

Preview of Period 14: Sensitive Systems and Computer Modeling

14.1 Sensitive and Non-Sensitive Systems

What determines if a system is sensitive to its initial conditions?

Why can we predict the motion of some objects, but not others?

14.2 Probability and Sensitive Systems

How is the sensitivity of a system related to the probability of a particular outcome?

14.3 Computer Simulations

What are the advantages of computer simulations? What are their limitations?

14.4 Balance of the Planet

How are the variables that describe our planet interrelated? Is the Earth's environment is a sensitive or a non-sensitive system?

Predictable and Unpredictable Systems

What is the difference between a system that is predictable and one that is not predictable?

- ◆ A **predictable system** is one that is not greatly affected by (is not sensitive to) the choice of the system's initial conditions.
- ◆ An **unpredictable system's** behavior is sensitive to its initial conditions.
- ◆ The outcomes of a non-sensitive system are predictable. But the outcomes of a sensitive system are not predictable

Deterministic Systems

- A **system** is a sequence of events and a set of rules that define the events and any relation between these events.
- 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

- ◆ Some deterministic systems are inherently sensitive to the initial conditions of the event, such as the initial position or velocity of an object.
- ◆ 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.
- ◆ This is known as the butterfly effect.

Computer Simulations

Computer programs are useful for:

- 1) Simulating dangerous, expensive or impossible experiments without actually doing them. (Examples: flight training, building designs, or experiments involving stars).
- 2) Quickly calculating the results of changing the value of variables. (Examples: weather forecasts, stock market projections or "Balance of the Planet")

Limitations of Computer Simulations

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

What is Balance of the Planet?

- ◆ Balance of the Planet is a simulation developed in the mid 1980's when environmental concerns were becoming of far-reaching importance.
- ◆ The program shows the effects of environmental policies to the year 2035.
- ◆ It allows you to become acquainted with world energy questions and environmental consequences.
- ◆ The program has related some basic facts about the environment. Through many simplifications, it reduces the world's energy parameters and consequences to 150 variables.
- ◆ The 150 equations relating the variables are solved self-consistently each time the program advances the world 5 years.
- ◆ The program ends in the year 2035.

Playing Balance of the Planet

You will have an opportunity to implement policies to try to improve the condition of the Earth's environment and inhabitants.

- ◆ You can discourage practices you think are harmful to the planet (burning fossil fuels, using pesticides, etc) by taxing them.
- ◆ You can encourage practices you think are beneficial (solar energy, recycling centers, etc) using the revenue from your taxes to subsidize beneficial practices.
- ◆ After making changes to tax rates and subsidies, you execute your changes and the game advances five years into the future, showing you the effect of your policies.
- ◆ The simulation also provides factual information on environmental issues and the interactive nature of our environmental challenges - how one environmental issue may impact a related issue.

Quick Instructions for Balance of the Planet

(See the instruction sheet on your table for more detailed instructions.)

- 1) Press **R** to go to the **Results** screen. Use the arrow keys to highlight an aspect of life you wish to improve and press "return" for info.
- 2) Press **P** to go to the **Policy** screen. Change the tax or subsidy by highlighting an item and moving the slider bar.
- 3) When you have made all your changes, press **E** to **execute** your policies. The simulation advances 5 years into the future and shows you the results of your policies.
- 4) Select **feedback** on the results screen to see the effect of your changes.
- 5) After every 5 year period, the changes you made to taxes (left side of the policy screen) **are reset to the initial percentages**. But the changes you made to funding (right side of screen) carry forward until you change them.
- 6) It's not an easy game to win. (The Earth has serious problems.) Even a good plan may not show positive results for the first 15 years or more!

Computer Simulations and Probabilities

How could a simulation program such as Balance of the Planet be used to develop a series of probable outcomes?

- ◆ A computer program is run many times with slightly different initial conditions.
- ◆ If the results form clusters, you can turn those clusters into probabilities.
- ◆ Example: If a simulation gives a particular result 10% of the time, then that result has a 10% probability of occurring, according to this simulation.

Note: The outcome of a sensitive system (sometimes called a chaotic system) is too uncertain to discuss in other than probabilities, such as a 40% predicted chance of rain tomorrow.

Period 14 Summary

14.1 A **system** is a sequence of events and a set of rules that define the possible events and any relation between events.

In a **deterministic system**, there is a well-defined relation between successive events. Each successive event may be determined from previous events.

Some deterministic systems are **sensitive to the initial conditions** of the event.

In sensitive systems, small changes to initial conditions can result in large differences in outcomes. (**butterfly effect**)

The outcome of a sensitive system is too uncertain to discuss in other than **probabilities**.

14.2 Computer simulations can be used to develop a series of **probable outcomes**.

A program is run many times with slightly different initial conditions. If the results form clusters, you can turn those clusters into probabilities.

Example: If a simulation gives a particular result 10% of the time, then that result has a 10% probability of occurring, according to the simulation.

Period 14 Summary, Continued

14.3 Computer simulations can be used to simulate an event that is dangerous, expensive, or complicated involving many variables.

14.4 Balance of the Planet simulates the effects of various policies on the economic, social, and environmental welfare of the Earth.

Practices can be discouraged by taxing them and encouraged by subsidizing them.

Period 15 Review Questions

- R.1** What is a system? What is a deterministic system? Give some common examples of systems.
- R.2** What is a sensitive system? What could happen to the outcome of a sensitive system that experiences small changes in its initial conditions? What is this effect called?
- R.3** Is weather a deterministic or a random system? Why is it so difficult to accurately predict weather? In what terms are weather forecasts often discussed?
- R.4** In what circumstances are computer simulations useful? What are some of the limitations of computer simulations? What are some limitations of the Balance of the Planet simulation?
- R.5** In your opinion, is the Earth's environment a sensitive system in which changes to one variable may produce large effects in other variables?