Cellular Automata and Game of Life : Viral Infection

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May 2020

Definition of Cellular Automaton

❖ **Definition : What is cellular automaton?**

Lattice of cells

Set of allowable states

Transition function

→

Cellular Automaton

A Special Case: Game of Life

- **The rules for the Game of Life**

  Proposition: 1 = alive, 0 = dead ; 8-cell Moore neighborhood

  At the Next Generation

  - dead to alive :

    if exactly 3 of its 8 neighbors are alive;

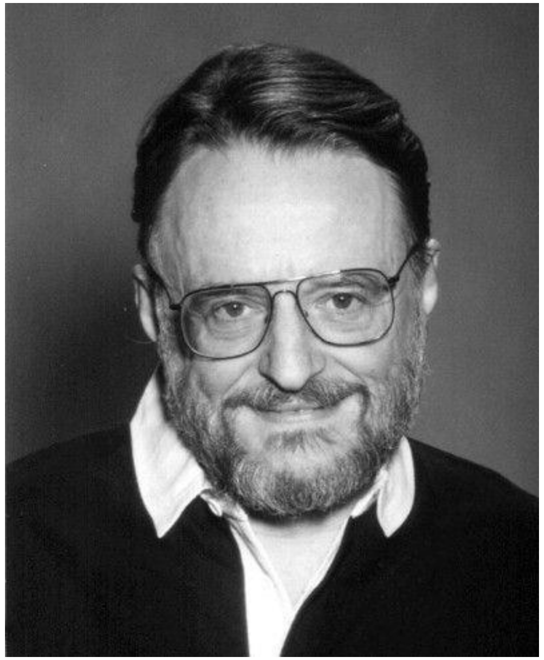
  - live remains alive

    if either 2 or 3 of its 8 neighbors is alive but otherwise it dies.

Game of Life and Viral infection

The Creator :
John Horton Conway

Die of COVID-19



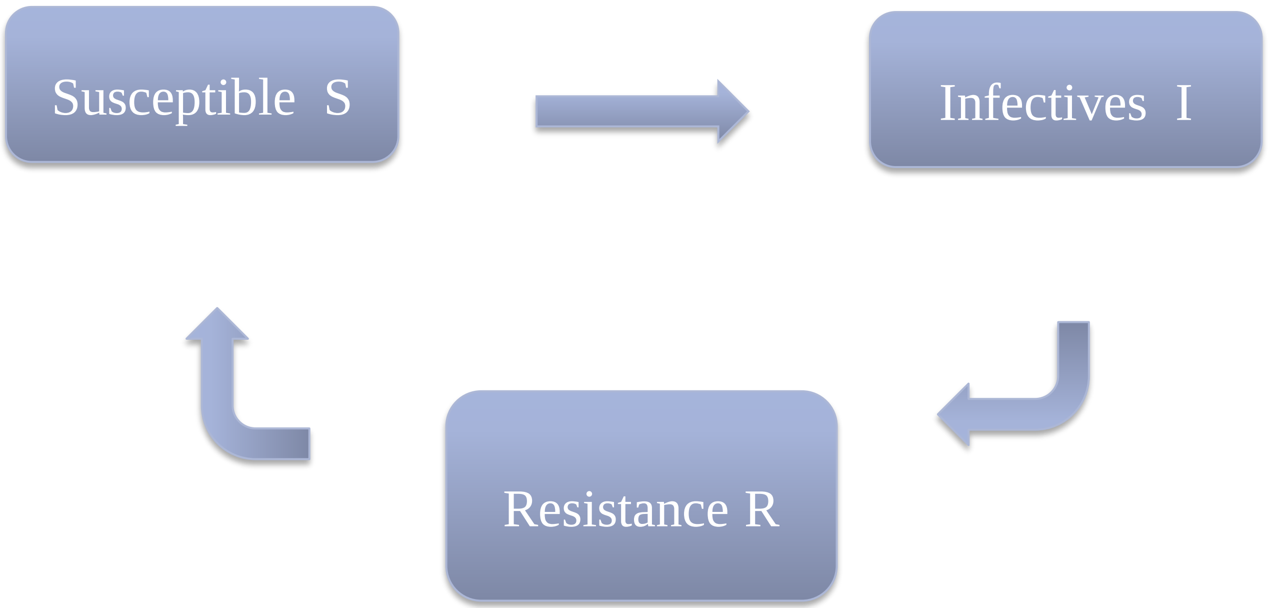
Model Specification

- *A=(Ld, S, N, f)*

  - *A= Cellular Automaton system*
  - *Ld = d dimension grid space, d=2*
  - *S =state set*
  - *N = neighbors set*
  - *f =transition function*

