

- d. Click on the rotation button from the handle style buttons, and practice rotating the dolphin about the three axes through its center. Use a matrix to represent the motion of the dolphin described. Assume the center of rotation of the dolphin is at the origin.
- Rotation counterclockwise one full turn about the z -axis
 - Rotation counterclockwise one half turn about the x -axis
- e. Select Edit Code from the screen. Drag and drop `this.dolphinturn` from the procedures menu and drop it into the declare procedures region on the right. Select from the drop-down menus: `this.dolphin turn LEFT 0.25` as seen by this duration 2.0 `BEGIN_AND_END_ABRUPTLY`. Then run the program. Describe what you see. Represent the motion using a matrix.
- f. Drag and drop `this.dolphinroll` from the procedures menu, and drop it into the declare procedures region on the right beneath the turn procedure. Select from the drop-down menus: `this.dolphin roll RIGHT 3.0` as seen by this duration 2.0 `BEGIN_AND_END_ABRUPTLY`. Then run the program. Describe what you see. Represent the motion using a matrix.

Exercises

1. Open ALICE 3.1. Select a background and 3 characters to create a scene. Describe the scene, including the coordinates of the pivot point for each character and the direction each character is facing.
 - a.
 - b.

2.
 - a. Describe the location of a plane $x = 5$ in your scene from the perspective of the viewer.

 - b. Determine the coordinates of the pivot points for each character if they were projected onto the plane $x = 5$.

3. Create a short scene that includes a one-step turn or roll procedure for each of the characters. The procedures should be unique. Write down the procedures in the space provided. After each procedure, describe what the character did in the context of the scene. Then describe the character's motion using transformational language. Finally, represent each procedure using matrix operations.

Problem Set

1. For the following commands, describe a matrix you can use to get the desired result. Assume the character is centered at the origin, facing in the negative z direction with positive x on its right for each command. Let c be a nonzero real number.

a. move LEFT c	i. turn FORWARD c
b. move RIGHT c	j. turn BACKWARD c
c. move UP c	k. roll LEFT c
d. move DOWN c	l. roll RIGHT c
e. move FORWARD c	m. resize c
f. move BACKWARD c	n. resizeWidth c
g. turn LEFT c	o. resizeHEIGHT c
h. turn RIGHT c	p. resizeDEPTH c

2. In each of the transformations above, we have assumed that each animation will take one second of time. If T is the number of seconds an animation takes and t is the current running time of the animation, then rewrite the following commands as a function of t .
 - a. move RIGHT c duration T
 - b. turn FORWARD c duration T
 - c. resize c duration T

3. For computational simplicity, we have been assuming that the pivot points of our characters occur at the origin.
 - a. If we apply a rotation matrix like we have been when the pivot point is at the origin, what will happen to characters that are not located around the origin?
 - b. Let $x = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$ be the pivot point of any three-dimensional object and $A = \begin{bmatrix} a \\ b \\ c \end{bmatrix}$ a point on the surface of the object. Moving the pivot point to the origin has what effect on A ? Find A' , the image of A after moving the object so that its pivot point is the origin.
 - c. Apply a rotation of θ about the x -axis to A' . Does this transformation cause a pivot or what you described in part (a)?
 - d. After applying the rotation, translate the object so that its pivot point returns to $x = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$. Was the x -coordinate affected by the rotation? Was the pivot point?
 - e. Summarize what you found in (a)–(d).

Extension:

4. In first-person computer games, we think of the camera moving left-right, forward-backward, and up-down. For computational simplicity, the camera and screen stays fixed and the objects in the game world move in the opposite direction instead. Let the camera be located at $(0,0,0)$, the screen be located at $z = 1$, and the point $v = \begin{bmatrix} 10 \\ 6 \\ 5 \end{bmatrix}$ represent the center of an object in the game world. If a character in ALICE is the camera, then answer the following questions.
- What are the coordinates of the projection of v on the screen?
 - What is the value of the image of v as the character moves 4 units closer to v in the x direction?
 - What are the coordinates of the projection of v' ?
 - If the character jumps up 6 units, then where does the image of v move on the screen?
 - In Lesson 26, you learned that if the camera is not in the standard orientation, that rotation matrices need to be applied to the camera first; in Lesson 27, you learned that rotation matrices only pivot an object if that object is located at the origin; if a camera is in a non-standard orientation and not located at the origin, then should the rotation matrices be applied first or a translation to the origin?