Exploring the Emergence of Cooperation

Complex Social Systems Group Project

14.10.2020 - Yanninimalhu

Social dilemmas in game theory

Social Dilemmas

incentive to free-ride (T) > incentives to cooperate (R)

P1 / P2	C	D
C	R, R	S, T
D	T, S	P,P

Enhancing cooperation

Iterated prisoner's dilemma (PD)

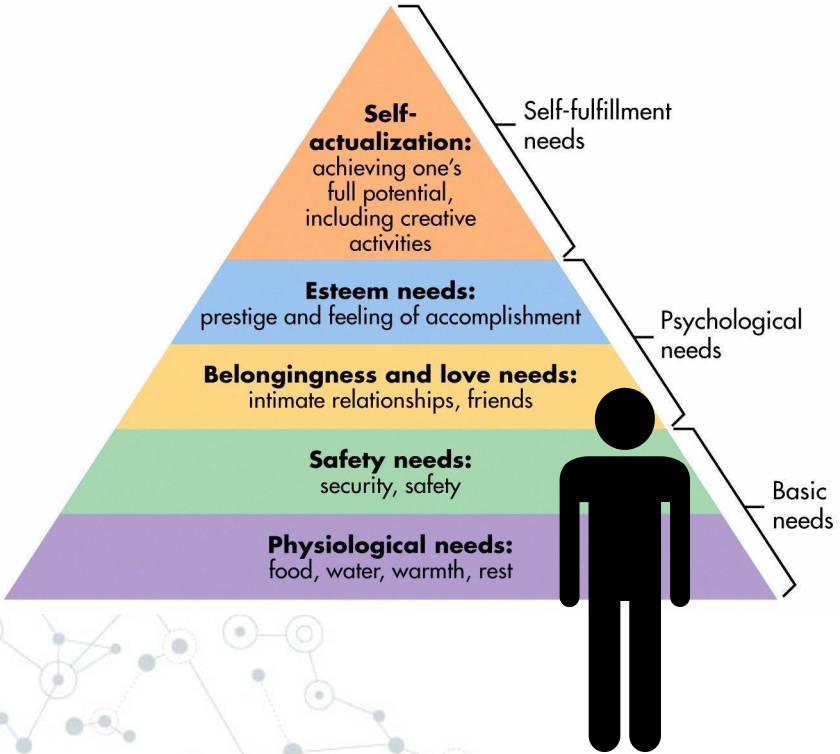
- Imitation

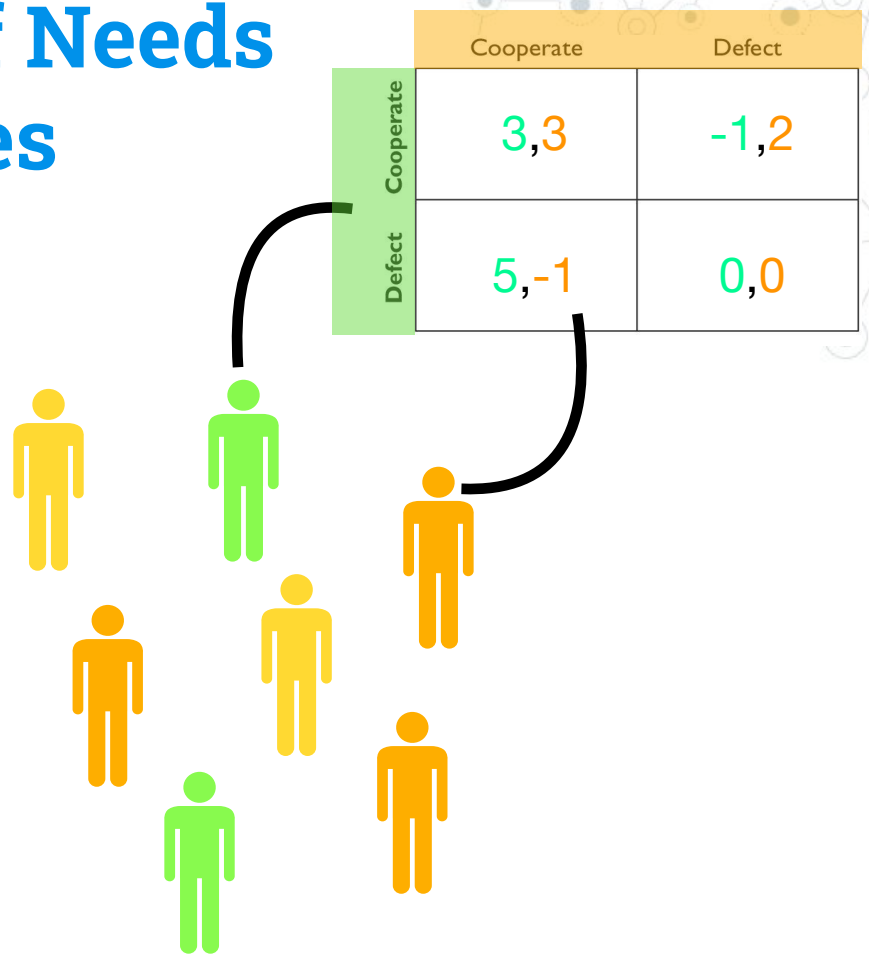
Spatial influences

- Small-world networks
- Migration

… and many other mechanisms

Maslow's Hierarchy of Needs and Asymmetric Games

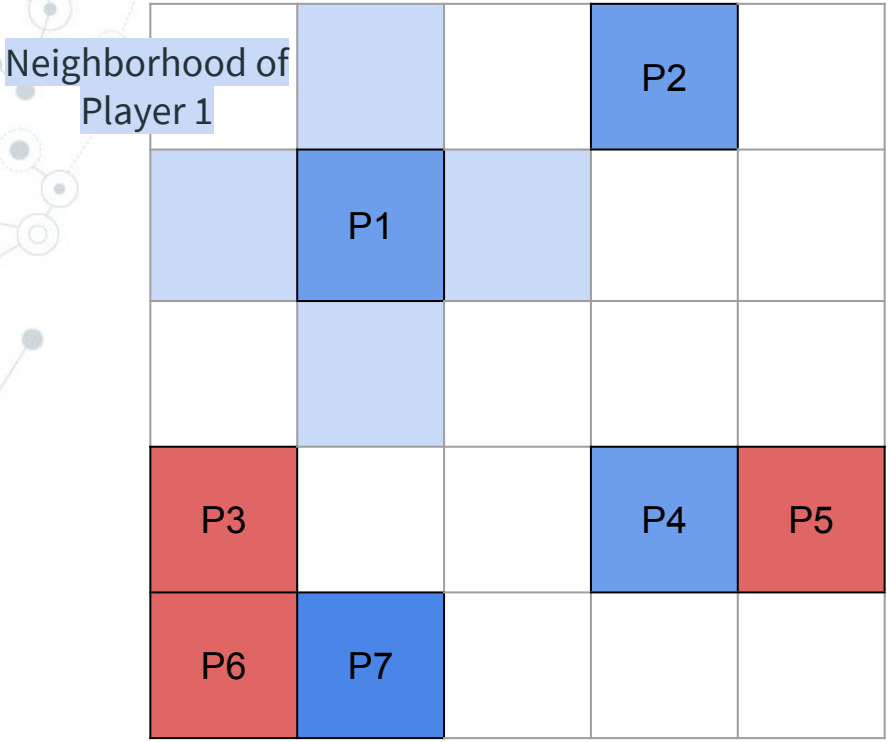




Objectives

Explore emergence of cooperation under

Basic Model



We model the world as a grid of cells, some of which are occupied by players.

Players play the prisoner's dilemma game with other players in their neighborhood. Players are either cooperative (C) or defecting (D).