Model: 3 Different States in Viral Infection

- **How do we get sick?**



Pi:感染
死亡
治愈
变异
再感染

Ti:感染
免疫

Model: Neighbors Set

(i-1, j-1)	*(i-1, j)*	*(i-1, j+1)*
(i, j-1)	***(i, j)***	*(i, j+1)*
(i+1, j-1)	*(i+1, j)*	*(i+1, j+1)*

Moore Neighbor r=1 3x3

r=2 5x5

Model: State Set

- $S_{i,j}^{t} = \{0,1,2\}$

  0 = susceptible , can not infected others but can be infected

  1 = infected, can infected others, create antibody eventually cured with time

  2 = cured or dead, can not infected others and immunity decreases with time

- Introduce $t(S_{i,j}^{t})$, $T(S_{i,j}^{t})$, $p(S_{i,j}^{t})$.

  $t(S_{i,j}^{t})$ =Duration of infected, $t_{max}(S_{i,j}^{t})$ =maximum of $t(S_{i,j}^{t})$

  $T(S_{i,j}^{t})$= Duration of immunity. $T_{max}(S_{i,j}^{t})$ =maximum of $T(S_{i,j}^{t})$

  $p(S_{i,j}^{t})$= probability of being infected

Model: Transition function

- Original state

$$S_{i,j}^{t} = \{0\}, \quad t(S_{i,j}^{t}) = 0, \quad \forall\, i,j$$

- Randomly choose several cell, let

$$S_{i,j}^{t} = \{1\}, \qquad t(S_{i,j}^{t}) = 1$$

Model: Transition function

- $S_{i,j}^{t} = 0$

If $\quad p(S_{i,j}^{t}) > 0.8,\ $ and $\ \sum_{i-1}^{i+1}\sum_{j-1}^{j+1} S_{i,j}^{t} > 0$

