Creating new worlds inside the computer

COS 116: 2/15/2007

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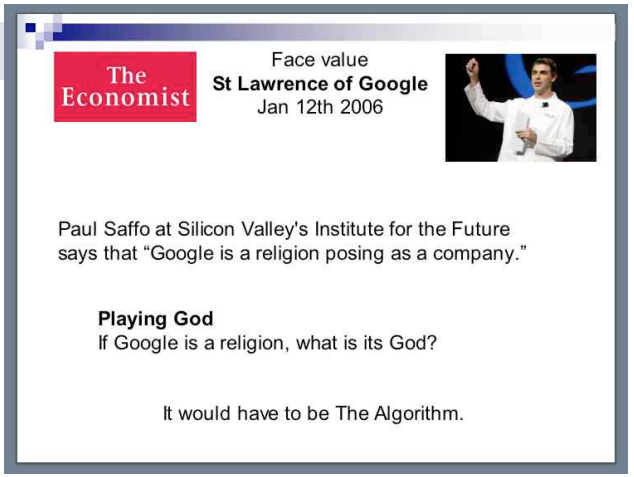
Pseudocode

- Simple instructions: involve +, -, ×, ÷
- Compound instructions
  - Conditionals
  - Loops

- Exact syntax unimportant
  (unless it changes meaning of program!)

Algorithm


The Economist

Face value
St Lawrence of Google
Jan 12th 2006

Paul Saffo at Silicon Valley's Institute for the Future says that "Google is a religion posing as a company."

Playing God
If Google is a religion, what is its God?

It would have to be The 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?

Clicker Question:

Did you read the Hayes article?

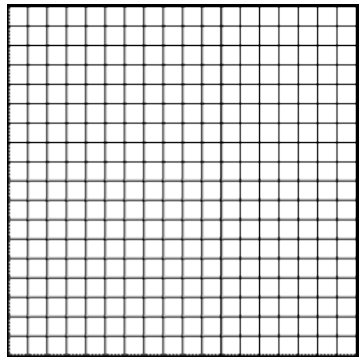
A=yes

B=no

Conway's Game of life

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

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



Pseudocode for each step

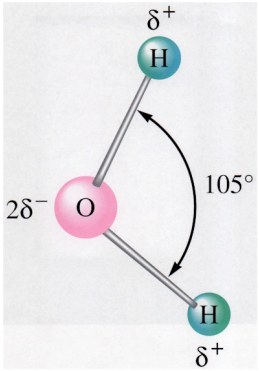
```
Do for i = 1 to n
{
    Do for  j = 1 to n
    {
        neighbors ← A[i – 1, j - 1] + A[i – 1, j] + A[i – 1,j + 1] +
                    A[i, j – 1] + A[i, j + 1] + A[i + 1, j – 1] +
                    A[i + 1, j] + A[i + 1, j + 1]
        if ( neighbors = 2 OR neighbors = 3 ) then
            { B[i, j] ← 1 }
        else if ( neighbors = 1 …)
            …etc. //see handout//
    }
}
Do for i = 1 to n
{
    Do for  j = 1 to n
        { A[i,j] ←B[i,j] }
}
```

Moral of the Game of Life?

- Simple local behavior can lead to complex global behavior

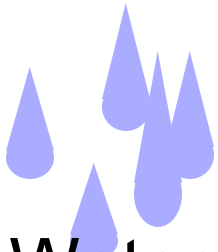
(cf. Brian Hayes article)