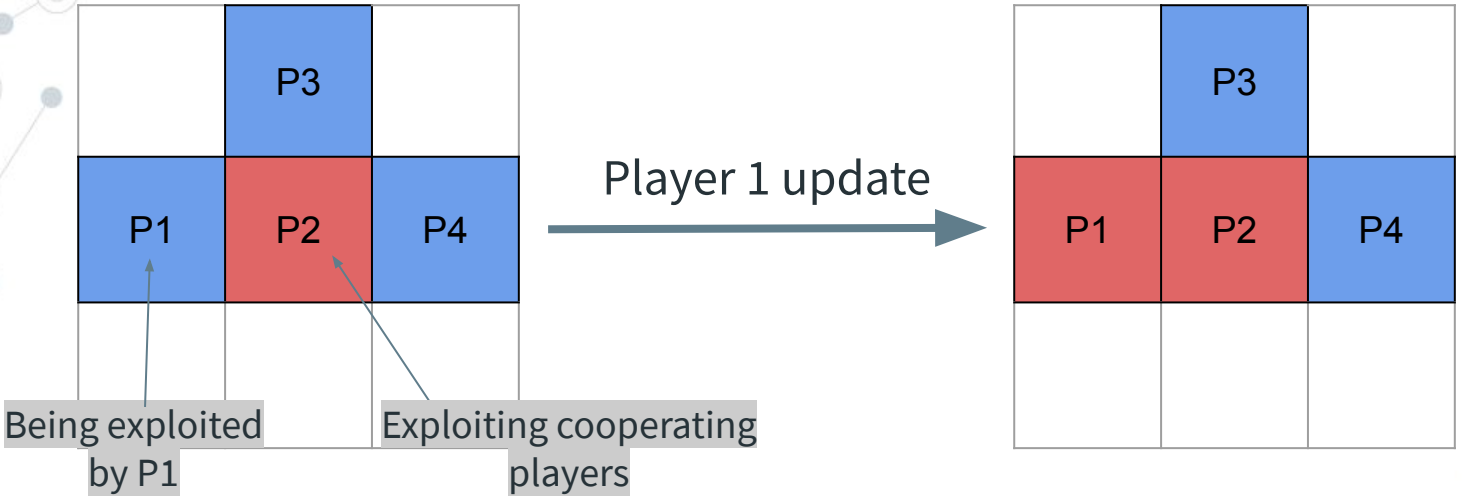
P1 / P2	C	D
C	R, R	S, T
D	T, S	P,P

Basic Model

Imitation

Players update their **strategy** by copying their most successful neighbor

P1 / P2	C	D
C	R, R	S, T
D	T, S	P,P



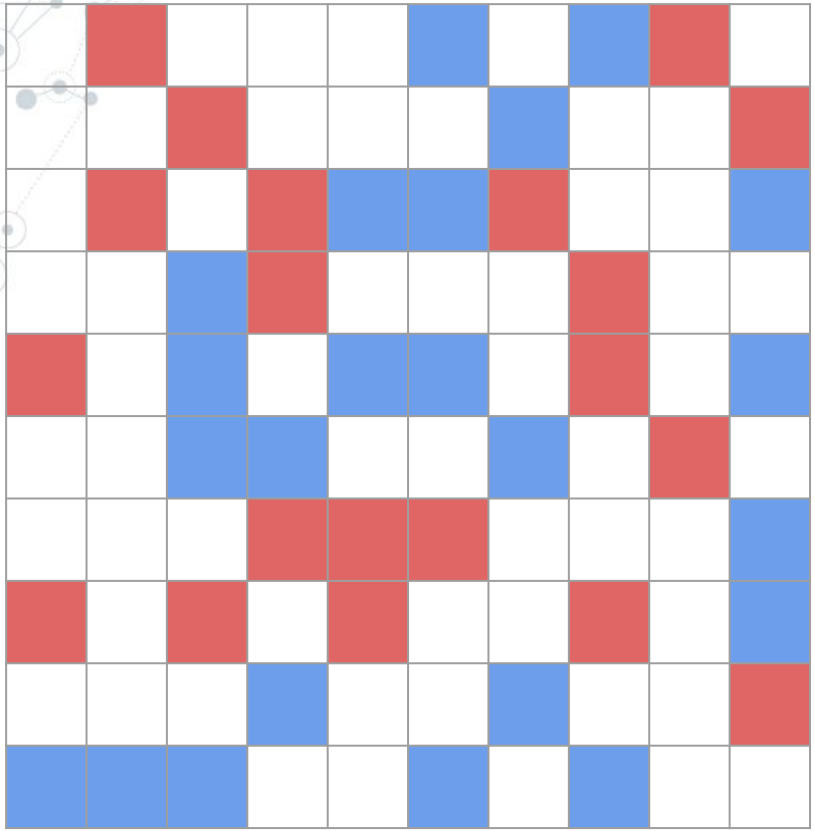
Basic Model

P1 / P2	C	D
C	R, R	S, T
D	T, S	P,P

Migration

Players update their **position** by moving to where they would get the best payoff with their current strategy.

Simulation



P1 / P2	C	D
C	R, R	S, T
D	T, S	P,P

Update all players in a random, sequential order, then iterate.

- Prisoner's Dilemma game
- Migration
- Imitation

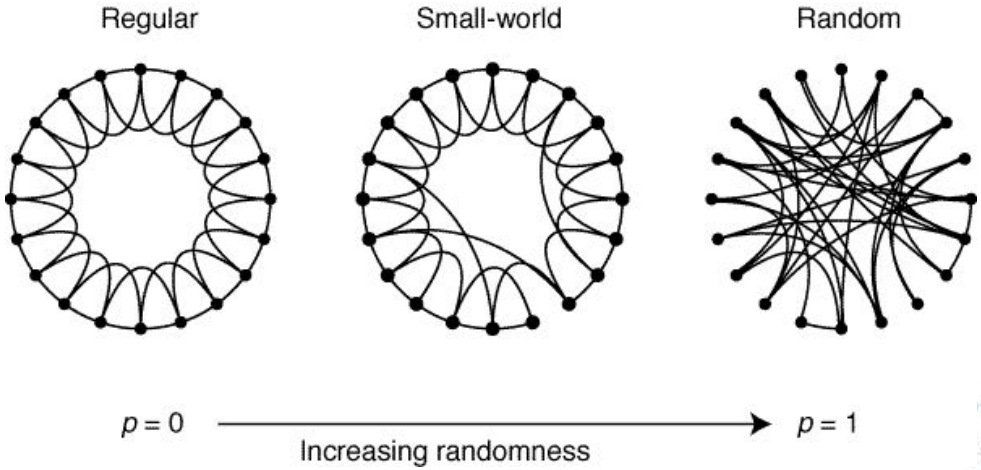
We introduce noise (random strategy mutations) simulate **trial-and-error** behaviour and **unsuccessful imitation**.

Small World Network

We replace the grid with a **small-world network** in which nodes represent players.

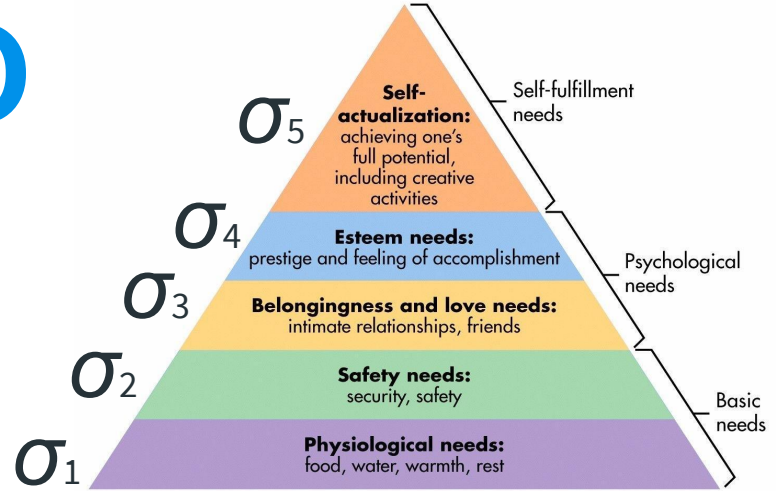
Small-world networks characterized by **small average node distance** and **large clustering coefficients**.

