Lecture 28 — Simulation

Patrick Lam & Jeff Zarnett
p.lam@ece.uwaterloo.ca & jzarnett@uwaterloo.ca

Department of Electrical and Computer Engineering
University of Waterloo

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Examples of simulations

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

aircraft:
`https://www.youtube.com/watch?v=L8JUWUKXV08`

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

Herbal Space Program:
`https://www.youtube.com/watch?v=bRgFuwG4nYg`

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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Models are Inherently Wrong

...essentially, all models are wrong, but some are useful.

George E. P. Box

Models are Inherently Wrong

Simulation is an abstraction and not as detailed as reality.

π has an infinite number of digits. After the first thousand digits, the error introduced by rounding is so small it has no relevance for architectural calculations.

How much is “enough” is a matter of engineering judgement.

Model Validity

Critical element: models have a range of validity.

This range must be respected if the model is useful.

Outside the range, the model is useless or misleading.

Model Validity Example: Physics

Newton's equations are valid at speeds below $0.1c$.
    Where c is the speed of light in a vacuum.

In that range, the error is small and can be ignored.

If you try to apply it at speeds of $0.5c$, your answer is wrong.

Instead, use Einstein's equations as the model.
    They have a different (larger) range of validity.

Key point: understand the model's limitations.

The Map and the Territory

The map is not the territory.

Alfred Korzybski

The Map and the Territory

Don't confuse the map (abstraction) and territory (reality).

The model can be helpful, but don't overdo it.

Don't spend all your time modelling or studying model output.

Also take time to understand the real challenges.

The Map and the Territory: Example

A literal example of the map and territory: Canada-US Border.

West of Ontario, the border drawn on most maps as being exactly the 49^{th} parallel.

This is, however, wrong.

The Map and the Territory: Example

Surveyors placed small monuments at discrete distances.

The border is legally the series of line segments connecting these monuments.

Given the level of technology available at the time of measurement, these are not in a perfectly straight line.

The Map and the Territory: Example

Even a map representing those is wrong.

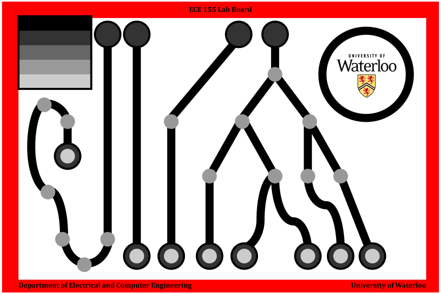
Shrinking thousands of kilometres of country down to centimetres will introduce error and inaccuracy.

How small can you print the dots marking the monuments?


ECE-NTX-02
NXT

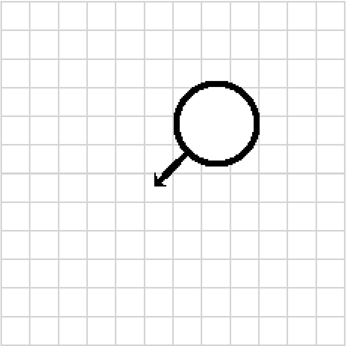
Create a set of classes:

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



Create a set of classes:

