Evolutionary Game theory in multiplex networks

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1 Evolution of cooperation

There is an enormous amount of examples of cooperation in nature from humans that cooperate to build complex societies to animals like wolves that hunt in packs in order to catch preys larger than they are, or meerkats that watch out for predators in turns while the rest of the colony feeds. Even small microorganisms cooperate to survive in hostile environments. For instance, the *Dictyostelium discoideumu*, usually a solitary amoeba, when starves it associates with others in order to form a multicellular slug for the sake of survival. Explaining how cooperation has emerged and has resisted against more selfish behaviours is one of the biggest challenges in natural and social sciences. Several mechanisms has been proposed in order to explain the evolution of cooperation [1][2][3], among them the structure of the interaction's network between individuals. From the mathematical point of view in order to study this kind of social interactions and conflicts in a graph is Evolutionary Game Theory [4][5][6][7], the evolutionary branch of the classical Game Theory.

The study of networks, their properties and dynamics, has experimented a huge advance in the last few decades, empowered by the technological advances that enable the acquisition of data about interactions between individuals from social networks [8][9], mobile communication networks [10] or collaborations between scientific authors [11]. The analysis of network dynamics arises the question of how cooperation evolves in such context[12]. There is a vast literature on the subject studding aspects like the effect of network topology [13], the effect of mesoscopic structure [16], network structures driven by the cooperation [15] and other spatial and temporal effects [14] that offer a novel interpretation of how cooperation can evolve in this scenario.

An innovative way of representing multiple types of social interactions in the same structure are multiplex networks [17][18], successfully applied to disease spreading [20] and synchronisation dynamics [21]. Multiplex networks are

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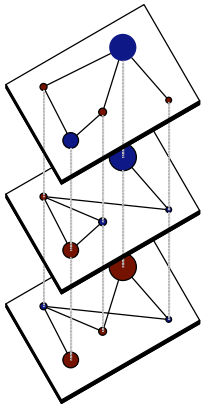

Fig. 1: Example of a multiplex network with 3 layers, 5 nodes per layer and 5 links in each layer. The color of the nodes represents the strategy played in that layer (red for cooperators, blue for defectors. Their size is proportional to their global payoff.

interesting in this field, because many social interactions can be understood as a superposition of interactions at different independent levels, each one representing a different social scenario like family relatives, friends, network of coworkers, etc. The behaviour of each individual can be different in each of these contexts, however is conditioned for each one of them [19][22]. How the evolution of cooperation works on top of this structure remains an open question.

2 Objectives

The objective of my thesis will be cover in depth all the possible implications of using multiplex networks in the field of evolutionary game theory. The subjects of study will be the effect of layer topology, the degree correlation between layers of different topology, percolation in multiplex networks driven by cooperation, dependence on the initial conditions... As a first step, we have made an exhaustive analysis of the resilience and propagation of cooperation in the central four dilemmas of game theory literature, how the convergence to a stationary state and which are the fluctuations at this state are affected by the number of layers of a multiplex.

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