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Evolutionary game theory to understand behavior dynamics during the Covid-19 pandemic

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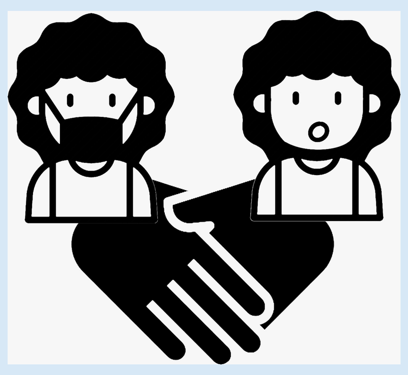
Problem Description

During **pandemics**, like Covid-19, **public safety** is a public good worth paying attention to. With this objective in mind, governments create **mechanisms** (e.g. use of **mask policy**) to control the spread of the virus to their citizens. In response, citizens behave differently and strategically (consciously or not), e.g. being **policy-compliant** or not **(free-riders)** towards these government measures, posing a **social dilemma**. **Evolutionary Game Theory (EGT)** offers useful tools [1], e.g. **Replicator Dynamics** or **Population-based Markov Process**, to understand the behavior of different groups in two-player social dilemmas games.



Evolutionary Methodologies

1. Replicator Dynamics

$$\dot{x}_i = x_i\left[(A\mathbf{x})_i - \mathbf{x}A\mathbf{x}\right] \quad (1)$$

where x_i is the frequency of strategies i in the population and A the payoff matrix with each strategy when interacting against any other strategy in the population.

Assumptions

- Population evolution based on survival of the fittest phenomena

Attributes

- Infinite Population
- Population proportion differentiable w.r.t time (continuous)
- Nash Equilibrium and Evolutionary Stable State (Coordinate-wise)

2. Population-based Markov Process

$$f_i(x_i, Z) = \frac{x_i - 1}{Z-1} * A_{ii} + \frac{Z - x_i}{Z-1} * A_{ij} \quad (2)$$

where f_i, the fitness of an strategy i against strategy j, depends on Z, the population, x_i, the frequency of a strategy i, and the respective strategy payoffs A_{ii} and A_{ij}.

Assumptions

- Social imitation governed by a stochastic Birth-death process (i.e. **Moran Process**)

$$p = \frac{1}{1 + e^{\beta(f_a - f_b)}} \quad (3)$$

where p, the probability that an individual a (selected for death) will copy the strategy of an individual b (selected for birth), depends on β is the intensity of selection and the respective fitness f_a and f_b.

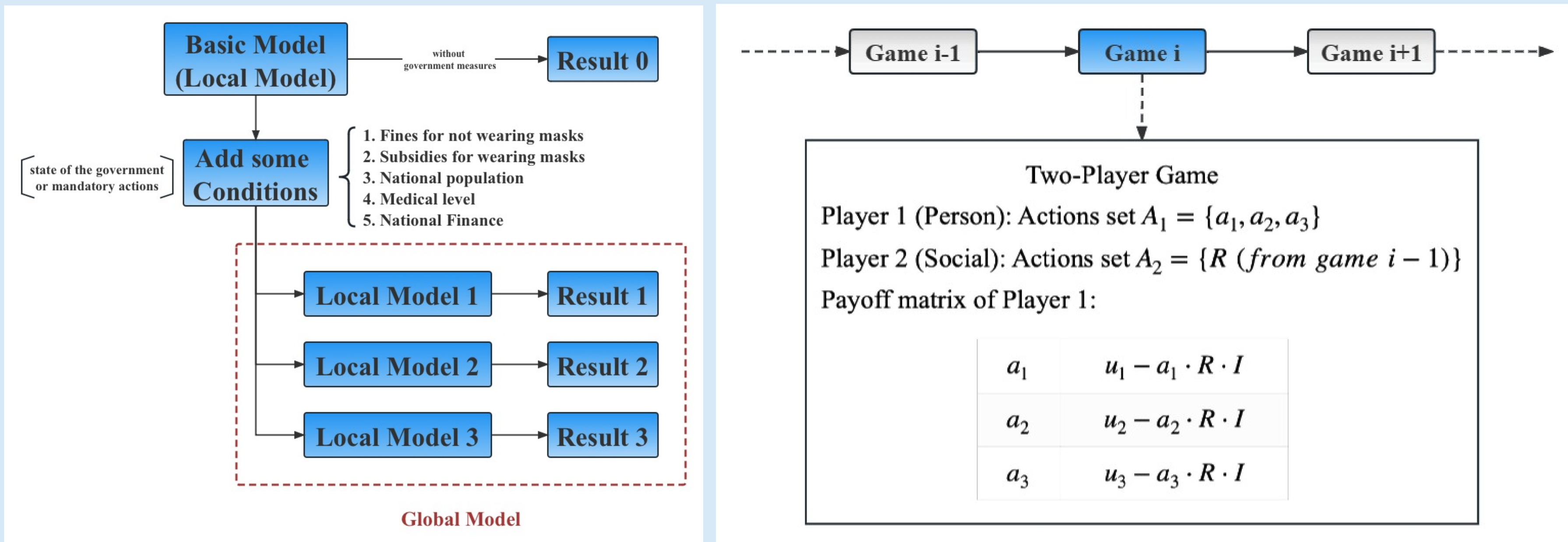
Attributes

- Infinite Population
- Discrete (non-differentiable)
- Nash Equilibrium and Evolutionary Stable State (Region-wise)

These evolutionary methods are implemented in the open-source library EGTTools [2] implemented in Python and C++.

