Lab 6: Star-Lab
15-424/15-624 Foundations of Cyber-Physical Systems

Test Due Date: Friday, 11/22/13, worth 20 points
Final Due Date: Friday, 12/02/13, worth 80 points
Term Paper Due Date: Friday, 12/06/13, worth 100 points
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The star-lab is a chance for you to creatively use what you've learned throughout the FCPS. The system you decide to model and how you design it is entirely up to you, but we recommend you first tackle a problem which has a straight-forward solution and then use that as a stepping-stone to a more difficult final project. This way, if the final project becomes too difficult, you can at least submit the simplified version and discuss the challenges for both problems in the term paper.

You are not required to include a "safety" verification in your final submission. If you want to do something more outrageous, feel free to propose it in the white paper. However, the canonical project would follow the lab format of: design a hybrid program, determine reasonable safety/liveness properties, prove those properties using KeYmaera.

Project ideas. You should feel free to come up with your own idea for lab6, but to get you started, below are some sample projects that we think could make successful submissions.

- A thermostat which controls one or more rooms.
- Proportional-integral-derivative (PID) controllers.
- Insulin pumps, pace makers, or other medical devices.
- Electrical circuits.
- Chemical reactions.
- Biological systems, for example predator/prey systems.
- Use $\mathsf{d}\mathcal{L}$ to solve the duck and fox interview question (link).
- The Knight Rider signature move (link).
- Extend lab5 in a significant way (for example by adding noisy sensors, extra obstacles, better distance measures, etc.)

1. [test] **White Paper.** The white paper will provide a description of the hybrid system you propose to study for lab6, and how you intend to model the hybrid system. You should discuss the properties that are core to the correct functioning of the system (for example, safety and liveness) and how you intend to prove or analyze the fulfillment of these properties. It is also a good idea, though not required, to propose a simplified model of your system which is easier to prove and could be used as a stepping-stone to a more complex model or controller. For properties you intend to prove using KeYmaera, discuss how you intend to approach the proof (for example, you might propose loop or differential invariants or explain how you might manage branching). The white paper should be **formatted as a pdf** and be roughly 1-2 pages long.

2. [test] **Proposed key file(s).** For every property you intend to prove in KeYmaera, submit a proposed .key file so that we can provide feedback and recommendations on how to proceed. Include a list of these files in your white paper, and be sure to reference and explain each one in the body of the paper.

3. [paper] **Term Paper.** The term paper should be an evaluation of the system you have designed. You should explain your system thoroughly; assume that the reader has an understanding of hybrid systems, but no exposure to the type of system you studied. For example, if you choose to extend lab5, you should still describe and defend each of the modeling choices as if the reader has not seen any of the lab assignments. Besides thoroughly covering your lab6 submission, you should also devote some space to relevant discussions about hybrid systems and logical analysis in a broader context.

   Some questions that your term paper might address include:
   - How useful is your system and proof?
   - How much behavior and flexibility does your controller have?
   - Can you make any guarantees on efficiency?
   - What kinds of safety guarantees can you prove?
   - What kinds of tradeoffs did you have to make while designing your system?
   - If you had more time and resources, what would you do to improve your system, model, or analysis?

   Your system and corresponding analysis should be complex enough that you require roughly 5-10 pages to describe: the system, safety or liveness properties, analysis of the usefulness or efficiency of your system, and methods needed to analyze your system (for example, if you submit a KeYmaera proof, explain the proof techniques that were most relevant). The term paper should be **formatted as a pdf**.

4. [final] **Proof(s) and updated key file(s).** For every property you proved in KeYmaera, submit a .key file and a corresponding .proof file. Include a list of these files in your term paper, as well as some relevant proof statistics.

5. **Submission Checklist.**

   Test submission (Due 11/22):
   Proposed theorems in .key file(s).
   `whitepaper_username.pdf` (1-2 pages)

   Final submission (Due 12/2):
   Theorems in .key file(s).
   KeYmaera proofs as .proof file(s).

   Term paper submission (Due 12/6):
   `lab6_username.pdf` (roughly 5-10 pages)