CSE 990-001: Cyber-Physical Systems HW #2

Assigned: 2015-08-27
Due: 2015-09-10 in class

Homework Overview

There are multiple objectives of this homework:

- Inform me about your strengths and weaknesses in designing a CPS from beginning to end
- Discover for yourself your strengths and weaknesses in designing a CPS from beginning to end
- Practice the parts of design you are good at, and learn some about the parts of design you're not good at

Note that I **do not** expect you to be able to complete this entire assignment. I want you to get as far as you can and **at least attempt** each part of the homework. If you cannot complete a question tell me what process you would use to find out how to answer the question appropriately. Indicate what tools you would use and your general process. **The goal of this homework is to move away from the mathematical narrow focus of any individual area and think on a more "systems" level. Use your creativity!!!** Also, on this particular assignment you cannot collaborate whatsoever with anyone else. You can use your own tools and resources but that is all.

Grading

I ONLY expect you to make a reasonable effort for full credit. So convince me.

HW #2

The CPS we will be designing in this homework is control of a simple car. A small sketch of the system can be seen in Figure 1.

You can make the following assumptions:

1. full-state feedback
2. reliable A/D and D/A conversion whose conversion times are 0 s
3. you can control the velocity of the rear wheels u_1
4. you can control the angle of the front wheels u_2 or ϕ in Figure 1

Any other assumptions your make are fine as long as you tell me what they are and why you made them.

Now complete the following:

1. Design the controller:
    (a) Derive equations of motion

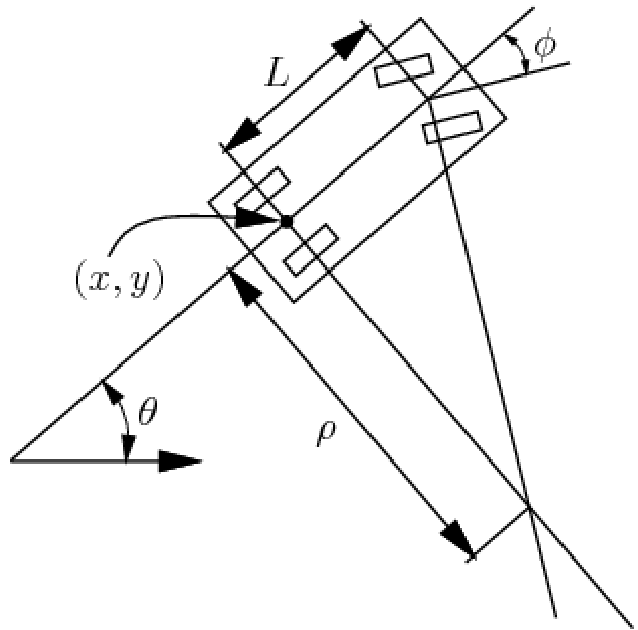

Figure 1: Use this model of a "simple car"

(b) If you were unable to derive the equations of motion here they are

$$\begin{aligned}\dot{x} &= u_1 \cos\theta \\ \dot{y} &= u_1 \sin\theta \\ \dot{\theta} &= \frac{u_1}{L} \tan u_2\end{aligned}$$

where u_1 is the speed of the rear wheels, and u_2 is the steering input. Use these equations to design a simple controller and tell me why you chose it.

(c) Prove stability of the controller

2. Design the guidance law or execution layer (hint: there's no magic here, the goal is translate higher-level planning objectives into tasks the reactive system can handle. So be creative!)

3. Design the planner layer (hint: look at Dubins paths or come up with your own planning algorithm)

4. Design the real-time system:

   (a) Write pseudocode for the following tasks and include the task period you've chosen in the design. In each case justify the task period and demonstrate how it connects to the corresponding layer you've designed. For example, if you chose period P_τ for the control task, tell me how P_τ relates to the design of your control law.

      i. Control task
      ii. Guidance task
      iii. Planning task

   (b) Tell me what OS or RTOS you would use and why.

   (c) What scheduling algorithm will you select, and why (RMS, EDF, Cyclic executive, etc.)?

   (d) Estimate the worst case execution time (WCET) of each task or describe how you might determine it.

(e) Assuming the WCET you've estimated, consider a 4 task system (scheduler, controller, executor, planner). Assuming the task periods you determined above and your chosen scheduler show that your tasks are schedulable.

5. Simulate the system and show plots.

6. Write a couple paragraphs on which parts were easy, which parts were hard and what you need to learn going forward to design this system well.