then let

$$S_{i,j}^{t} = 0 \quad \rightarrow \quad S_{i,j}^{t} = 1$$

$$t(S_{i,j}^{t}) = t(S_{i,j}^{t}) + 1$$

- **Where**

$p(S_{i,j}^{t}) =$ Random（0,1）

Model: Transition function

- $S_{i,j}^{t} = \{1\}$,

If $t(S_{i,j}^{t}) < t_{max}(S_{i,j}^{t})$, remain infected

$$t(S_{i,j}^{t}) = t(S_{i,j}^{t}) + 1$$

if $t(S_{i,j}^{t}) > t_{max}(S_{i,j}^{t})$,

Then let $S_{i,j}^{t} = 1 \rightarrow S_{i,j}^{t} = 2$

$$t(S_{i,j}^{t}) = 0, \quad T(S_{i,j}^{t}) = T(S_{i,j}^{t}) + 1$$

Results and development

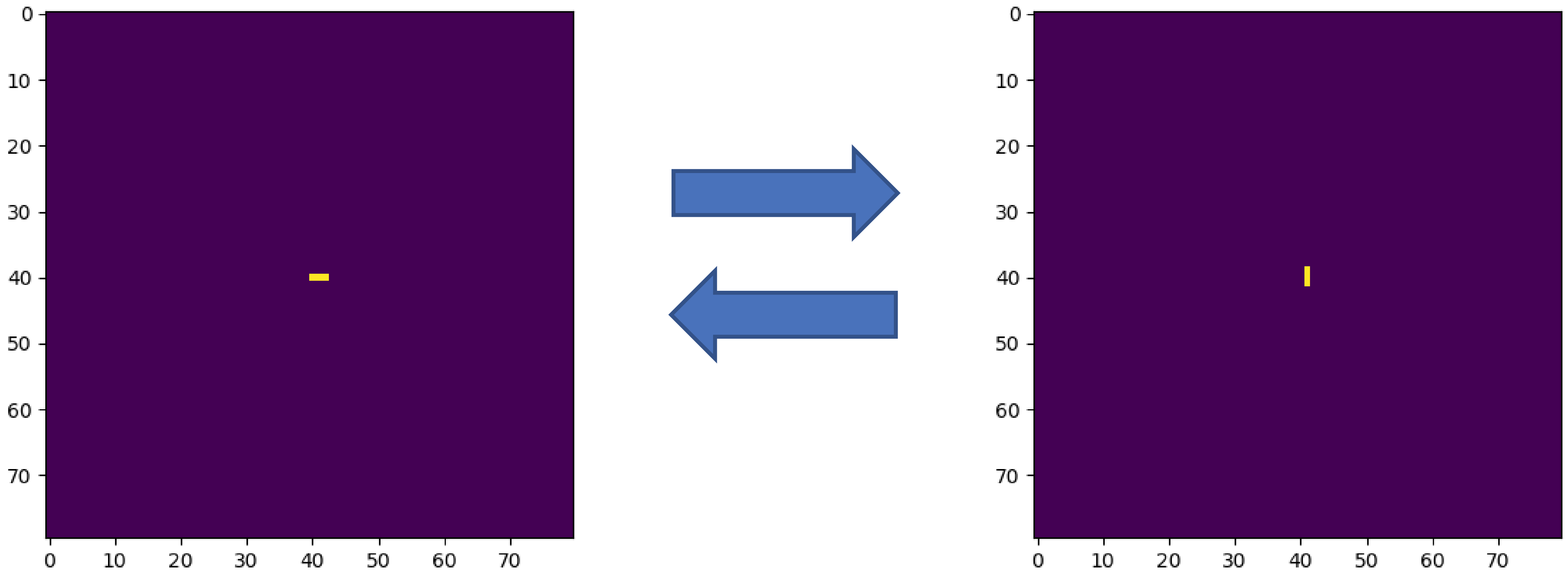
