SCUDEM 2023-2024
Problem B: Punishing Infants

Team Number: 1002

Team Members:

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Problem Overview

Punishing infants problem:

- Research shows that some infants develop a propensity to react to third party transgressions by punishing those they perceive as acting out against others
- We suppose this proportion of infants is fixed
- We seek to study interactions between individuals and the long-term dynamics of the system

Our Goals

1

Develop a model that includes different populations with different propensities of retribution

2

Incorporate various behaviors, especially varying degrees of retribution and alternative actions

3

Study the long-term effects of model's interactions

4

Generalize and apply our model to real-world scenarios

Definitions

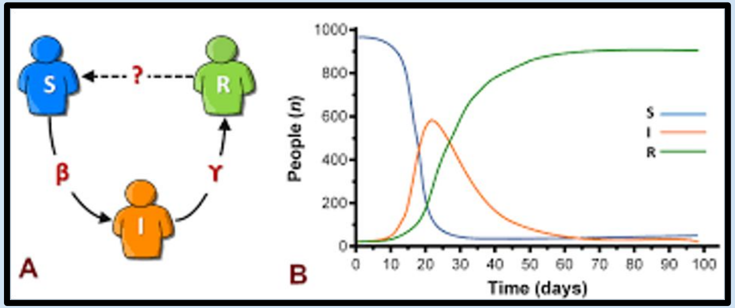
- Propensity of retribution: The likelihood of an observer to punish a third-party aggressor
- Propensity to aggress: The likelihood of every party to commit aggressions
- An individual can take 1 of 3 roles at any given moment:
  - Observer/bystander: Observing a conflict take place
  - Victim: Currently being “aggressed” or attacked
  - Aggressor: Currently aggressing, threatening to attack the victim

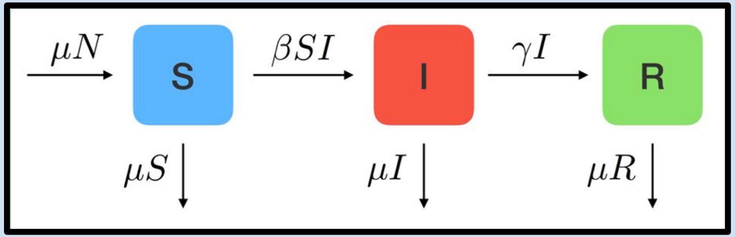
Assumptions

- Population beliefs and distributions for each party is uniform
- There is always at least one ongoing conflict/instance of aggression
- Individuals can only be involved in one conflict at a time
- Actions should be cyclical, i.e. individuals can always cease action
- Linear progression between states of involvement in conflict
    - Movement between roles suggested the efficacy of an SIR model

SIR Model of Epidemiology

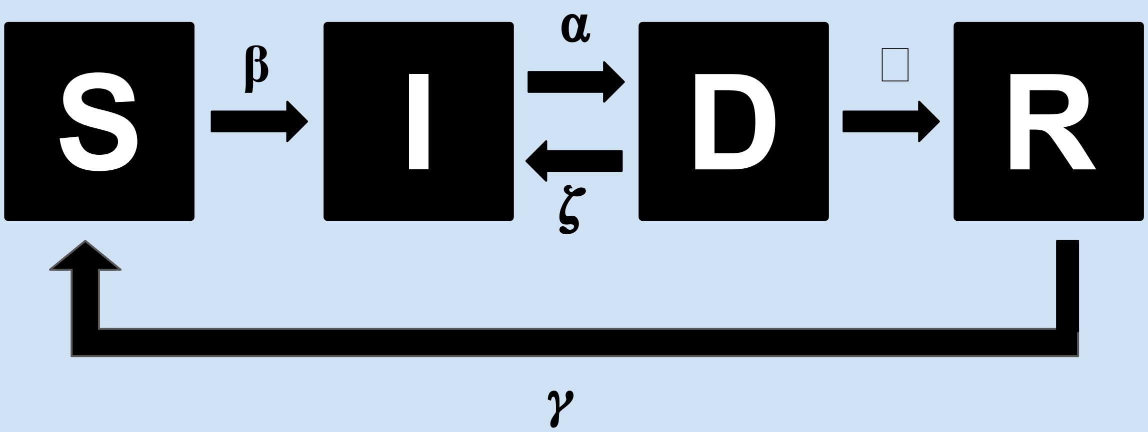
- Susceptible-Infectious-Recovered model
- Infectious Disease Modeling
- Analyzing cross-compartmental interactions
- Application of Differential Equations





