UNIT 12A
Simulation: Basics, Example
Simulation

• The imitative representation of the functioning of one system or process by means of the functioning of another [e. g., a computer program]. (Merriam Webster)

• In what contexts do we use simulation?
  – Performance optimization, safety engineering, testing of new technologies
  – Providing lifelike experiences in training, education, games
  – Gaining a better understanding of natural and human systems
This Lecture

- Simulation as an enabler for computational science
- Thought process that goes into developing simulations
Modeling

• The act of simulating something requires that a model be developed first.

• The model represents the system itself, whereas the simulation represents the operation of the system over time.
Computational Models

• Physical models: small-replicas
  – May not exist, may be unsafe to work with, expensive to build and modify.
  – Some change too slowly over time.

• Computational models deal with these issues better.

• Computational sciences use computational models as the basis of obtaining scientific knowledge.
Computational Science

• Unifies
  – Modeling, algorithms, simulations
  – Computing environment developed to solve science, engineering, medicine, and humanities problems

• Helps explain and predict phenomena using a mechanistic view
Abstraction

- In building models a major issue is to achieve a certain level of accuracy while keeping the complexity manageable
  - Identify factors that are the most relevant to the functioning of the system.
Stochastic Components

• Parts of the system may be stochastic (may exhibit random behavior).
  – Use statistical approximations
Large Scale Simulations

• Computing power of today enables large scale simulations. For example,
  – Department of Defense: Battle simulations
  – National Center for Atmospheric Research: 1,000 year of climactic changes
  – Blue Brain Project at EPFL to reverse engineer the human brain

http://www.youtube.com/watch?v=ySgmZOTkQA8
A Breakthrough in Computational Biology

A whole-cell computational model for Mycoplasma genitalium (the fewest number of genes any living organism has) by Jonathan Karr at Stanford 2012

www.stanford.edu/~jkarr/wholecell-news.html
Example from Public Health Domain

• Use of modeling and simulation for disease spread

https://www.youtube.com/watch?v=nZxXqWM8nP4
Example from Public Health Domain

• Texas Pandemic Flu Toolkit

https://www.youtube.com/watch?v=0Q7zBk-PpRc
Example: Flu Virus Simulation

• Goal: Develop a simple graphical simulation that shows how disease spreads through a population.
Model Assumptions

• A person starts off as healthy.
• Each day, a healthy person comes in contact with 4 random people. If any of those random people is contagious, then the healthy person becomes infected.
• It takes one day for the infected person to become contagious.
• After a person has been contagious for 4 days, then the person is non-contagious and cannot spread the virus nor can the person get the virus again due to immunity.
Data Abstractions

• Population
• Person
• Health state of a person
Displaying the Population

(0,0) +x

+y

200 pixels
Displaying One Person

(row, col)
(0,0)

(row * 10 + 10, col * 10 + 10)
(10, 10)
Health States

0  white  healthy
1  pink  infected
2  red  contagious (day 1)
3  red  contagious (day 2)
4  red  contagious (day 3)
5  red  contagious (day 4)
6  purple  immune (non-contagious)
Display of 400 people

(0,0) +x +y

200 pixels

200 pixels

200 pixels
Graphical Simulation
Displaying the matrix

def display(matrix)
    for row in 0..matrix.length-1 do
        for col in 0..matrix[row].length-1 do
            person = matrix[row][col]
            if person == 0       #healthy
                color = "white"
            elsif person == 1    #infected
                color = "pink"
            elsif person >= 2 and person <= 5   #contagious
                color = "red"
            else  #non-contagious or wrong input
                color = "purple"
            end
            Canvas::Rectangle.new(col*10, row*10, col*10+10, row*10+10,
                                    :fill => color, :outline => "black")
        end
    end
end
def test_display()
    # create a canvas of size 200 x 200
    Canvas.init(200, 200, "Testing_Display")
    # initialize matrix a randomly
    a = Array.new(20)
    for i in 0..19 do
        a[i] = Array.new(20)
        for j in 0..19 do
            a[i][j] = rand(7)
        end
    end
    # display the matrix using your display function
    # display(a)
end
Checking Health State

def immune?(matrix, i, j)
    if matrix[i][j] == 6 then
        return true
    else
        return false
    end
end

def contagious?(matrix, i, j)
    if matrix[i][j] >= 2 and matrix[i][j] <= 5 then
        return true
    else
        return false
    end
end

def infected?(matrix, i, j)
    if matrix[i][j] == 1 then
        return true
    else
        return false
    end
end

def healthy?(matrix, i, j)
    if matrix[i][j] == 0 then
        return true
    else
        return false
    end
end
Updating the matrix

def update(matrix):
    # create new matrix, initialized to all zeroes
    newmatrix = Array.new(20)
    for i in 0..19 do
        newmatrix[i] = Array.new(20)
        for j in 0..19 do
            newmatrix[i][j] = 0
        end
    end
end
#create next day

    for i in 0..19 do
        for j in 0..19 do
            if immune?(matrix, i, j)
                newmatrix[i][j] = 6
            elsif infected?(matrix, i, j) or contagious?(matrix, i, j)
                newmatrix[i][j] = matrix[i][j] + 1
            elsif healthy?(matrix, i, j)
                for k in 1..4 do          # repeat 4 times
                    if contagious?(matrix, rand(20), rand(20)) then
                        newmatrix[i][j] = 1
                    end
                end
            end
        end
    end
    return newmatrix
end
def test_update():
    # create a canvas of size 200 X 200
    Canvas.init(200, 200, "Testing_Update")
    # initialize matrix a to all healthy individuals
    a = Array.new(20)
    for i in 0..19:
        a[i] = Array.new(20)
        for j in 0..19:
            a[i][j] = 0
    end
    # infect one random person
    a[rand(20)][rand(20)] = 1
    display(a)
    sleep(2)
    # run the simulation for 10 "days"
    for day in 1..10:
        a = update(a)
        display(a)
        sleep(2)
    end
end
What if Our Model Changes?

• If a healthy person contacts a contagious person, she gets sick 40% of the time.

```python
if contagious?(matrix, rand(20), rand(20))
    and rand(100) < 40 then
    newmatrix[i][j] = 1
end
```
What if Our Model Changes?

• If a healthy person has at least one contagious neighbor.
Neighbors

cell = matrix[i][j]

north = matrix[i-1][j]  NO!

if i == 0 then  YES!
    north = nil
else
    north = matrix[i-1][j]