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Individual Project
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# Impact of Immunizations on the Spread of Measles

## Proposal:

For this project, I originally intended to provide a means for learning the SIR model in an interactive way. Upon getting feedback from the teaching team and my peers, I decided to narrow the scope and focus on one particular disease and how the SIR model can help us understand it better. I decided to focus on the measles since it is a disease that has a recent and relevant scope, and I decided to further focus it on the impact that immunizations has on that disease, again for the relevancy of the scope. In the end, I decided to have an interactive way for a user to manipulate the rate of immunization in a community and to see the impact that it has on the spread of the disease.

## Process:

I first created sketches (as per the round robin assignment) and received feedback on them from classmates and the teaching team. From there, I further explored the SIR model and tried to understand the concepts. I used the Udacity course: Differential Equations in Action to help me understand how the SIR model works. From there, I continued constructing my idea and composed a sketch of my final idea to work from.

To create the simulation, I referred to real-life examples of measles and immunizations. Using the case example of the Measles outbreak in Ohio 2014, I constructed a scenario of a set population, transmission rate, and recovery rate based off of those numbers. Understanding how the equations would work in that scenario helped me to begin constructing the actual visualization.

I then did research on D3 libraries and explored the documentation to help me start building the visualization. Since I have limited experience using D3 (I have only used it for this class), most of my time was spent exploring related examples, understanding the code, and creating the line graph/slider visualization and connecting my equation to it. Finally, I created the webpage by putting the visualization in a bootstrap template and summarized some of the interesting points about the topic so as to give more context to the visualization.

While I was not able to fully implement all of my original ideas (I originally intended to have a simulation that was also controlled by the slider to visually show the spread of disease), I implemented a very specific idea, which may put a larger emphasis on my topic of measles and immunizations.

For further reference, I've included a rough sketch of my idea after receiving feedback from the class sessions below, as well as sketches of my process while figuring out the equation as it relates to this project and the case study.


Content References Used:

1. A Measles Outbreak in an Underimmunized Amish Community in Ohio
2. CDC: Measles
3. Contagion: A Study in Infectious Disease
4. Differential Equations in Action: Analyzing the Spread of Disease
5. Hans Nesse - Global Health - SIR Model
6. Simulating an Epidemic
7. Running the SIR Model
8. Watch how the measles outbreak spreads when kids get vaccinated – and when they don't

Code References Used:

1. http://www.d3noob.org/2014/04/using-html-inputs-with-d3js.html
2. https://bl.ocks.org/pstuffa/26363646c478b2028d36e7274cedefa6
3. http://blockbuilder.org/khan2sa/39a84b898887646a6d59b81eccffd498
4. https://github.com/d3/d3-selection
5. http://bl.ocks.org/d3noob/a22c42db65eb00d4e369
6. https://startbootstrap.com/template-overviews/resume/

Images Used:

1. https://icons8.com/icon/set/health/all

vaccine rate = input
// (0% - 100%)

S = pop. - pop * vaccine rate

pop = 100

$a = .027$

// $.90 \cdot \frac{S(t)}{100}$ · 3 person contact a day

$b = 1/14$

$I = .011 * S$

// 383 cases / 32630 in Amish pop.

$S_{rate} = -aSI$

$I_{rate} = aSI - bI$

$R_{rate} = bI$

R = pop * vaccine rate plus ______?

// % of I who recover

[illegible]

[illegible]

[illegible]

