Episode: "Bettor or Worse"

Original airing: September 30, 2005

Activity: Shifting Cells

Topic: Finding Patterns Using Cellular Automata
Objective: Introduce cellular automata

Introduction

Cellular automata are lists of rules, similar to computer programs. If the rules are geometric, then they ofte produce interesting patterns. Cellular automata are often shown as a collection of cells on a grid. The cell change each step according to a set of rules based on the states of neighbor cells. The rules are used repeatedly, each time making a potentially different pattern.
Cellular automata have been used to model populations of living organisms, among other things. If the cells represent small groups of living creatures, their survival is influenced by how many neighboring groups there are; overcrowding and isolation lead to death.

In **"Bettor or Worse,"** Charlie uses cellular automata to visualize a repeated message that is being changed each time it is sent. He is looking for patterns so that he can determine what the next coded message will look like.
NUMB3RS **Example** By figuring out the rules, Charlie can create the next message in the sequence. The first message, shown as a cellular automaton, is the following:

Charlie has discovered that the message is governed by the following rules:
• In the next step, a cell will be **alive** if **exactly one** of its immediate neighbors is currently **alive**. Alive cells are shaded.
• In the next step, a cell will be **dead** if **zero or two** of its immediate neighbors are currently **alive**. Dead cells are unshaded.

To make the next step in the life of this automaton, look at each cell starting with the cell on the far left. Note that the end cells have only one neighbor to consider.
So, the next step of this automaton will look like this:

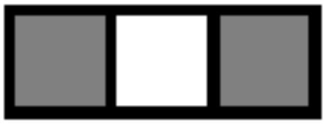
When working with cellular automata, it is sometimes necessary to work in both directions. That is, you may have the rules and create the next step, or you may have a series of steps and have to discover the rules.

Assignment: Shifting Cells

Consider simple cellular automata that follow the rules given below. Use the rules governing the automata to answer the questions.

- In the next generation, a cell will be alive if **exactly one** of its immediate neighbors is **currently alive**. Alive cells are shaded.
- In the next generation, a cell will be dead if **zero or two** of its current neighbors **are currently alive**. Dead cells are unshaded.

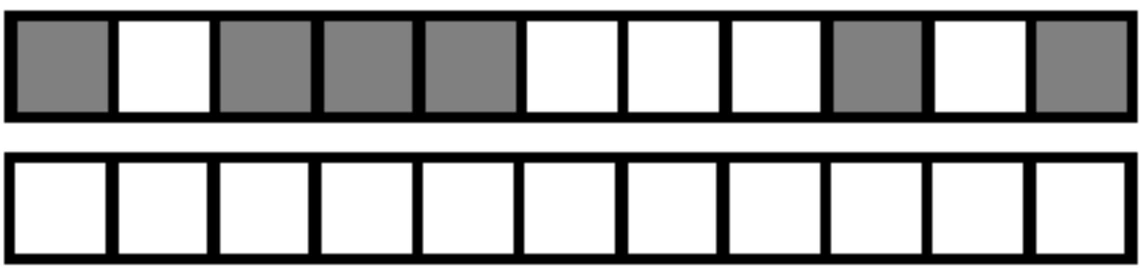
1. You are given the following three cells. Will the next generation of the middle cell be alive or dead? Why?



2. You are given the following three cells. Will the next generation of the middle cell be alive or dead? Why?

3. Does the fact that a cell is alive or dead in one step affect if it will be alive or dead in the next generation? Why or why not?

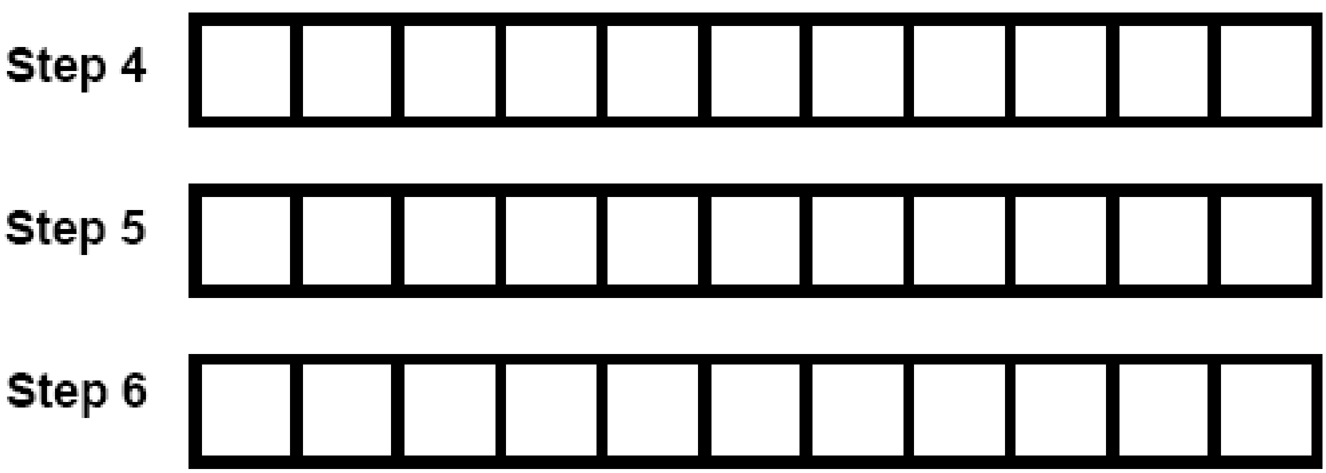
4. Using the rules given above and the cellular automaton below, fill in cells to represent the next generation in the life of this cellular automaton.



