Exercise Problems for Module 4

[P4.1] Obtain the condition for a four-bar mechanism to be a *double crank* from literature. Can this be obtained using the procedure discussed in Lecture 3?

[P4.2] Plot ϕ_1, ϕ_2 and ϕ_3 versus θ_1, and plot the coupler curve for a chosen double crank configuration.

[P4.3] Figure 1 shows a two-degree-of-freedom planar five-bar mechanism. Assume that θ_1 and θ_2 are actuated variables. Determine expressions for the passive variables ϕ_1, ϕ_2, and ϕ_3 in terms of the link lengths as shown in the figure 1.

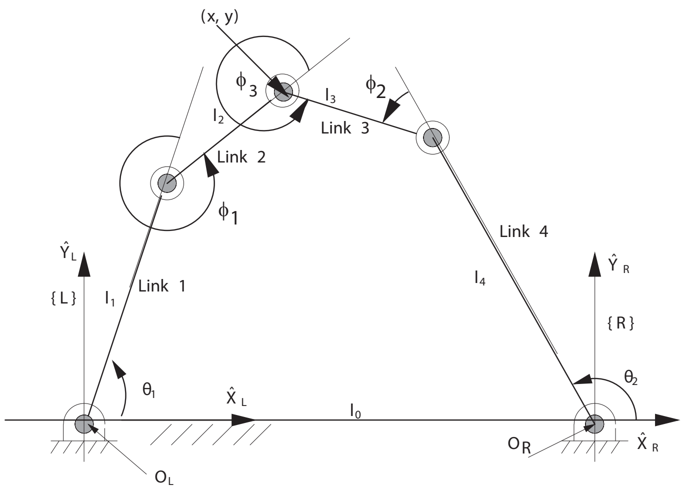

Figure 1: The planar five-bar mechanism

[P4.4] Determine the expression for the workspace of the five-bar shown in figure 1.

[P4.5] Use a symbolic manipulation software such as *MAPLE*® to derive and verify the constraint equations for the 3-RPS parallel manipulator. Obtain the eighth-degree polynomial after elimination.

[P4.6] Figure 2 shows a spatial parallel manipulator. The joints at the connection points at the base and the top platform are Hooke (U) joints, and each leg has a 'U-P-U' configuration. Verify that the parallel manipulator has three degrees of freedom. Formulate and solve the direct kinematics problem for the U-P-U parallel manipulator shown in Figure 2.

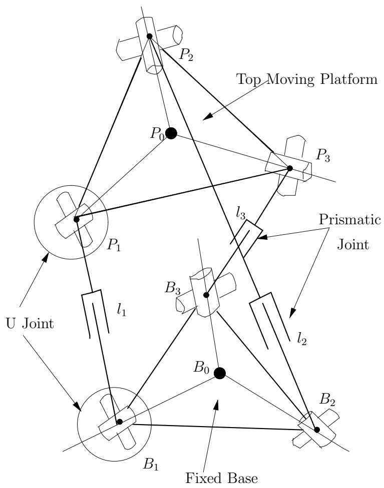

Figure 2: The U-P-U parallel manipulator

[**P4.7**] Figure 3 shows the Stewart platform in the 3–3 configuration. As discussed in Lecture 5, solve the direct kinematics problem for this manipulator.

[**P4.8**] Figure 4 show the 6–3 configuration of a Stewart platform. As discussed in Lecture 5, solve the direct kinematics problem for this manipulator.

[**P4.9**] Figure 5 shows two planar 2R manipulators handling an object. We assume that the point of contact between the two manipulators and the object can be modelled as a rotary (R) joint. What is the degree of freedom of the resulting parallel manipulator? Formulate and solve the direct kinematics problem for this equivalent parallel manipulator.

