Creating new worlds inside the computer

2/15/2006

COS 116

Instructor: Sanjeev Arora

Recap: Pseudocode

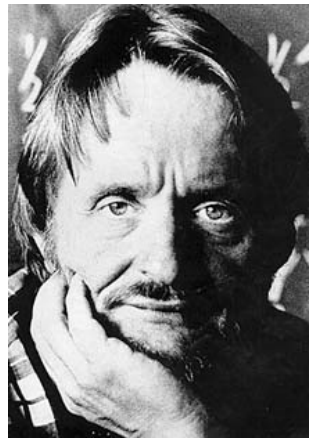
- Simple instructions: involve +, -, ×, ÷
- Compound instructions
  - Conditionals
  - Loops
- Exact syntax unimportant (unless it changes meaning of program !)

Algorithm

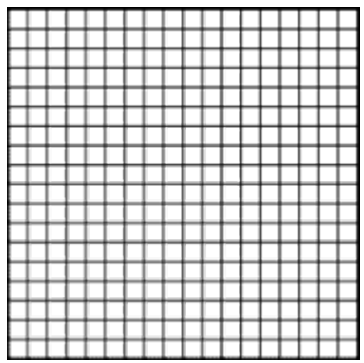
- Pseudocode for turning a set of inputs into outputs in a finite amount of time

- Questions to think about:
  - What class of computational tasks can be solved by algorithms?
  - How dependent is this class on the exact definition of pseudocode?

Conway's Game of life



- Rules: At each step, in each cell
  - Survival: Critter survives if it has exactly 2 or 3 neighbors
  - Death: Critter dies if it has 1 or fewer neighbors, or more than 3.
  - Birth: If cell was empty and has 3 critters as neighbors, new critter is born.



n x *n* array *A*
A[i, j] = 1 means critter lives in square, 0 means empty square

Pseudocode for each step

Do for i = 1 to n,
{Do for j = 1 to n
{
Num-of-neighbors $\leftarrow A[i-1, j-1] + A[i-1, j] + A[i-1, j+1] + A[i, j-1] + A[i, j+1] + A[i+1, j-1] + A[i+1, j] + A[i+1, j+1]$

if (Number-of-neighbors = 3) then
{ $B[i, j] \leftarrow 1$}
else {
if (Number-of-neighbors = 2)

etc. etc.//see handout//

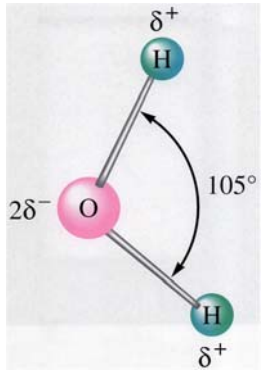
}
}
Do for i = 1 to n,
{Do for j = 1 to n
{A[i,j] $\leftarrow$B[i,j] }
}

Moral of the Game of Life?

- Simple local behavior can lead to complex global behavior

(cf. Brian Hayes article)

Physics of snow crystals



Water vapor

cooling

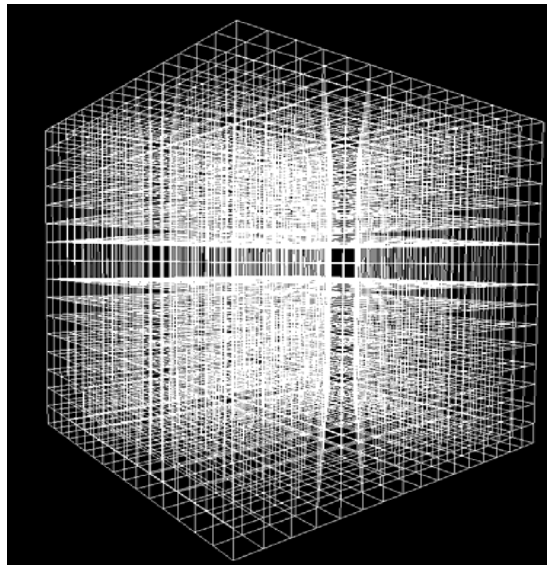
Water

further cooling

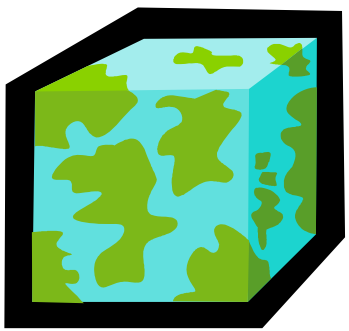
Snow crystals

- “Cooling” – reduce amount of molecular motion
- Crystal growth: capture of nearby floating molecules

Twister simulation



- Divide region into 3D grid
- Identify laws of physics for air



Navier Stokes equations:

How does a block of air move when certain pressure, temperature and velocity differentials exist on its boundary?

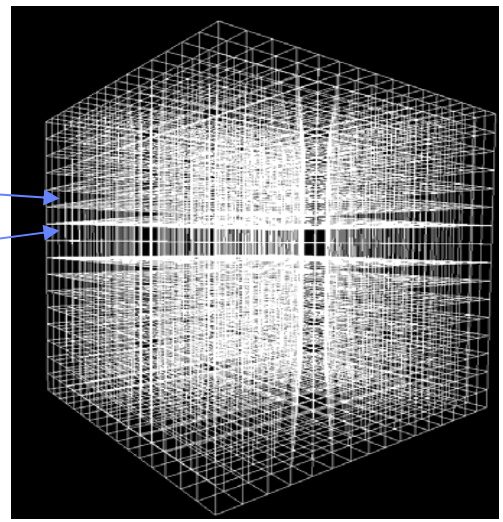
Simulator pseudocode

- Initialize Grid using data from observations: surface and aircraft measurements, radar (NEXRAD) readings, etc.

