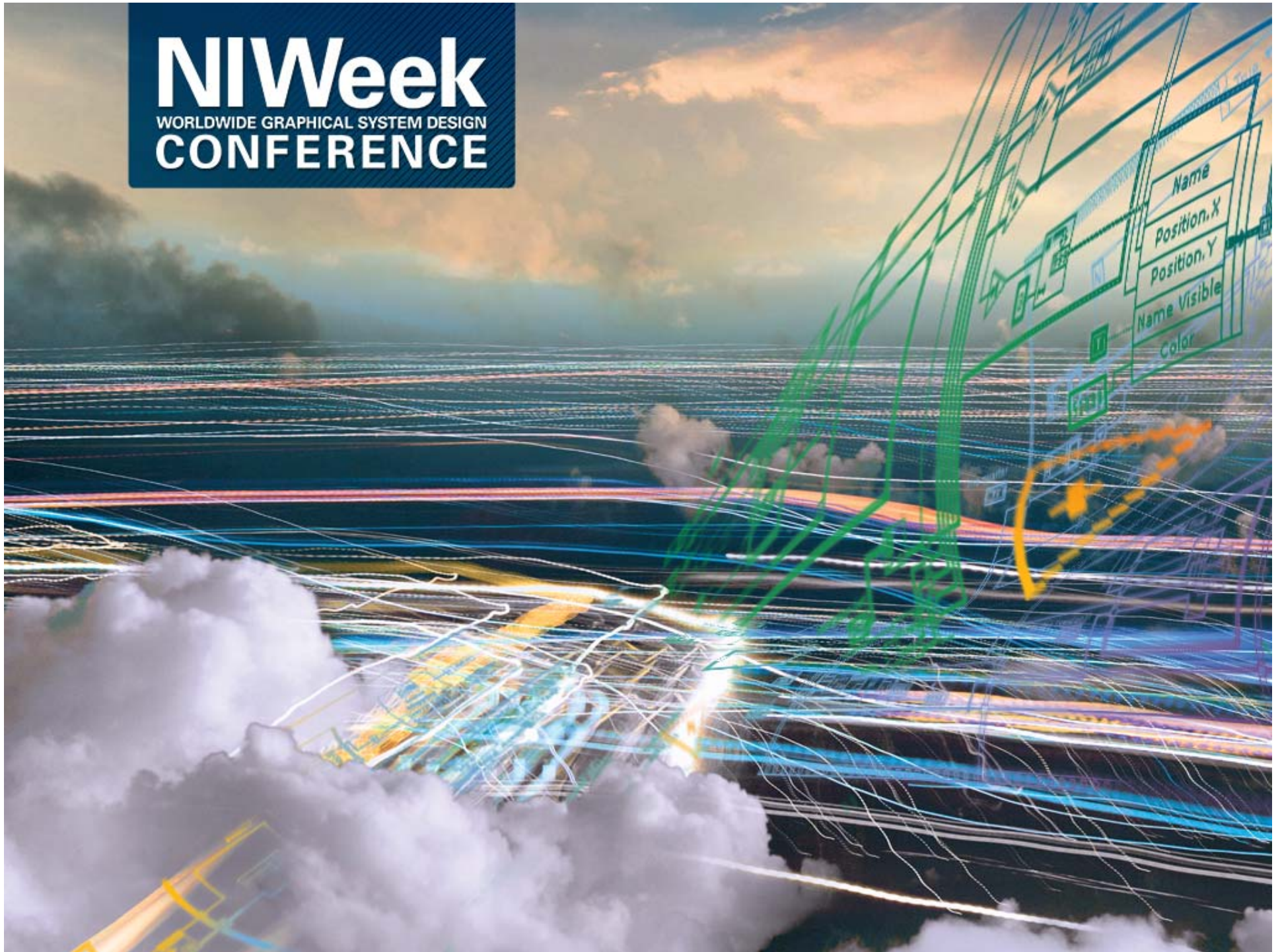


NIWeek

WORLDWIDE GRAPHICAL SYSTEM DESIGN
CONFERENCE



Towards Lab-Based MOOCs: Embedded Systems, Robotics, and Beyond

Sanjit A. Seshia

UC Berkeley

Joint work with:

Edward A. Lee, Jeff. C. Jensen, Alexandre Donzé,
Garvit Juniwal, Andy Chang

UC Berkeley & NI



NIWeek 2014
August 4, 2014



Massive Open Online Courses (MOOCs)

