# Research with Zombies

Jean Marie Linhart

TEXAS A&M UNIVERSITY

jmlinhart@math.tamu.edu

2013

# Why zombies?



1. Students love them.
   - Humans vs. Zombies (HvZ) (HvZauthors [2012])
   - World War Z: ∼$500 million box office receipts worldwide (7/23/2013)
   - Zombies are worth $5 billion in today's economy. (Ogg [2011])
2. Accessible to calculus students.
3. Room for creativity.
4. Lots of interesting math.

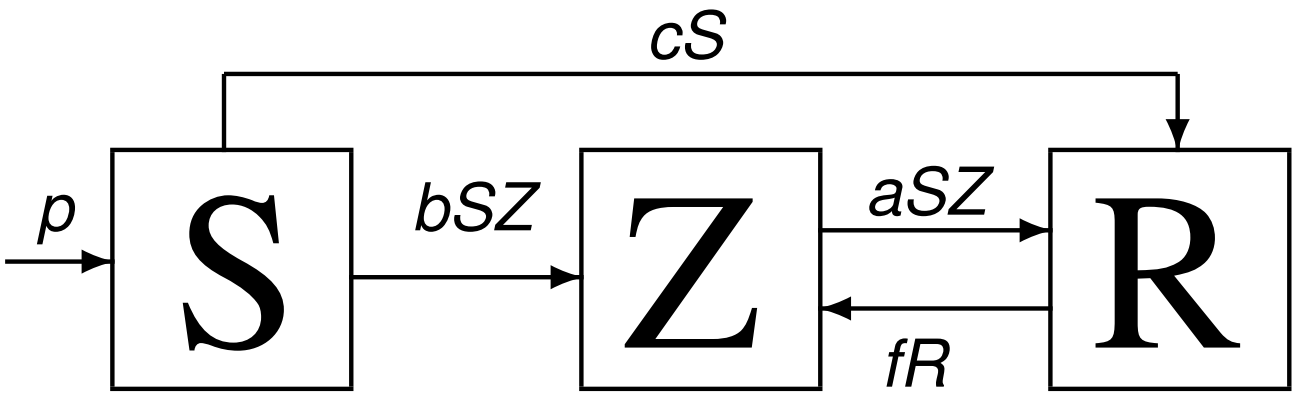
# Epidemiological models for a Zombie outbreak

Zombie disease models were popularized in 2009 with the publication of "When Zombies Attack" in *Infectious Disease Modelling Research Progress*. (Munz et al. [2009])

- $S$: Susceptibles, uninfected humans
- $Z$: Zombies (normally $I$ for infected)
- $R$: Removed, the dead

# Basic Zombie Model






$$\frac{dS}{dt} = p - bSZ - cS$$
$$\frac{dZ}{dt} = bSZ - aSZ + fR$$
$$\frac{dR}{dt} = aSZ - fR + cS$$