10ºC, 15 psi, 20% humidity

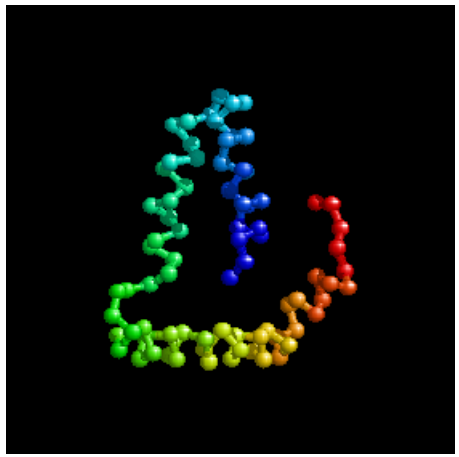
11ºC, 15 psi, 23% humidity

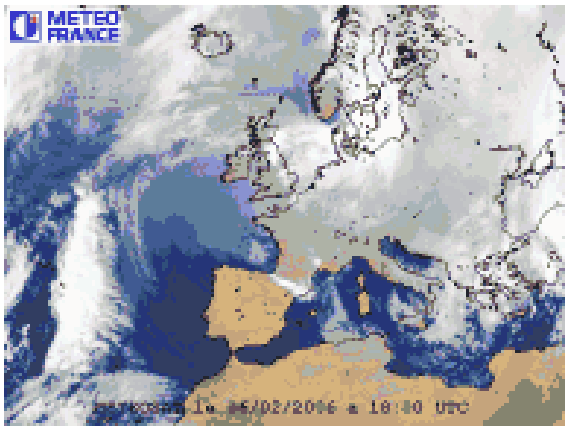
etc.



```
Do for i = 1 to n
{
    Do for j = 1 to n
    {
        Do for k = 1 to n
        { Update state of Grid[i, j, k] }
    }
}
```

Other examples of simulation





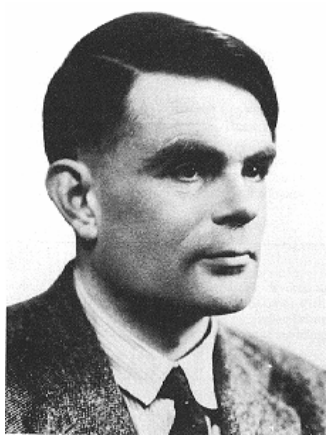
Question

- How does result of simulation get displayed?

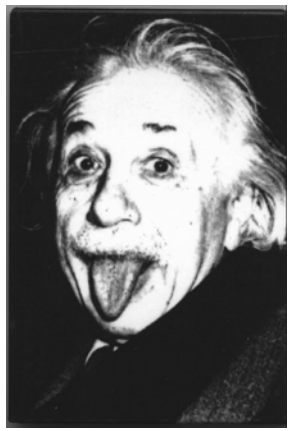
Computer graphics (will discuss in future lecture)

[Burns 05] (Princeton grad student)

Bigger questions



Alan Turing

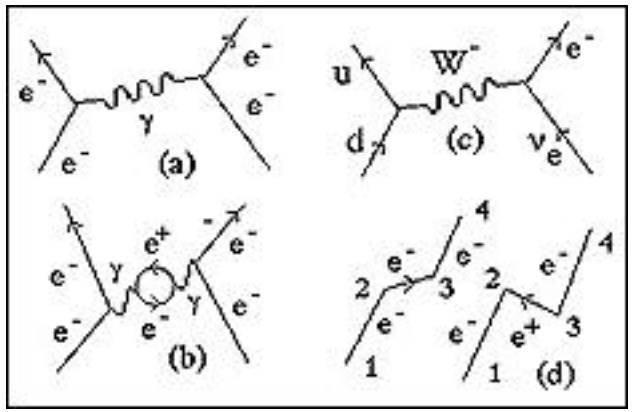


Albert Einstein

- Can computer simulation be replaced by a “theory of weather”? A “theory of tornadoes”?
- Is there a “theory” that answers following type of problem:
  - Given: A starting configuration in the game of life
  - Output: “Yes” if the cell at position (100, 100) is ever occuped, “No” otherwise

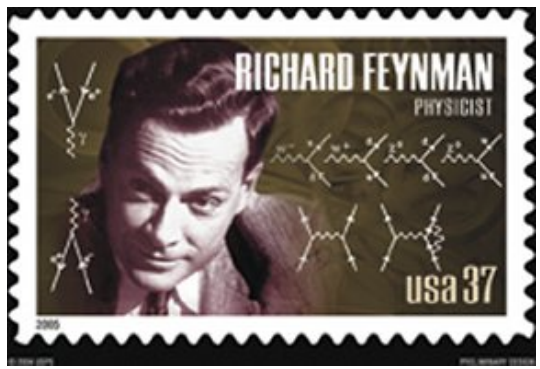
Actually, reverse trend: “theory of matter” (particle physics) is becoming computational.

1670 F = ma etc.



QED

Today



Hayes: The universe as a “cellular automaton”

Another startling fact:

Game of life is actually a “computer.”