Assignment 1

a) You have seen several actuators types such as hydraulic, pneumatic, and piezo-electric. Assign the characteristics from the following list to the different actuators. Characteristics: damage safe in stall, large forces, noisy exhaust, small travel, high voltage, double function, cheap, bulky, precise.

Pneumatic:

Hydraulic:

Piezo-electric:

b) Explain the difference between degree of freedom of the end effector (DOF EE), and degree of mobility (DOM) of a robot.

c) Consider the robotic arm illustrated in the following figure. Define the Degrees of Freedom (DoF), Degree of Freedom of the End Effector (DoF EE), and the Degrees of Mobility (DoM). Will these values (DoF, DoF EE, DoM) change if the robotic arm is in a straight configuration (i.e. $\theta_1 = 90°$ and $\theta_3 = 90°$)?

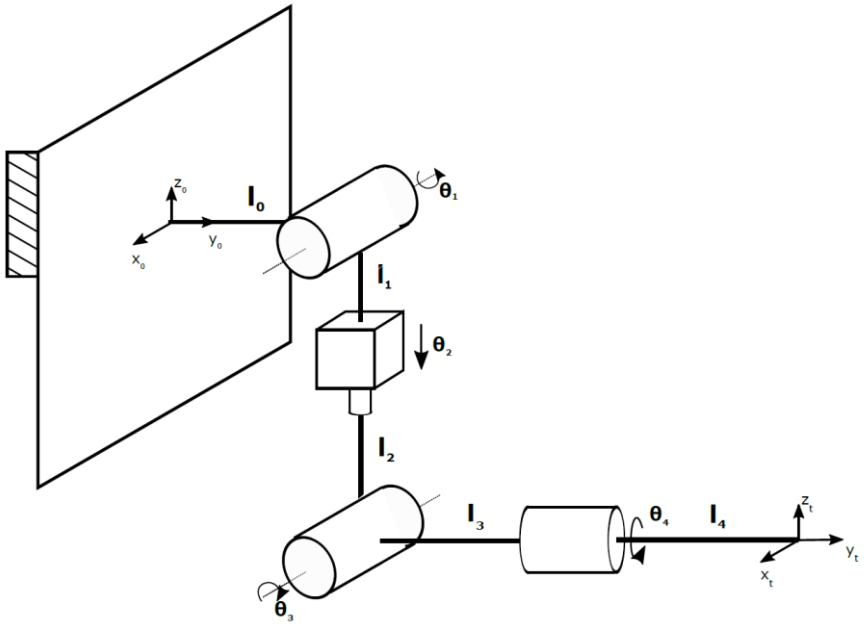

Figure 1: Robotic arm in its initial configuration.

d) You measure something several times and all measured values are close. What can you say about precision and accuracy of the measurement device?

e) You measure something once, and you know that the measured value is far away from the real value. What can you say about precision and accuracy of the measurement device?

f) You are asked to choose between two sensors. You are given 100 error values of both sensors ("sensor1.txt" and "sensor2.txt"). What is the accuracy, resolution, and precision of the sensors? Which one would you choose? Why?

g) Consider the robotic arm if Figure 1. Determine the orientation of the end effector when you move joint 3 by $\theta_3 = 90°$, joint 4 by $\theta_4 = 180°$, and at last joint 1 by $\theta_1 = 90°$. Express the rotation matrix in frame 0.

h) For calculations, write a MATLAB script to solve the problems numerically using the functions given in the MATLAB Kinematics Toolbox (when possible).

i. Consider Figure 2. A robot is set up 1m away from a table, which is $1m^2$ on top, and 1m high. A cube measuring 20cm on each side is centered on the table. A camera is placed directly above the center of the cube, 2m above the table. The robot, table, object, and camera each have a coordinate frame as shown. Find the homogenous transformation describing all of these frames with respect to the 0^{th} (robot's) frame.

ii. A simple pin-hole lens camera model is shown in Figure 3. The lens system of the video camera projects a scene onto the flat sensor plane of the camera to generate an image. In other words, a point in space that has (X_C, Y_C, Z_C) coordinates with respect to the camera frame (Frame 3 in this problem) is projected (mapped) to the point (x_s, y_s) on the sensor plane. The camera frame is attached to the center of the lens system and the sensor plate is located at a distance *f* (the focal length) beyond this point. Derive this mapping.

iii. The units of x_s and y_s are meters. Describe in words how you would change it to pixels? (Pixels should have non-negative numbers only.)

iv. What are the image plane coordinates (in pixels) of the corner of the cube where the coordinate frame is attached? (Assume a focal length of 10cm, a pixel size of $10x10\mu m^2$, and a CCD dimension of 1024x1024 pixels.)

v. The robot moves the object from its position in Figure 2 as follows: It is first rotated about the z_2 axis by +25° then moved along the (current) x_2 axis by 6cm and finally rotated by +45° about the current y_2 axis. In what direction is the final z_2 axis pointing as seen from the camera frame (Frame 3)?