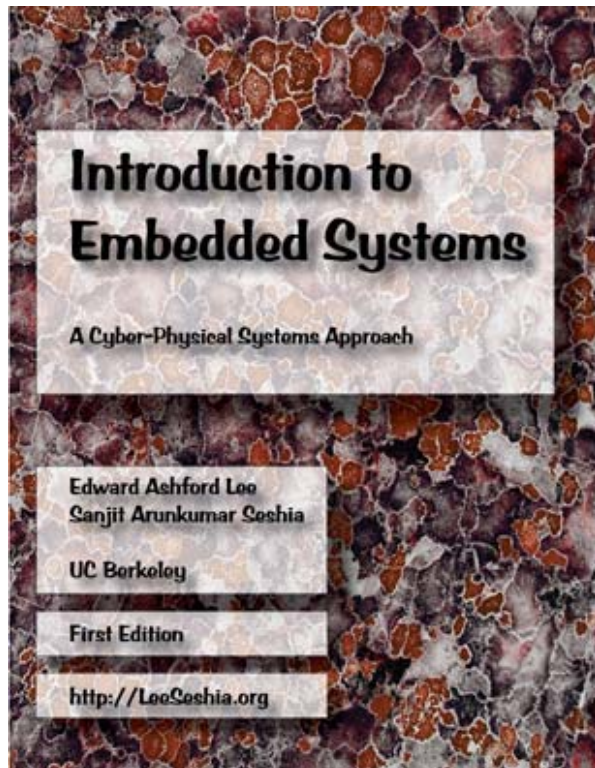


Courses from universities world-wide available
to any one with an Internet connection

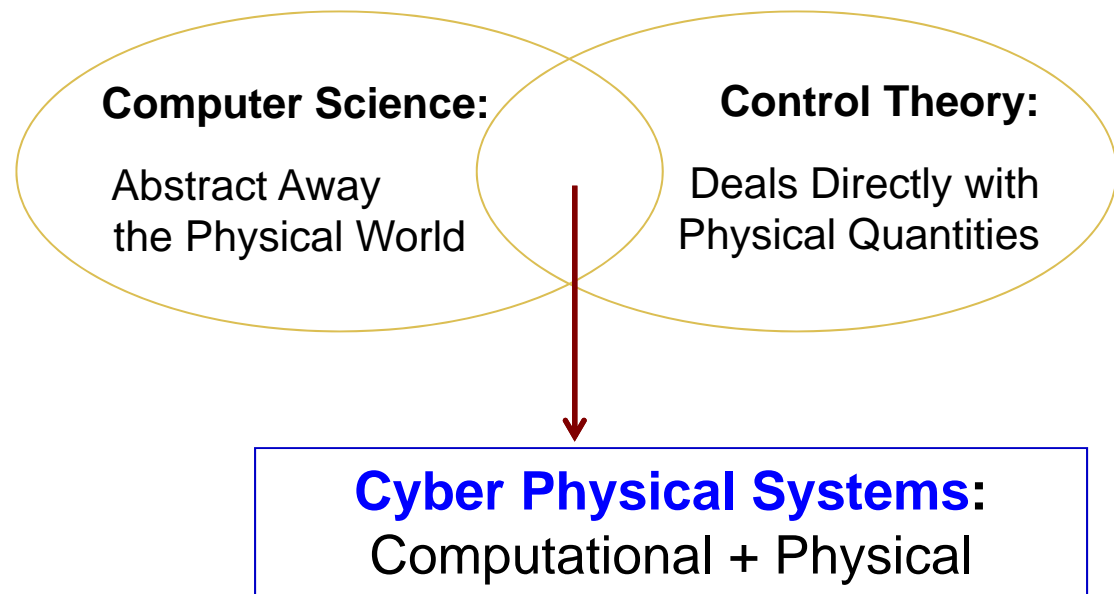
EECS 149: Introduction to Embedded Systems

UC Berkeley

This course introduces the *modeling, design and analysis* of *computational systems that interact with physical processes*.



<http://leeseshia.org/>



On-campus course gets somewhat diverse enrollment
(EE/CS, ME, CE, ...)

The Traditional View of Embedded Systems



SPECIAL PURPOSE:
Embedded computer
with a special-
purpose processor



INTERFACING to
sensors and
actuators



Designing under
RESOURCE
CONSTRAINTS
(memory, time, energy,
...)