- More realistic modelling of real-world interactions



Asymmetric PD

P1 / P2	C	D
C	$\beta_1 R, \beta_2 R$	$\gamma_1 S, \alpha_2 T$
D	$\alpha_1 T, \gamma_2 S$	$\delta_1 P, \delta_2 P$



Temptation to defect:

$$\alpha \propto 1/(sum\ all\ needs)$$

Reward for cooperating:

$$if\ physiological\ needs\ met\colon \beta \propto other\ needs$$

Sucker's payoff

$$\gamma \propto self\ \ fulfillment\ needs$$

Punishment for mutual defection:

$$\partial \propto psychological\ needs$$

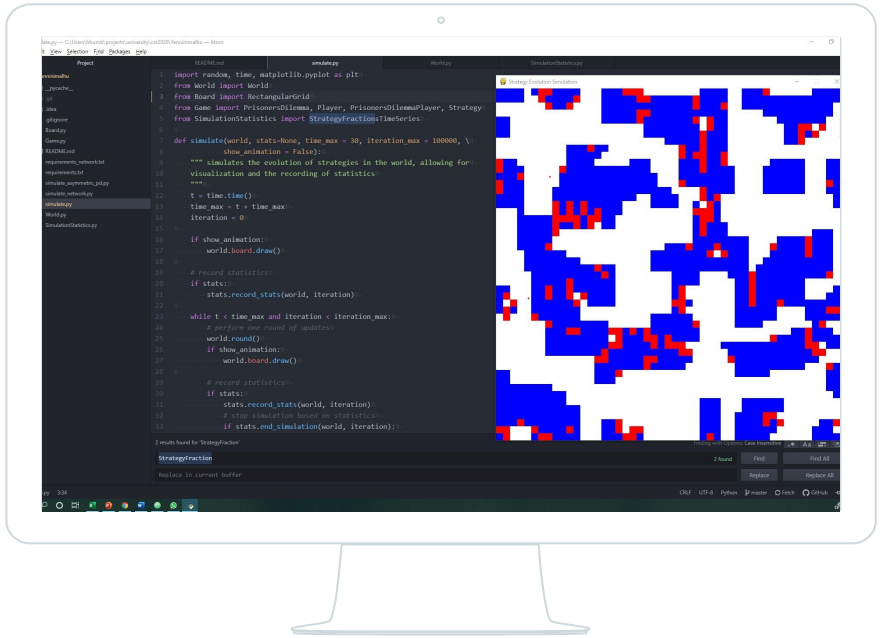
$$\alpha = \frac{2}{1 + \frac{\Sigma_{i=1}^{5} \sigma_i}{\Sigma_{i=1}^{5} i}}$$

$$\gamma = 1 + \sigma_5$$

$$\delta = 1 + \frac{(\sigma_3 + \sigma_4)}{2}$$

$$\beta = 1 + \frac{\Sigma_{i=1}^{5} \sigma_i}{\Sigma_{i=1}^{5} i}$$

Implementation

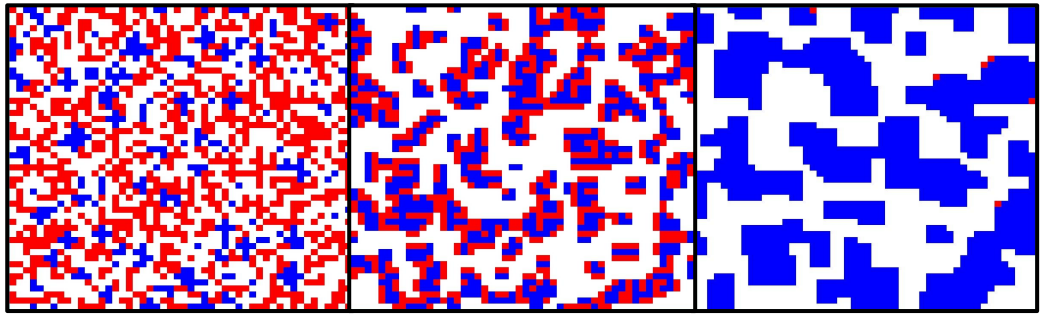


100% Python

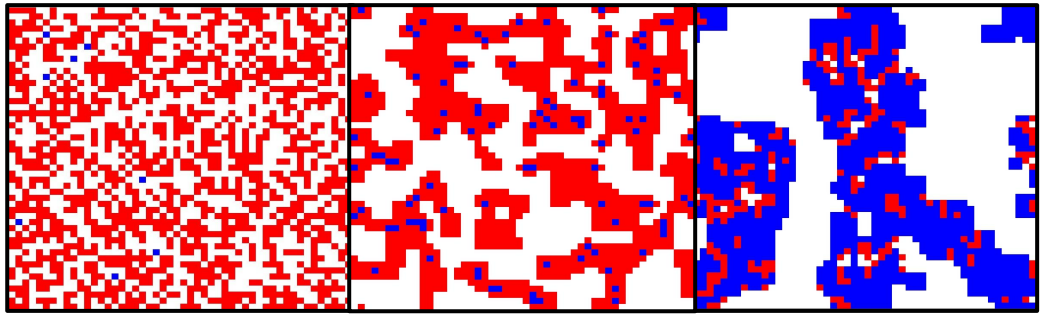
All code was written in Python, making use of public modules for animation and network analysis.

