Homework #9 is due today.

Midterm 1: Wed, Feb 13, 7:45 pm – 8:55 pm.

Review: Tues, Feb 12, 6:30 pm in 2005 SM

Drop-in: Weds, Feb 13, 6:00 – 7:20 pm in 2005 SM

See handout for more information.
• What are predictable and non-predictable systems?
• How can feedback loops affect climate change?
• How are computer simulations used to determine the probability of occurrences?
Predictable and non-predictable systems

A system is a sequence of events and rules that define

- the possible events and
- any relationships between these events.

A **predictable system** has a strong relationship between events and is not sensitive to the choice of initial conditions.

An **unpredictable system** has a weak relationship between events and is sensitive to differences in the initial conditions.
Deterministic systems

- In a deterministic system, there is a well-defined relation between successive events.
- Each successive event may be determined from previous events.
- All systems in nature are deterministic.
- If we know all of the equations that govern the behavior of any system, the subsequent behavior of that system can be determined by previous events.
Sensitive systems and initial conditions

- A predictable system is not greatly affected by (is not sensitive to) the system’s initial conditions.

- An unpredictable system is sensitive to the initial conditions.

Therefore,

- The outcomes of a non-sensitive system are predictable.
- The outcomes of a sensitive system are not predictable.
Sensitive systems and the butterfly effect

- In sensitive systems, small changes to initial conditions can result in large differences in outcomes.

- Two similar sensitive systems that start off with very similar initial conditions can behave very differently after a short time.

- These systems may be predictable in the short term, but unpredictable in the long term.

- This is known as the butterfly effect or chaos.
Feedback loops

A feedback loop is a series of events that affects the same system of events in the future.

A **positive feedback loop** enhances the outcome of the initial series of events. Examples:

- When the stock market is rising, investors buy more stock and prices **rise further**.
- When the stock prices fall, some investors stop buying stocks, and prices **fall further**.

A **negative feedback loop** diminishes the outcome.

When the stock prices fall, some investors looking for a bargain buy more stock. This tends to stabilize stock prices and they fall at a slower rate.
A major cause of increased average temperatures is the addition of carbon dioxide and methane gas to the atmosphere.

A major source of carbon dioxide is combustion of fossil fuels.

A major source of methane is the decay of organic (plant and animal) materials.

Carbon dioxide is dissolved in sea water. Warmer water can hold less dissolved carbon dioxide than colder water.

How do these ideas produce feedback loops that further increase warming?
Computer simulations

- In the balloon release, the motion of each balloon was determined by the initial conditions of how you inflated and held the balloon.

- Your balloon’s motion may also have been affected by the motion of other nearby balloons.

- Such deterministic systems are complicated.

Complicated systems sensitive to initial conditions are well suited to computer simulations, especially for:

1) Quickly calculating the results when variable values change: weather forecasts or stock market projections

2) Dangerous or expensive activities: flight training, building design.
Limitations of computer simulations

- Computer simulations can only reflect reality to the extent that it is understood.
- The simulation may reflect the bias or opinions of those who wrote the computer program.
- Simulations may oversimplify reality.
- Simulations cannot predict the future.
Computer simulations and probabilities

To turn a simulation’s results into probable outcomes,

✓ A computer program is run many times with slightly different initial conditions.

✓ If the results form clusters, the clusters can be turned into probabilities.

✓ If a simulation gives a particular result 10% of the time, then that result has a 10% probability of occurring, according to this simulation.
Using probabilities

✓ Probabilities are useful for describing the outcome of complicated systems sensitive to initial conditions (chaotic systems)

✓ Such system may be predictable in the short term, but unpredictable in the long term.

✓ Weather forecasting is an example of such a system where the outcomes are too uncertain to discuss in other than probabilities, such as a 40% chance of rain tomorrow.
BEFORE THE NEXT CLASS…

✓ Read textbook chapter 11.
✓ Complete Homework Exercise 10.
✓ Print out Activity Sheet 11.

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