The Berkeley View of Embedded Systems

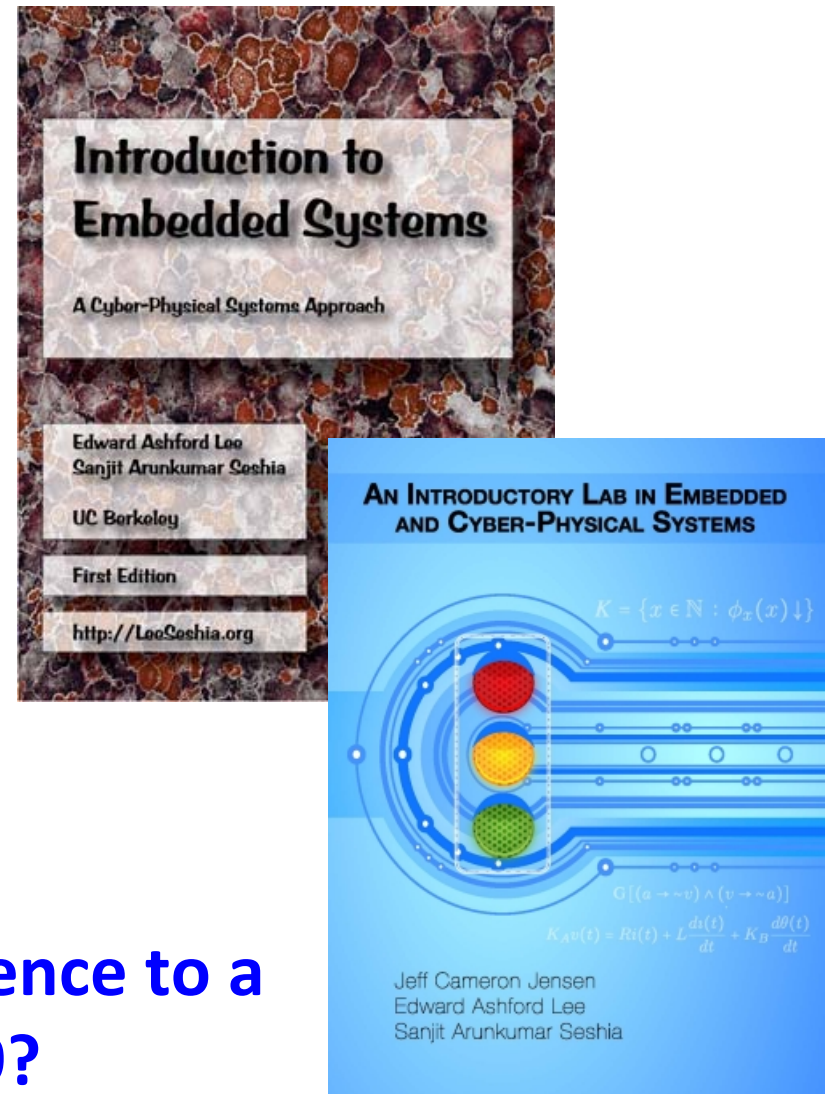
We hold that embedded systems should be:

- characterized by **interactions with the physical world**, not resource constraints
- introduced through **formal modeling, design and analysis**, not ad-hoc engineering practices

The Core Learning Experience: Exercises and Labs

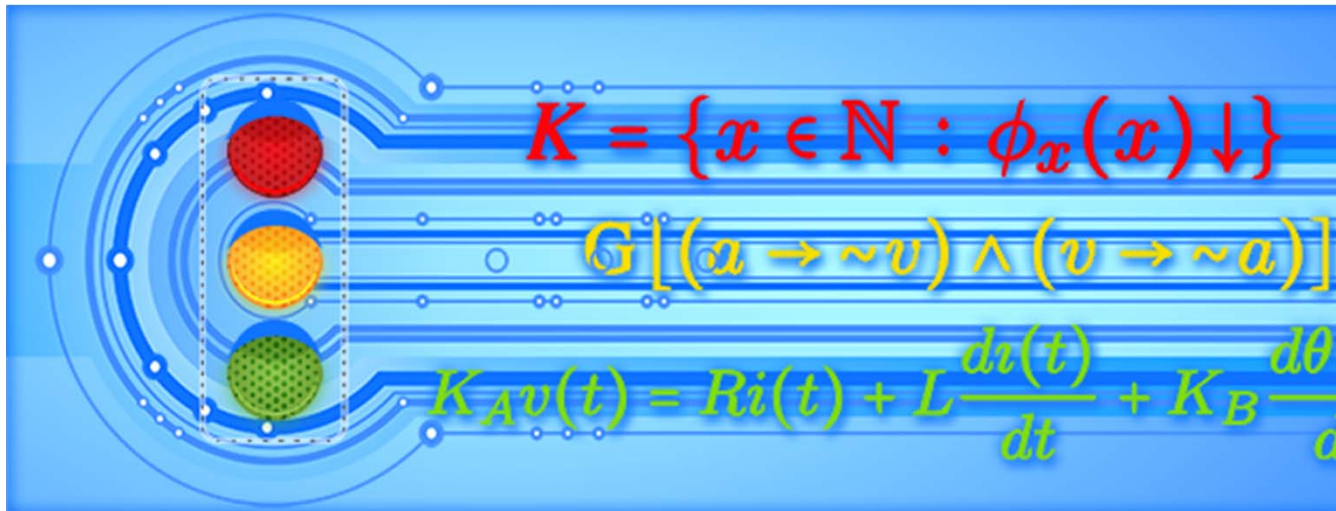
- Textbook Exercises:
 - High-level modeling with FSMs, ODEs, temporal logic, etc.
 - Programming in various languages (C, LabVIEW, etc.)
 - Algorithm design and analysis (scheduling, verification, etc.)
- Laboratory (6 weeks)
- Capstone design project (12 weeks)