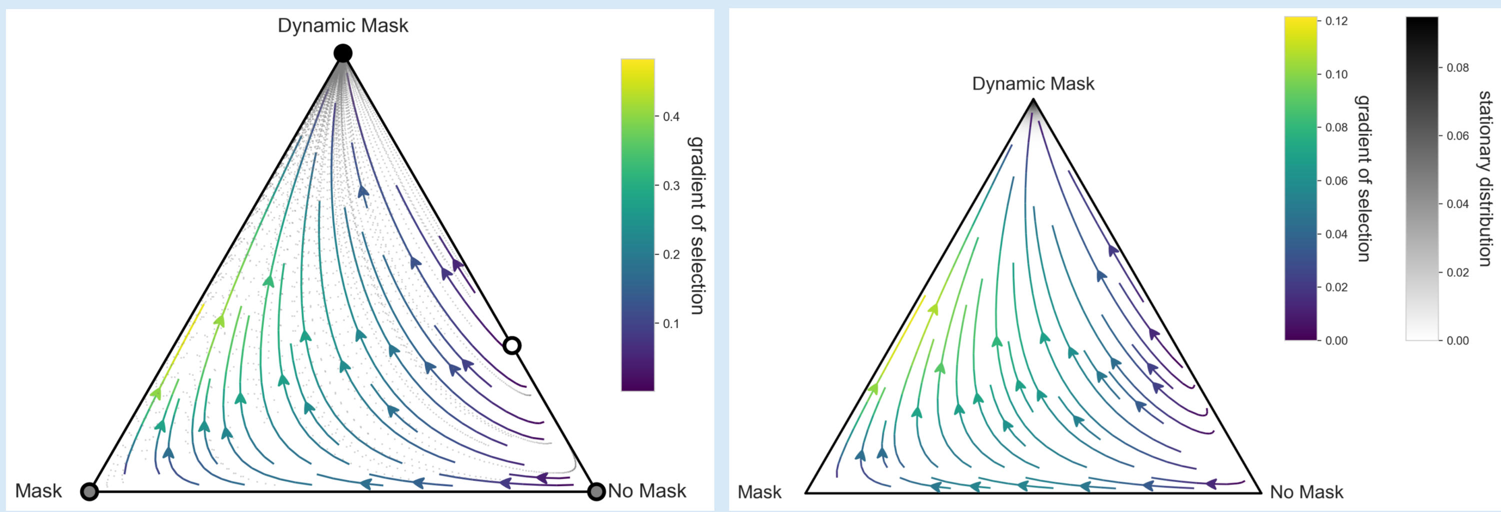
Model & Payoff Methodology

Schematic of our global model: We introduce various conditions to the basic model derived from governmental actions. By comparing the performance of the basic model under various conditions, we can analyze the influence of government actions on individuals' decision-making.



Intermediate results

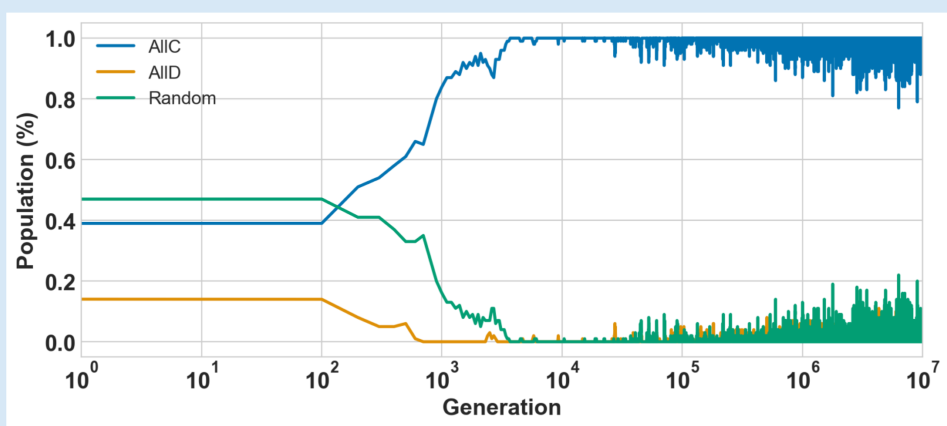
On the left, a social dilemma evolved by replicator dynamics methodology is represented. On the right, the same dilemma now evolved through a population-based Markov process.



Link under development: https://l-vicen-gtn-case-studies-documentation-rokqn8.streamlit.app/

Ongoing research

Work in progress on two fronts: (1) reasonable parameter search (i.e. better payoffs and intensity of selection values) and (2) consideration of an Agent-Based Simulation approach. The ladder imposes higher technical complexity but proposes higher flexibility of game settings addressing limitations of the two evolutionary methodologies considered [3].



References

[1] Oliver Gloor, Beatrice Amrhein, and Roman E. Maeder, editors. *Illustrierte Mathematik: Visualisierung von mathematischen Gegenständen.* BirCom. Birkhäuser, Basel, 1994.

[2] Elias Fernández Domingos. Egttools: Toolbox for evolutionary game theory. https://github.com/Socrats/EGTTools, 2020.

[3] Eitan Altman, Mandar Datar, Francesco De Pellegrini, Samir Perlaza, and Daniel Sadoc Menasché. The mask game with multiple populations. *Dynamic games and applications*, 12(1):147–167, 2022.