Center for Embedded Computer Systems
University of California · Irvine

CPS Design Group
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A Ball Goes to School -
Our Experiences from a Cyber Physical Systems Design Experiment

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Motivation/Approach

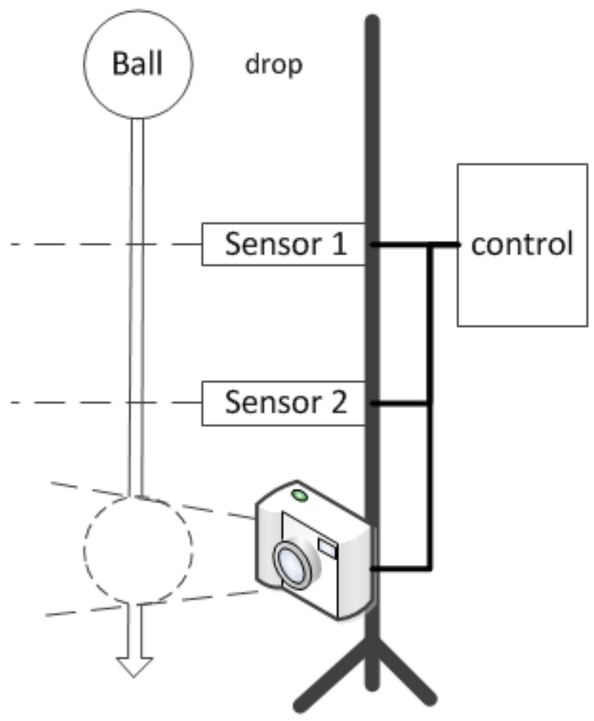
Develop an educational program to teach CPS design to graduate Computer Science students.

Improve understanding of CPS design and sharpen attention in crafting solutions by teaching:

- Typical design flows for CPS design
- Importance of models and their limitations
- Introduction to state-of-the art simulation and modeling tools

Apply small examples, that are:

- Easy to understand
- Possible to design and evaluate using a variety of tools and methodologies
- Is implementable in the lab



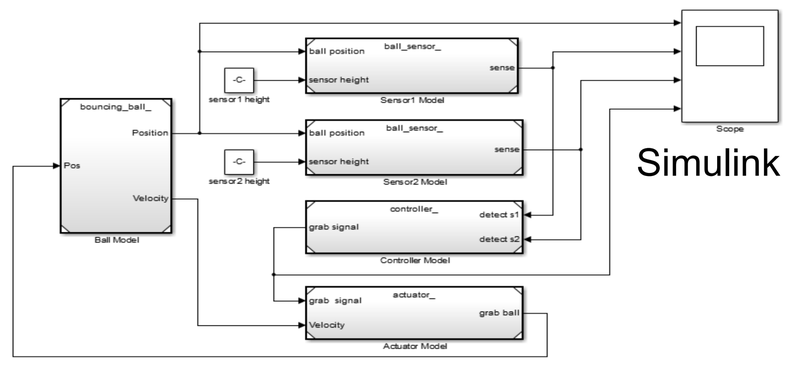
The Falling Ball Example

- A camera should take a picture of a falling ball that is dropped from a variable height.
- Sensors mounted above the camera detect the ball.
- A program in the cyber part of the system estimates the approaching time.

Benefits:
- Easily understood
- Need for precise timing
- Physical process needing mathematical modeling
- No perfect precision in cyber part
- Can be build in the lab

Modeling and Implementation

- Students modeled or implemented the system applying a range of tools (one per student)
- Progress, advantages and problems of the selected tools are discussed in the group



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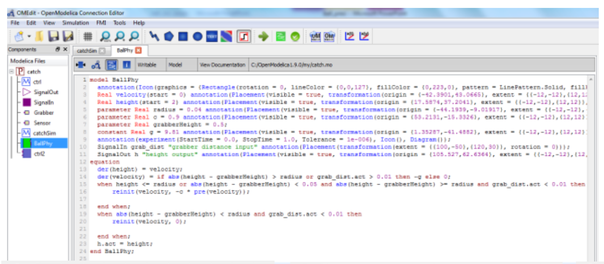

