

Experiences with A First Course on CPS

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The Big Picture

Goal: A CPS appreciation course for

- B.A. and B.Sc. programs at Rice and Halmstad
 - Several departments (and schools?)
- M.Sc. programs
- PhD students

So far: Halmstad's M.Sc. in Emb. & Intel. Sys.

- 2 year program (1.5 courses, 0.5 thesis)
- diverse, international student body
- graduates work in Sweden and abroad

Technical Contents

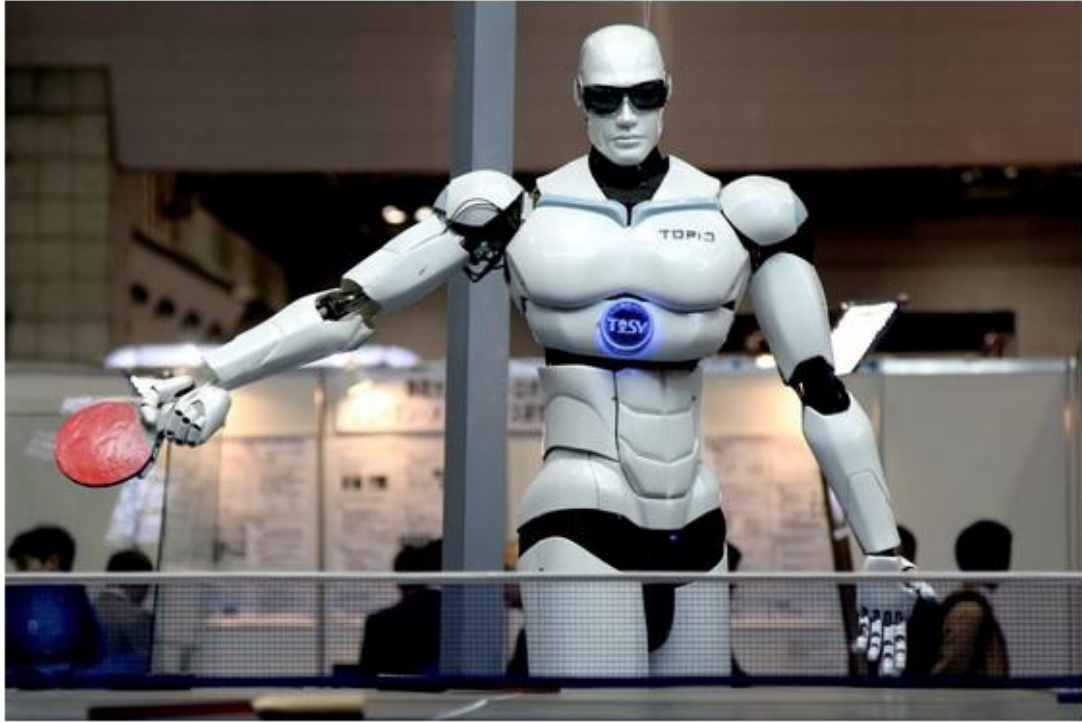
1. What is CPS?
2. Modeling Physical Systems
3. Hybrid Systems
4. Control
5. Modeling Computational Systems
6. Communications
7. Single-Link Robot (case study)
8. Game theory

Lecture Notes on Cyber-Ph...

https://docs.google.com/document/d/1OUxykVdw8400vwGnG9t7R2yMv5n2xSPWHneM8liC...

Docs Family Atlassian EMG Gmail Mailbox Quran Q4U Tafseer TODO

Search the menus (Alt /) Normal text Arial 11 B I U A - A -



Lecture Notes on Cyber Physical Systems

by [Walid Taha](#)

Approach

- Lectures (and external resources)
- Labs (Acumen, our free SW tool)
- Reading (Notes free online)
- Homeworks
- Final exam
- Course project (Acumen)
 - Design a Ping Pong playing robot
 - Design by iterative refinement
 - Three tournaments during the term