➤ **How to extend this experience to a MOOC version of EECS 149?**



EECS149.1x: Cyber-Physical Systems

- MOOC offering on edX: May 6 to June 24, 2014
- Berkeley-NI collaboration
- Virtual lab technology for CPS: [CyberSim](#)
- First course to employ formal verification in auto-grader: [CPSGrader](#)



Roadmap for Rest of this Talk

- CyberSim + CPSGrader Demo
 - NI Robotics Simulator + UC Berkeley Auto-Grader
- The EECS149.1x Experience
 - Statistics, Survey Results, Feedback
- Future Directions

On-Campus Lab Assignment: The “Hill-Climbing” Robot



Virtual Lab Assignment (Demo)

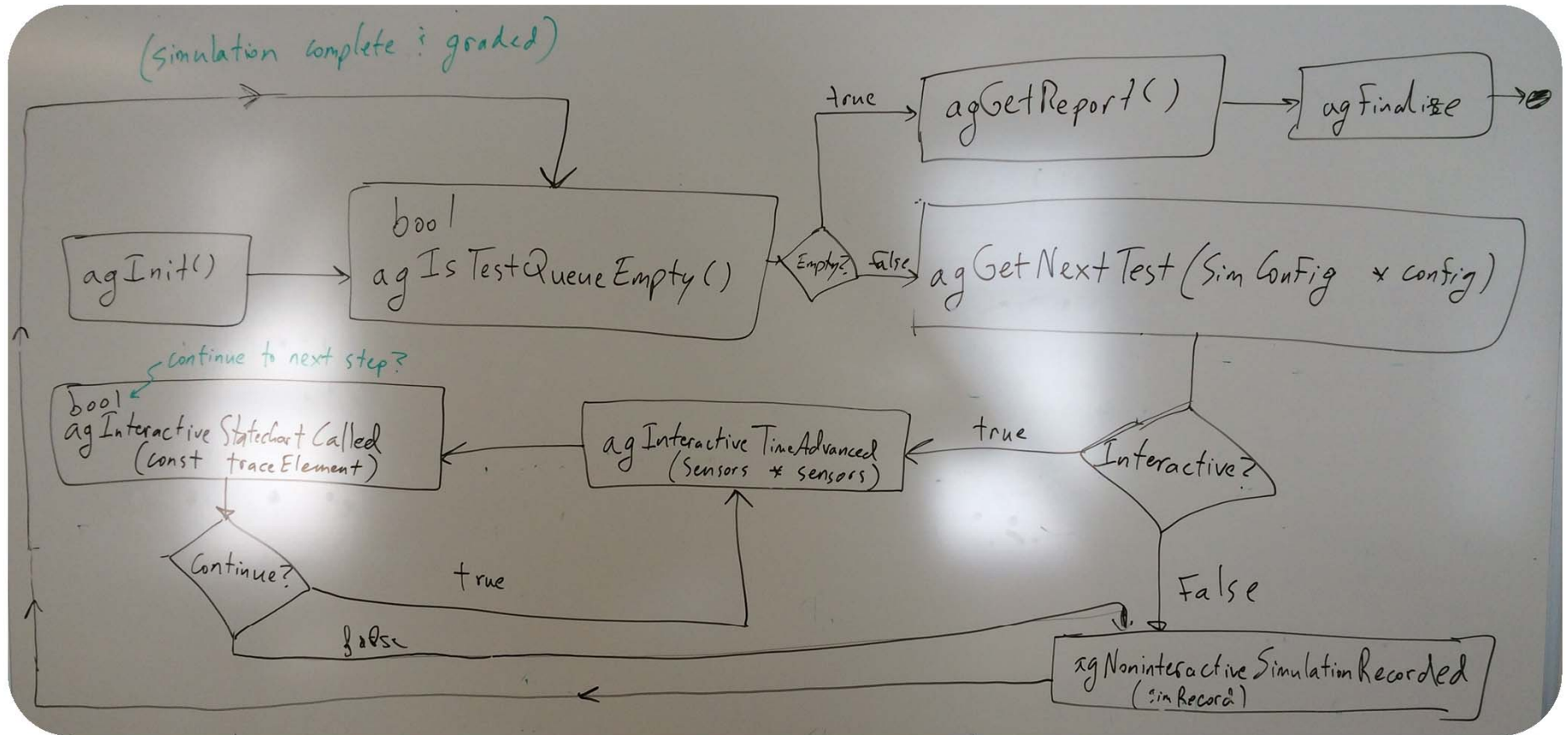
The image displays the CyberSim software interface, which is used for simulating a robot's behavior. The interface is divided into several sections:

