Spatial Divergence & Oscillatory TOCs

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The tragedy of the commons

Garrett Hardin:

The population problem has no technical solution; it requires a fundamental extensioin in morality.

The tragedy of the commons

A tragedy of the commons (TOC) occurs when individuals acting in their own self-interest deplete commonly held resources, leading to a worse outcome than had they cooperated.

Keys to TOC

- Macro-scale:
  - game
  - environment
- Individual level:
  - divergence of incentives & pay-offs

Current frameworks

- Evolutionary dynamics arising from a TOC dilemma can be modeled in terms of changes in the frequencies of individuals from two populations, cooperaters and defecters.
- Individuals interact and receive payoffs that depend on their strategy and the strategy of their opponent, where payoff can be modeled by the payoff matrix,

$$A = \begin{Bmatrix} R & S \\ T & P \end{Bmatrix}$$

  representing the system's fitness.
- The outcome of TOC is measured by the frequency of co-operators and defectors $(x, 1-x)$, and the resources.
- This framework is not a zero-sum game.

Current frameworks – equations & conditions

PhysRevLett.122.148102

- fitness

$$\dot{x} = x(1-x)[r_c(x,A) - r_D(x,A)] \tag{1}$$

r_C, r_D : context-dependent fitness payoff to cooperators and defectors, respectively.

  - TOC's occurrence condition: $T > R > P > S$.

- To address the reproductive case: resource-dependent payoff matrices

$$A(n) = A_0(1-n) + A_1(n),$$

where $n \in [0,1]$.

Individual-based coevolutionary game

- Intuitions on the emergent dynamics of social context and resources:
  1. to assess the influence of noise
  2. spatially explicit interactions
- Schemes:

$$
\begin{array}{ccccccccccc}
\overbrace{C}^{\text{focal}} & + & \overbrace{C}^{\text{opponent}} & + & \overbrace{D}^{\substack{\text{random}\\ \text{player}}} & \xrightarrow{k_1} & \overbrace{C}^{\text{focal}} & + & \overbrace{C}^{\text{opponent}} & + & \overbrace{C}^{\text{replaced}} \\
C & + & D & + & D & \xrightarrow{k_2} & C & + & D & + & C \\
D & + & C & + & C & \xrightarrow{k_3} & D & + & C & + & D \\
D & + & D & + & C & \xrightarrow{k_4} & D & + & D & + & D,
\end{array}
$$

Figure: Transitions of cooperaters and defectors.

Individual-based coevolutionary game

- Results
  - Transition rate for #C and #D. Furthermore, the limiting frequency of cooperaters $\lim_{N,n_c\to\infty} \frac{n_C}{N}$
- Problems: is such frequency convergent or divergent?
  - Recalling a Cauchy distribution, or a Lorenz oscillator.
  - In other words, is the society ending up in tragedy?

Demongraphic noise and spatial structure

References

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