Modeling Zombies and Infection

Ricky Marske and Steven Rosendahl

A Simple Model

Population Decay

- Population decay can be modeled by

$$y = a(1 - r)^x$$

Population Decay

- Population decay can be modeled by

$$y = a(1 - r)^x$$

- a : Initial amount of population

Population Decay

- Population decay can be modeled by

$$y = a(1 - r)^x$$

- a : Initial amount of population
- r : Decay rate

Population Decay

- Population decay can be modeled by

$$y = a(1 - r)^x$$

- a : Initial amount of population
- r : Decay rate
- x : The amount of time that has passed

A Zombie Model

- Population decay model is a good starting point, but is not strong enough to model zombie outbreak

A Zombie Model

- Population decay model is a good starting point, but is not strong enough to model zombie outbreak
- Final size population model

A Zombie Model

- Population decay model is a good starting point, but is not strong enough to model zombie outbreak
- Final size population model
  - Size of the population as $t \to \infty$.

A Zombie Model

- Population decay model is a good starting point, but is not strong enough to model zombie outbreak
- Final size population model
  - Size of the population as $t \to \infty$.
  - Let S_∞ be final size of susceptible population

A Zombie Model

- Population decay model is a good starting point, but is not strong enough to model zombie outbreak
- Final size population model
  - Size of the population as $t \to \infty$.
  - Let S_∞ be final size of susceptible population
  - Let I_∞ be final size of infected population

A Zombie Model

- Population decay model is a good starting point, but is not strong enough to model zombie outbreak
- Final size population model
  - Size of the population as $t \to \infty$.
  - Let S_∞ be final size of susceptible population
  - Let I_∞ be final size of infected population
  - Let R_∞ be final size of removed population

A Zombie Model

- Population decay model is a good starting point, but is not strong enough to model zombie outbreak
- Final size population model
  - Size of the population as $t \to \infty$.
  - Let S_∞ be final size of susceptible population
  - Let I_∞ be final size of infected population
  - Let R_∞ be final size of removed population
  - Left with the system

$$\begin{cases} S' = -\beta(t)SI \\ I' = \beta(t)SI - vI \\ R' = vI \end{cases}$$

Adding Complexity

- In the initial model, we assumed

Probability

- In the initial model, we assumed
    1. Non-Infected would have no response to infected

Probability

- In the initial model, we assumed
    1. Non-Infected would have no response to infected
    2. No one was immune

Probability

- In the initial model, we assumed
  1. Non-Infected would have no response to infected
  2. No one was immune
  3. No one could survive the virus or be cured

Probability

- In the initial model, we assumed
  1. Non-Infected would have no response to infected
  2. No one was immune
  3. No one could survive the virus or be cured

  We will look at each one of these additional features individually

Reaction to Zombies

- The heat equation can be used to model the spread of zombies

Reaction to Zombies

- The heat equation can be used to model the spread of zombies
- Happens when humans randomly flee from zombies

$$\frac{\partial Z}{\partial t}(x,t) = D\frac{\partial^2 Z}{\partial x^2}(x,t) \qquad \text{(the partial differential equation)}$$

Reaction to Zombies

- The heat equation can be used to model the spread of zombies
- Happens when humans randomly flee from zombies

$$\frac{\partial Z}{\partial t}(x,t) = D\frac{\partial^2 Z}{\partial x^2}(x,t) \qquad \text{(the partial differential equation)}$$

$$Z(x,0) = \begin{cases} Z_0 & \text{for } 0 \leq x \leq 1 \\ 0 & \text{for } x > 1 \end{cases} \qquad \text{(the initial condition)}$$

Reaction to Zombies

- The heat equation can be used to model the spread of zombies
- Happens when humans randomly flee from zombies

$$\frac{\partial Z}{\partial t}(x,t) = D\frac{\partial^2 Z}{\partial x^2}(x,t) \qquad \text{(the partial differential equation)}$$

$$Z(x,0) = \begin{cases} Z_0 & \text{for } 0 \le x \le 1 \\ 0 & \text{for } x > 1 \end{cases} \qquad \text{(the initial condition)}$$

$$\frac{\partial Z}{\partial x}(0,t) = 0 = \frac{\partial Z}{\partial x}(L,t) \qquad \text{(zero-flux boundary condition)}$$

Reaction to Zombies

- The heat equation can be used to model the spread of zombies
- Happens when humans randomly flee from zombies

$$\frac{\partial Z}{\partial t}(x,t) = D\frac{\partial^2 Z}{\partial x^2}(x,t) \qquad \text{(the partial differential equation)}$$

$$Z(x,0) = \begin{cases} Z_0 & \text{for } 0 \le x \le 1 \\ 0 & \text{for } x > 1 \end{cases} \qquad \text{(the initial condition)}$$

$$\frac{\partial Z}{\partial x}(0,t) = 0 = \frac{\partial Z}{\partial x}(L,t) \qquad \text{(zero-flux boundary condition)}$$

$$Z(x,t) = \frac{Z_0}{L} + \sum_{n=1}^{\infty} \frac{2Z_0}{n\pi}\sin\left(\frac{n\pi}{L}\right)\cos\left(\frac{n\pi}{L}x\right)e^{\left(-\left(\frac{n\pi}{L}\right)^2 Dt\right)}$$