- Statechart Display:** Located at the top left, it shows a statechart diagram with states like "No Obstacles" and "Obstacle", and transitions between them. The diagram includes sub-states for "Drive Mode" (Straight, Climb) and "Avoidance Mode" (Avoid, Recross).
- 3D Simulation:** At the bottom left, a 3D view shows a robot on a green field with various obstacles and buildings in the background.
- Robot Dashboard:** On the right side, a detailed view of the robot's front panel is shown. It includes:
 - Sensors:** Front Left Cliff (787), Front Right Cliff (787), Wall (0), Left Cliff (782), Right Cliff (782).
 - Actuators:** Left Wheel (mm/s), Right Wheel (mm/s), Left Wheel Drop, Right Wheel Drop.
 - Other Sensors:** Left Bump, Right Bump, Caster Wheel Drop, accelerometer.
 - Navigation Data:** Net Dist (mm) 978, Net Angle (deg) 1.
 - Positioning:** x: -0.03, y: -0.00, z: 0.99.
- Simulation Status:** At the bottom center, it shows "simulation running" (green dot), "sequence number 0", and "simulation time (s) 7.235".
- Control Panel:** At the bottom right, there are buttons for Start, Camera, Check Grade, Pause, Stop, and Exit.

April 4th, 2014:

Development team decides to re-architect CyberSim.

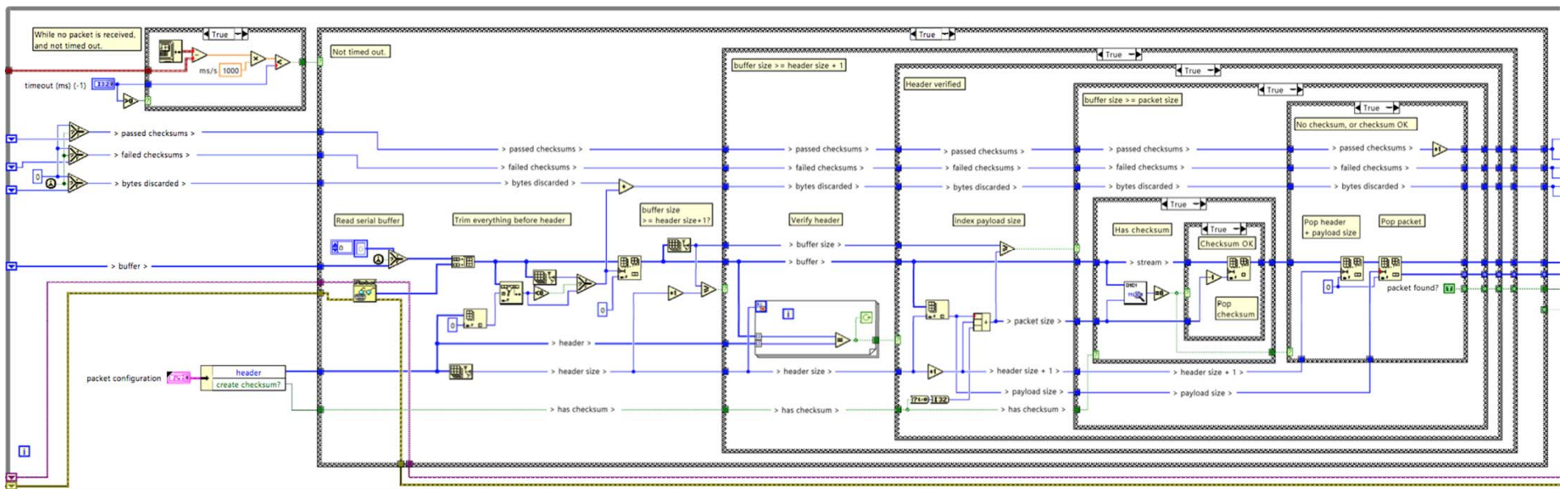
32 days prior to launch.