Physics of snow crystals



Water vapor

cooling



Water

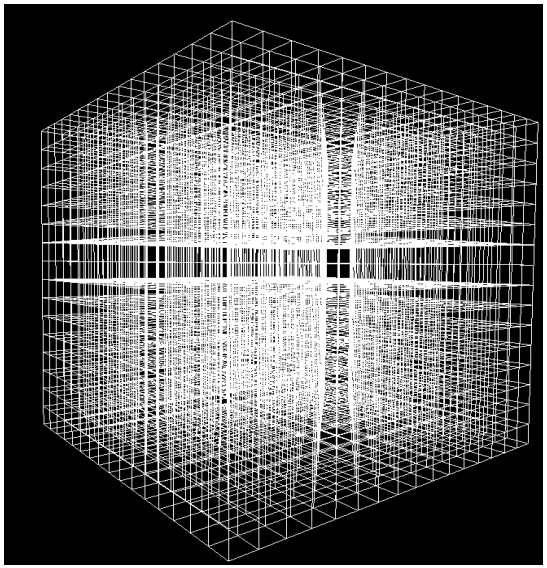
further cooling

Snow crystals

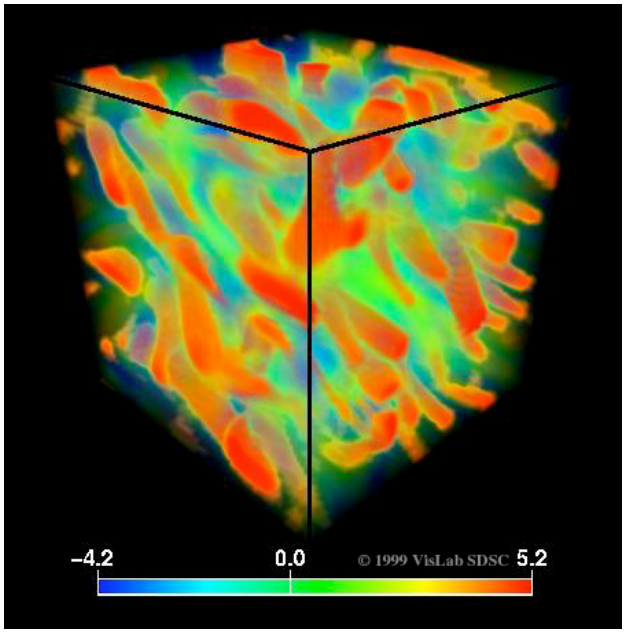
- “Cooling” – reduce amount of molecular motion
- Crystal growth: capture of nearby floating molecules

Movie

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?

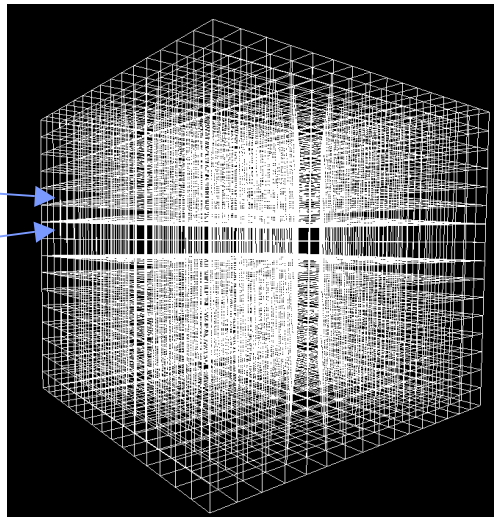
Simulator pseudocode

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

10ºC, 15 psi, 20% humidity

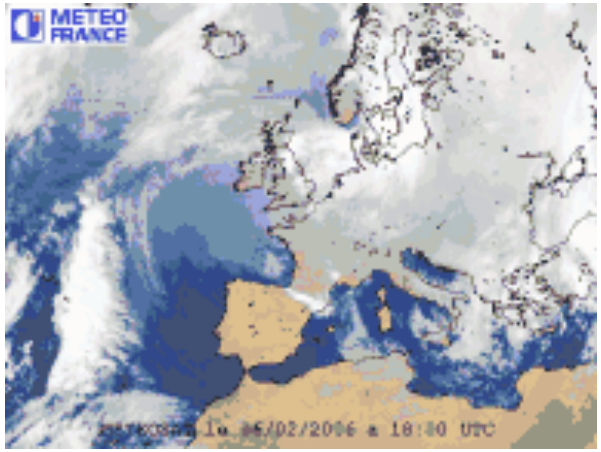
11ºC, 15 psi, 23% humidity

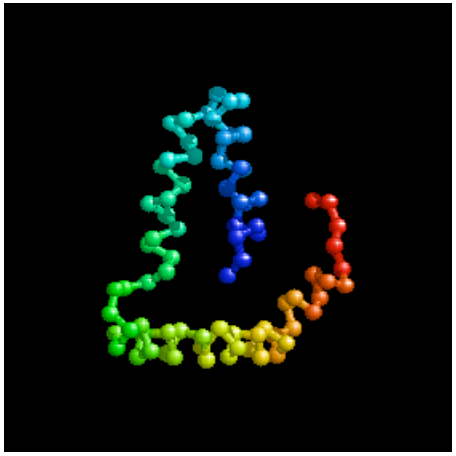
etc.