Non-Infected Responses

- Humans will have a natural response to virus outbreak

Non-Infected Responses

- Humans will have a natural response to virus outbreak
    - One reaction may be to form groups away from the infected

Non-Infected Responses

- Humans will have a natural response to virus outbreak
    - One reaction may be to form groups away from the infected
    - Prevalent in a zombie scenario

Non-Infected Responses

- Humans will have a natural response to virus outbreak
    - One reaction may be to form groups away from the infected
    - Prevalent in a zombie scenario
    - Twitch.tv provides a real life example of this

Non-Infected Responses

- Humans will have a natural response to virus outbreak
  - One reaction may be to form groups away from the infected
  - Prevalent in a zombie scenario
  - Twitch.tv provides a real life example of this
  - Popular users are like the groups of non-infected

Non-Infected Responses

- Humans will have a natural response to virus outbreak
  - One reaction may be to form groups away from the infected
  - Prevalent in a zombie scenario
  - Twitch.tv provides a real life example of this
  - Popular users are like the groups of non-infected
  - We can analyze what happens when these large groups of non-infected are suddenly hit with the zombie virus

Non-Infected Responses

- Humans will have a natural response to virus outbreak
  - One reaction may be to form groups away from the infected
  - Prevalent in a zombie scenario
  - Twitch.tv provides a real life example of this
  - Popular users are like the groups of non-infected
  - We can analyze what happens when these large groups of non-infected are suddenly hit with the zombie virus
- This behavior can be modeled using NetLogo

NetLogo Zombie Model

- Four different scenarios

NetLogo Zombie Model

- Four different scenarios
    1. Zombies age and die

NetLogo Zombie Model

- Four different scenarios
    1. Zombies age and die
    2. Virus dying out in carriers

NetLogo Zombie Model

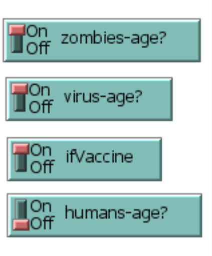
- Four different scenarios
    1. Zombies age and die
    2. Virus dying out in carriers
    3. Vaccination combating virus

NetLogo Zombie Model

- Four different scenarios
    1. Zombies age and die
    2. Virus dying out in carriers
    3. Vaccination combating virus
    4. Humans dying from old age

NetLogo Zombie Model

- Four different scenarios
  1. Zombies age and die
  2. Virus dying out in carriers
  3. Vaccination combating virus
  4. Humans dying from old age



Twitch Zombie Outbreak

- We created a program to “infect” twitch users

Twitch Zombie Outbreak

- We created a program to “infect” twitch users
    1. Start with initial user/users

Twitch Zombie Outbreak

- We created a program to “infect” twitch users
    1. Start with initial user/users
    2. Mark all users in that chat as infected

Twitch Zombie Outbreak

- We created a program to “infect” twitch users
    1. Start with initial user/users
    2. Mark all users in that chat as infected
    3. Look through all the infected users

Twitch Zombie Outbreak

- We created a program to "infect" twitch users
    1. Start with initial user/users
    2. Mark all users in that chat as infected
    3. Look through all the infected users
        - If the user is streaming, then infect all their viewers in their chat

Twitch Zombie Outbreak

- We created a program to “infect” twitch users
  1. Start with initial user/users
  2. Mark all users in that chat as infected
  3. Look through all the infected users
     - If the user is streaming, then infect all their viewers in their chat
  4. Repeat indefinitely

Twitch Zombie Outbreak

- We created a program to "infect" twitch users
  1. Start with initial user/users
  2. Mark all users in that chat as infected
  3. Look through all the infected users
     - If the user is streaming, then infect all their viewers in their chat
  4. Repeat indefinitely
- We expect to see bursts of infected after lulls of no infected

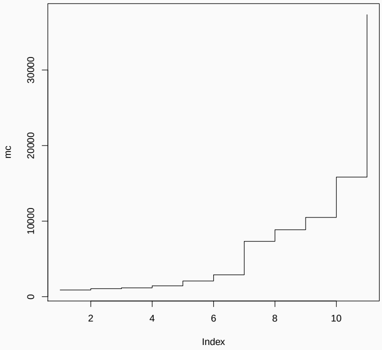
Twitch Zombie Outbreak

- We created a program to "infect" twitch users
  1. Start with initial user/users
  2. Mark all users in that chat as infected
  3. Look through all the infected users
     - If the user is streaming, then infect all their viewers in their chat
  4. Repeat indefinitely
- We expect to see bursts of infected after lulls of no infected
- This can be modeled by