S	**Susceptible**: Countries that are aware of ongoing conflict
I	**Infected**: Countries that are involved in ongoing conflict
D	**Diplomatic**: Countries that choose to pursue a course of action
D_1	**Diplomatic (1)**: Countries that pursue a mild course of action (Sanctions, Treaties)
D_2	**Diplomatic (2)**: Countries that pursue a harsh course of action (War, Armed Attacks)
R	**Recovered**: Countries that stop pursuing course of action

Susceptible-Infected-Diplomatic-Recovered Model (Stage 1)



$$dS/dt = \gamma R - \beta SI/N$$

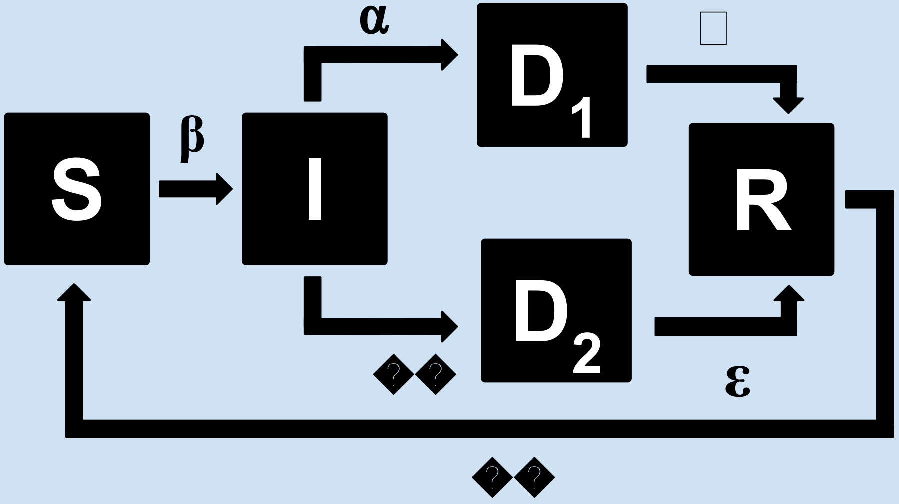
$$dI/dt = \beta SI/N + \zeta D - \alpha I$$

$$dD/dt = \alpha I - \zeta D - \delta D$$

$$dR/dt = \delta D - \gamma R$$

Parameter	Description
β	Rate at which a country is infected with conflict (how often conflict occurs)
α	Rate at which a country pursues a diplomatic course of action
ζ	Rate at which a country stops pursuing course of action
δ	Rate at which a country recovers from course of action
γ	Rate at which a country is re-susceptible to conflict

Susceptible-Infected-D_1-D_2-Recovered Model (Stage 2)



Parameter	Description
β	Rate at which a country is infected with conflict (how often conflict occurs)
α	Rate at which a country pursues a mild course of action (Sanctions, Treaties)
ζ	Rate at which a country pursues harsh course of action (War, Military Attack)
δ	Rate at which a country stops pursuing mild course of action
ε	Rate at which a country stops pursuing harsh course of action
γ	Rate at which a country is re-susceptible to conflict

$$dS/dt = \gamma R - \beta SI/N$$

$$dI/dt = \beta SI/N + \zeta D - \alpha I$$

$$dD1/dt = \alpha I - \delta D1$$

$$dD2/dt = \zeta I - \varepsilon D2$$

$$dR/dt = \delta D1 + \varepsilon D2 - \gamma R$$

Stability Analysis

- Systematic evaluation of the behavior of a system
- Determine whether it remains within desired bounds
- Ensures reliability and predictability of systems,
- Prevents unexpected or undesirable behaviors