Step1: Run the original model

Step2: Introduce government control

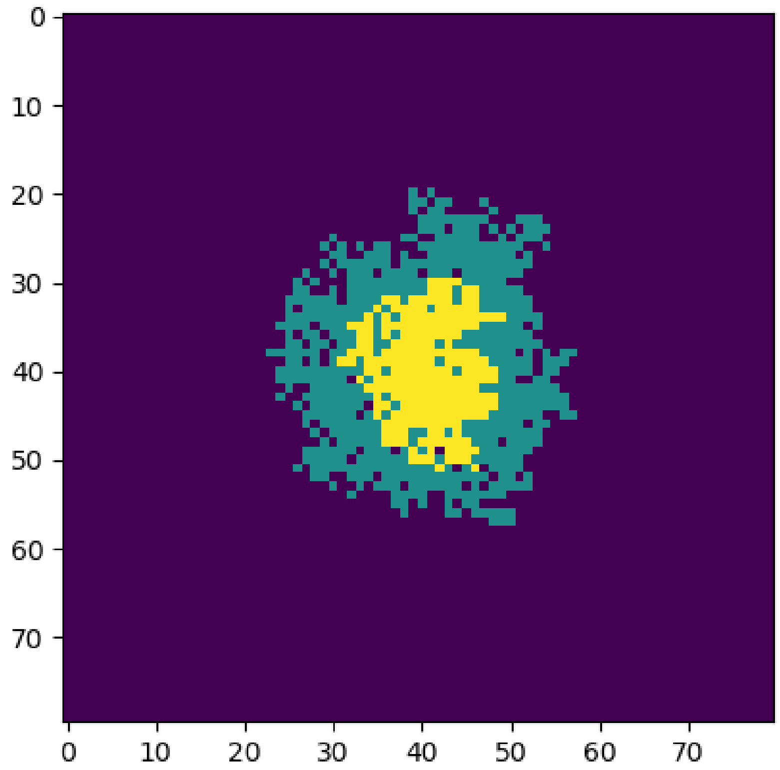
Step3: Introduce virus mutation

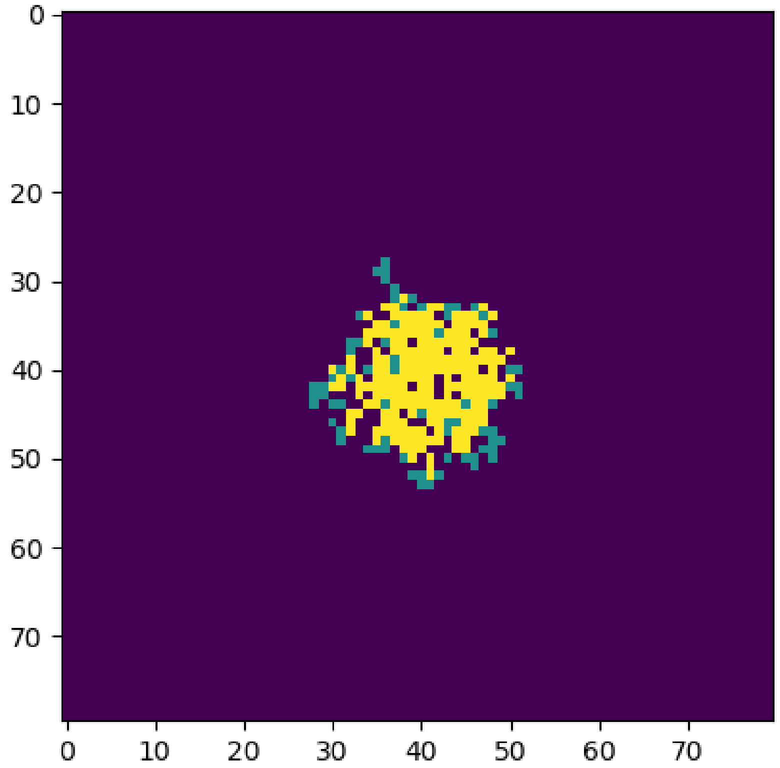
Step4: Introduce health care

Results 1: Original model(∞)



Results 2: Government Control(30days)

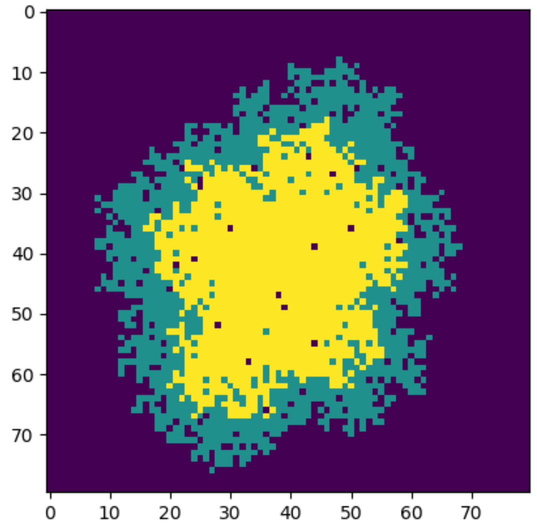




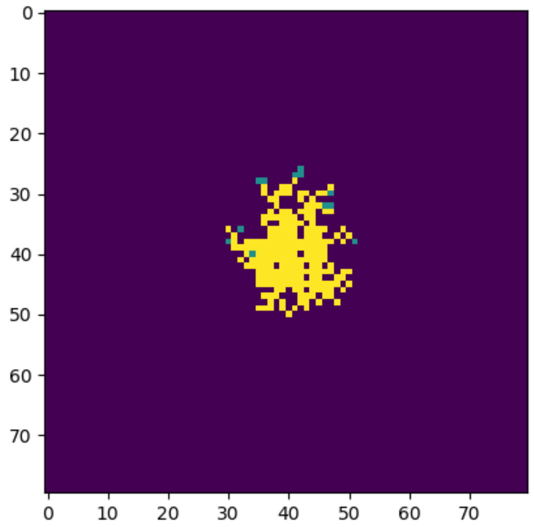
Infected: 554 Dead: 220 Survivor: 5626

Infected: 71 Dead: 198 Survivor: 6131

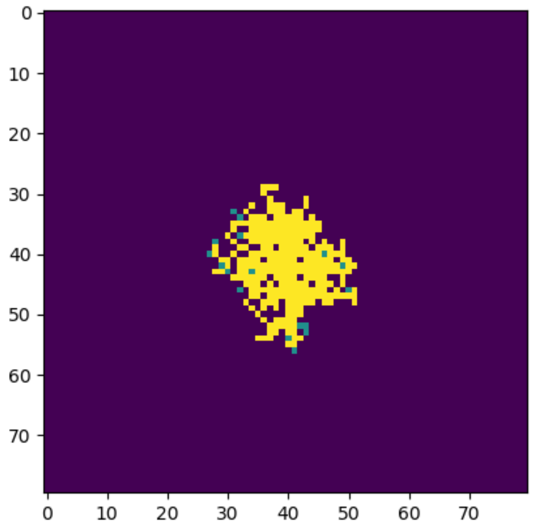
Results 3: Virus Mutation(50 days)