Code Validation

No Noise



Noise



Imitation | Migration | Imitation & Migration

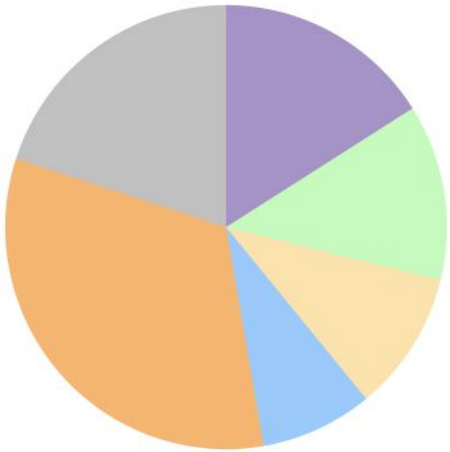
Cooperative behaviour robust to noise!

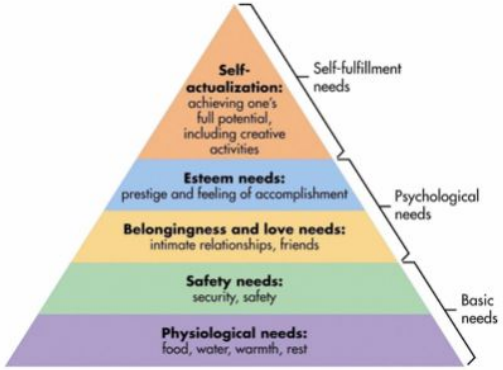
Results I: Population structure

p= probability that need is not met

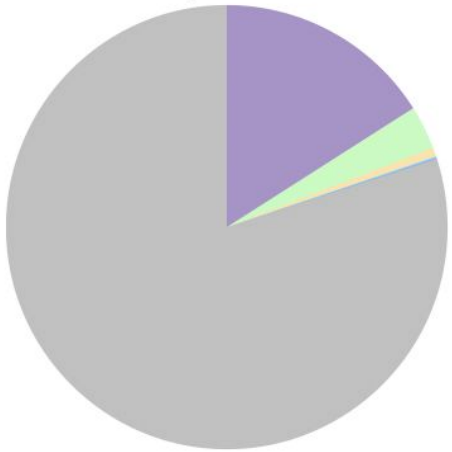
Physiological Security Love Esteem Self-Actualisation None

