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6.894 Legged Locomotion in Robots and Animals

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Problem Set 4

Problem 1

Kajita and Tani use the Linear inverted pendulum mode for their walking robot. With this algorithm, the robot maintains constant height, z_h. Assume the robot is a point mass body and has no ankles (point contact with the ground). Also assume (which holds by constant height) that the initial and final velocities are in the same direction so that if another step is taken, the initial and final conditions match. Because there can be no torque at the point feet, the resultant force, F_b, on the body due to all sources must lie along the "virtual leg" as in Figure 1.

1.1 How much mechanical work must be done in order for the robot to move from point A to point B as in Figure 2?

Hint: The incremental mechanical work is the dot product of the force and the incremental displacement. Since the incremental displacement is along the line from point A to point B, you can use the following equations and Figure 3 for help. We take the absolute value since we assume there is no energy storage and thus negative and positive work are treated equally:

$$\delta E = |f_x \delta x|, \qquad E = \int_{-x_0}^{x_f} |f_x \delta x|$$

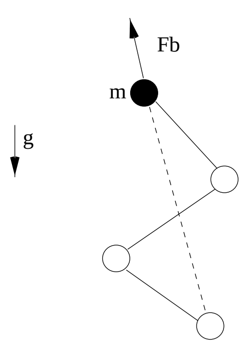

Fig. 1

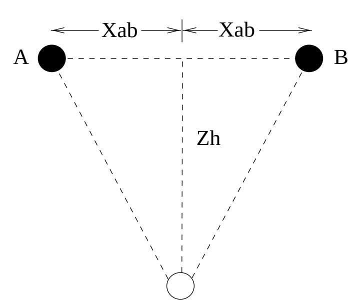

Fig. 2

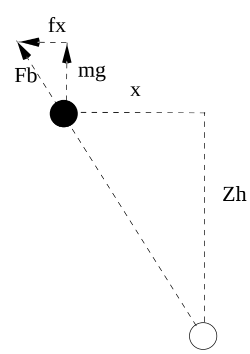

Fig. 3

1.2 Is this the most efficient way for the robot to get from point A to point B (still assuming point feet and no internal energy storage and that the initial and final velocities of the robot are in the same direction)? If not, what is a more efficient way? Hint: An arc centered about the point foot takes zero mechanical work. However, it doesn't meet the requirement that the initial and final velocity are in the same direction.

1.3 (Extra) What's the most efficient way to get from point A to point B in Figure 2? This is a fairly tough problem and would be good for a final project. For now just outline how one could go about answering the question.

Problem 2

The previous three bipedal walking robots we studied (Honda P2, Waseda WL-12, and University of Tokyo BIPER) all used some form of trajectory planning and trajectory tracking control. In each of these robots, a fairly accurate dynamic model was used to compute dynamically admissible joint trajectories offline. These trajectories were then played back during walking and modified online through feedback to maintain stability.

The three robots for this week (Harvard Timmy, MIT Spring Flamingo, and MEL Meltran) all use heuristic methods of control. Instead of precomputing joint trajectories, simple feedback rules are used online to control the robots. Only simplified dynamic models of the robots are used.

Further describe and compare the two different approaches. What are the advantages and disadvantages of each? If you were to build a bipedal walking robot, which of these approaches would you use, or would you try something completely different? Why?