Infected: 1272
Dead: 1259
Survivor: 3869

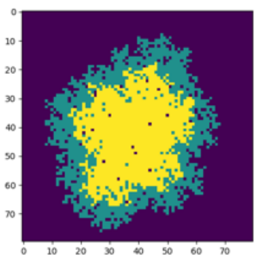


Infected: 12
Dead: 208
Survivor: 6180

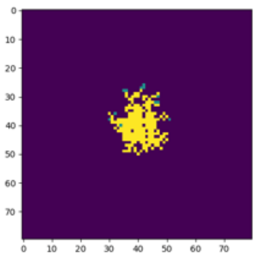


Infected: 17
Dead: 272
Survivor: 6111

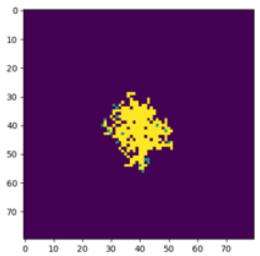
Results 4: Health Care(50 days)



Infected: 1272
Dead: 1259
Survivor: 3869

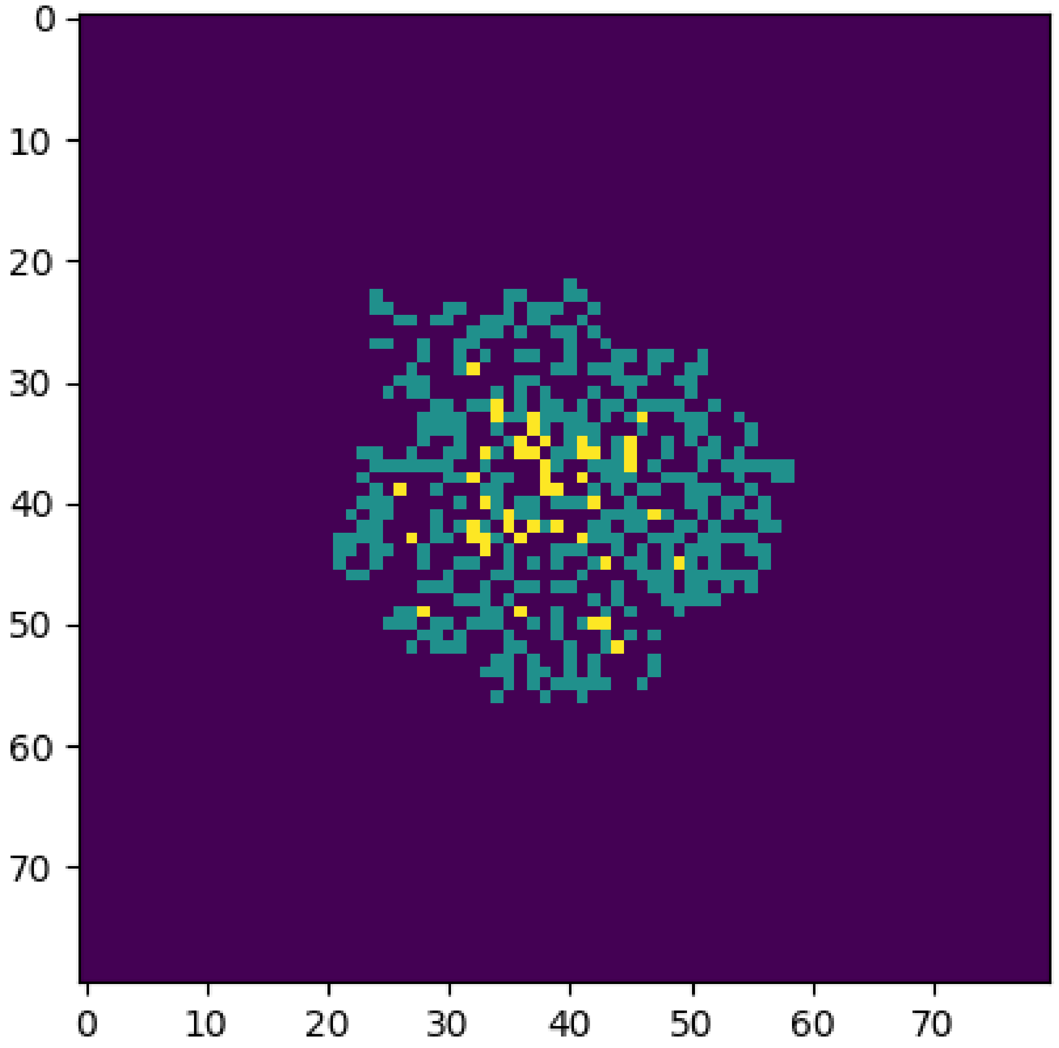


Infected: 12
Dead: 208
Survivor: 6180



Infected: 17
Dead: 272
Survivor: 6111

Infected: 390
Dead: 45
Survivor: 5965
CURED: 539



Thank You !