p=0.2



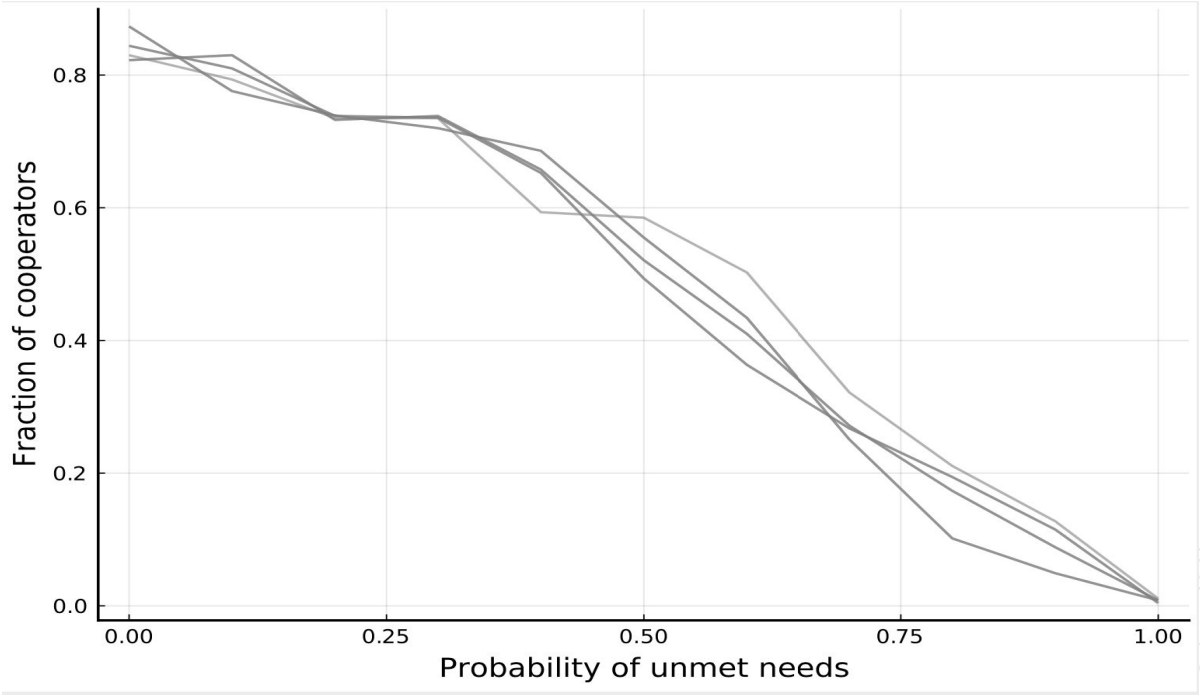


p=0.8



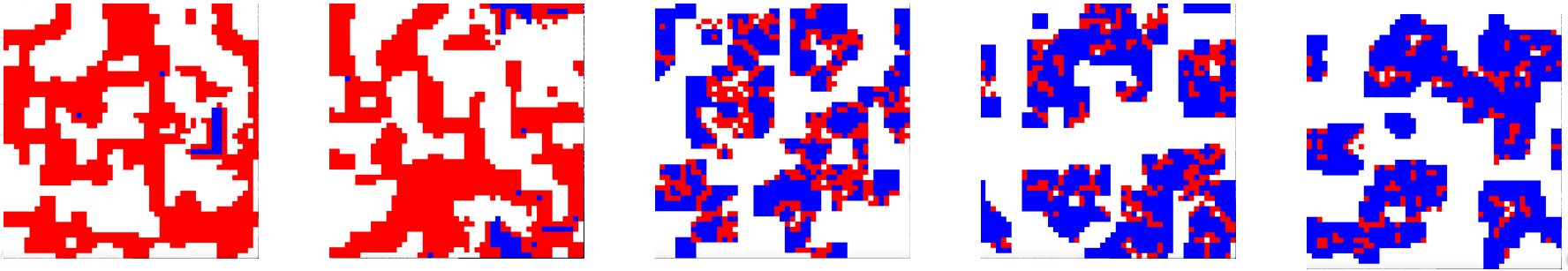
Results I

1. Cooperation is strongly contingent upon the fulfilment of needs



Results I

2. Cooperation cannot exist in societies where basic needs aren't met



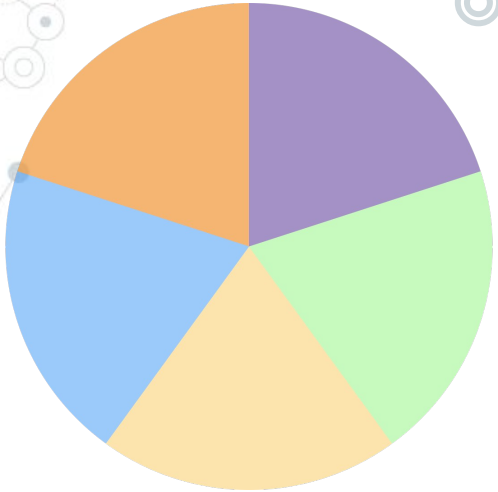
Needs

Physio. Security Love Esteem Self-Act.

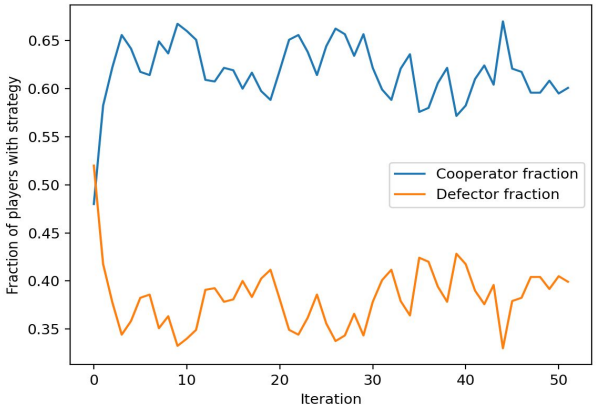