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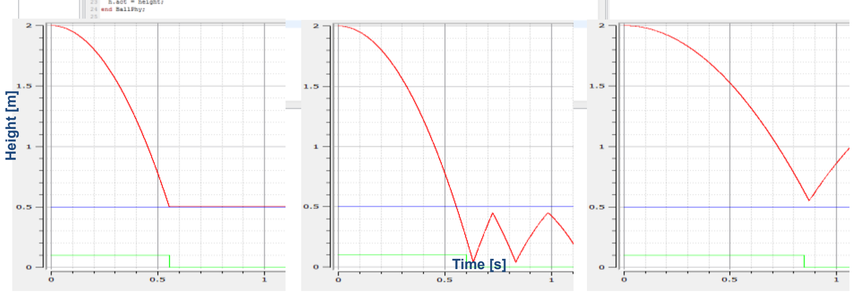
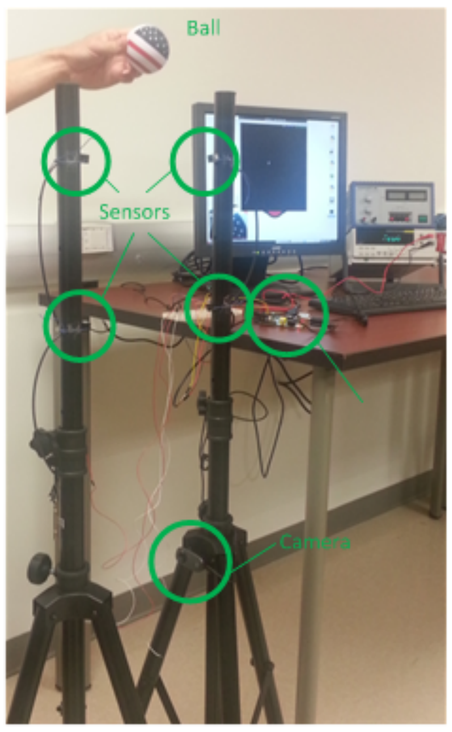




Lab implementation running on Raspberry Pie board

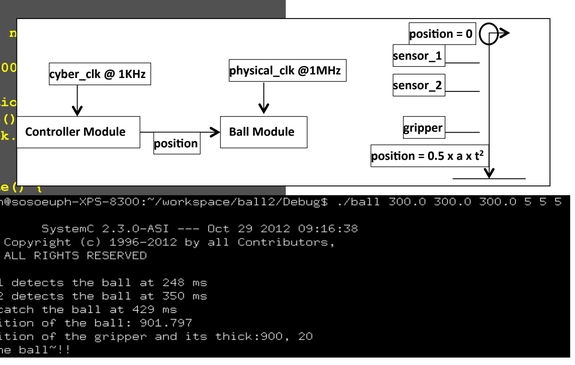
```
//=========================================================
// Name        : ball.cpp
//=========================================================
#include <iostream>
#include "ball.h"

Ball::Ball(sc_module_name n
          time_us = 0;
          g_force = 0.00000

          SC_METHOD(positic
          dont_initialize()
          sensitive << clk.
}

void Ball::position_update() {
          position
          //cout <
          //cout <

          time_us+
}
```




```
sosoeuph@sosoeuph-XPS-8300:~/workspace/ball2/Debug$ ./ball 300.0 300.0 300.0 5 5 5

        SystemC 2.3.0-ASI --- Oct 29 2012 09:16:38
        Copyright (c) 1996-2012 by all Contributors,
        ALL RIGHTS RESERVED

Sensor 1 detects the ball at 248 ms
Sensor 2 detects the ball at 350 ms
Try to catch the ball at 429 ms
The position of the ball: 901.797
The position of the gripper and its thick:900, 20
catch the ball~!!
```

SystemC

Results:

Discovered and discussed challenges:
- Math and modeling the physical system
- Separation of physical and cyber part
- Design methodologies of graphical design tools
- Selection of an appropriate Model of Computation
- Zeno behavior and simulation time resolution issues

Conclusions:
- The Falling Ball example is a suitable use case to teach CPS design
- Simplicity of the example allows students to focus on the actual CPS design challenges
- In four weeks (10h/week) students learned how to use tools, model the system, run simulations, test the system and evaluate the results
- Discovered design challenges are good support for lecture

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