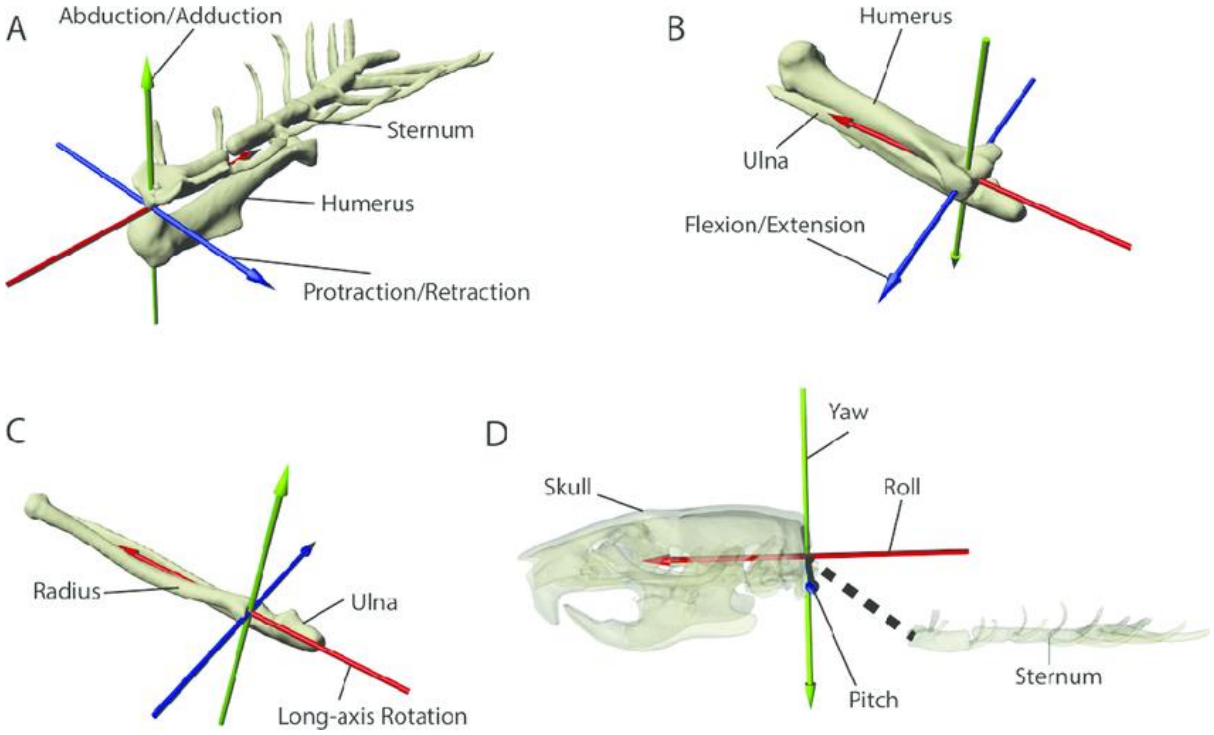
# ROBOTIC COORDINATE SYSTEM

Robotic systems use different coordinate systems to determine the position and orientation of the robot and objects around it. A coordinate system defines a plane or space by axes from a fixed point called the origin. Robot targets and positions are located by measurements along the axes of coordinate systems. A robot uses several coordinate systems, each suitable for specific types of jogging or programming.

**Joint coordinate system:** The joint coordinate system is a way to represent the position of a robot in space using the values of its joints. Here is an example of how the joint coordinate system works:

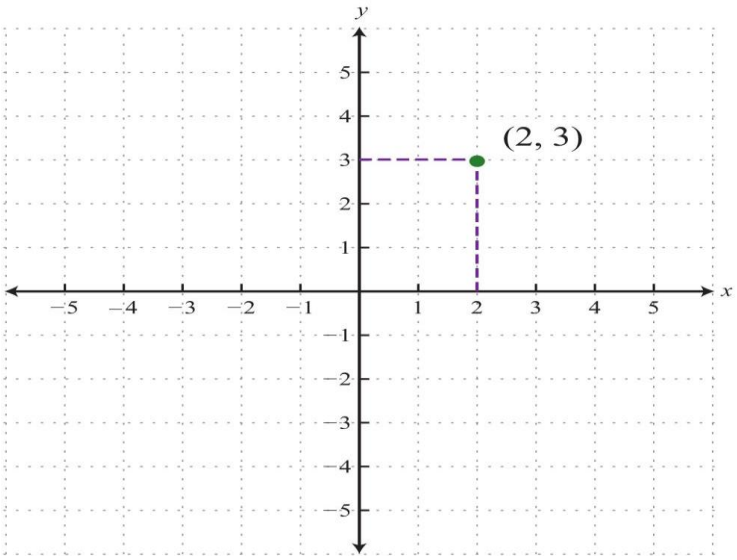
- The joint angles of the robot are measured and recorded.
- The robot's direct geometric model is used to determine the location of the end-effector in terms of the joint coordinates.
- The joint coordinates are used to move each robot axis particularly in a positive or negative sense of rotation.
- The robot's configuration is a minimal expression of its links position, and usually consists of the robot's joint angles.
- The joint coordinate system is used to describe the orientation of the robot's TCP exactly.



**Rectangular coordinate system:**

- The rectangular coordinate system consists of two real number lines that intersect at a right angle. The horizontal number line is called the x-axis, and the vertical number line is called the y-axis.
- Each point on this plane is associated with an ordered pair of real numbers (x, y), where the first number is the x-coordinate, and the second number is the y-coordinate.
- The origin is the point where the x-axis and y-axis intersect, and it is always located at (0,0).
- An ordered pair (x, y) represents the position of a point relative to the origin, where the x-coordinate represents a position to the right of the origin if it is positive and to the left of the origin if it is negative, and the y-coordinate represents a position above the origin if it is positive and below the origin if it is negative.
- Using this system, every position (point) in the plane is uniquely identified.

