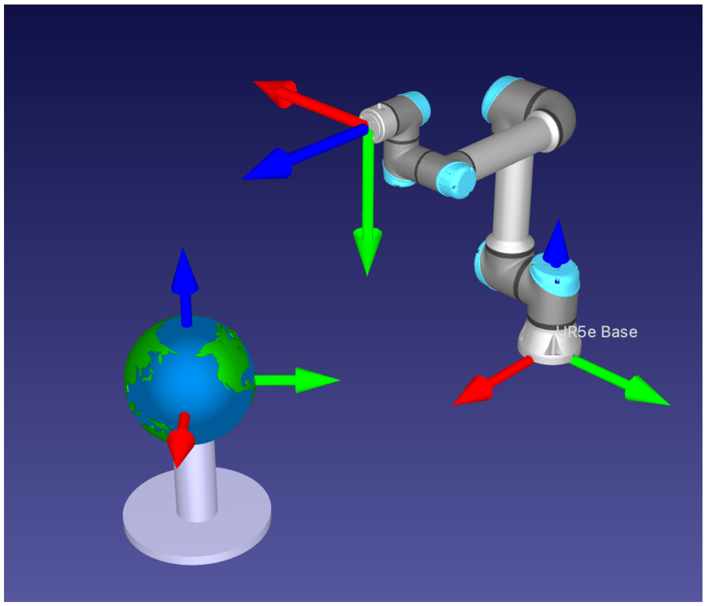
Note: You can use MATLAB/Python to do the matrix multiplication.

Question 1. Consider a robot shown in its home pose with an end-effector that needs to orient itself to pick up an object from the ground. The robot has a base frame {s}, and an end-effector frame {e} as shown. Note that red denotes the x-axis, green denotes the y-axis and blue is the z-axis.

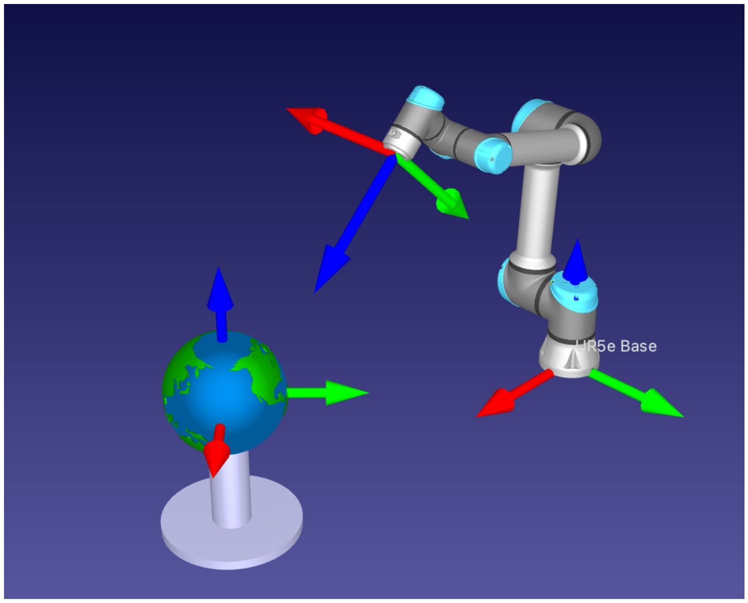


Part 1. Find the orientation of the end-effector w.r.t the base frame in the home position. Verify that this orientation can be achieved by the end effector frame being initially oriented like the base frame and then going through a -90 deg rotation about the base frame's x-axis, followed by a -90 deg rotation about the base frame's z-axis (verify this both mathematically and using your coordinate frame).

The object has the object frame {o}. The robot's perception system estimates the object frame {o} is oriented with a rotation matrix R_{so} that represents a 45 degree rotation about the {s}-frame z-axis.

Part 2. Find the rotation matrix representing the orientation of the object R_{so} with respect to the base frame.

Part 3. The robot needs to perform an **additional** -45 deg rotation about its own x-axis (from the home pose) to orient its end-effector to be able to approach and pick up the object. What is the new orientation of the end-effector w.r.t the base frame after this additional rotation? Show that this orientation is the same as rotating the initial {e} frame with the same orientation as the {s} frame by -135 about the base frame's x-axis followed by a -90 deg rotation about the base frame's z-axis. You should expect an orientation like this figure:



Question 2. What is the primary purpose of a rotation matrix in robotics?

a) To translate coordinates from one frame to another.

b) To perform scaling operations on vectors.

c) To represent the orientation of one frame w.r.t another frame.

d) To calculate the determinant of a matrix.

Question 3. Which of the following statements about rotation matrices is true?

a) The inverse of a rotation matrix is always equal to the transpose of the matrix.

b) A rotation matrix can only rotate vectors but not frames.

c) A rotation matrix can change the reference frame of a vector but not a frame.

d) Rotation matrices can only represent rotations about the z-axis.

Question 4. If you want to express a vector in the {b} frame coordinates instead of the {a} coordinates, which operation would you use?

a) Post-multiply the vector by ‘R_{ab}‘

b) Pre-multiply the vector by ‘R_{ab}‘

c) Post-multiply the vector by ‘R_{ba}‘

d) Pre-multiply the vector by ‘R_{ba}‘

Question 5. What is the rotation matrix representing the orientation of frame {a} w.r.t the base frame {s}?