data.datasets.data[0] = 3

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chart.js

contagion.js

# The impact of immunizations on the Spread of Measles

History / Characteristics of Measles

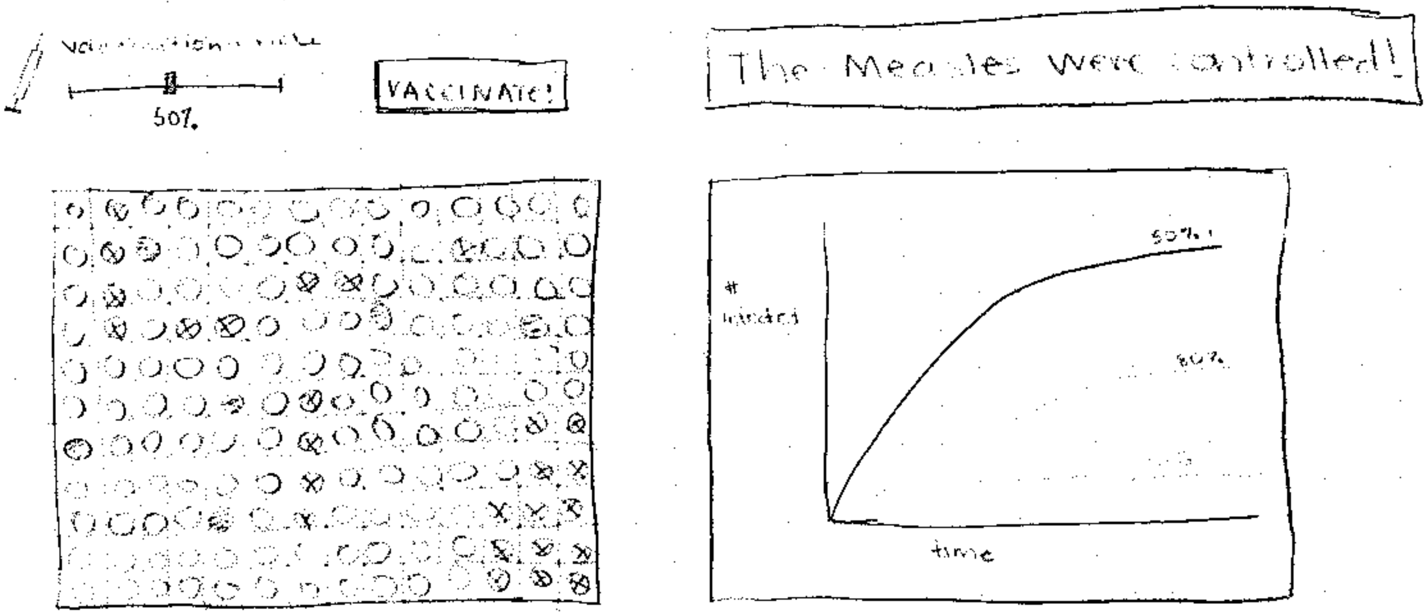
- disease
- spread
- in U.S. & world

Event in Ohio 2014

- briefly talk about it

How would immunizations impacted outcome?

- explore below
- explain what each graph shows




Talk about SIR & Herd Immunity

- 95% vaccinated
- impacts abroad

Takeaways

- still get immunized
- people [illegible]
  bring it back

TODAY (1)

$S' = -(.021)(250)(1)$

$= -6.75$ → newly infected

$I' = 6.75 - (1/14)(1)$

$= 6.67$ → total infected

$$\left.\begin{aligned} S &= pop - pop(imp) \\ S &= 1000 - 1000(75/100) \\ S &= 250 \\ I &= 1 \end{aligned}\right\}$$ DAY 0 (0)

DAY 2 (2)

$S(1) = S(0) + S'(0)$
$= 250 + (-6.75)$
$= 243.25$

Srate =
$-(.027)(243.25)(7.67)$
$= -50.37$

$I(1) = 1 + 6.67$
$= 7.67$

I rate
$(50.37) - (1/14)(7.67)$
$= 49.82$

Day 3 (3)

$S(2) = S(1) + S'(1)$
$= 243.25 + (-50.37$
$= 192.88$

Srate =
$(-.027)(192.88)(57.49)$
$= -299.39$

$I(2) = I(1) + I(1)'$
$= 7.67 + 49.82$
$= 57.49$

Irate =

Day 4 (4)

$S(3) = S(2) + S'(2)$
$= 192.88 +$

CDC data → in 2014 667 measles cases

U.S. pop. → 318 million

383 in OHIO
9 countie

OHIO 2014
11.6 mil

32630
pop in Amish community

measles run for ~2 weeks

$b \approx 1/14$ $a = 9/10$?

90% chance of getting infected

$S(0) = 318$ million

$I(0) = 667$

100 = pop
3 people a day contact
10% = chance of infection

$\frac{S(t)}{100}$, 3 s  a = .027?