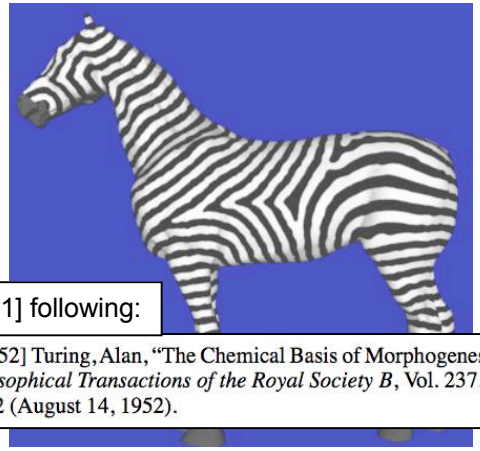


```
Do for i = 1 to n
{
    Do for j = 1 to n
    {
        Do for k = 1 to n
        { Update state of Grid[i, j, k] }
    }
}
```

Other examples of simulation

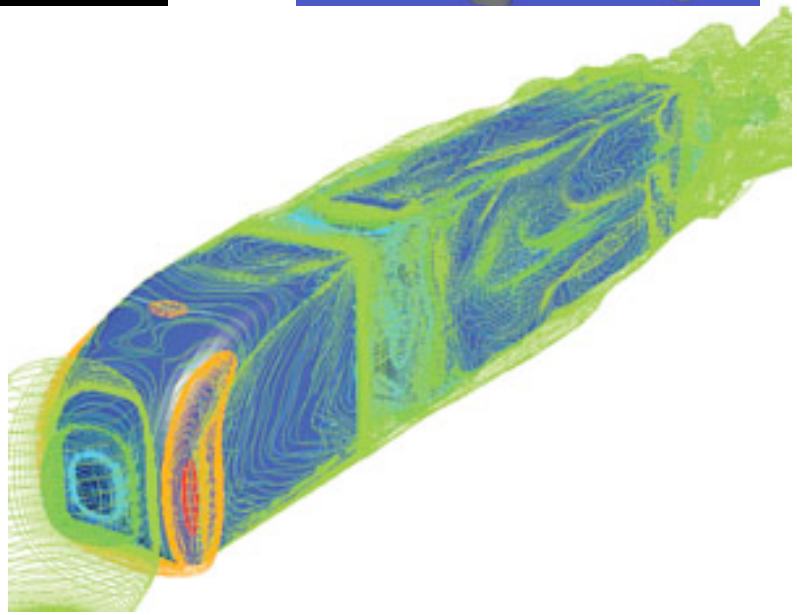






[Turk 91] following:

