ME 449 Robotic Manipulation
Fall 2014
Problem Set 4
Due Tuesday November 18 at beginning of class

Turn in your homework on canvas, as one pdf file with your answers to the questions and one file with your code.

1. You are teaching Newton-Euler inverse dynamics, and you are using the 2R robot from the beginning of Chapter 8 (see also Figure 1) as an example. Each link has length L_i and the mass of each link is m_i, concentrated at a point at the end of the link. You already know the correct dynamics from the Lagrangian derivation. Now you will show how to arrive at the same answer using Newton-Euler.

You will be graded on **clarity, completeness, and correctness**. Go through the method step by step, showing intermediate results if it is helpful.

- **Preliminaries**: Give the $\mathcal{M}_i$, $\mathcal{M}_{i-1,i}$, $\mathcal{A}_i$, $\mathcal{S}_i$, $\mathfrak{g}$, and $\mathcal{G}_i$. You can assume the frame $\{3\}$ is coincident with $\{2\}$ and $\mathcal{F}_{\text{tip}}$ is zero.
- **Initialization**
- **Forward Iteration**: First calculate the transformation, twist, and twist derivative for link 1, then calculate them for link 2.
- **Backward Iteration**: First calculate $\mathcal{F}_2$ and τ_2, then calculate $\mathcal{F}_1$ and τ_1. Confirm that your final result agrees with the result in the notes.

You may use your software to do the symbolic calculations, but the final document should be a clear explanation. You can achieve this by using comments in a Mathematica notebook, for example, or by writing everything out by hand and just plugging in the results of calculations from your code.

2. Write code that takes as input the $\mathcal{M}_{i-1,i}$, $\mathcal{S}_i$, $\mathcal{G}_i$, $\mathfrak{g}$, $\mathcal{F}_{\text{tip}}$, θ, $\dot{\theta}$, and $\ddot{\theta}$ and returns τ.

3. Test your code on the 2R robot in Figure 1. Set $m_1 = 2$, $m_2 = 1$ and $L_1 = L_2 = 3$. The acceleration of gravity is 10 units in the $-\hat{y}_0$ direction.
(a) Set $\theta = \dot{\theta} = \ddot{\theta} = 0$ and $\mathcal{F}_{\text{tip}} = 0$ and return τ.
(b) Keep everything else the same as (a), but set $\mathcal{F}_{\text{tip}}$ to be 5 units in the upward direction.
(c) Keep everything else the same as (b), but set $\dot{\theta}_1 = 1$, $\dot{\theta}_2 = 2$, $\ddot{\theta}_1 = 3$, and $\ddot{\theta}_2 = 4$.

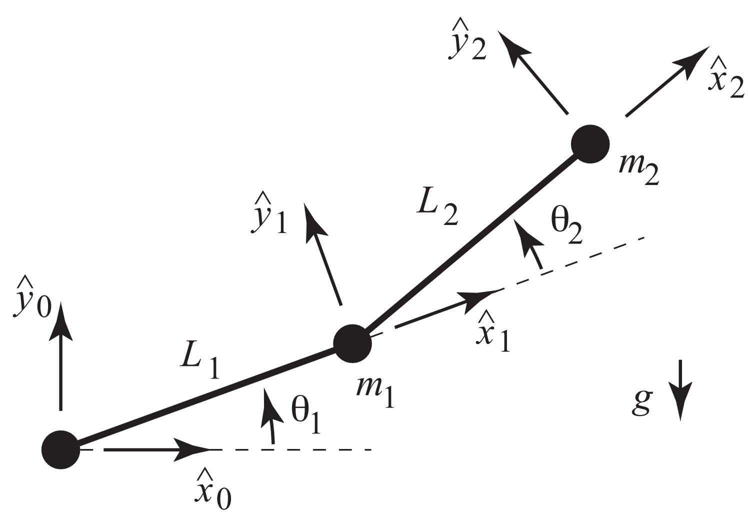

Figure 1: 2R robot in gravity.