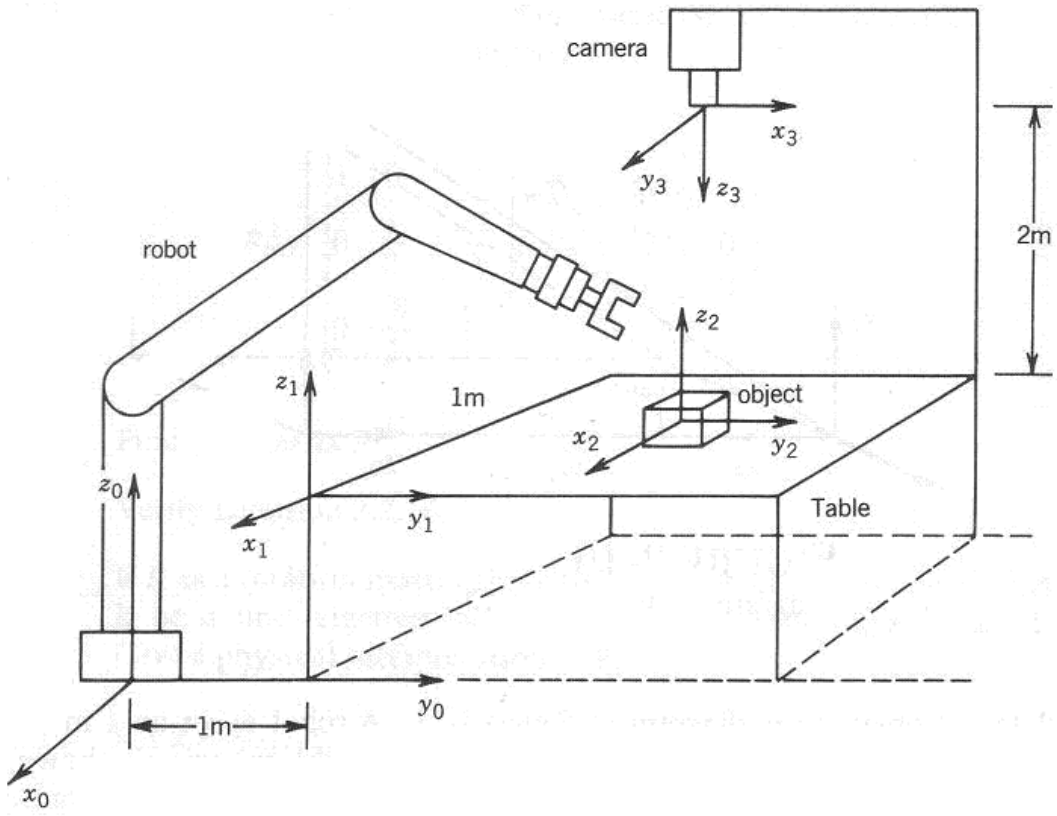

Figure 2:

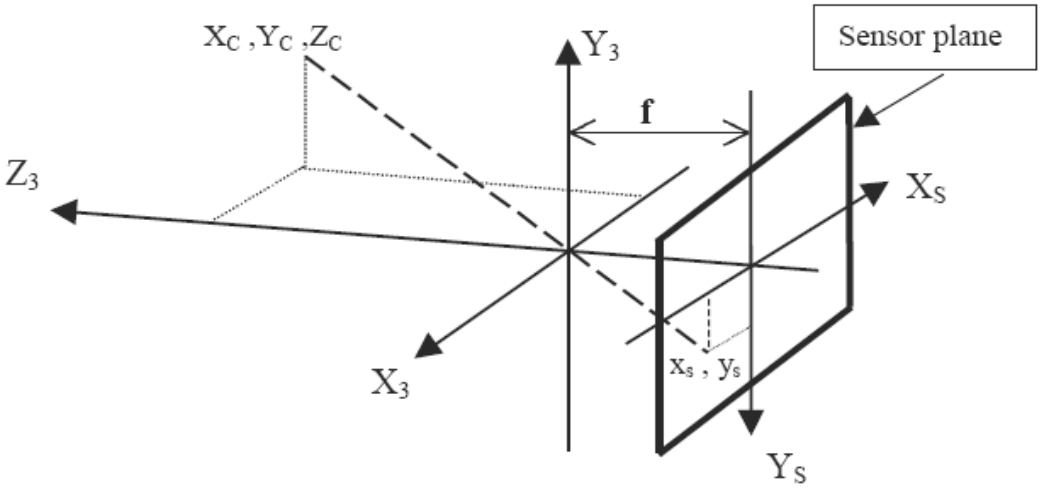

Figure 3: