Introducing Discrete-Event Systems (DES) into an Undergraduate Controls Course

University of Michigan, Department of Mechanical Engineering

Nominated for Best Paper

PROBLEM:

- Students don't understand limitations and context of their controls knowledge
- Don't know how to address systems that aren't linear and SISO
- Specifically aren't aware of DES and Hybrid Systems (even at graduate level)

OBJECTIVE:

- Demonstrate to students the limits of linear control theory
- Make students aware of DES and Hybrid systems and the need for formal methods
- Reinforce big-picture concepts: modeling, simulation

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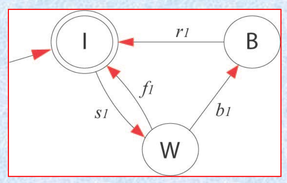
BACKGROUND:

What is a DES?

- NOT a digital control system
- discrete state space
- event-driven
- representation: finite state machines (FSM)



What is a Hybrid System?

- has continuous and discrete dynamics
- example: automobile transmission
- classical control theory doesn't apply

Need for formal methods: State Explosion

- 3 station, 11 motors, 14 sensors
- open loop model has 1,179,648 states

Station	Inputs	Outputs	# States
Drill	Limit Switches (up, down)	Motor (up, down, off) Spindle (on, off) Rotate (on,off)	8
Vertical Mill	Limit Switches (1,2,3) Limit Switches (up, down)	Motor (up, down, off) Spindle (on, off)	48
Horizontal Mill	Limit Switches (back, front) Limit Switches (up, down)	Motor (in,out,off) Motor (up, down, off) Spindle (on, off)	32
Conveyor1 Conveyor2 Conveyor3	Part Sensor (in, drill) Part Sensor (v-mill) Part Sensor (h-mill)	Motor (on, off) Motor (on, off) Motor (on, off)	96

Total number of states 8 x 48 x 32 x 96 = 1,179,648

INSTRUCTIONAL MODULE:

Current Curriculum

- 1 required course (ME 360)
  - system modeling and analysis
  - introduction of feedback control
- 1 elective course (ME 461)
  - controller design
  - graphical methods, some state space
- DES topics are more common in computer science and outside U.S.

Module Overview

- curriculum is already crowded
- Goal: introduce DES, increase awareness, reinforce big picture concepts
- Covered in ME461 over the course of 2 - 50 minute class periods

Module Content

- introduced what a DES is
- taught how to model with FSMs
- used opportunity to reinforce general modeling concepts
- demonstrated how complexity arises
- introduced what a Hybrid system is
- taught how to simulate Hybrid systems, reinforced usefulness of simulation

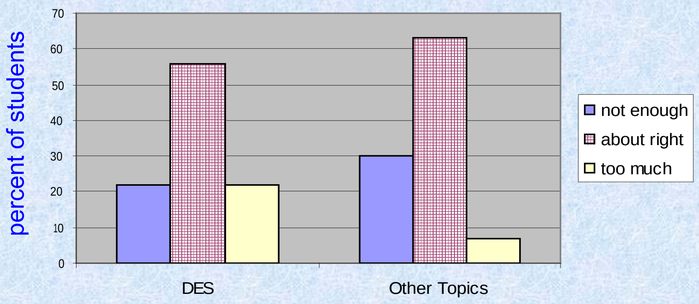
ASSESSMENT:

Assessment Overview

- 2 homework problems
- 1 exam problem
- End-of-course Survey

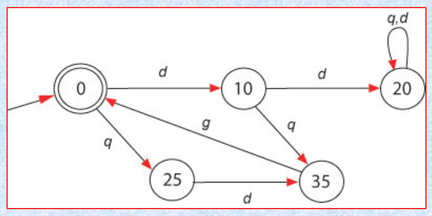
End-of-course survey

- was module useful?
- was module enjoyable?
- was enough/too much time spent on module?

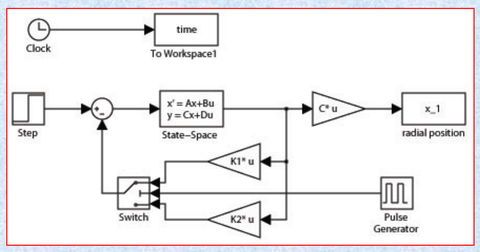


DES-type problem: 35¢ gumball machine

- event set: d = dime input
  q = quarter input
  g = gumball output
- each state represents how much money has been input



Hybrid-type problem: switching control



- possible questions
  - what happens when two dimes are input followed by a quarter?
  - what are some limitations of this design? (reaches a deadlock if 35 cents is not entered exactly, doesn't have logic for an input of 2 quarters, doesn't accept nickels, doesn't provide change)
  - design a new machine that improves upon this model
  - how many states are possible if two machines are working concurrently?
- have students design two controllers to place poles at specified locations
- simulate closed loop system switching between stable controllers with a prescribed frequency
- demonstrates switching between stable controllers does not guarantee stable operation

CONCLUSIONS :

- Students performed well on homework and exam problems
- Students achieve desired level of understanding
- Most students enjoyed the module and felt that it was valuable

FUTURE WORK :

- Design DES module for precursor system modeling course (ME 360)
- Design DES module for a graduate controls course
- Implement some concepts as part of a lab class

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