Emergence of cooperation: Growing habitat with empty sites

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Motivation

Prisoner's dilemma game
- Possible action: Cooperation (C) and Defection (D)
- Payoff matrix

\[ \begin{array}{c|cc}
 & C & D \\
\hline
C & 1 & -1 \\
D & -1 & 0 \\
\end{array} \]

Social dilemma: \( 2R > T + S \)

Nash equilibrium: Mutual defection

How does cooperation emerge?

Combining strategy dynamics and population dynamics

Without mutation

Absorbing transition points \( \lambda \)

ACTIVE Phase
- Finite number of realizations survive at infinite time.

EXTINCTION Phase
- All realizations fall into the absorbing state eventually.

The number of surviving realizations

Mean-field calculation

\[ V_0 = \frac{1}{1 + N e^{\omega n}} \]

Death probability

\[ \mu_i = \text{total payoff} \times \text{selection} (\mu = 1) \times \omega \]

Phase diagram

In the region II, only the cooperators can survive.

With mutation

Absorbing transition points \( \lambda \)

Initial condition dependency disappears.

Phase diagram (\( \mu = 0.001 \))

Empty sites protect the cooperators from the invasion of defectors, and cooperators can survive even though \( c/b > 1/k \).

Summary and discussion

- We have considered the population dynamics as well as the strategy dynamics by introducing empty sites.
- We have found that the empty sites created from population dynamics construct spatial structure and develop the cooperative society.
- Our model in 2-dimensional lattice: future research.

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