Real Time Systems and Control Applications

Contents

Information about 4AA4

Introduction of RT systems

Welcome to SFWR ENG 4AA4

- Instructor: Wenbo He (hew11@mcmaster.ca)

- Lectures: TuThFr 11:30AM - 12:20PM (Location LRW B1007)

- Lab Location:
  ITB235 for labs

- TAs: Liuyin Shi (shil9@mcmaster.ca)
  Chengqi Li (lic222@mcmaster.ca)
  Xunzhou Ye (yex33@mcmaster.ca)
  Celine Sana (sanay@mcmaster.ca)

Course Outline

- Major Contents:
  - Introduction to Real-time Systems
  - Real-time Scheduling Algorithms
  - Introduction to Digital Control Systems

- Labs
  - Fulfill your engineering degree requirements
  - Enrich your experience dealing the RT systems and control applications
  - Helps understanding of concepts and algorithms

Course Information

- Course materials are available at Avenue:
  http://avenue.mcmaster.ca

- Labs:
  - Check mosaic for your lab sessions.
  - Note that you will need to conduct the labs **in a group of two**

Lab Information

- Lab Schedule
  - Weekly lab sessions begin on Week of Sept. 9
  - First lab about safety quizzes are scheduled in the week of Sept. 9
  - There are no labs in the midterm recess
  - Makeup labs can be conducted in the week of Nov. 25th, but need to make an appointment with TA

Grading Policy

- 10 Labs 30% (3 each lab)
- Midterm 30% (the first week after the reading week)
- Final 40% (TBA)
- Bonus Points
  - **McMaster Engineering Competition (MEC)**
    - **1%** bonus for participating in MEC
    - **+1%** bonus for securing third place
    - **+2%** bonus for second place
    - **+3%** bonus for first place
  - Bonus project (**+2%** talk to me for details)
- Friday lectures are used for tutorials
  - A TA will introduce the lab in the following week
  - Online Quizzes and solutions
    - Quizzes will not be accounted in final officially, but will be used to adjust your mark if your final mark is on the boarder of next letter grade level.

References for Real Time Systems

- Real-time Systems:
  - Jane W. S. Liu, *Real Time Systems*, Prentice Hall, 2000. ISBN 0-13-099651-3
  - Giorgio C. Buttazzo, Hard Real-time Computing Systems, Springer, 2011, ISBN 978-1-4614-0676-1
- Control Application
  - C.L. Phillips, H.T. Nagle, A. Chakrabortty, Digital Control System Analysis and Design (4^{th} edition), Pearson

Lab Plans

- One lab will be scheduled every week except on the week of Oct. 14th.
  - Lab 1: Introduction and Safety Test
  - Lab 2: Module
  - Lab 3: Use of Eclipse and ThreadedRT
  - Lab 4: Control LEDs
  - Lab 5: Control External LEDs
  - Lab 6: Multitasking and Synchronization
  - Lab 7: Priority Inversion and Scheduler
  - Lab 8: Control Motor
  - Lab 9: Obtain Characteristics of Control Systems
  - Lab 10: Implement PID Controller
  - Last Week: Makeup labs (Need to inform TA before you do the makeup labs)

How To Prepare Labs

- On the Friday (in class) before a lab, a TA will give an instruction on lab for the following weeks.
- Read the handouts for labs **carefully** and get well prepared before labs. If you have any questions please let the TAs know.
- It is your responsibility to inform TA or instructor to reschedule your lab beforehand, if you cannot make it. Any missed lab without prior notice is not allowed to make up.
- For a make up lab scheduled at the end of the semester, you will need to complete the lab independently, without any help from TAs.

Office Hours

- My office hours are flexible. You can catch me online if you see I am available on TEAMS to answer questions. Or email me to setup an appointment either in person or online.

- When email me about 4AA4 questions, please start your title using “4AA4:”

Academic Integrity

- https://www.mcmaster.ca/academicintegrity/students/typeofad/plagiarism/

- Also

Your labs, quizzes, exams in this class **must** be on your own or between partners.

If students are found to have cheated, **all** involved will receive **zero** grade in the corresponding assignment for the first infraction.

For later infractions, students will be failed in this class.

But you are encouraged to discuss when preparing labs and exams.