[**P4.10**] For the six- degree-of-freedom (6-RRRS) parallel manipulator, discussed in Lecture 2, assume $2d = 1$, $h = \sqrt{3}/2$, and $k_{12} = k_{23} = k_{31} = \sqrt{3}k$. Further assume that all the 'fingers' are identical and $l_{11} = 1$, $l_{12} = 1/2$, and $l_{13} = 1/4$. Write a Matlab program to vary the six actuated joints, in convenient steps, and collect the coordinates (x, y, z)

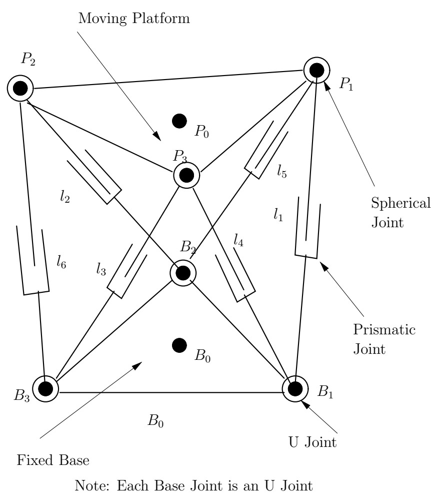

Figure 3: The 3-3 Stewart platform manipulator

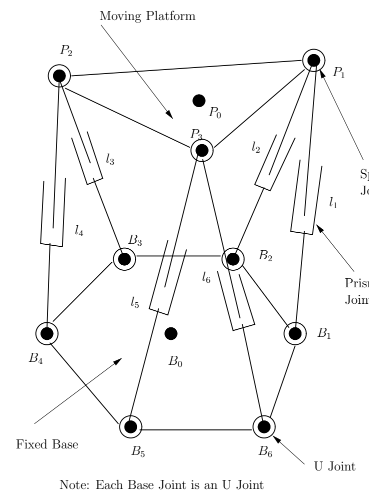

Figure 4: The 6-3 Stewart platform manipulator

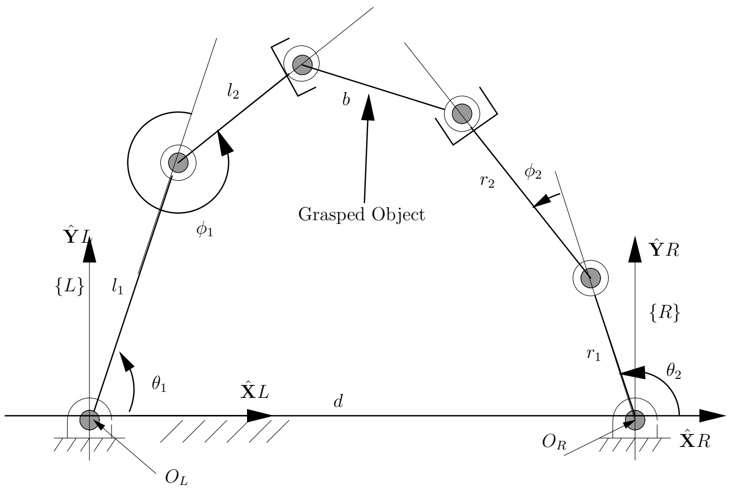

Figure 5: Two 2R manipulators handling an object

of the centroid of the gripped object for which the direct kinematics problem can be solved. Numerically obtain and plot the cloud of points (x, y, z) for $k = 1$.

[**P4.11**] Intuitively, as the size of the 'gripped' object (or k) becomes large or very small with other dimensions remaining the same, the workspace of the gripped object or the possible range of (x, y, z) is expected to be small. Perform the numerical analysis in problem **P4.11** for several values of k greater and less than 1. Discuss what happens to the 'volume' of the cloud of points as k increases or decreases from 1.

[**P4.12**] While designing a Stewart platform one of the important tasks is choosing the spherical joint. From a purely kinematic perspective, to choose a spherical joint, we need to know the possible range of rotations at the spherical joint. Assume each leg of a Stewart platform can be modelled as an R-R-P-R-R-R serial manipulator where the last three R joints intersect and model an S joint. Derive analytical expressions to obtain the rotations at a spherical joint given a translation vector and the orientation of the top platform. Assume that the moving top and fixed base platforms are regular hexagons circumscribed by circles of radii r and R, respectively.