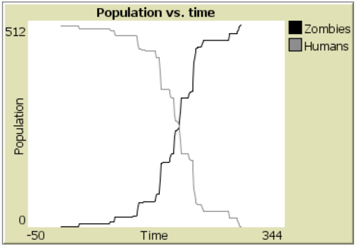
$$y = 3122.33 + 0.580e^{x}$$

Twitch Zombie Outbreak

Data From Twitch



Data From NetLogo



Cures and Survival

- The time at which a cure is introduced affects the model

Cures and Survival

- The time at which a cure is introduced affects the model
- Can be represented by a wave equation:

$$u_{tt} - k^2 u_{xx} = 0$$

Cures and Survival

- The time at which a cure is introduced affects the model
- Can be represented by a wave equation:

$$u_{tt} - k^2 u_{xx} = 0$$

- To show the offset, we have

$$u_{tt} - k^2 u_{xx} = \zeta$$

Cures and Survival

- The time at which a cure is introduced affects the model
- Can be represented by a wave equation:

$$u_{tt} - k^2 u_{xx} = 0$$

- To show the offset, we have

$$u_{tt} - k^2 u_{xx} = \zeta$$

- ζ represents the time offset

Cures and Survival

- The time at which a cure is introduced affects the model
- Can be represented by a wave equation:

$$u_{tt} - k^2 u_{xx} = 0$$

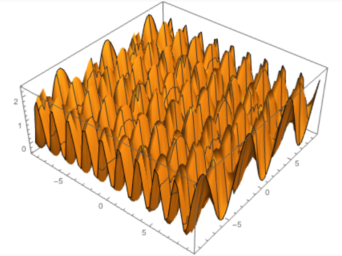
- To show the offset, we have

$$u_{tt} - k^2 u_{xx} = \zeta$$

- ζ represents the time offset
- This yields the solution

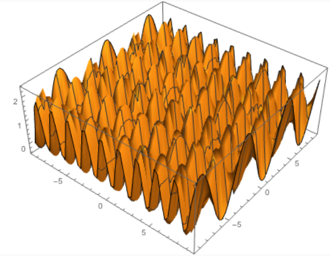
$$u(x,t) = \zeta + \sum_{n=1}^{\infty} (k_1 \sin t + k_2 \cos t) \sin n\pi x$$

Cures and Survival

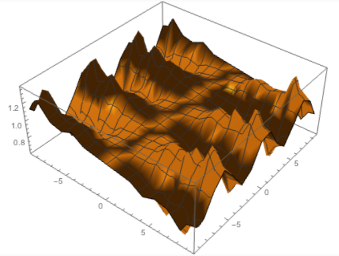


$n = 1$

Cures and Survival

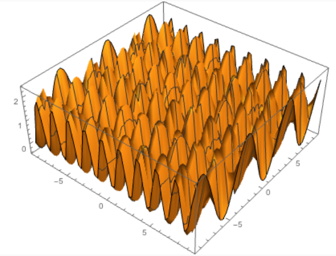


$n = 1$

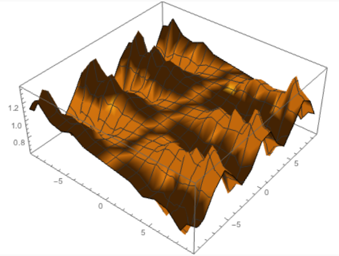


$n = 100$

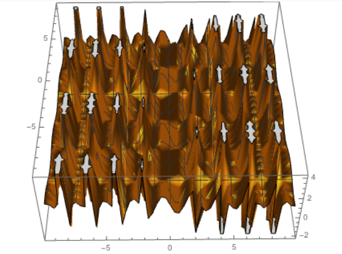
Cures and Survival



$n = 1$

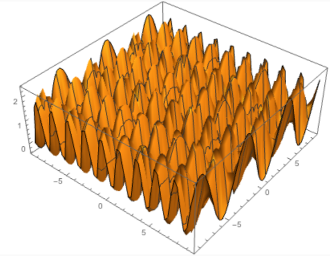


$n = 100$

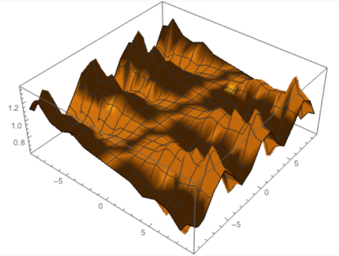


$n = 500$

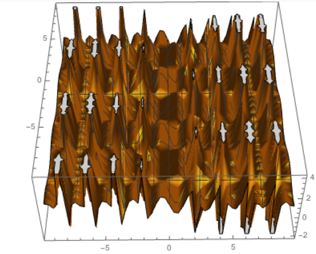
Cures and Survival



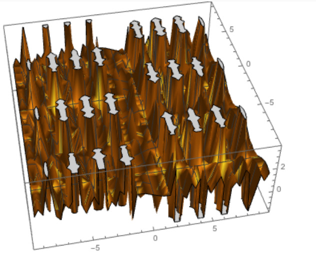
$n = 1$



$n = 100$



$n = 500$



$n = 1000$

Cures and Survival

$$u(x,t) = \zeta + \sum_{n=1}^{\infty} (k_1 \sin t + k_2 \cos t) \sin n\pi x$$

- There is a saddle regardless of ζ

Cures and Survival

$$u(x,t) = \zeta + \sum_{n=1}^{\infty} (k_1 \sin t + k_2 \cos t) \sin n\pi x$$

- There is a saddle regardless of ζ
- The system will move towards the saddle no matter what

References