Lecture 9: Simulation

Engineering Design with Embedded Systems

Patrick Lam
University of Waterloo

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Examples of simulations

physics N-body simulation:
`http://www.youtube.com/watch?v=HUGjUvjtwS8`

aircraft:
`http://www.youtube.com/watch?v=JGyJqXJWkuY`

nuclear plant control room:
`http://www.youtube.com/watch?v=No5N6uYJaNk`

Basic Idea

A **simulation** evaluates a mathematical model of a system to estimate the behaviour of the system.

Why simulate?

It's never as good as the real thing. But:

(credit Spaceaero2, wikipedia)

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(credit Thermos, wikipedia)

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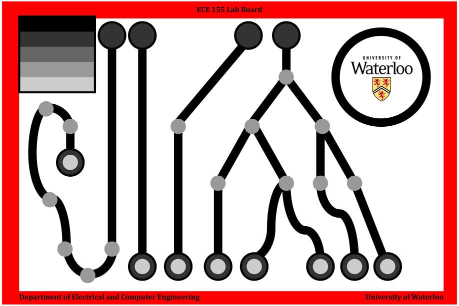
Case studies

Coarse Simulation

Create a set of classes:

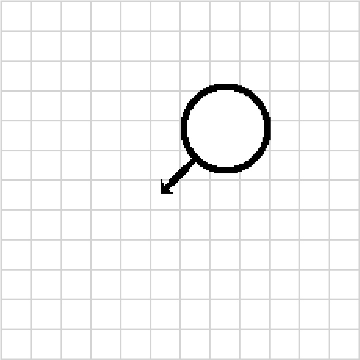
- class Board: says whether the class is black or white at a point.



Coarse Simulation

Create a set of classes:

- class Robot: simulates the position and velocity of the robot; contains main logic.



Coarse Simulation

Create a set of classes:

- class LightSensor: provides an interface between the `Robot` and the `Board`.

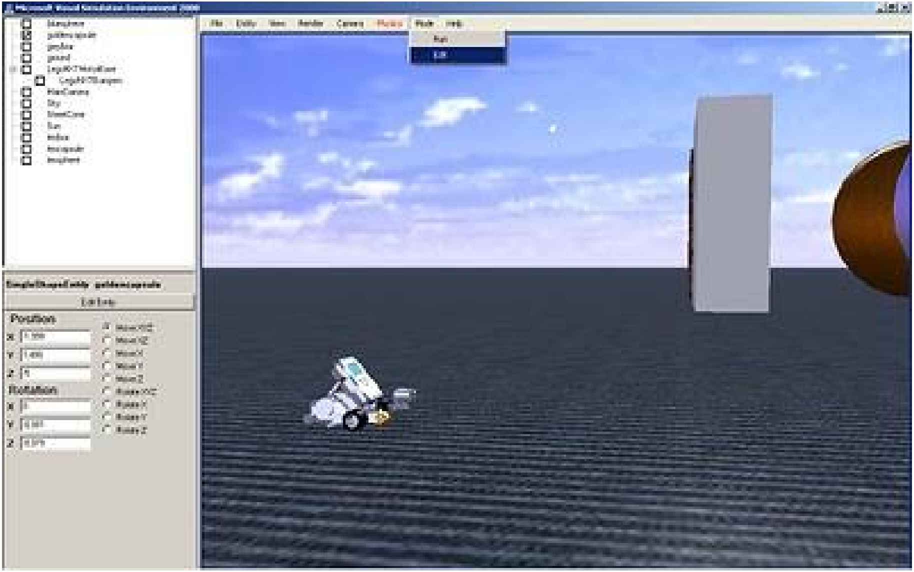
Coding the Coarse Simulation

You'd provide a main simulation driver, which calls the `Robot` to:

- update its position according to its velocity;
- turn the robot if necessary.

Each call to the `Robot`'s update simulates the effect of time moving forward by one time-step.

