Entanglement of evolutionary game theory and statistical physics

(Az evolúciós játékelmélet és a statisztikus fizika összefonódása)

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Development of the evolutionary game theory reached the state three decades ago, when the sophisticated mathematical methods of the solid state and statistical physics could also help to reveal more effectively the connection between biological or social phenomena. In the physical models these methods have ensured the determination of thermodynamic properties of materials depending on interactions among the atoms. The utility of this knowledge is justified by many new devices developed via this approach.

In the models of evolutionary games the decisions (strategies) of the players correspond to possible behavior of the social actors, which usefulness (depending on their choice) is described by the elements of a payoff matrix. In the biological systems the game theoretical strategies represent different living objects and the utility quantifies their reproduction capability. The adoption of successful physical approaches naturally arose in the multiplayer systems to explore relationships existing in large biological and social systems.

It was revealed during analysis of the payoff matrix that this interaction contains characteristics of Ising and Potts models studied for 100 years in physics. Additionally, there occurred social trap situations being responsible for the parasitism, and the (rock-paper-scissors type) cyclic dominance ensuring the maintenance of biodiversity. The difference between the living and non-living (thermodynamic) systems can be observed in the wider scale of dynamics in the individual strategy changes, and also in the connectivity structure among the participants. These novelties have initiated further developments within the non-equilibrium statistical physics too. In the light of the recent processes the exploration of further interesting and relevant mathematical relationships is expected in these scientific fields.

References:

https://fizikaiszemle.elft.hu/uploads/2025/04/07_szabogy_12_01_35_1744279295.5627.pdf