The equilibrium solution is asymptotically stable as t → ∞ for all positive values of the rates α, β, γ, σ and ζ.

$$\mathrm{S} = \frac{\sigma}{\beta} N$$

$$\mathrm{I} = \frac{\zeta\gamma}{\beta} \frac{\beta-\sigma}{\alpha\gamma+\gamma\zeta+\sigma\zeta} N$$

$$\mathrm{D} = \frac{\alpha\gamma}{\beta} \frac{\beta-\sigma}{\alpha\gamma+\gamma\zeta+\sigma\zeta} N$$

$$\mathrm{R} = \frac{\zeta\sigma}{\beta} \frac{\beta-\sigma}{\alpha\gamma+\gamma\zeta+\sigma\zeta} N$$

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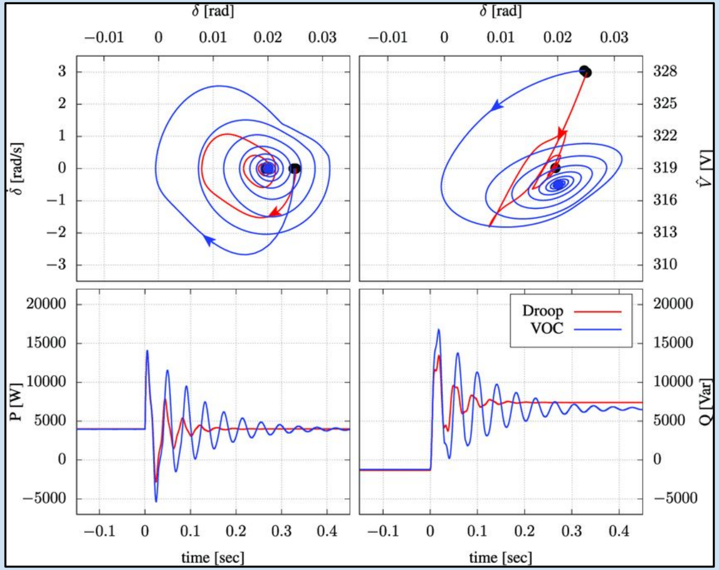

Visualization of stability analysis

Hyperparameter Tuning

- Using data to optimize model parameters
- Obtained data from the Global Sanctions Database
- Numerically scaled objectives and successes
- Centroid: (6.793, 3.040)
    - Retributive tendencies
    - Using this value to investigate specific cases