$a, b, c, p, f$ are all constants (parameters) in the model

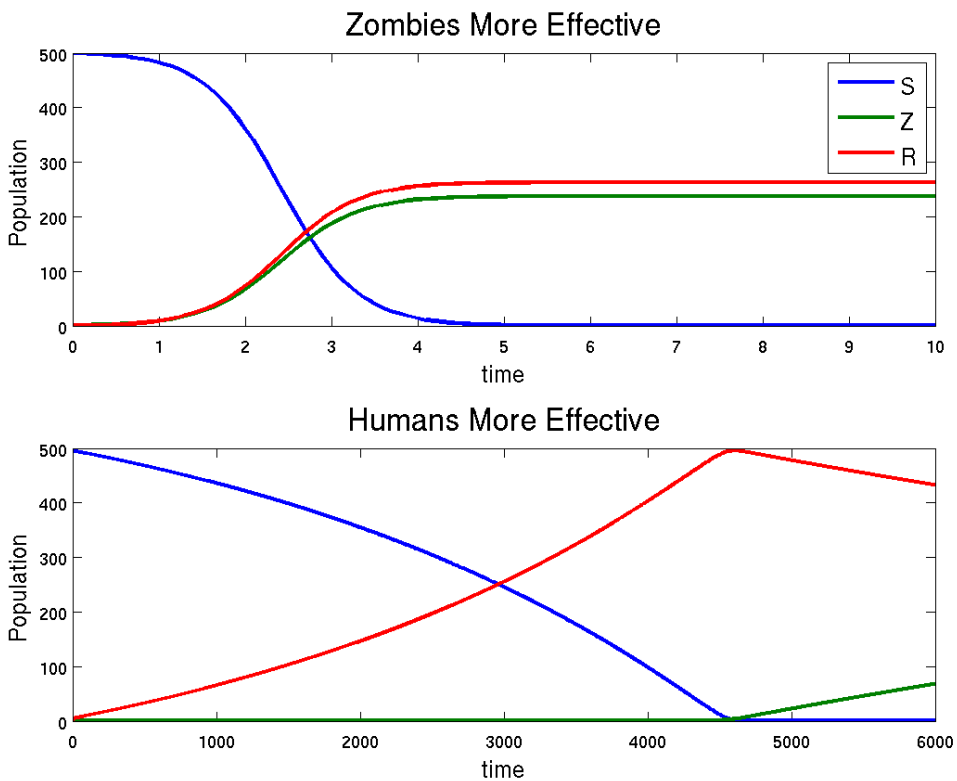
# Model Results: doomsday



Parameter values $p = 0.0001, \quad f = 0.0001, \quad c = 0.0001$

Both started with 500 humans, 1 zombie.

First plot $a = 0.005 < b = 0.0095$; zombies more effective
Second plot $a = 0.01 > b = 0.008$; humans more effective



# Zombie Mathematics

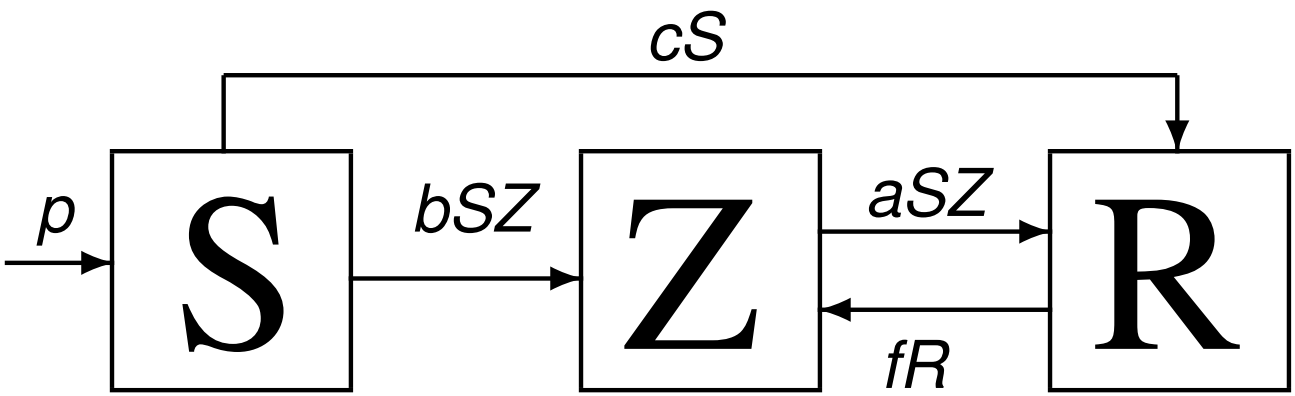




- Mathematical modeling/Epidemiological modeling
- Applications of ordinary differential equations (ODEs)
- Autonomous differential equations
- Equilibria
- Stability
- Numerical methods for solving ODEs
- Use of a computer algebra system
- Reality into mathematics

# Is this model correct?






What do you think? Is this model correct?

# Criticisms/Changes



- Shouldn't dead mean **dead**?
- Zombies should decay
- Better population model
- Necromancers
- Element of uncertainty

# Create a stochastic model

**stochastic** (adj.) involving chance or probability: probabilistic (Merriam-Webster.com [2013])

$$\begin{aligned} \frac{dS}{dt} &= pS - bSZ - cS \\ \frac{dZ}{dt} &= bSZ - aSZ + fR \\ \frac{dR}{dt} &= aSZ - fR + cS \end{aligned}$$

Break model into events:

| | | | |
|---|---|---|---|
| human births | $pS$ | humans $\rightarrow$ zombies | $bSZ$ |
| human deaths | $cS$ | zombie deaths | $aSZ$ |
| | | dead $\rightarrow$ zombies | $fR$ |

# Markov Process

All events: $T(S, Z, R) = pS + bSZ + cS + aSZ + fR$

- Choose a uniform random value between 0 and 1.
- What happens is determined by where it falls in the interval.


