over the y-axis (image)
(-13, 6)	
(-5, 6)	
	(6, 2)
(-10, -2)	
(-13, -6)	
	(7, -6)

5.7 Using the table on page 5.6, explain the relationship between the coordinates of a point and its reflection over the *y*-axis.

5.8 Predict the coordinates of the points given in the table below if they are reflected over the *y*-axis.

Coordinates of a point (image)	Coordinates of the point reflected over the y-axis (pre-image)
(-9, 4)	
	(4, 2)
	(3, -2)

Check your answers in the table by moving the "Points" switch to MORE on page 5.4.

Directions: Complete the following questions independently.

On TI-Nspire page 6.2, you will find partial words, ON and OFF. Use the TI-Nspire transformations tool to complete the words on the left of the screen by translating the "F" and "O".

To translate an object:

- Press **menu** and select **B: Transformation > 3: Translation**. Select **one** segment by clicking on it once the selector changes to a hand. It will flash when it is selected.
- Select one endpoint of the segment in the same manner.
- Translate the image to its new location by dragging your finger across the touchpad and then clicking once it is in the right location.
- Repeat these steps for each segment.

6.3 Describe the translation(s) of the given letter "F" needed to complete the word OFF. Explain how the coordinates changed from the given "F" to the translated "F".

6.4 Describe the translation(s) of the given letter "O" needed to complete the word ON. Explain how the coordinates changed from the given "O" to the translated "O".

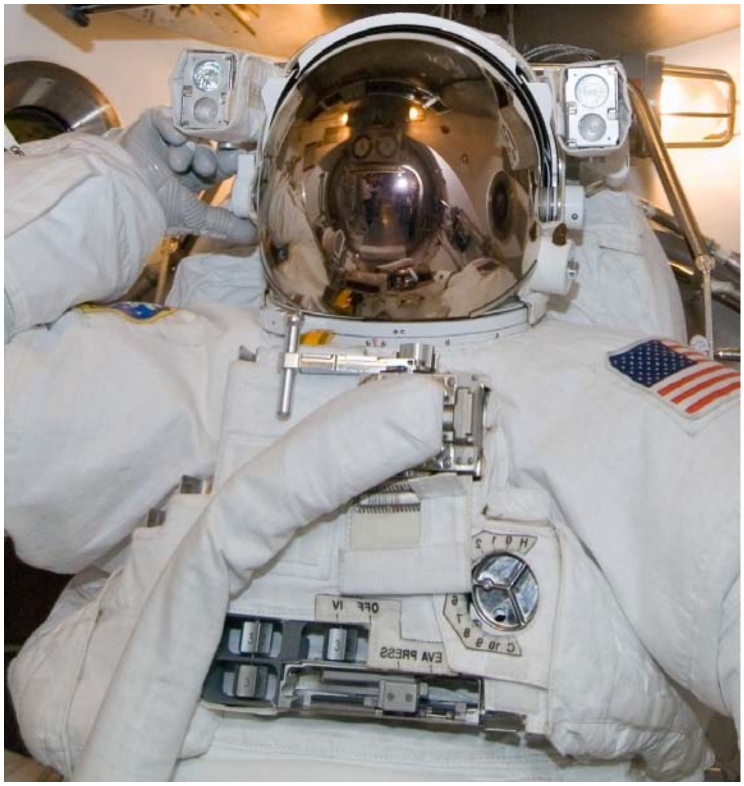

Figure 3: Image of an astronaut in a space suit

6.5 Use the created image on page 6.2 to design a patch for an astronaut's space suit with the words "ON/OFF". In order for the astronaut to read the patch while inside the suit, what transformation will be used to finish the design? Predict how the coordinates will change from the given "ON/OFF" to the "ON/OFF" patch design. Refer to Figure 3 which shows some patches on a space suit.

On page 6.2, use the Nspire transformations tool to make the words readable by an astronaut in a space suit and verify your prediction.

To reflect an object:

- Press **menu** and select **B: Transformation > 2: Reflection**.
- Select the line of reflection (*y*-axis) by clicking on it. It will flash when selected.
- Select the segment to be reflected.
- Repeat these steps for each segment.