Basic needs Psychological

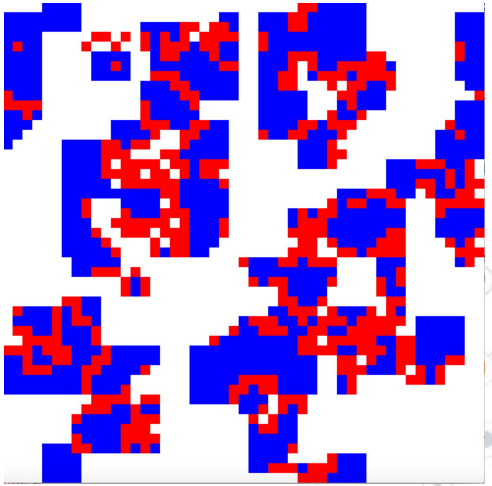
Results I

3. Heterogeneous population structures enhance cooperation



- Expected fraction ~ 0.5
- Not just a sum of its parts!

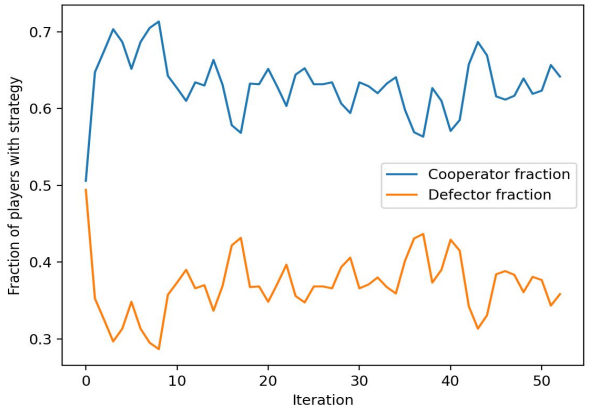


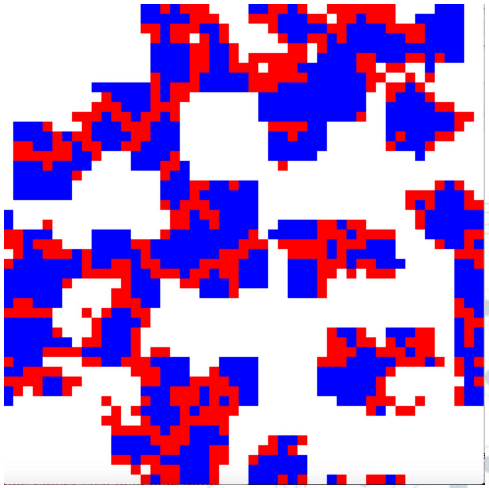


Results I

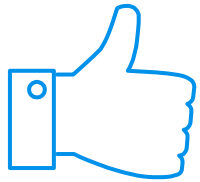
3. Heterogeneous population structures enable cooperation