Detailed Simulation: Visual Simulation Environment

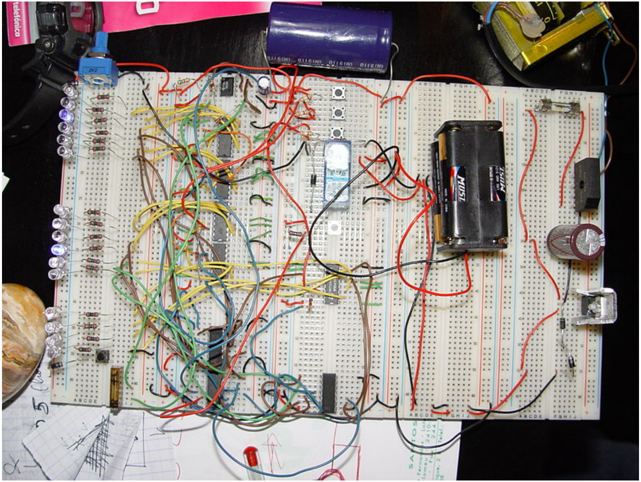


Implements physics. Calls your actual code.

Simulation Caveat

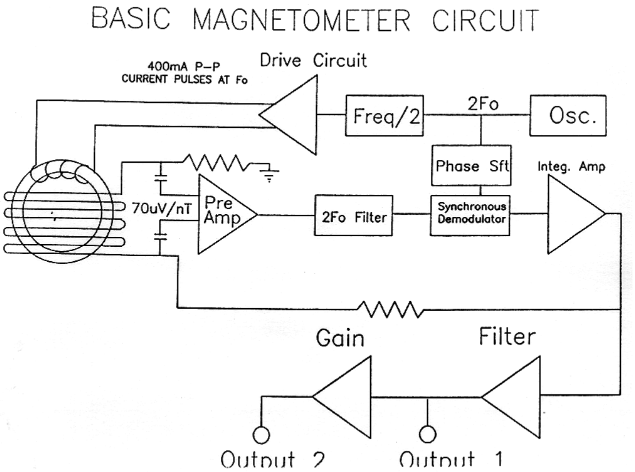
Paraphrased: “Everything worked fine in simulation, but needed lots more work in reality.”

Other Simulation Examples



Use discrete techniques: gates change values at specific times, in response to changing inputs.

Other Simulation Examples



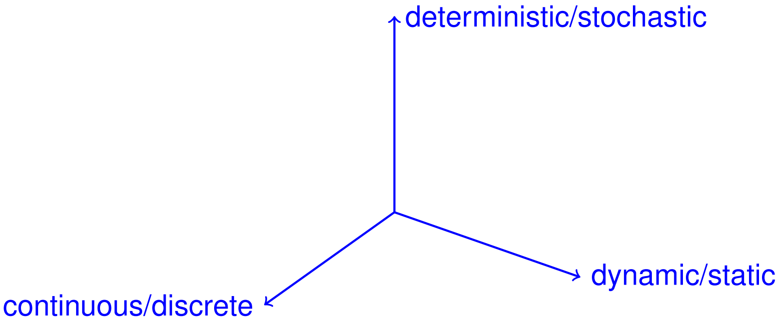
(credit: Russell et al, `http://www-ssc.igpp.ucla.edu/personnel/russell/papers/ggs-polar/`)

Analog circuit: continuous techniques.

Techniques for simulation

- Discrete: use an event queue.
- Continuous: numerically integrate an ordinary differential equation repeatedly (ECE204).

Classifying simulations: Three axes



Discrete versus Continuous

- Discrete: time steps ahead in increments (e.g. finite state machine)
- Continuous: evaluate at discrete times, but system has values at all times.

Dynamic versus Static

- Dynamic: system evolves over time; recomputes state.
- Static: one-shot deal (e.g. what-if simulations).

Deterministic versus Stochastic

- Deterministic: exactly computes state at every step
- Stochastic: uses randomness to guess expected behaviour (with high accuracy).

Simulation Tools

Some examples:

- *Microsoft Visual Simulation Environment*: MS robotics.
- *Arena*: businesses, services, and manufacturing processes.
- *Simulink*: time-varying systems, e.g. communications, controls, signal processing, video processing, and image processing.
- *SPICE* & variants: analog circuits.

Also: simulator-building languages.