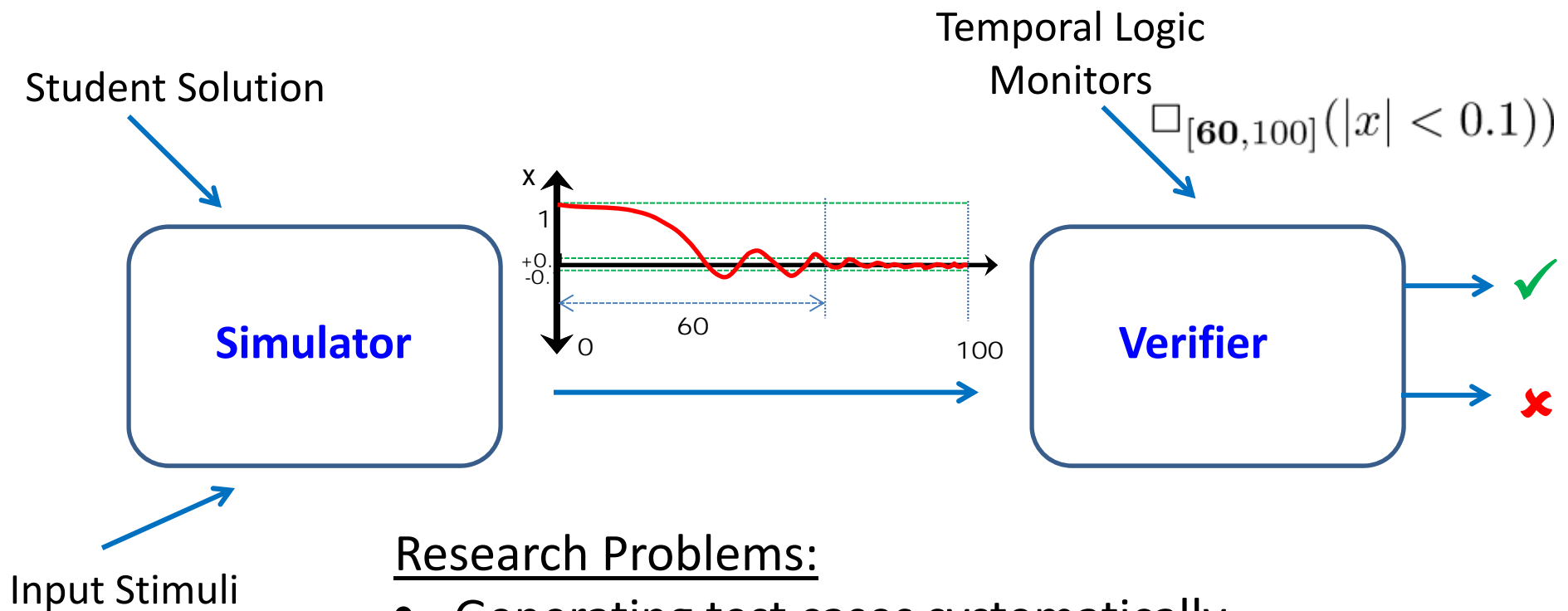
CyberSim C++ Lines of Code: 14,345

```
void xqueue_pop_buffer(xqueue_t * const queue, uint8_t * values, const size_t nvalues){  
    size_t ii;  
    for(ii = 0; ii < nvalues && !xqueue_empty(queue); ii++){  
        *values++ = *(queue->data + queue->tail);  
        queue->tail = (queue->tail + 1) & queue->capacityMask;  
        queue->rCount++;  
    }  
}
```

CyberSim LabVIEW VIs: 119



Underlying Technology in CPSGrader: “Temporal Logic Run-Time Verification”

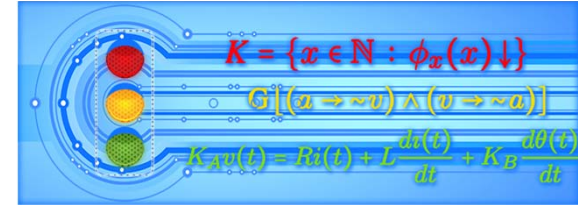


Research Problems:

- Generating test cases systematically
- Synthesizing assertions that account for legal variation in student solutions
- ...

