"BREAKOUT" IS A STUPID GAME.
Cellular Automata Simulator with Genetic Algorithms

C.A.S.G.A.

Presented by

Jeremy White
C.A.S.G.A.
Overview

• Brief Introduction
  – What is Cellular Automata?
  – What is Genetic Algorithms?

• Program features

• Applications of CASGA

• Future of the program
Cellular Automata (modified)

- State based decision making
- Every state results in an action
- Our states are based on 9 cell neighborhood
- $X = \text{Organism}$
- Example:

State: $21001022 = \text{Move Up}$
C.A. in CASGA

- 8 positions around the organism

Each position can take on 1 of 4 values.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>X</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

0 = space
1 = obstacle
2 = food
3 = another organism
Movments

- 1 of 9 possible movements associated with each state

### Movements:

<table>
<thead>
<tr>
<th>Movement</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up,</td>
<td>2</td>
</tr>
<tr>
<td>Up-Left,</td>
<td>1</td>
</tr>
<tr>
<td>Left,</td>
<td>8</td>
</tr>
<tr>
<td>Down-Left,</td>
<td>3</td>
</tr>
<tr>
<td>Down,</td>
<td>9</td>
</tr>
<tr>
<td>Down-Right,</td>
<td>7</td>
</tr>
<tr>
<td>Right,</td>
<td>4</td>
</tr>
<tr>
<td>Up-Right</td>
<td>5</td>
</tr>
<tr>
<td>No movement</td>
<td>6</td>
</tr>
</tbody>
</table>
State list/movement

• 4 possible values in 8 positions makes $4^8 = 65536$ states

• Each organism has a movement associated with each state

<table>
<thead>
<tr>
<th>State</th>
<th>Example Move</th>
</tr>
</thead>
<tbody>
<tr>
<td>000000000</td>
<td>(all space state, special case)</td>
</tr>
<tr>
<td>000000001</td>
<td>move down</td>
</tr>
<tr>
<td>000000002</td>
<td>move right</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>33333331</td>
<td>move left</td>
</tr>
<tr>
<td>33333332</td>
<td>move up</td>
</tr>
<tr>
<td>33333333</td>
<td>move up-left</td>
</tr>
</tbody>
</table>
All Space State Search Algorithm

- Executes movements in order of a search algorithm

Example search algorithm:

```
0 0 0
0 X 0
0 0 0
```

Up, Left, Down, Up, Down-Left, Up-Right,

- Search sequence loops when end is reached
Oh the Possibilities!

- 65535 states
- 1 of 9 possible values associated with each state
- \(9^{65535} = 1.918 \times 10^{62536}\) total possible organisms
- How many species exist on Earth?
- Estimates range from 5 to 100 million; science has only identified 2 million

- www.MSNBC.MSN.com
Finally...

Calculated using Big Number Calculator Applet available at

http://world.std.com/~reinhold/BigNumCalc.html
Great.... Now what?

- Let's find the best organisms, but how?
Great…. Now what?

- Lets find the best organisms, but how?

- **Solution**: Genetic Algorithms
Genetic Algorithms

• Evolution: How nature finds the best organisms

• Evolutinary/Genetic algorithms : mutation, cross over, selection, etc...
CASGA Genetic Algorithm

• CASGA uses mutation

• The top organisms (ones that collected the most food) are cloned to make the next generation.

• After cloning, N number of their states are mutated, where N is user-defined
Over the Long Run...

• Organisms that collect the most food will pass on their genes

• Run over many generations

• Results in best organisms passing on their genes and the rest dieing off
Program Features

1) Fine grain tweaking of simulation

2) Customizable simulation boards

3) Interfacing with Minitab (statistical software)
Fine grain tweaking of simulation

Main Menu

Settings Menu
Simulation Boards

- Boards can be user designed
- Easy to create in any bitmap editor (ms paint)
- Custom boards allow the user to further adapt the simulator to their needs

- Some examples:
  - AllFood.bmp
  - LineFollow.bmp
  - Maze.bmp
  - Egg.bmp
Interfaces with Minitab
Welcome to Minitab, press F1 for help.

Entering data from file: C:\DOCUMENTS AND SETTINGS\JOE\DESKTOP\WHITE_JEREMY_ASSIGN_3_FINAL\FULLTEST500.DAT
100 rows read.