case_id	sanctioned	sanctionin	begin	end	trade	descr_trac	arms	military	financial	travel	other	target_mu	sender_m	objective	success
1	German D	Germany	1949	1973	0		0	0	0	0	1	0	0	territorial_	success_total
2	Pakistan	India	1949	1951	1	exp_comp	0	0	0	0	0	0	0	policy_cha	nego_settlement
3	Bulgaria	United Sta	1950	1966	0		0	0	0	0	1	0	0	destab_re	failed
4	Bulgaria	United Sta	1950	1959	0		0	0	0	1	0	0	0	destab_re	success_part
5	Bulgaria	United Sta	1950	1963	0		0	0	1	0	0	0	0	destab_re	success_part
6	China	CoCom	1950	1985	1	exp_part	0	0	0	0	0	0	1	destab_re	nego_settlement
7	China	New Zeala	1950	1956	1	exp_part	0	0	0	0	0	0	0	destab_re	failed
8	China	Organizati	1950	1985	1	exp_part	0	0	0	0	0	0	1	destab_re	failed
9	China	South Afri	1950	1985	1	exp_part	0	0	0	0	0	0	0	destab_re	failed
10	China	United Kin	1950	1956	1	exp_part	0	0	0	0	0	0	0	destab_re	failed
11	China	United Sta	1950	1972	1	exp_comp	0	0	0	1	0	0	0	destab_re	nego_settlement
12	Comecon	Austria, Fi	1950	1994	1	exp_part	0	0	0	0	0	1	1	prevent_w	success_total,failed
13	Comecon	CoCom	1950	1994	1	exp_part	0	0	0	0	0	1	1	prevent_w	success_total,failed
14	Israel	Egypt, Ara	1950	1957	1	exp_comp	0	0	0	0	1	0	0	prevent_w	failed
15	Israel	France	1950	1955	0		1	0	0	0	0	0	0	prevent_w	failed
16	Israel	League of	1950	2022	1	exp_comp	0	0	0	0	0	0	1	territorial_	ongoing
17	Korea, No	United Sta	1950	1954	1	exp_comp	0	0	1	0	0	0	0	end_war	success_total
18	Palestine	League of	1950	1994	1	exp_comp	0	0	0	0	0	0	1	territorial_	failed
19	Taiwan	United Sta	1950	1953	0		0	0	0	0	1	0	0	prevent_w	success_total
20	Yugoslavia	Soviet Uni	1950	1955	1	exp_comp	0	0	0	0	0	0	0	policy_cha	success_part
21	China	Hong Kon	1951	1954	1	exp_part	0	0	0	0	0	0	0	destab_re	failed
22	China	UN	1951	1953	0		1	0	0	0	0	0	1	end_war,d	success_total,failed
23	China	United Sta	1951	1979	0		0	0	1	0	0	0	0	destab_re	success_part
24	Egypt, Ara	United Kin	1951	1954	0		1	0	0	0	0	0	0	prevent_w	success_part
25	Hungary	United Sta	1951	1973	0		0	0	1	1	1	0	0	human_rig	nego_settlement
26	Korea, No	UN	1951	2022	0		1	0	0	0	0	0	1	end_war	ongoing

