SIGCSE Workshop 407
Advancing Your Arduino Game:
Early and Engaging Scaffolding for Advanced CS

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Introductions

- Organizers – we are all faculty at Washington Univ. in St. Louis
  - Roger Chamberlain
  - James Orr
  - Bill Siever
- Participants
  - Please tell us 3 things:
    - Who you are
    - What level of students you regularly teach
    - Whether or not you have written any Arduino sketches before
  - Pay attention to answers to the last question, as we'll be forming teams

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Welcome!
Why are we here?

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Workshop Purposes

- Provide familiarity with easy-to-use microcontroller platform
  - Arduino Uno has wide popularity in the hobbyist/maker community
- Expand notion of I/O beyond keyboard and screen
  - Computers interacting with the physical world
    - Sensors and actuators
    - Time as a functional requirement
- Introduce formalism as a useful tool
- Make curricular materials available for use
  - Accessible to first-year students

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Studio-based Learning

- A form of flipped classroom
- Guided exercises – teach the material in a learn-by-doing modality, typically in peer groups
- Lots of help available – that's us!
- Today there are 2 studios:
  - Studio A – Finite-state machines
  - Studio B – Delta timing and emulating crickets

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Schedule

- 3:00 – 3:20 Introduction
- 3:20 – 4:10 Studio A – Finite-state machines
- 4:10 – 4:30 Break
- 4:30 – 4:50 Presentation of curricular materials
- 4:50 – 5:40 Studio B – Delta timing and emulating crickets
- 5:40 – 6:00 Discussion, Q&A, Feedback, Wrap-up

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Getting Started

- Form groups of 2 to 3 individuals
- Navigate to the following URL:

rogerchamberlain.github.io

- Need one laptop with software installed, instructions on website
  - Copy files from 'Arduino' on thumb drive to 'Arduino' on laptop
- Scroll down to "Workshop Schedule"
  - Click on link for Studio A
  - No need for physical construction first, go to "Programming the Arduino"
  - Return to "Assembling the Arduino Board" before Studio B

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Studio A
"Hello world!" and
Finite-State Machines

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Break
Be back at 4:30!

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A full semester's worth
of material

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Computing in the Physical World

- Input is not just keyboard and mouse
  - Temperature sensor
    - Analog-to-digital conversion
  - Light sensor
    - Is the room light or dark right now?
- Output is not just display
  - Physical actuators
- Not all compute engines are equal
  - 3 GHz desktop boxes and/or rack-mounted servers
  - 16 MHz microcontrollers size of postage stamp

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Traditional Approach

- First things:
  - CS1 (write simple programs)
  - Data structures and algorithms
  - Input is keyboard and mouse (or disk file)
  - Output is screen (or disk file)
  - Functional correctness and asymptotic analysis is emphasis
- Upper division course:
  - Embedded systems or cyber-physical systems

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Let's Introduce Topics Much Earlier

- New course in 2nd semester of first year[1]
  - After CS1
  - Before data structures and algorithms
- Required of all CS and CoE majors at WashU
  - Meets tech. elective requirement for CS minors and EE majors
- Very popular with wider maker community
  - Significant numbers of ME and BME students

[1]Chamberlain et al., "Computers Interacting with the Physical World: A First-Year Course," WESE 2018.

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Focus is on the Following

1. Timing
   - Authoring programs in which "when" something happens is a formal correctness criterion
2. Input and Output
   - Both analog and digital
   - Turning raw inputs into useful information
3. Information representation
   - There are differences between authoring in Java on a PC vs. authoring in C on a microcontroller

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Also Included

4. Computer to computer communications
   - A common form of I/O
   - Ties strongly to information representation
5. Finite automata
   - Finite state machine organization is ubiquitous in microcontroller systems
6. Simple computer architecture / assembly language
   - A brief view "under the hood"

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1. Simple Timing

- What are possible issues with this code?

```
repeat:
    wait for 1 second
    do some work
    output results
end
```

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1. Better Approach to Time

repeat:
  overlap 1st with 2nd and 3rd:
    wait for 1 second
    do some work
    output results
  end
end

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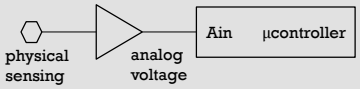
2. Analog Input Example

- You have a temperature sensor that varies its output voltage 10 mV per degree C
- You have a 10-bit analog-to-digital converter with a selectable reference voltage



- Your program calls the routine that performs an A/D conversion, and it returns 523
- What is the temperature?

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2. I/O Processing Writ Large

- In general, raw inputs are not immediately usable, but typically need some processing
- E.g.,
  - Conversion from raw input to appropriate engineering units
  - Filtering of sampled values
  - Feature extraction (e.g., peak detection to count steps)
- Running example is some cyber-physical system
  - Build FitBit before semester is complete
  - Build robotic vehicle

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3. Information Representation

- Binary number representations and their implications for characterizing physical phenomena
- E.g.,
  - Measure accelerometer on microcontroller
    - Sample rate too fast for analysis on microcontroller
    - Integer precision IIR filter is inadequate
  - Send raw data to PC
    - Filter and peak detection on PC
    - Display graph of raw data and steps

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3. Information Representation

- Binary and hexadecimal
- Negative numbers
  - 2's complement
- Fixed-point and floating-point numbers
- Text
  - Null-terminated array of single-byte chars in C
  - String Object in Java
    - Array of 2-byte Unicode chars (UTF-16)
    - Count to record string length (an instance variable in the object)

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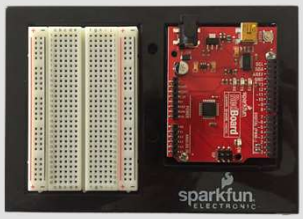
Execution Platform

- Arduino Uno microcontroller
  - Uses subset of C language
  - Large hobbyist community
- Desktop PC
  - Using Java



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Active Learning

- Course is studio-based and lecture-free
- Two 1.5-hour meetings per week
  - Both in instructional lab spaces
  - Staffed with undergraduate TAs and instructor
- Material organized in modules, 1 per week
  - First meeting of week is studio
  - Second meeting of week is assignment

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Studio

- Guided exercises
- Videos and reading required prior to studio
  - Short (~5-10 min) videos
- Work in groups of 2 to 4 students
  - Peer instruction is crucial
  - Primary mechanism for learning material
- Graded on participation, not results
  - Gives freedom to explore, minimum consequence

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Typical Week

- Do prep work (videos, reading material)
- 1st meeting is studio
- 2nd meeting is for assignments
  - Demo last week's assignment
  - Spend time in lab working on this week's assignment
- Lots of consulting/help hours through the week

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Summary and Future Directions

- Focus of course is computers interacting with the physical world
- Targeting first-year students
  - Before data structures and algorithms course
- Material
  - 1 → Timing, I/O, information representation
  - 2 → Communication, automata, assembly lang
- Delivered using active learning techniques – studio-based
- All curricular materials (including textbook) are open access and freely usable

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Studio B
Delta Timing and Emulating Crickets

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Discussion and Feedback

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Discussion and Feedback

- Questions?
- Thoughts?
- Ideas?
- Please navigate to the following URL:

https://bit.ly/sigcse2022-ws-sat

to give feedback to conference organizers

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Stay in touch!

My contact information: roger@wustl.edu

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