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4M20 Robotics (2019)   Coursework 2 and Competition Project

Instructions

Objective	Experimental investigation of a 3-link robotic kit with position control. Test calculations and algorithms on the real-world platform.
Report	A group presentation and demonstration in the last lecture on 28th of November 2019. In addition each student should attempt the questions below individually and submit a written final report of maximum 10 pages A4, minimum font size 11. Undergrad students should use the designated cover sheet with "candidate ID". Postgrad students should indicate name/CRS-ID on cover page.
Presentation	On the 28th November 2019, 2pm-4pm. Each team should give a 5-minute brief presentation of the robot design and control strategy, and a 5-minute demonstration and competition of the hardware.
Submission	Individual 10 page report due on the 20th of December 2019 (4pm) Submission via Moodle: https://www.vle.cam.ac.uk/course/view.php?id=94122

Coursework 2

Q1. (30%) Consider a two-legged robot shown in Figure 1 below. By using its three joint motors (shown by white circles), it can walk forward by swinging Foot 2 forward, then Foot 1 forward, for example. Assuming that Foot 1 is fixed on the ground at first, calculate the joint angles θ_1, θ_2, θ_3 to achieve the end of Foot 2 [X_5, Y_5] to be at [0.15m, 0.05m] (with respect to [X_1, Y_1] = [0.0m, 0.0m]. Then what are those joint angles for Foot 2 landing at [X_5, Y_5] =[0.12m, 0.0m] with the forth link perpendicular to the ground plane. L_1= L_2= L_3= L_4= 0.10m. In the same two-legged robot, what is the role of the Centre of Mass (M_{COM})? Discuss the importance of it in the context of Static Legged Locomotion (introduced in Lecture 2).

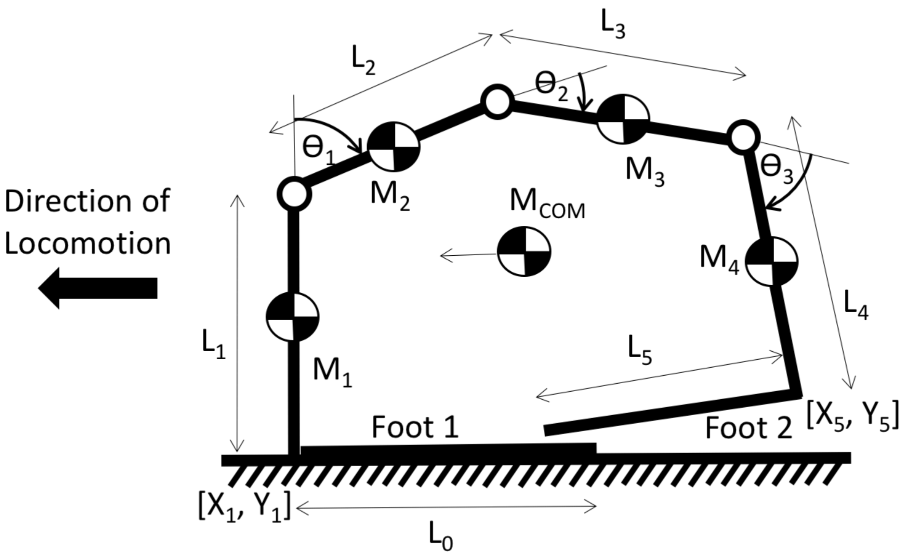

Figure 1: Two-Legged Robot

Q2. (20%) Develop a simulator of the two-legged robot in Q1, and a joint planning algorithm to make it walk with a constant "stride length" 0.15m. Plot the joint trajectories of θ_1, θ_2, θ_3 as functions of time, while the robot is making one step.

Q3. (20%) Implement the joint trajectories of Q2 in the physical robot kit, and measure manually stride length of each step when the physical robot walks consecutive 10 steps. Derive the mean and standard deviation of stride lengths in the physical experiments. Consider the state variables $\mathbf{X_k}=[X_1(k), dX_1(k)]^T$, where $X_1(k)$ is the forefoot position at step k and dX_1 is its stride length, develop a linear dynamics model of this robot in the form of $\mathbf{X_{k+1}}=\mathbf{AX_k} + \mathbf{Bu_k}$. Then discuss how a Kalman-filter algorithm can be used to avoid accumulated errors of the robot position that you measured above. Describe the details of what sensors to be used, and how these sensor signals can be eventually reflected on to the calculation of joint trajectories θ_1, θ_2, θ_3.

Q4. (30%) Develop a planning algorithm for your simulated robot in Q2, and demonstrate that your planner can find automatically the joint trajectories to traverse the terrain shown below. Plot the foot trajectories of $[X_1, Y_1]$ and $[X_5, Y_5]$ as functions of time, while the robot climbs up the stairs, and discuss the influence of physical design changes you made for the competition below. Then implement the controller to the physical robot kit, and discuss the performance compared to the simulation.

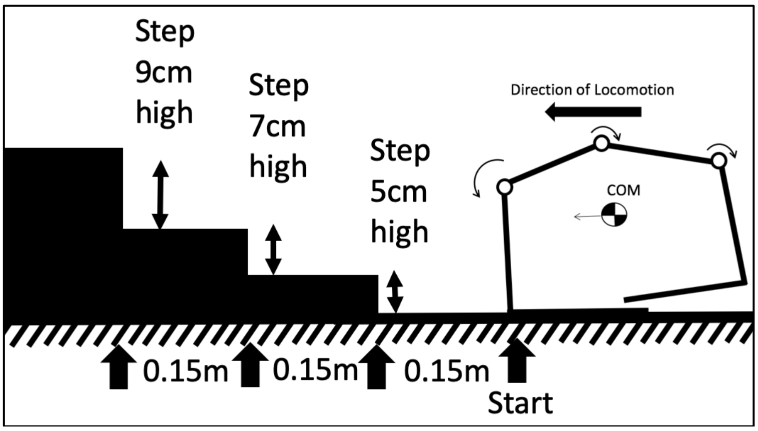

Figure 2: Locomotion Task

Competition (on 28th November): By using the provided robot kit, design and build a robot that can solve the locomotion problem shown in Figure 2. You are allowed to modify or replace the mechanical parts but allowed to use only up to 3 servomotors provided. Evaluation criteria are: speed of locomotion, reliability, and predictability. You will be asked the expected performance (speed/time and trajectories of your robot) before the demonstrations, and to repeat each locomotion twice. Presentations should include the basic strategies, theories, and tools (that you learnt in the lectures presumably) needed to develop the robot.