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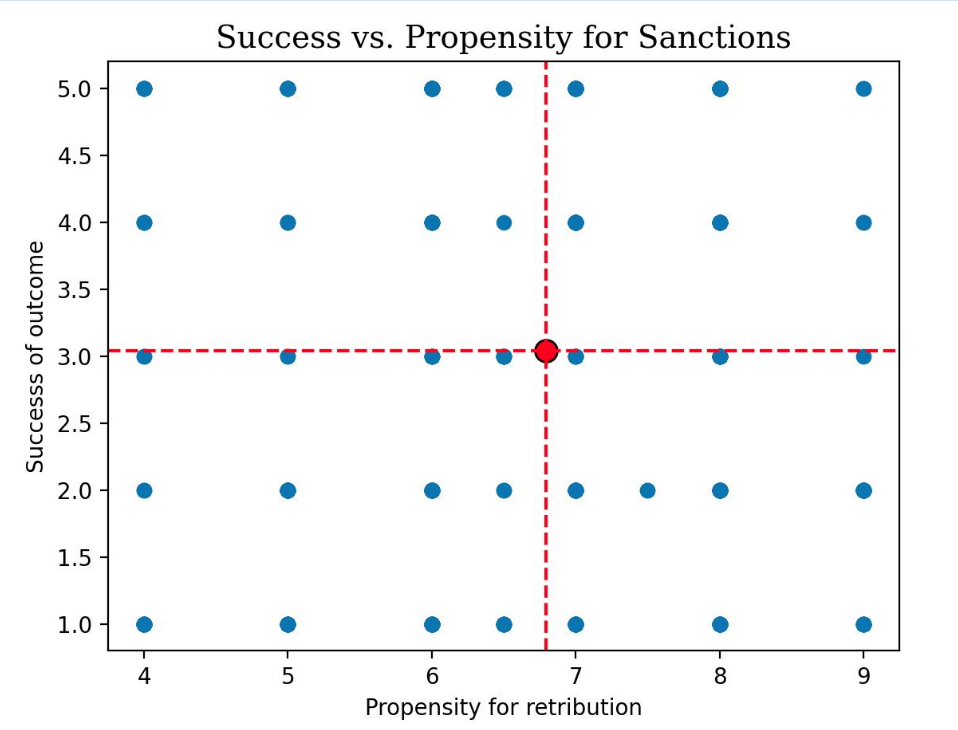
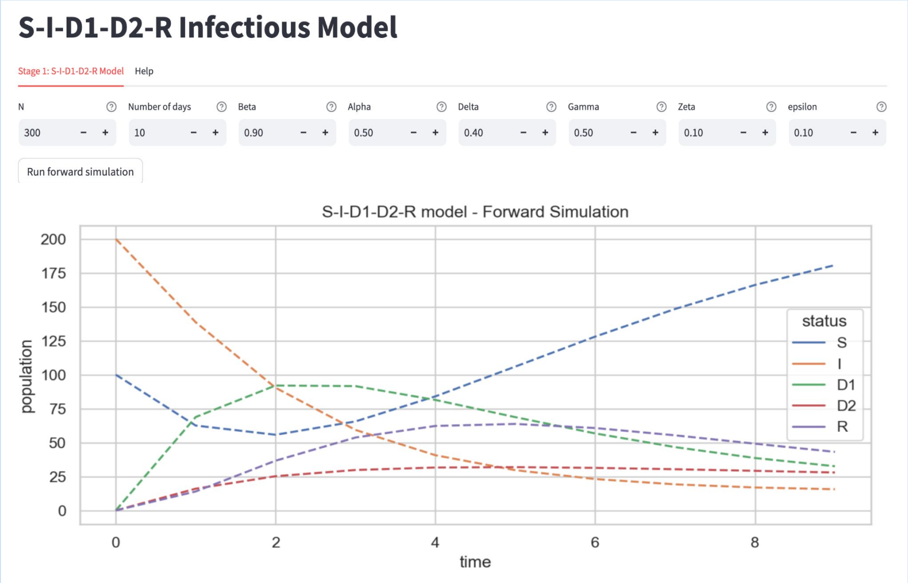
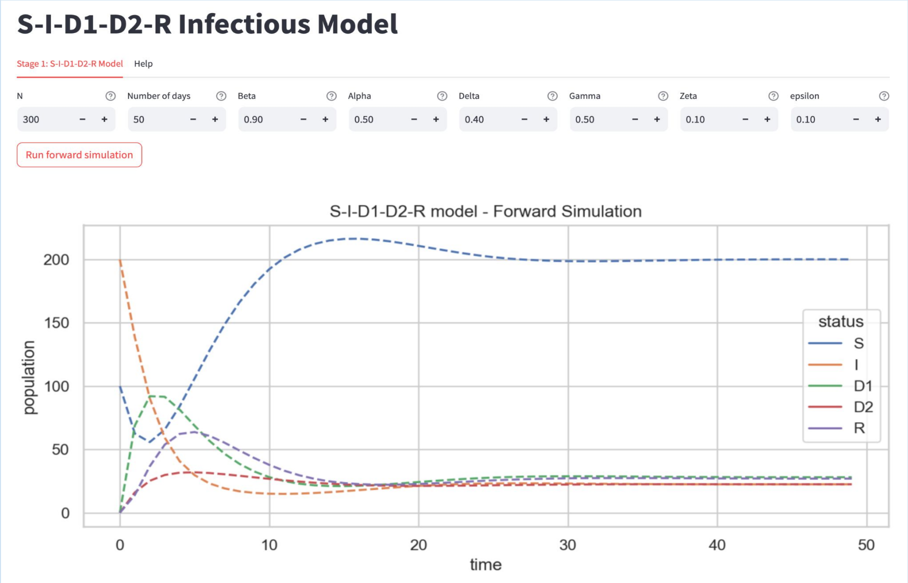


Case 1 (3rd Party - Diplomacy-Weighted)