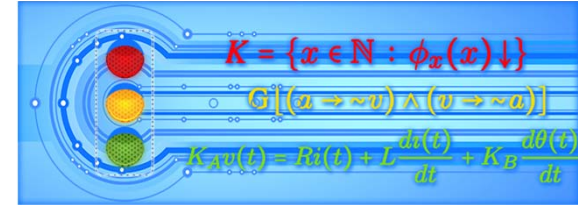
Described in more depth tomorrow 1:30-2:30 PM

EECS149.1x: Basic Statistics



- 6-7 weeks
- 49 lectures, 10 hours 50 minutes of video
- 6 weekly lab assignments
 - 1 LabVIEW and Dev Tools tutorial
 - 1 Memory Architectures “lab”
 - 4 Virtual Lab exercises:
 - Week 1: Navigation, programming in C
 - Week 2: Hill climb, programming in C
 - Week 3: Navigation, programming in LabVIEW
 - Week 4: Hill climb, programming in LabVIEW
 - Hardware track optional

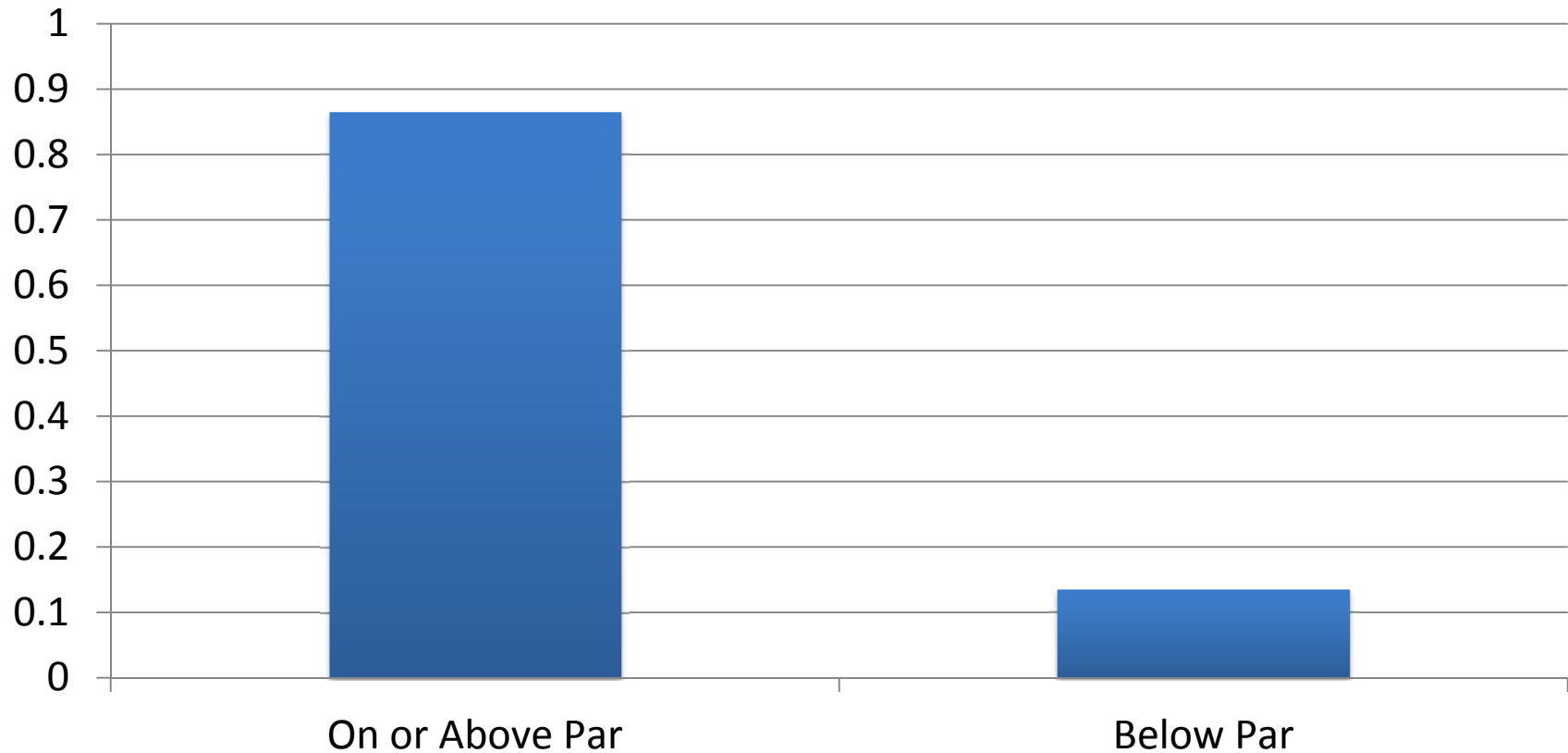
EECS149.1x: Basic Statistics



- 6-7 weeks
- 49 lectures, 10 hours 50 minutes of video
- 6 weekly lab assignments
- Peak Enrollment: 8767
- Largest number submitting any lab: 2213
- Number scoring more than 0: 1543
- Number who passed: 342 (4% of peak enrollment)

