Audiovisual Experiments with Evolutionary Games, and the Evolution of a Work-in-progress

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Abstract

This artistic project abstract describes ongoing and work-in-progress audiovisual exploration of a simple multi-agent system borrowed from evolutionary game theory: a Demographic Prisoner's Dilemma (DPD). Several versions of the DPD are explored, by gradually increasing the properties of the agents (e.g., maximum age, mutation of strategy). Starting as literal implementations of the formal game, intended as an audiovisual aid to the game's dynamics, the examples gradually depart from strict functionality to embrace a more 'artistic' and arbitrary approach. These experiments are both evolutionary games and the evolution of the author's aesthetic experimentation with the subject matter. A DPD is a type of evolutionary game where all agents are indistinguishable and they inherit a fixed (immutable) strategy (either cooperate or defect). [1] It differs from other games in that is memoryless. Each agent, at each stage game, has no knowledge of the past interactions. It is based on the Prisoner's Dilemma (PD), a popular imperfect information coordination game where two players abide by the normal form shown in Table 1, where *c* (cooperate) and *d* (defect) are the two strategies available to the two players, and the tuples in the matrix correspond to the payoffs for each pairwise combination of strategies, with T>R>P>S. [2]

	c	d
c	(R,R)	(S,T)
d	(T,S)	(P,P)

Table 1. *Prisoner's Dilemma* normal form.

For a *one-shot* PD game, it has been shown that the Nash Equilibrium is the pure strategy *dd*. [3] It has also been shown that in DPD cooperation can emerge and endure, unlike in a repeated PD game with memory, where the dominant strategy would still be to defect. [1]

Practically, agents have the following properties: vision, wealth, age and strategy. Upon initializing the game, a random number of agents is placed on the grid and each agent is born with a fixed strategy. Each agent looks around its vision perimeter, choses a random neighbor within it, and plays a PD game with that neighbor. Payoffs add to the agent's wealth. If such wealth exceeds a given threshold, the agent can reproduce within its vision perimeter and the offspring will inherit the parent's strategy. Conversely, if an agent's wealth falls below zero, the agent dies.

The game was coded using the p5.js Javascript library and the Web Audio API. [4] [5] Each agent is represented as a colored position in a square grid of variable dimensions. The color code corresponds to the agent's strategy (green for *c*, red for *d*). The edge roundness of the agents is proportional to their wealth. Each agent is also a frequency modulation (FM) unit, whose carrier frequency is proportional to a fundamental frequency and the agent's position on the grid. [6] Such fundamental frequency is different depending on the agent's strategy, with defectors having a long period and an element of randomness. Thus, defectors have a 'noisy' sound texture associated with them, whereas cooperators are contributing to a harmonic texture which is richer as their number grows. Moreover, each

sound source (active agent) is spatialized using the binaural panner of the Web Audio API. [5] The correspondence between cooperation and a harmonic sound is rather simplistic or perhaps even cliché, as is the choice of colors that represent the two strategies. Nevertheless, such a simple mapping is sufficient to render the game dynamics at an audiovisual level, and it's only the first step in an exploratory process which is still ongoing and liable to further changes.

The first version of the audiovisual DPD does not set an upper bound on the agents' age, nor does it allow for mutation of their offspring's strategy. The second implementation, instead, limits the age to an arbitrary value which can be experimented with heuristically. Once and if the whole population dies out, the game is automatically restarted. Age is represented both in the visual domain, as the transparency value (the older the agent, the more transparent it is), and in the audio domain, being mapped to the amplitude of both oscillators for any given active agent. The third version of the game adds a probability that a given child might mutate strategy instead of inheriting the parent's one. This probability is set at 0.5 but can be changed arbitrarily. In all three examples, cooperation seems to emerge, which sonically translates to a harmonic sound that is obtained thanks to the superposition of the cooperator's partials over the randomness of the defectors.

In the subsequent implementation of the DPD, the author used images taken from the digits MNIST and the Fashion-MNIST datasets as occasional backgrounds to the game. [7] [8] Their occurrence is dictated by, for example, the grid not changing its global state between two consecutive frames, or the extinction of all agents (thus the re-initiation of the grid), although this can be experimented with. Similarly, sound files are triggered stochastically when (arbitrarily) analogous conditions are met.

Fig. 1 shows screenshots of the "max age – no mutation" case, with and without the MNIST background, with the third screenshot suggesting a possible departure from the simplistic representation of the agents.

Fig. 1. *DPD*: "max age – no mutation" screenshots ©Kalonaris.

Substituting the agents' visual appearance, the mapping between the latter's parameters, the audio parameters and the game's dynamics is the subject of future work and development. The author's aim is to further explore the aesthetic implications of the DPD game at an audiovisual level.

References

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Biography

Stefano Kalonaris is a sound technologist, musician and researcher who specialises in interactive music systems and improvisation. He holds a PhD in Sonic Arts and he is currently a postdoctoral researcher at RIKEN-AIP, Japan.