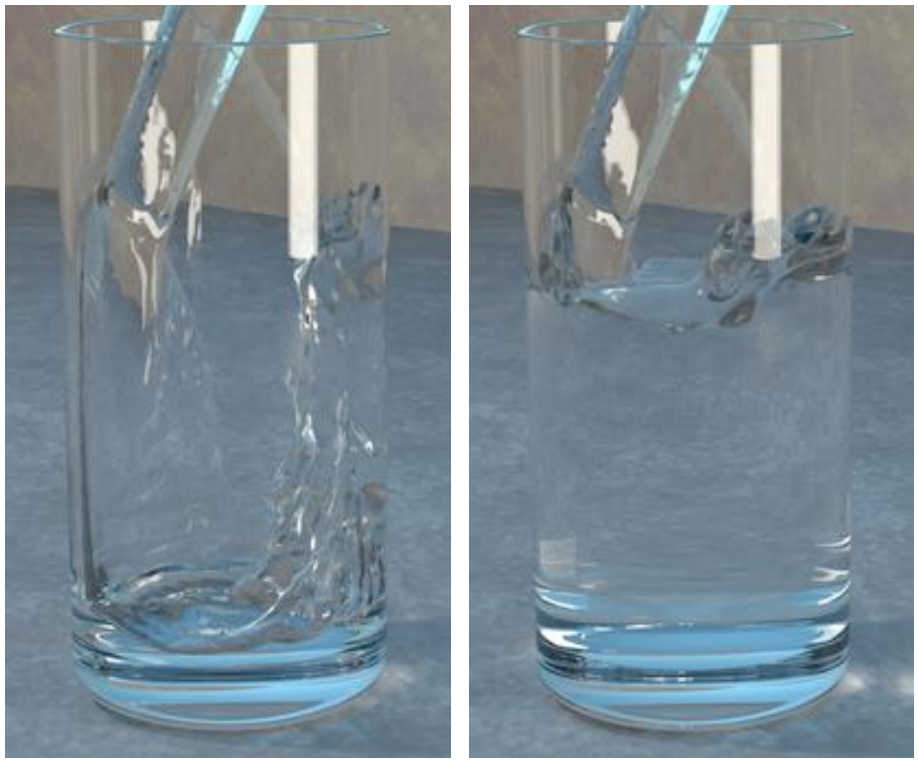
[Turing 52] Turing, Alan, "The Chemical Basis of Morphogenesis," *Philosophical Transactions of the Royal Society B*, Vol. 237, pp. 37–72 (August 14, 1952).



Display

Q: How to display result of simulation?

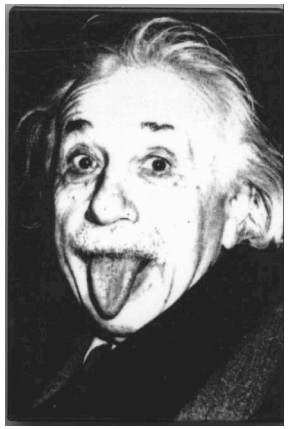
A: Computer graphics (later in course)



[Enright and Fedkiw 02]

Bigger questions

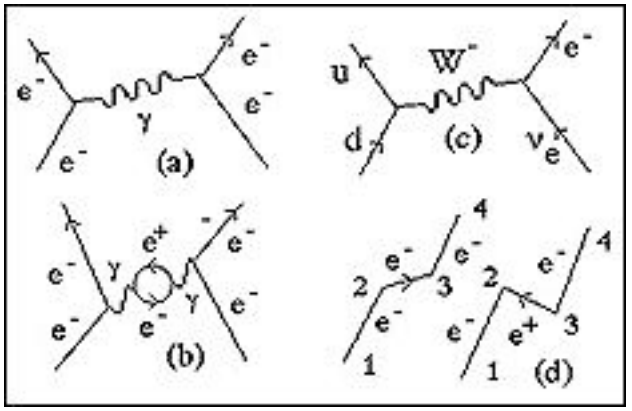
Alan Turing 

 Albert Einstein

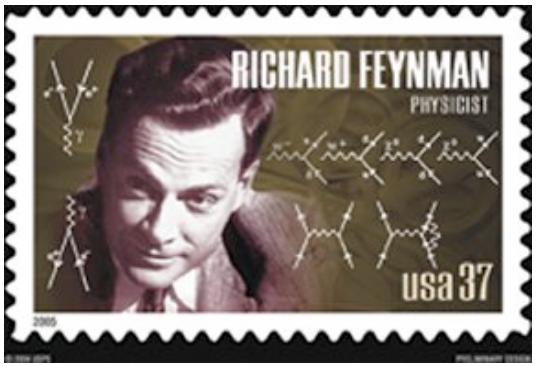
- Can computer simulation be replaced by a "theory of weather"? A "theory of tornadoes"?
- Is there a "theory" that answers this type of problem:
  - Given: A starting configuration in the game of life
  - Output: "Yes" if the cell at position (100, 100) is ever occupied, "No" otherwise

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

1670 F = ma



Today



Hayes: The universe as a “cellular automaton”

Another startling fact:

Game of life is actually a “computer.”