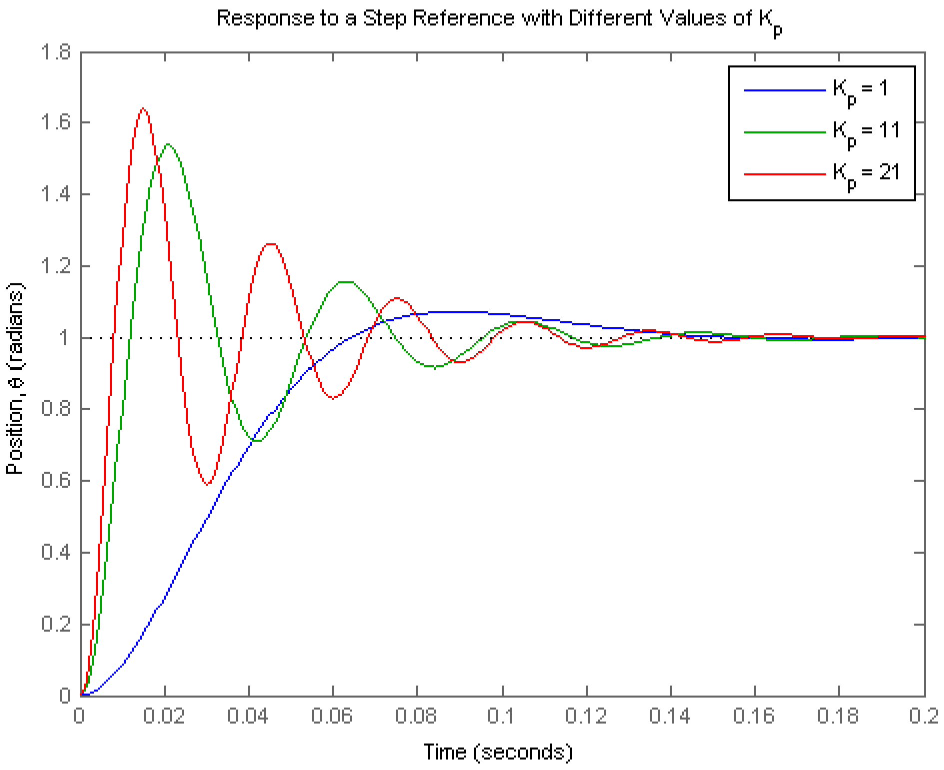
Questions?

- Don’t forget to bring your laptop with you when you come, especially on Fridays.

Introduction to Real-time Systems

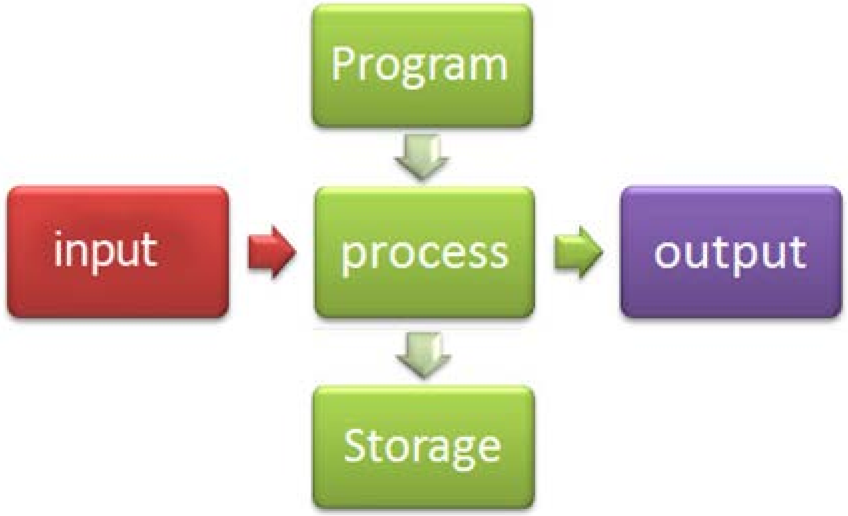
General Systems

- A set of interacting or independent component parts forming a complex/intricate whole (Wikipedia)



- In control systems and applications, response delay is an important characteristic of the given system.

Computing Systems



- Characteristics of computing systems
  - Accuracy
  - Functionality
  - Robustness
  - Usability
  - Response Speed (Delay)
  - …

A *real-time system* is a system in which the correctness of the system behavior depends not only on the logical results of the computations, but also on the time when these results are produced.

Real-Time Systems (RTS)

- Response time
  - Time interval between a stimulus (or input) and the corresponding response (or output).

- A Real Time System
  - A possible definition:

    " A system where a **timely** response to external stimuli is vital"

    What is meant by "timely"?

  - A system that must satisfy explicit response-time constraints, otherwise severe consequences may occur, including failure.

How to Measure Time?

- Clock is used to measure time.

  C: True time → Clock time

- Several desirable properties of Clock:
  - Correctness
  - Bounded Drift
  - Monotonicity

Correctness

- The clock should be a reasonable approximation to the correct time.

- More precisely, at any time, its value should be within some bound of a standard clock:

$$|C(t) – Cs(t)| < \varepsilon$$

Note that ε cannot be less than the granularity of the clock --- the time between ticks.

Bounded Drift

- Drift is the rate of change of the clock value away from a perfect clock.