Acumen

File View Plotting Semantics Help

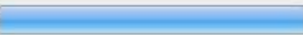
[Untitled] (changed)

```
// Model : 2012_hh_1T.acm, First Tournament (3D Ping Pong)
// Acumen : http://www.acumen-language.org/2013/01/a-preview-of-acu
// Author : Yingfu Zeng, Walid Taha, and others (see below)
// Date : 2012/02/11
// Revision: 2013/02/06 New syntax for assignments (= and :=)
// Ideas : Bat has no mass. Focus is on: Impact,
//         problem decomposition, and systems modeling
// License: BSD, GPL(V2), or other by agreement with Walid Taha

class Ball ()
private
mode := "Fly";
k_z := [1.1,-0.99]; // Coefficient of restitution
k2 := 1/6; // Coefficient of the air resistance
p := [0.0,0.5]; // Position of the ball
p' := [5.1,-3];
p'' := [0.0,0];
_3D := ["Sphere",[0.0,0.5],0.03,[1.1,1],[0.0,0]];
end
_3D = ["Sphere",p,0.03,[1.1,1],[0.0,0]];
// If mode is not valid then make mode "Panic!"
if mode == "Fly" && mode == "Bounce" && mode == "Freeze"
mode := "Panic!";
end;
// Behavior of ball in different modes
switch mode
case "Fly"
if dot(p,[0,0,1]) < 0 && dot(p',[0,0,1]) < 0
mode := "Bounce";
else // Acceleration is air resistance and gravity
p'' = -k2 * norm(p') * p' + [0.0,-9.8];
end;
case "Bounce"
p' := p' .* k_z; // Bounce losing k_z energy
mode := "Fly";
case "Freeze" // The ball becomes red and freezes for a bit
```



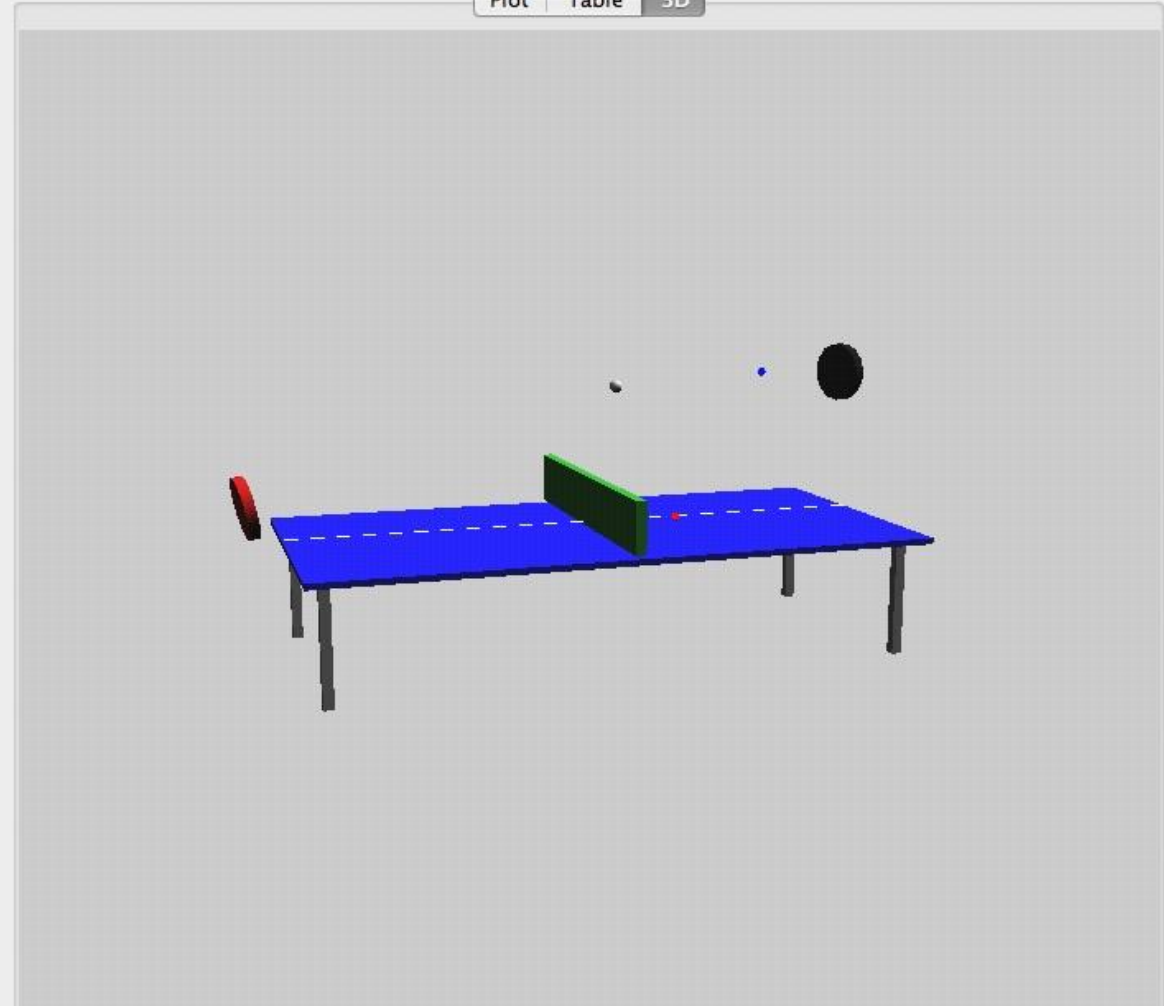
Progress:



