AME 3623: Embedded Real-Time Systems

Andrew H. Fagg
Symbiotic Computing Laboratory
School of Computer Science
University of Oklahoma

Teaching Assistant: Andrew Kooiman
What is an Embedded System?
What is an Embedded System?

- Computing system with a non-standard interface (often no keyboard or screen)
- Often involved in sensing and control (and may not even talk to a human)
- Typically a custom system for a very specific application
What is an Embedded System? (cont)

• Limited processing capabilities:
  – Can be extremely small
  – Can require a small amount of power

• Can have significant real-time constraints
  – Act on inputs very quickly
  – Generate high-frequency outputs

• Often a higher expectation of reliability
Examples of Embedded Systems
Robotics

Mark Tilden
Los Alamos National Labs
and Wowwee

picture from *Robosapiens*
Humanoid Robotics

NASA/JSC Robonaut

UMass Torso
Real-Time Robotic Control

Hula-Hoop Juggling
UMass Torso
Dual-Limb Coordination
Personal Satellite Assistants

NASA Ames Research Center

picture from *Robosapiens*
Intelligent Prosthetics

Hugh Herr
MIT Leg Lab

picture from Robosapiens
Brain-Machine Interfaces

Estimate of intended movement

Command prosthetic arm

Predictive model

Multiunit recording

In collaboration with Nicholas G. Hatsopoulos and Lee E. Miller
Real-Time Activity Recognition for Assistive Robotics

OU Crawling Assistant
(Kolobe, Fagg, Miller, Southerland)
Sensor Networks

1000 sensor nodes
Embedded Systems Challenges
Embedded Systems Challenges

• Sensing the environment:
  – Sensors are typically far from ideal (noise, non-linearities, etc.)
  – Sensors/subsystems can fail
  – Hard to get a ‘complete’ view of the environment

• Affecting the environment through “actuators”
  – Application can require fast, precise responses
Embedded Systems Challenges (cont)

• Testing/debugging can be very difficult:
  – Hard to identify and replicate all possible situations
  – Often involves the interaction of many different components
  – Often no standard user interface
  – Limited on-board resources with which to record system state

• Competing requirements of cost, complexity, design time, size, power…
Embedded Systems Challenges (cont)

• Lack of reliability can be a killer ….. literally
My Assumptions About You

• Circuits and sensors class (or equivalent):
  – Boolean logic and circuits (AND/OR/NOT gates)
  – Analog circuits (in particular, resistive-capacitive circuits)

• Some background in programming
  – We will be using C for all projects

• Everyone has a functional laptop that can be used for the projects
Course Goals

By the end of this course, you will be able to:

• design and implement embedded circuits involving microcontrollers, sensors and actuators,
• use code and circuit design tools,
• design, program and debug embedded sensing and control software,
• work in collaborative teams to solve system design and implementation challenges, and
• communicate in both oral and written forms with team members.
Sources of Information

- Primary readings: web pages and book sections (posted on D2L & linked in the schedule)
- Pencasts: recorded audio & writing
- Other textbooks:
  - Optional reference material listed on the class website
- Class web page: www.cs.ou.edu/~fagg/classes/ame3623
- Desire2Learn: learn.ou.edu

You are responsible for making sure that you have access to all of these resources

“Flipped” Class Structure

We will be experimenting some with a new class structure this semester:

• Some lecture material will be presented as pencasts. You are responsible for viewing these before our class time. (this is your homework)

• In class, we will address any questions that you have about the pencasts, expand on the material and do in-class exercises (some of which will be graded)
Class Schedule

www.cs.ou.edu/~fagg/classes/ame3623/schedule.html

- Lecture plans
- Required reading and pencast viewing
Channels of Communication

• Lecture
• Class email list: time-critical messages to the class
• Desire2Learn announcements
• Desire2Learn discussion group: you may post questions (and answers)
• Private email or office hours for non-public questions/discussions
Grading

• Components of your grade:
  – Midterm exam: 10%
  – Final exam: 20%
  – In-class exercises: 25%
  – Four projects: 40%
  – In-class participation: 5%

• Grades will be posted on the Desire2Learn

• Final grades boundaries will be selected based on the overall class distribution
Exams

• Closed book/closed notes
  – Exception: you are allowed 1 page of your own notes

• Assigned seating

• No electronic devices

• Grading questions must be addressed before the returned exams leave the classroom
In-Class Exercises

• Mixture of individual and paired work
• Some will be graded
Group Projects

• Four group projects will focus on sensor processing and design of robot control circuits

• Project Topics:
  – Digital and Analog I/O
  – Intra-processor communication
  – Motor control
  – Finite-state machines and microcontrollers
Project Grading

Group grades are a function of:
• Code correctness and readability
• Documentation
• Demonstration and presentation

Individual grades:
• Group grade scaled by your personal contribution, plus
• Personal contribution (must have 2 significant contributions over the course of the semester)
Group Projects (cont)

• Lab space: Felgar Hall 300
• Groups will be of size 2-3 and will be assigned
• Be ready to demonstrate project by the due date
• Projects require more than a day to complete
• Project reports in \textit{pdf or postscript} format
• Code handed in through your group’s “subversion” tree
• Projects may be late (but I do not recommend this): 0-24 hrs: 10\% penalty; 24-48 hrs: 20\% penalty; 48+ hrs: 100\% penalty
Classroom Conduct

• Ask plenty of questions
• Contribute to the discussions
• No: cell phone use (including texting)
• No: laptop use (except for classroom exercises)
• More details in the syllabus
Proper Academic Conduct

Projects:

• All work must be that of your group: no looking at, discussing or copying solutions from other groups or from the net

• General discussion is (again) OK

Secure your data
Next Time

• Analog circuits review
• Review readings and pencasts: see the schedule page