- The time to next event is exponentially distributed.
- To determine it choose $u$ a second uniform random value between 0 and 1 and calculate

$$\Delta t = -\frac{\log(u)}{T(S, Z, R)}$$

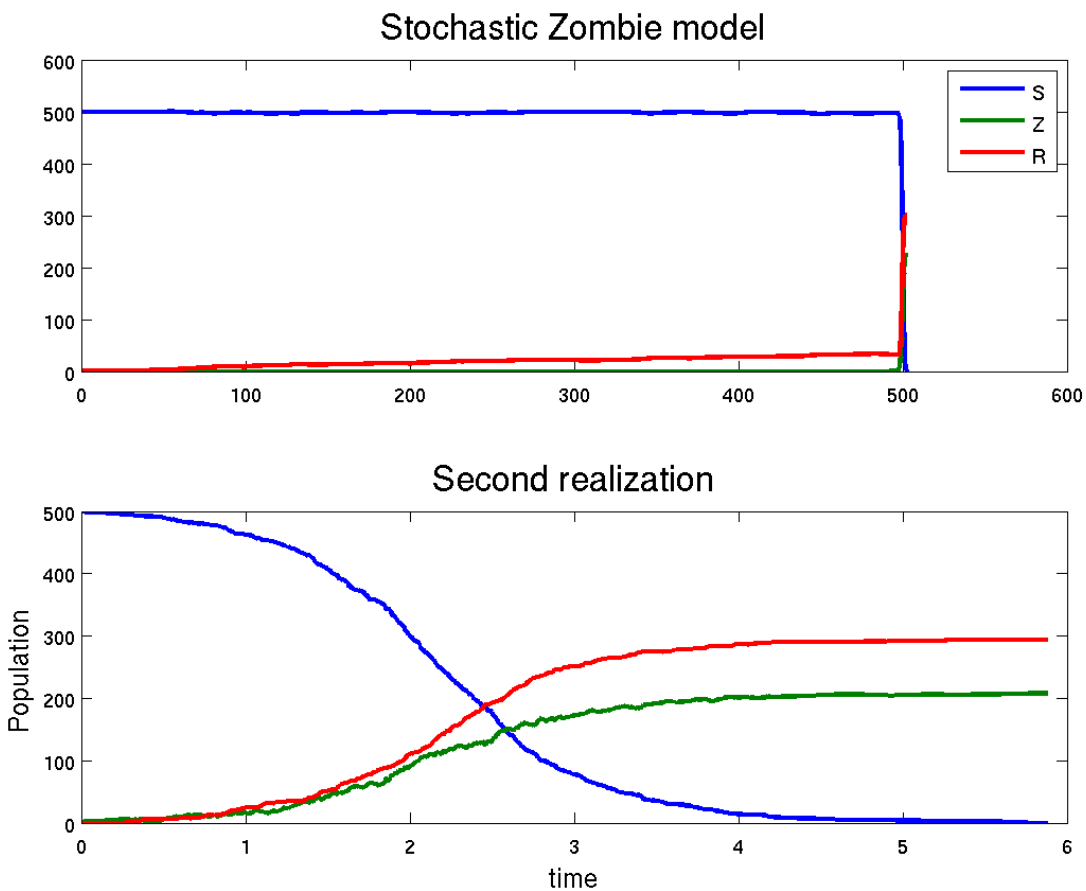
# Stochastic Realizations



Parameter values

$p = 0.0001, f = 0.0001, c = 0.0001, a = 0.005, b = 0.0095$

Started with 500 humans, 1 zombie.



# More Zombie Mathematics



- Stochastic processes
- Markov chains
- Mean, standard deviation
- Probability distributions

What will your students come up with?


Thanks for coming and thanks for listening!

# References



Shaun of the dead, 2004. URL http://www.imdb.com/title/tt0365748/combined. Edgar Wright (director).

Kelli Bordner and Noah Bordner. Zombieville. MikaMobile, 2010. URL http://www.zombievilleusa.com/. Videogame for iOS.

Leonardo Finocci. Friendly zombie. WWW, 2010. URL http://leonardofinocchi.deviantart.com/art/Friendly-Zombie-151356204?q=&qo=.

HvZauthors. Humans vs. zombies (hvz), 2012. URL http://humansvszombies.org/.

Merriam-Webster.com. "stochastic". Web, 2013. URL http://www.merriam-webster.com/dictionary/stochastic.

P. Munz, I. Hudea, J. Imad, and R. J. Smith? When zombies attack! Mathematical modeling of an outbreak of zombie infection. In J. M. Tchuenche and C. Chiyaka, editors, *Infectious Disease Modelling Research Progress*, pages 133–150. July 2009. ISBN 978-1-60741-347-9. URL http://mysite.science.uottawa.ca/rsmith43/Zombies.pdf.

John C. Ogg. Zombies worth over $5 billion to economy, October 2011. URL http://www.msnbc.msn.com/id/45079546/ns/business-stocks_and_economy/t/zombies-worth-over-billion-economy.