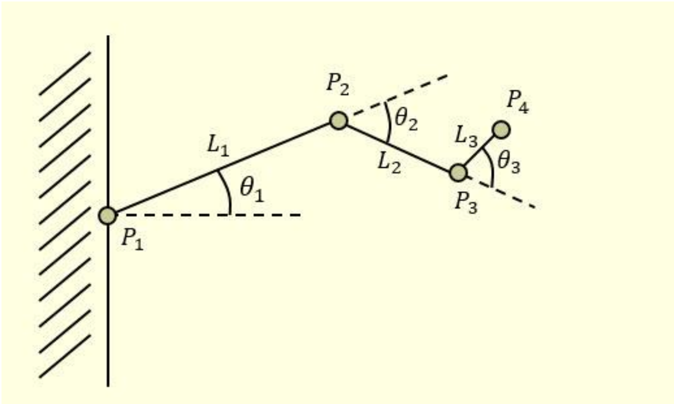
CS633 3D Computer Animation
Homework Assignment 5 (40 points)
Due: 4/5/2018

1. Use a drawing to show the "reachable workspace" of the following robot arm. Here we assume $|L_2| = 2|L_3| = |L_1|/2$, θ_2 and θ_3 can be any value, and $-\pi/2 \le \theta_1 \le \pi/2$. (5 points)



2. When solving a *kinematic modeling problem* (such as moving the end effector of a robotic manipulator from one point to another point), we prefer *iterative numeric method* to *analytic method*. Why? If necessary, use an example to justify your answer. (5 points)

3. One possible way to find a solution to an underdetermined system like the following one

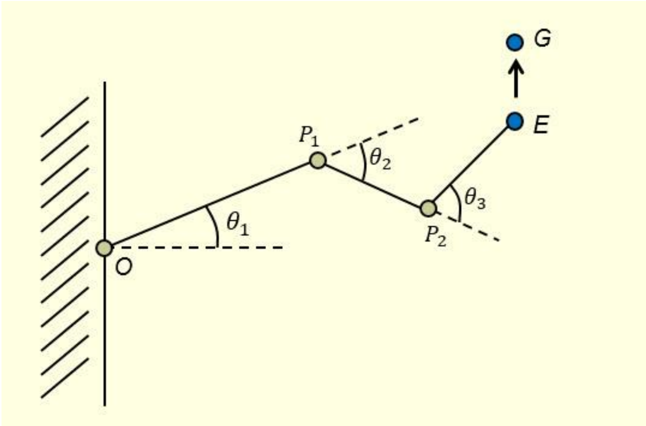
$$M\,\mathbf{X} = \mathbf{Y}$$

(M is an $m \times n$ matrix with $n > m$, **X** is an unknown vector of dimension n and **Y** is a constant vector of dimension m) is to solve the following system for **X**. Why?

$$(M^T M)\,\mathbf{X} = M^T\mathbf{Y}$$

Note that here $M^T M$ is a square matrix of dimension $n \times n$ and $M^T\mathbf{Y}$ is a constant vector of dimension n. This is a very important technique in solving an underdetermined system (of course, important for us as well). (10 points)

4. For a robotic manipulator with three joints (see the following figure), what is the corresponding $V = J \cdot \dot{\theta}$ if we want to move the end effector **E** to the global location **G**. The origin of the coordinate system is at **O** and orientation of the end effector is of no concern. (5 points)



5. The purpose of adding a "control expression" to a pseudo-inverse Jacobian solution is to better control the kinematic model. In the above example, if we want to move the end effector (**E**) to a new location **G**, and if we would like the rotation to be performed mostly on the second joint **P₁**, then how should the "control expression" be defined in this case? (5 points)

6. In the paper "Surface Simplification Using Quadric Metrics", the squared distance (error) of a point **v** = (*x*, *y*, *z*) to a plane can be defined as $\Delta(\mathrm{v}) = \mathrm{vQv}^{\mathrm{T}}$ for a symmetric matrix **Q** (slide 13 of notes: Special Models for Animation I). Why? (10 points)