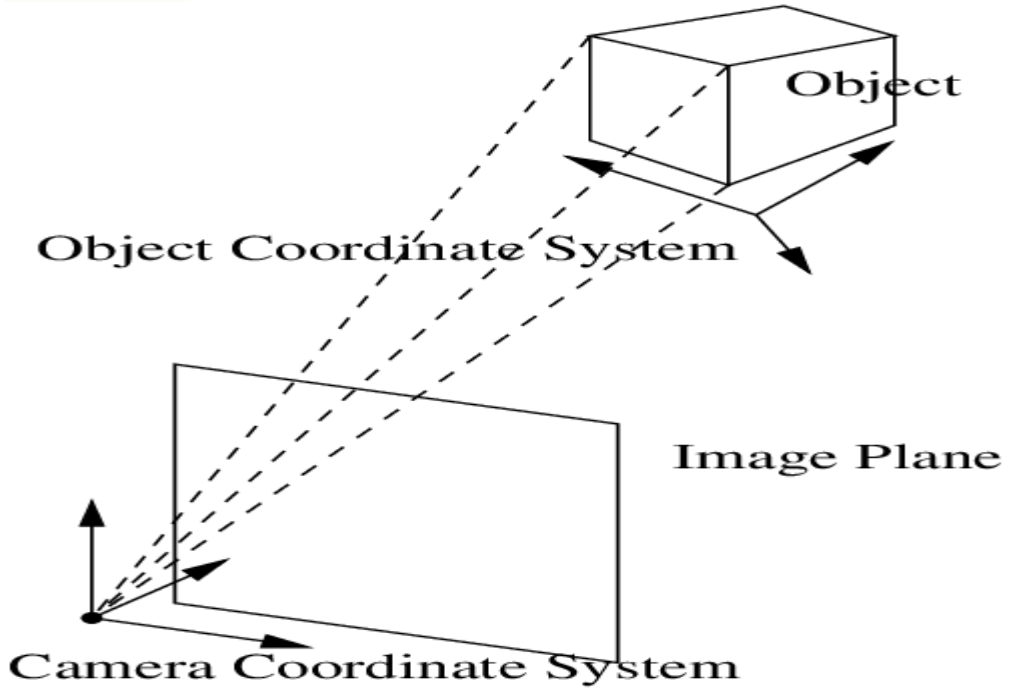
For example, to plot the point (2, 3) on the rectangular coordinate system, we move two units to the right of the origin in the horizontal direction and three units up in the vertical direction. The point (2, 3) is located at the intersection of the horizontal line passing through 2 and the vertical line passing through 3.




**Object coordinate system:**

- The object coordinate system is a relative coordinate system used to describe the position and orientation of an object in space.
- The object coordinate system is chosen to be convenient for the object that is being drawn or modeled.
- A modeling transformation can then be applied to set the size, orientation, and position of the object in the overall scene or in the object coordinate system of a larger, more complex object.
- In robotics, the object coordinate system is used to describe the position and orientation of an object relative to the robot or the field.
- For example, let's say we have object A in its own "right-hand rule" 3D XYZ coordinate system, "floating in space" at no particular location or coordinates, with one point P defined in this object, at X=2, Y=4, Z=7. Let's say we have object B with its own 3D XYZ coordinate system, and this object initially was in the same position and the same orientation as A, their

coordinate systems matched (and therefore P would have the same XYZ values in B as in A). But now B is separated from A, in A's coordinates, 10 units on X, 5 units on Y, and 4 on Z. B is additionally rotated, in order and in its coordinates, 45 degrees on the Z-axis, 225 degrees on the Y-axis, and 3 on the X-axis. To find the XYZ values of P in B's coordinates, we need to apply a transformation matrix that takes into account the translation and rotation of B relative to A. The transformation matrix can be calculated using trigonometry, vectors, matrices, quaternions, Euler angles, or other methods. Once we have the transformation matrix, we can apply it to the coordinates of P in A's coordinates to get the coordinates of P in B's coordinates.




**Tool coordinate system**:

The tool coordinate system is a relative coordinate system used in robotics to define the orientation of the tool at a programmed position.

- The tool coordinate system refers to the wrist coordinate system, defined at the mounting flange on the wrist of the robot.
- The tool coordinate system is defined by specifying the origin and the rotation angles of the tool coordinate system relative to the base robot flange coordinate system, and the tool overhang.
- To define the tool coordinate system, the position and orientation of the tool head are set up for the project, and the calibration of the tool coordinate system is performed on the real robot following the instructions from the robot's manual.
- The positive Z-axis of the tool coordinate system should look down the direction of the tool overhang after the calibration.
- For every new tool used in the operations of the project, the tool overhang must be specified.
- The tool overhang and the three coordinates of the tool center point (TCP) in the tool flange coordinate system (X-red, Y-green, Z-blue) will be shown in the graphic view.

- The tool coordinate system is used in conjunction with other coordinate systems, such as the robot coordinate system, workpiece and/or base coordinate system, and flange coordinate system, to describe the position and orientation of the robot's end effector.
- The tool coordinate system can also be used to get appropriate motion directions when jogging the robot.
- If a tool is damaged or replaced, the tool coordinate system must be redefined.
- The tool coordinate system is created by a calibration method that involves adjusting the direction of the end effector to make the Tool Center Point (TCP) align with the same reference point in three different directions to obtain the position offset of the end effector. Then, the robot is jogged to three other points (A, B, C) to obtain the angle offset.
- After adding or modifying a tool coordinate system, the robot arm can be jogged using the tool coordinate system.