Israel & Hamas (USA acting as 3rd Party)



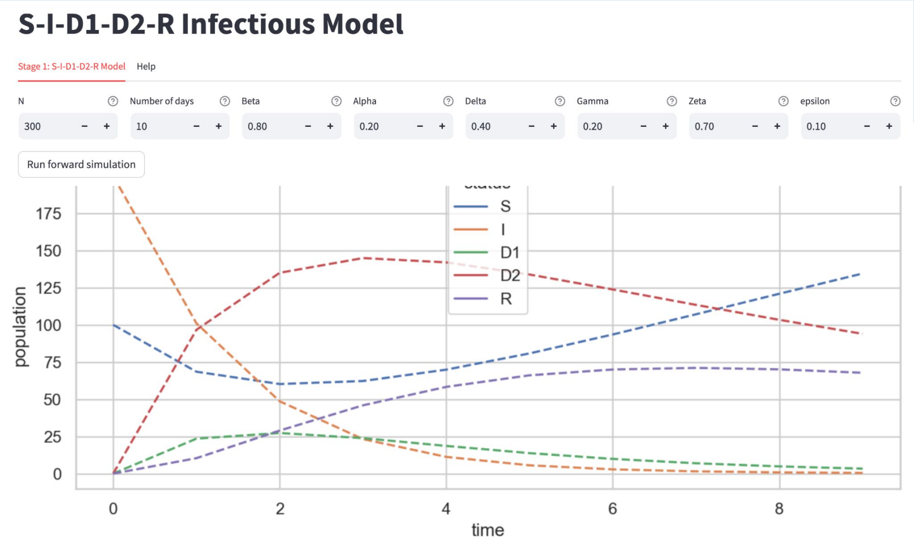
10 Day Simulation



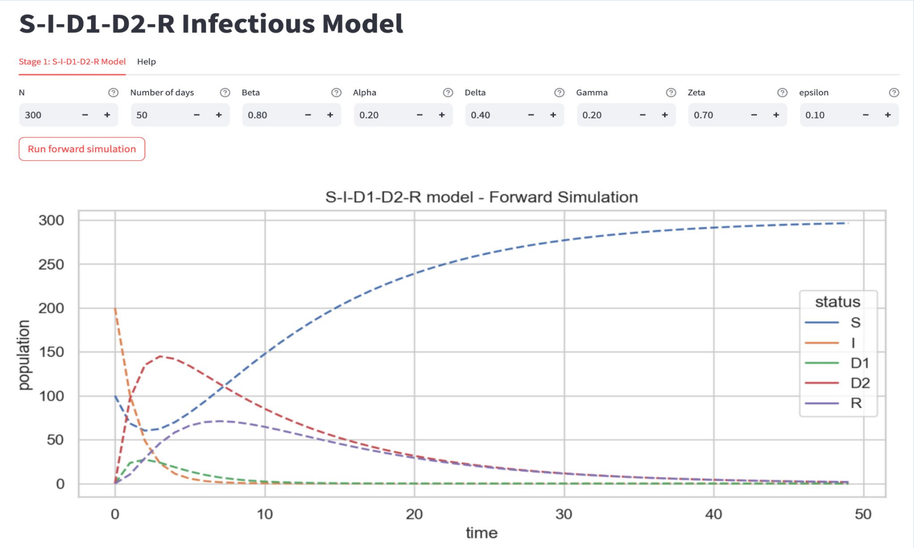
60 Day Simulation

Case 2 (3rd Party - Retributive-Weighted)

Russia & Ukraine (USA acting as 3rd Party)



10 Day Simulation



60 Day Simulation

Final Thoughts & Future Work

- Created an SIR-based model of the punishing infants problem
- Incorporated varying degrees of retributive behavior
- Limitations of our model:
  - Only considers one conflict at a time
  - Movement between compartments was restricted
  - Likelihood of aggression is not considered
- Future Work
  - Including additional variables
  - Considering environmental factors
- Feedback

References

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Thank you!