5. Below is a cellular automaton which follows a new, unknown set of rules. Find the new set of rules that governs the cellular automaton below.

- **a**. For this set of rules, a cell is alive if
- **b**. For this set of rules, a cell is dead if
- **c**. Explain how you found the rules for this automaton.

6. Now continue the process and fill in the next 3 steps where each step is based on the results of the previous step.



7. Does the pattern above have a predictable end? Explain your answer.

Extensions

Activity: Two-dimensional cellular automata & the Game of Life

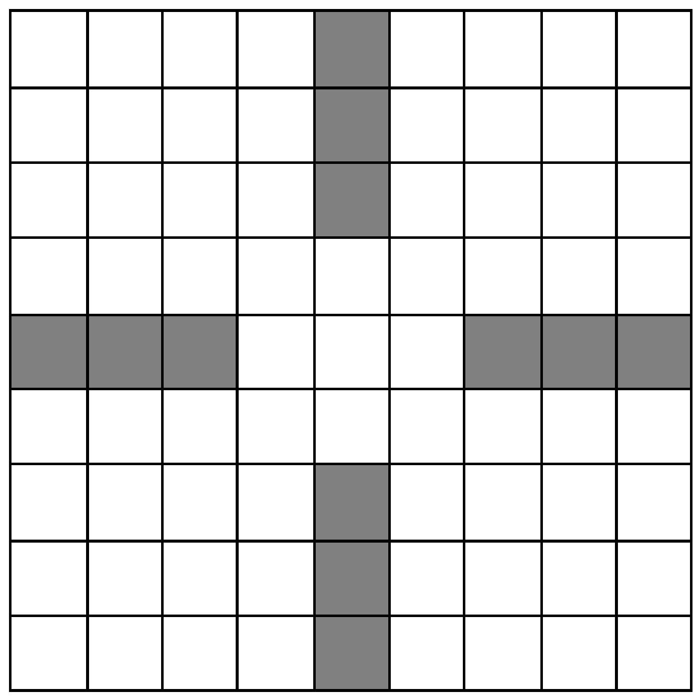
<u>Introduction</u>

Cellular automaton can come in different formats. In particular, the single line of cells can be expanded into the second dimension to become a grid of cells. One of the most common of these is referred to as the "Game of Life." In the game of life, a cell is affected by the cells surrounding it (including diagonals). Interior cells have 8 surrounding cells, corner cells have 3, and edge cells have 5. The rules are as follows:

- If the cell is currently living and it has 0 or 1 neighbor, the cell dies from loneliness.
- If the cell is currently living and it has 4 or more neighbors, the cell dies from overcrowding.
- If the cell is currently dead, it takes at least 3 neighbors for the cell to come to life.

<u>Assignment:</u>

- Make up an initial pattern on a grid. Then on a new set of grids, create the next iterations of the 2-D cellular automaton that you created by following the Game of Life rules. Watch for patterns.
- Create a new initial pattern that is symmetrical in shape. Find its next set of iterations by following the Game of Life rules. Does it follow a pattern?
- Use the pattern at right as your initial pattern for the Game of Life. What are its next 5 successive iterations? What is special about this? Can the pattern ever be broken? Explain.



<u>Additional Resources</u>

http://www.bitstorm.org/gameoflife/This site is an automated Game of Life. Students can watch as the game plays out over hundreds of generations.

http://mathworld.wolfram.com/ElementaryCellularAutomaton.html and
http://mathworld.wolfram.com/CellularAutomaton.html
These Wolfram Mathworld sites may be more appropriate for higher-level students who are looking for more information on Cellular Automaton. Stephen Wolfram has worked extensively in the area of cellular automaton, which is published primarily in his book *A New Kind of Science.*

http://www.rufenacht.com/CA/AnimalSim.htmlThis site makes the connection between cellular automaton and animal patterns, though with little formal mathematical explanation.

Related Topic: More on Cellular Automata

- Explore chaos and other mathematical topics that utilize cellular automata of one or two dimensions.
- Explore real-world applications of cellular automata, including land use, traffic flow, epidemiology, and biological growth.
- Experiment with creating rules for cellular automata that allow for more color options.