- A perfect clock has first derivative 1, since its value Cs (t) = t, so drift is

$$dC(t)/dt - 1$$

- If a clock has bounded drift ρ, then

$$\left| dC(t)/dt - 1 \right| < \rho$$

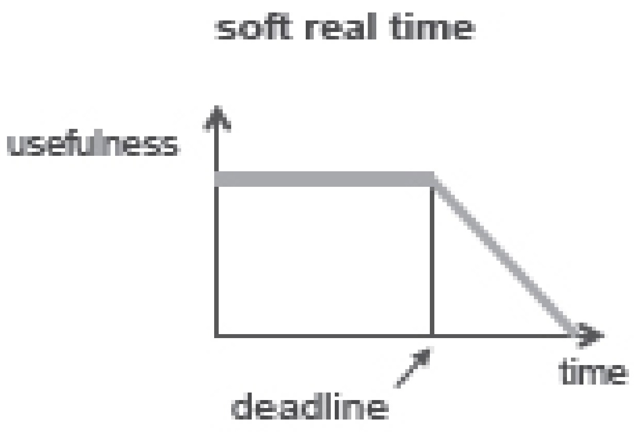
- Typically, crystal-controlled clocks in computers have drift ρ less than 10^{-5}. This translates to a maximum loss or gain of 10 microseconds every second or roughly 1 second per day.

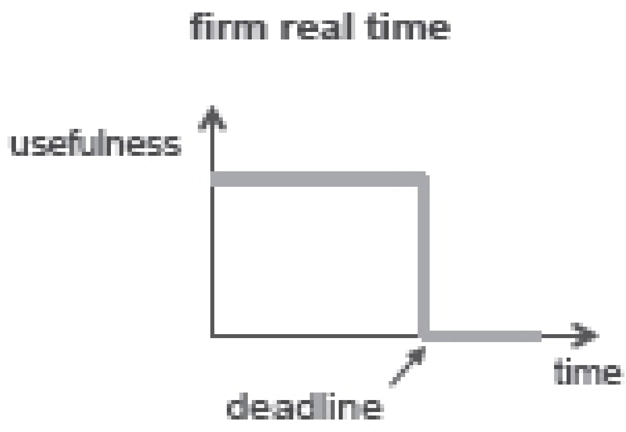
Monotonicity

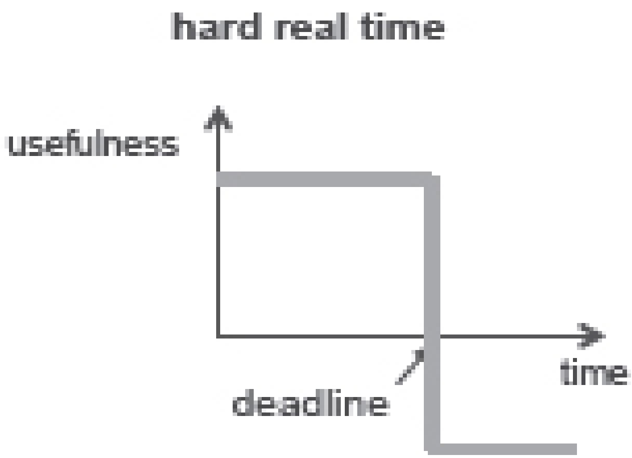
- We expect clocks to be monotonically increasing in value, in other words
  $$\forall t2 > t1; C(t2) > C(t1)$$
- It is especially important if we are using time to represent causality of events
- Monotonicity is violated whenever we correct a fast clock by setting its value backwards.
- When a clock is moved backward, must ensure that scheduled events are not repeated
- When a clock is moved forward, we also must ensure that scheduled events are not missed

Classification of RTS

- A soft RTS is one in which performance is degraded but not destroyed by failure to meet response-time constraints.
- A firm RTS is one in which missing a few deadlines will not lead to total failure, but missing more than a few may lead to a complete and catastrophic system failure.
- A hard RTS is one in which failure to meet a single deadline may lead to complete and catastrophic system failure.

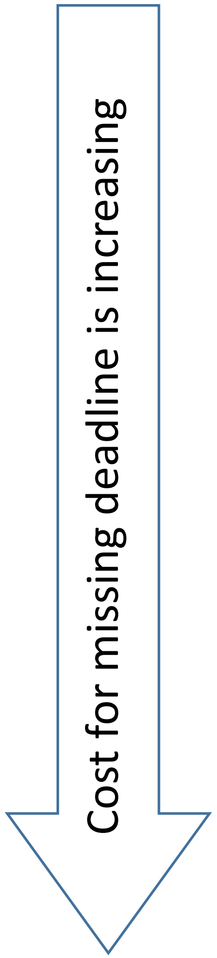






Examples of RTS

Note: There is a great deal of latitude for interpretation of hard, firm and soft real time systems



- Soft RTS
  - Streaming videos
  - Computer games
  - Online chatting
- Firm RTS
  - Manufacturing systems with robot assembly lines
  - Coursework Submission
- Hard RTS
  - Mission critical systems
  - Nuclear systems
  - Medical applications such as pacemakers

Comments About RTS

- Multitasks
  - Periodic tasks
  - Aperiodic tasks

- Schedulability
  - The ability of tasks to meet all hard deadlines

Questions:
1. Does a real-time system mean a “fast system”?
2. What should we do if not all deadlines can be met?