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



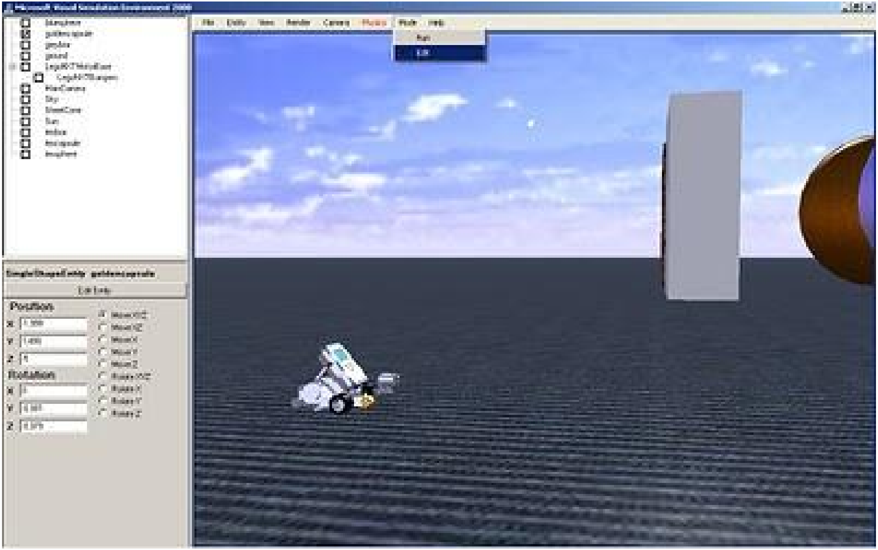
Create a set of classes:

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

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

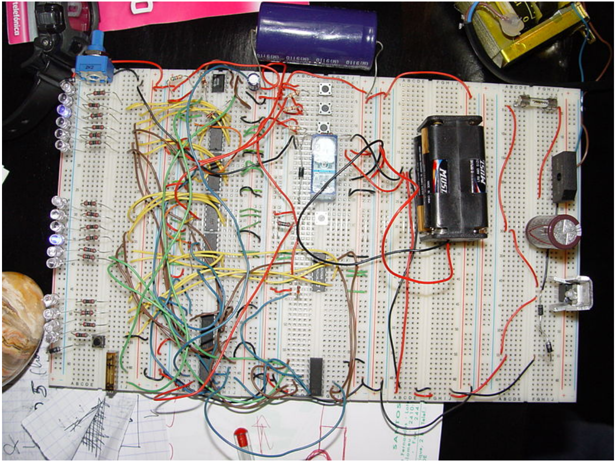
- update its position according to its velocity;
- turn the robot if necessary.

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

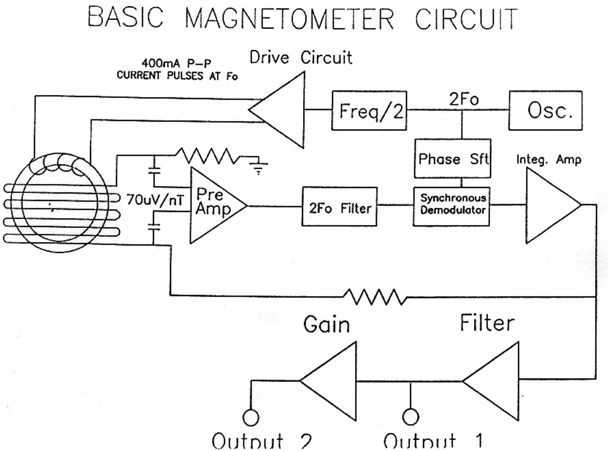


Implements physics. Calls your actual code.

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



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



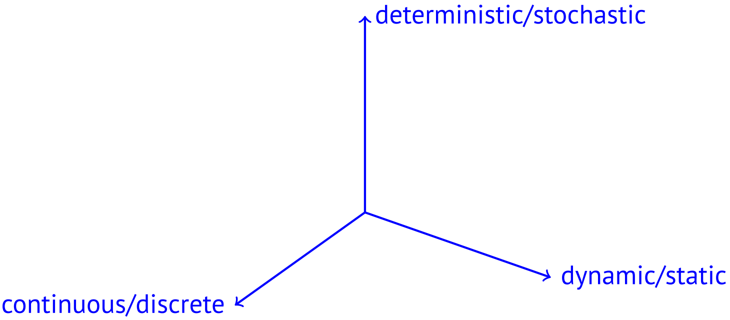
(credit: Russell et al, `http://www-ssc.igpp.ucla.edu/personnel/russell/papers/ggs-polar/`)

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

- 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).

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.