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>C9</th>
<th>C10</th>
<th>C11</th>
<th>C12</th>
<th>C13</th>
<th>C14</th>
<th>C15</th>
<th>C16</th>
<th>C17</th>
<th>C18</th>
<th>C19</th>
<th>C20</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>14</td>
<td>20</td>
<td>16</td>
<td>600</td>
<td>31</td>
<td>10</td>
<td>13</td>
<td>15</td>
<td>500</td>
<td>13</td>
<td>600</td>
<td>16</td>
<td>29</td>
<td>23</td>
<td>500</td>
<td>19</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>419</td>
<td>5</td>
<td>20</td>
<td>2</td>
<td>500</td>
<td>16</td>
<td>7</td>
<td>39</td>
<td>38</td>
<td>4</td>
<td>13</td>
<td>8</td>
<td>500</td>
<td>500</td>
<td>3</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>10</td>
<td>5</td>
<td>22</td>
<td>500</td>
<td>7</td>
<td>12</td>
<td>10</td>
<td>18</td>
<td>500</td>
<td>19</td>
<td>7</td>
<td>500</td>
<td>24</td>
<td>46</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>3</td>
<td>39</td>
<td>412</td>
<td>500</td>
<td>500</td>
<td>14</td>
<td>11</td>
<td>22</td>
<td>22</td>
<td>7</td>
<td>500</td>
<td>9</td>
<td>12</td>
<td>500</td>
<td>302</td>
<td>13</td>
<td>21</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>42</td>
<td>600</td>
<td>34</td>
<td>11</td>
<td>5</td>
<td>498</td>
<td>500</td>
<td>5</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>16</td>
<td>500</td>
<td>43</td>
<td>8</td>
<td>39</td>
<td>379</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>500</td>
<td>4</td>
<td>500</td>
<td>29</td>
<td>13</td>
<td>21</td>
<td>25</td>
<td>17</td>
<td>500</td>
<td>4</td>
<td>40</td>
<td>14</td>
<td>3</td>
<td>9</td>
<td>13</td>
<td>29</td>
<td>32</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>14</td>
<td>7</td>
<td>3</td>
<td>21</td>
<td>600</td>
<td>497</td>
<td>500</td>
<td>500</td>
<td>25</td>
<td>29</td>
<td>17</td>
<td>500</td>
<td>650</td>
<td>10</td>
<td>499</td>
<td>600</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>21</td>
<td>16</td>
<td>31</td>
<td>6</td>
<td>25</td>
<td>500</td>
<td>4</td>
<td>500</td>
<td>14</td>
<td>22</td>
<td>500</td>
<td>2</td>
<td>500</td>
<td>650</td>
<td>5</td>
<td>12</td>
<td>27</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>193</td>
<td>11</td>
<td>3</td>
<td>28</td>
<td>23</td>
<td>500</td>
<td>11</td>
<td>22</td>
<td>9</td>
<td>26</td>
<td>500</td>
<td>1</td>
<td>3</td>
<td>500</td>
<td>24</td>
<td>8</td>
<td>10</td>
<td>302</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>4</td>
<td>32</td>
<td>23</td>
<td>16</td>
<td>500</td>
<td>8</td>
<td>31</td>
<td>31</td>
<td>26</td>
<td>16</td>
<td>29</td>
<td>500</td>
<td>500</td>
<td>55</td>
<td>32</td>
<td>4</td>
<td>9</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>
All Food Board

1000 Organisms; TimeSteps 1000; 5 champs; 25 simulations
Applications
(why we should care about this program)

• Study evolution by tweaking it

• Model biological systems: ants, bees, etc...

• Games – evolving opponents

• Study swarming behavior
Time Step Comparisons: AllFood board

- 10 Time Steps
- 100 Time Steps
- 1000 Time Steps
- 2000 Time Steps

Food Collected vs Time Steps
Future of CASGA

• More genetic algorithms added
  – Ex: cross over, multiple combinations, virus manipulation
• More attributes accessible from interface
• Multi-threaded to take advantage of multi-core processors
Thanks for listening

Simulator and presentation available for download at:

http://www-personal.umd.umich.edu/~jeremywl/CASGA.zip

You can contact me at jeremyWL@umd.umich.edu

Any Questions?