- **Comparable to unrealistic homogenous populations**





Conclusions I



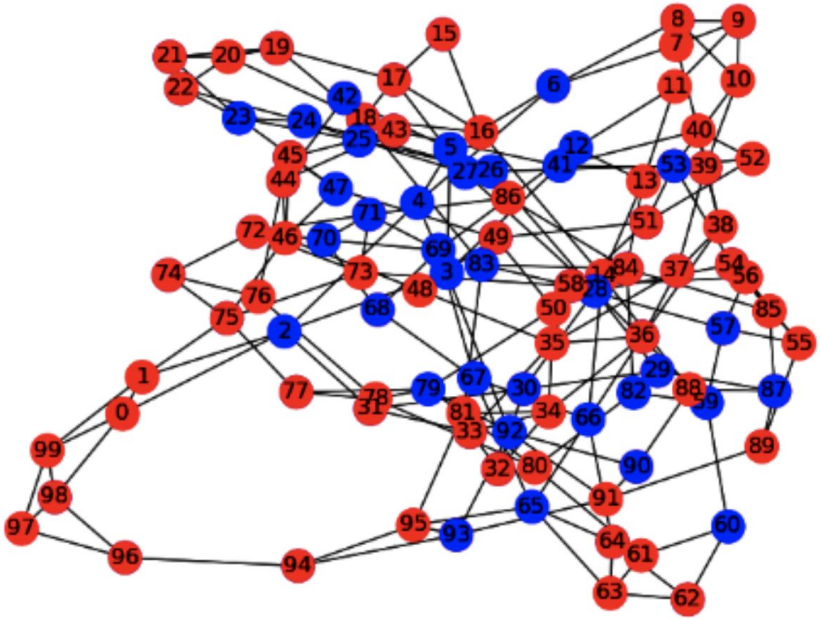
Results highlight the importance of “role-models” in society

Socio-political implication:

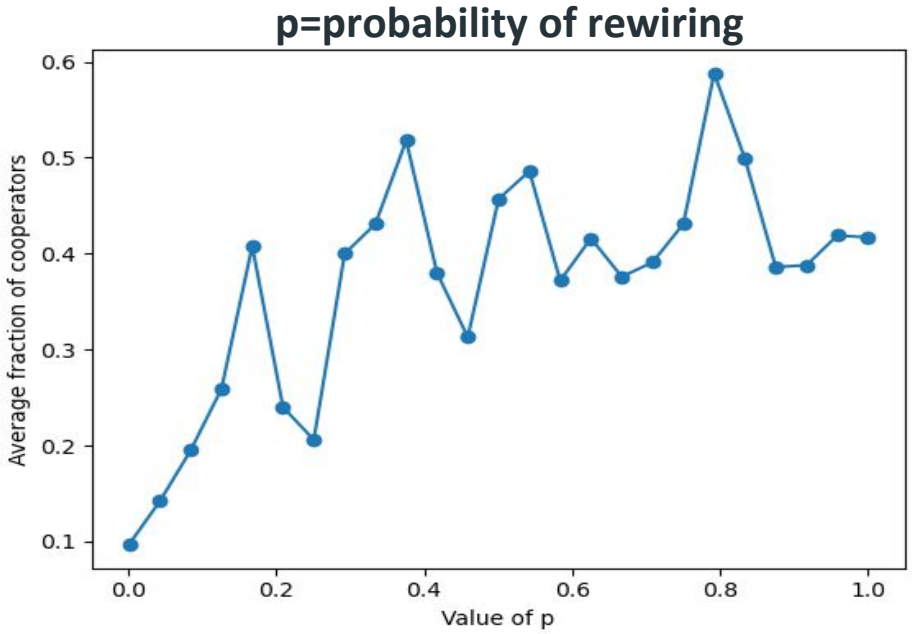
… theories of communism and capitalism do not need to be considered opposites or alternatives, but rather systems that satisfy different stages of humanity's technological development.