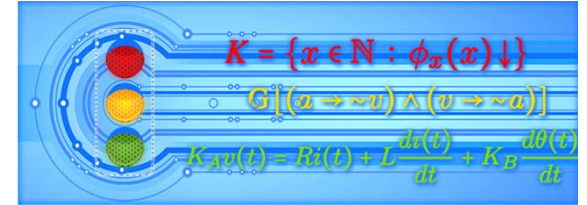
Student Survey

Comparison with other MOOCs



54% of students had taken 3 or more (other) MOOCs already

EECS149.1x: LabVIEW Stats



(About 200-300 survey respondents)

- Prior Experience: **59%** NEW to LabVIEW
- LabVIEW vs. C for the labs:
 - LabVIEW was superior: **26%**
 - LabVIEW was equally capable: **56%**
 - LabVIEW was inferior: **18%**
- Repeating lab in LabVIEW after doing it in C:
 - 73%** felt it is a good thing
 - teaches different concepts and skills

Hardware Track: When deploying to the *real robot*, did you modify your solution from the simulator?

>90%

of controllers that passed the Virtual Lab auto-grader worked on the real robot with no or minor modifications

Students Reporting
Auto-grader Feedback as Useful:

86%

[staff] Exciting Lab 3

+ 2

juanmiami

25 days ago

Truly amazing simulator. It's like if you were running in a real physical world (how it back and turns when hitting an obstacle, how it behaves when jump off a cliff, wow!). A true piece of art.

ksgkrishnan

17 days ago



+ 0

Thanks for the solution, i learnt a lot, Somehow I managed to avoid obstacle when moving left, but the right side is always a problem, I never thought about the REORIENT state in my solution, now everything is CLEAR!!!

ChristopherMalek

3 days ago



This course is my first MOOC, and it surpassed all of my expectations. I learned a great deal and was a load of fun! It made me excited enough about this subject that I plan to continue tinkering with hobbyist robotics, something I had never expected to take away from this class.

If 149.2x were to be offered, I would sign up for it instantly!

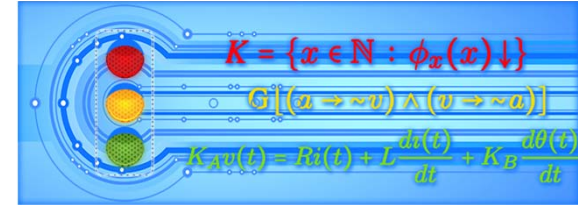
AchilleTalon

5 days ago

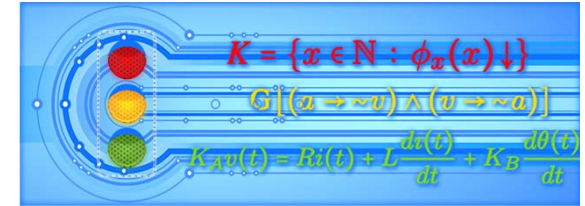


Thanks to all of you who made this course possible. Lectures were simply awesome and material covered among the most interesting stuff I got from a MOOC and I completed nearly 30 so far and almost all in CS and EE. I believe you should put in place a long version of this course with all the material you have in the on campus version.

EECS149.1x: Lecture Modules



1. Introduction to CPS
2. Memory Architectures
3. Interrupts
4. Modeling Continuous Dynamics
5. Sensors and Actuators
6. Modeling Discrete Dynamics
7. Extended and Hybrid Automata
8. Composition of State Machines
9. Hierarchical State Machines
10. Specification & Temporal Logic



Survey on Lecture Modules

1. Introduction to CPS
2. Memory Architectures (1)
3. Interrupts (2)
4. Modeling Continuous Dynamics
5. Sensors and Actuators (1)
6. Modeling Discrete Dynamics
7. Extended and Hybrid Automata
8. Composition of State Machines (3)
9. Hierarchical State Machines (2)
10. Specification & Temporal Logic (3)

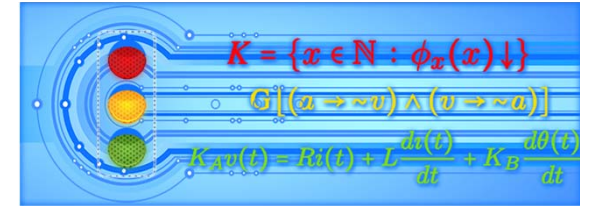
1

Top Theory Topic

1

Top Lab-Relevant
Topic

Conclusion



- EECS149.1x: A first step towards enabling Lab-based MOOCs
 - Useful for growing enrollments on campus too!
- CPSGrader architected to be reusable for other courses
 - Circuits
 - Robotics
 - Mechatronics
 - ...
- Formal Methods can offer much to Education in Science and Engineering
 - Virtual Science & Engineering Labs with built-in Auto-Grading can broaden participation

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