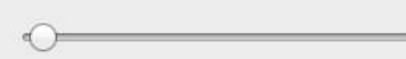
Console

Starting...Stopped.
Stopped.
Welcome to Acumen.
Please see LICENSE file for licensing details.

Plot Table 3D



Axis



Time: 2.00
Speed:1.0x

Plot Table 3D

(#0.1.3 : BallObserver).pp[1] @ 1.4700000000000001 = -0.2797027471773268



Plot



Hint: Right click on image & drag to move

Feedback on First Offering

- "it was fun to run the design"
- "support for 3D visualization was very useful"
- requests for "more intermediate exercises"
 - improved in 2nd offering
- "the current project is difficult enough"
- "too much reading on something easy"
 - improved in 2nd offering

Overall Student Satisfaction

- 5 on a scale from 1 (worst) to 6 (best)

Feedback on Second Offering

Things that work:

- lecturing style: whiteboard, no slides, interactive, conversational
- open access course material
- collaborative real-time note taking

Things that can be improved:

- gap between lectures and assignments: need more progressive levels of difficulty
- some open-ended problems are too big and difficult
- chapter on communication "is too abstract"

Preparations for Third Offering

- New class is 55 students
- Revising ping pong model
 - The need for path planning
 - More cooperative utility functions
- Last three chapters
 - Comm., case study, & game theory
- Incorporating past exam questions
- Online quiz questions
- Consolidated manual for Acumen
- Using Piazza for Q&A

Working with Acumen (2x slow mo)

The screenshot displays the Acumen IDE interface. The window title is "Acumen". The menu bar includes "File", "Edit", "View", "Plotting", "Model", "Semantics", and "Help". The main editor window shows a file named "2013_hh_1T.acm" with the following code:

```
/**
 * The parent of all the other classes, who controls the
 * whole process of the game.
 */
class Game ()
private
player1 := create Terminator (1); // First Player;
player2 := create Transporter(2); // Second Player;
ball := create Ball ();
ballob := create BallObserver();
actuator:= create BallActuator();
batActuator1 := create BatActuator([-1.6,0,0.2]);
batActuator2 := create BatActuator([1.6,0,0.2]);
bat1 := create Bat(1,[-1.6,0,0.2]);
bat2 := create Bat(2,[1.6,0,0.2]);
table := create Table();
gameMonitor := create Referee();
mode := "Player2Serve"; // Player2 starts first
player2Score := 0;
player1Score := 0;
serveNumber := 2;
t := 0;
...

```

Below the code editor is a control panel with a "Progress:" slider and buttons for play, pause, and stop. A checkbox labeled "Synch File Browser and Editor" is checked. Below this is a "Console" tab showing the following output:

```
Starting...Stopped.
Starting...Stopped.
Starting...Stopped.
Starting...Stopped.
Starting...Stopped.
Starting...Stopped.
Stopped.
Welcome to Acumen.
Please see LICENSE file for licensing details.
```

The right side of the interface features a 3D plot area with tabs for "Plot", "Table", and "3D". The plot area is currently empty. At the bottom of the interface is a control bar with a checkbox for "Axis", buttons for play, pause, stop, and a slider, and a status display showing "Time: 0.39" and "Speed:0.5x".



Conclusions

Everyone happy, engaged

- Course become a required first-year course

Takeaway:

- The current topic selection works
- Tournament project works
- Acumen provides "language" and "virtual lab"
 - Interactive IDE
 - Chronological or "animated" 3D visualization

For More Information

<http://bit.ly/CPS-course>