Results II: Network topology

100 nodes, mean degree=4 and probability of rewiring=0.2



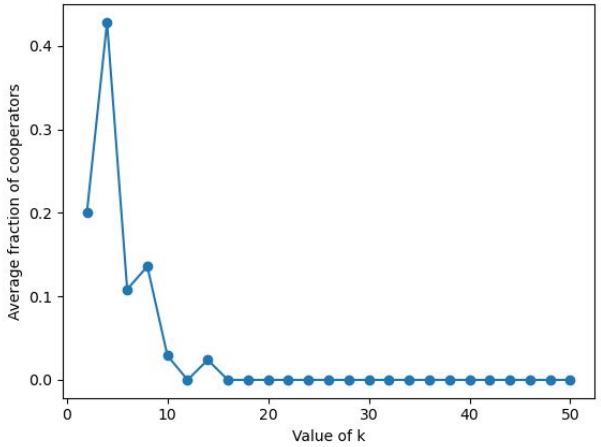
Results II



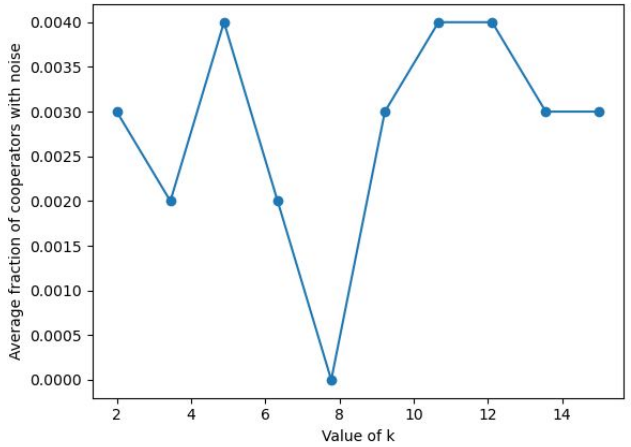
Cooperators vs p

Results II

k=mean degree of the network



(1) Cooperators vs k, noise off



(2) Cooperators vs k, noise on

Conclusions II

- Hubs promote cooperation
- Cooperator hubs are good as long as not too accessible

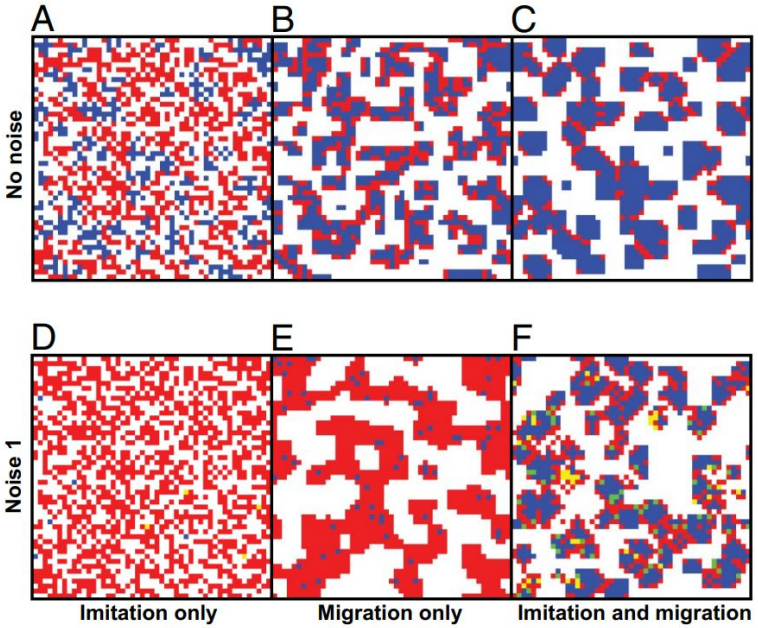
Discussion and extensions

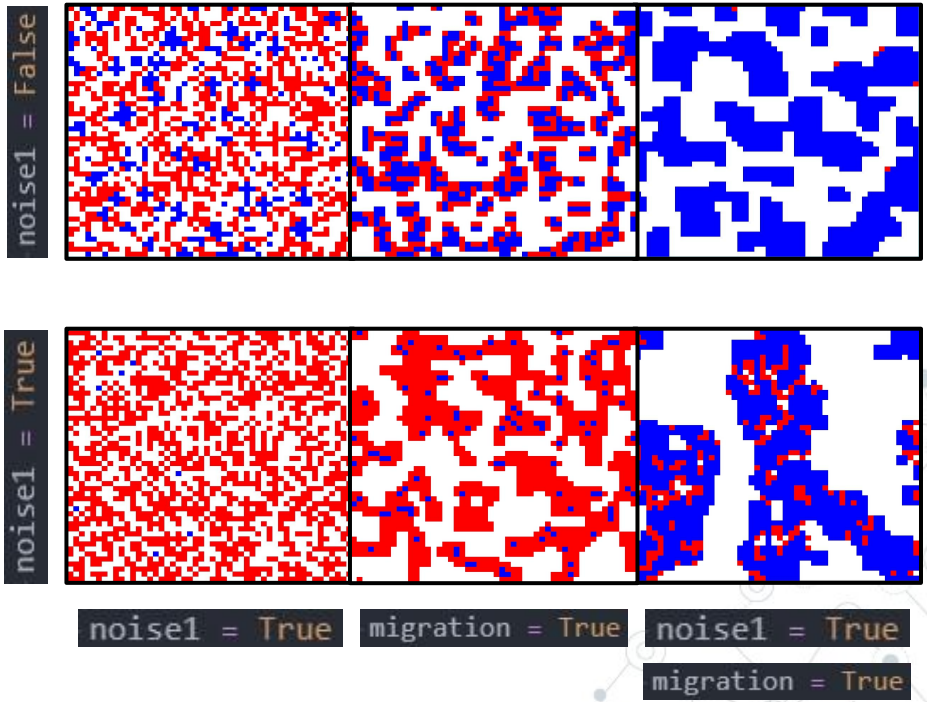
- Nodes inside are always cooperating
- Nodes on the “walls” are vulnerable but can be lucky…
- Hubs are not robust
- **Possible extensions:**
  - adaptive networks (structure ⇔ dynamics)
  - higher order networks (group games)

Thank you!

Any questions?

Appendix


A
B
C
No noise
D
E
F
Noise 1
Imitation only
Migration only
Imitation and migration


noise1 = False
noise1 = True
noise1 = True
migration = True
noise1 = True
migration = True