.90 $\frac{?}{100}$, 3 person

to survive epidemic

- decrease a! (wash hands, sick kids @ home)
- decrease S! vaccines
- increase b? (doesn't work too well

critical community size for measles = 250,000

herd immunity needs 95% of community to be vaccinated

if $S > b/a$,
$I' > 0$,
epidemic grows

if $S < b/a$,
$I' < 0$,
epidemic shrinks

$\frac{b}{a}$ = threshold

S = # of susceptible
(healthy, no measles, not immune

I = # of infected

R = # of recovered
(immune, won't get sick or infect anyone)

$\left\{\begin{matrix} S' \\ I' \\ R' \end{matrix}\right\}$ = rate @ which $\left\{\begin{matrix} S \\ I \\ R \end{matrix}\right\}$ changes

per day
or
per week

$(S) \xrightarrow[\text{gets sick}]{(aSI)} (I) \xrightarrow[\text{recovers}]{bI} (R)$

everyday, a fraction "b" of sick kids recover $R' = bI$

rate at which kids get sick = $aSI$
- proportional to # of S
- proportional to # of I

a = transmission co-efficient

$$\boxed{\begin{aligned} S' &= -aSI \\ I' &= aSI - bI \\ R' &= bI \end{aligned}}$$

a = transmission, depends on condition

b = rate of recovery depends on disease

total pop = 50,000

$S' = -.00001\ SI$

$I' = .0001\ SI - 1/14\ I$

$R' = 1/14\ I$

init vals $S(0) = 45400$

$I(0) = 2100$

$R(0) = 2500$

<u>Today</u>

newly infected

$S' = -.0001(45400)(2100) = -953.4\ \frac{\text{kids}}{\text{day}}$

$I' = 953.4 - \frac{2100}{140} = 803.4$ → net infected

$R' = \frac{2100}{140} = 150\ \frac{\text{Kids}}{\text{day}}$ (recovered)

<u>Tomorrow:</u>

$S(1) \approx S(0) + S'(0) \cdot 1\ \text{day}$

$= 45400 - 953.4 = 44446.6$

$I(1) \approx I(0) + I'(0) \cdot 1\ \text{day} = 2903.4$

$R(1) \approx R(0) + R'(0) \cdot 1\ \text{day} = 2650$

<u>Day after tomorrow:</u>

Use $S(1), I(1), R(1)$ & rate equations to get $S'(1), I'(1), R'(1)$

$S(2) \approx S(1) + S'(1) \cdot 1\ \text{day}$

* repeat to advance time

<u>yesterday</u>

$S(-1) \approx S(0) - S'(0) \cdot 1\ \text{day} = 46353.4$

$I(-1) \approx I(0) - I'(0) \cdot 1\ \text{day} = 1296.6$

$R(-1) \approx R(0) - R'(0) \cdot 1\ \text{day} = 2350$

$$\frac{383}{32630} = \frac{x}{1000}$$

$x = \sim 11$

input = 50 → immunization

$S'$ rate kids get sick $= -\underset{\text{(original)}}{(.027)(100)}(1)$

$= -2.7$

$S = 100 - (100 \cdot \overset{\text{input}}{50/100})$

$100 - 50$

$S = 50$

$-(.027)(50)(1)$

$= -1.35$

init

$S = 1000$ ppl

$I = 1$ prsn

$R = 1$ prsn

infected persons

among them, $\frac{S(t)}{1000} \cdot 25$ susceptible

# new infection / day → infects $0.9 \cdot \frac{S(t)}{1000} \cdot 25 \frac{\text{persons}}{\text{day}} = \frac{.000225}{\text{day} \cdot \text{person}}$

pop = 1000

$S = \text{pop} - \left(\text{pop} \times \frac{\text{input}}{100}\right)$

$I = 1$

$R = 1 + \left(\text{pop} \times \frac{\text{input}}{100}\right)$

$I\_\text{rate} = .9 \cdot \frac{1}{S} \cdot \frac{25\,p}{\text{day}}$

$I(t) = \underbrace{(a\,SI - S)}_{0}\, I(t)$

$\Rightarrow S(t) = $ % of pop

$\Rightarrow R(t) = 100 - $ % of pop $=$ needed for herd immunity