Promoting Fair Proposers, Fair Responders or Both? Cost-Efficient Interference in the Spatial Ultimatum Game

Extended Abstract

Theodor Cimpeanu
Teesside University
Middlesbrough
t.cimpeanu@tees.ac.uk

Cedric Perret
University of Exeter
Exeter
c.perret@exeter.ac.uk

The Anh Han
Teesside University
Middlesbrough
T.Han@tees.ac.uk

ABSTRACT

Institutions and investors face the constant challenge of making accurate decisions and predictions regarding how best they should distribute their endowments. The problem of achieving an optimal outcome at minimal cost has been extensively studied and resolved using several heuristics. However, these works fail to address how an external decision maker can target different types of fair behaviour and how limited information can shape this complex interplay. Here, we consider the well-known Ultimatum game in a spatial setting and propose a hierarchy of interference mechanisms based on the amount of information available to the external decision maker and desired standards of fairness. Our key findings show that asymmetric interactions have drastically different dynamics when compared to symmetric games, such as the Prisoner's Dilemma, and discuss why gathering information about the agents' behaviour allows for the most efficient investment strategies.

KEYWORDS

Ultimatum Game; Interference; Evolutionary Game Theory; Complex Networks

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1 INTRODUCTION

The problem of how collective behaviours such as cooperation, coordination, safety compliance and fairness among self-interested agents emerge in evolving, dynamical systems has fascinated researchers from many disciplines, including Biology, Economics, and Computer Science [1, 11, 13, 15, 16, 23, 26, 28]. Several mechanisms that are responsible for promoting the emergence of cooperation have been proposed, including direct reciprocity [23, 25], kin selection [10] and network reciprocity [19] (for review, see [17, 28]). In these works, the evolution of desired collective behaviour is typically shaped by the combined actions of agents within the systems.

This paper contributes to advancing the state-of-the-art on optimal interference in evolving, dynamical systems [2, 3, 12, 14, 27] by analysing such interference in a spatial Ultimatum Game (UG), a popular bargaining game for investigating fairness in decision making [5, 5–9, 22]. In a standard UG, players have different roles, proposer and receiver (or responder), with different bargaining powers (See Section 2 for a detailed description). We consider the spatial version of the game [20] where players are distributed on a network in order to examine how to exploit the roles' asymmetry in both global and local interference strategies [12].

The main motivation of research on the UG arises from the gap between theoretical predictions, in which proposers keep most of the endowment and responders accept any positive proposition however small it may be, and experiments, in which individuals propose 40% to 50% of their endowment (and often get punished if they propose less) [9]. That said, previous works have investigated how fairness can evolve in models of UG, wherein several mechanisms promoting the emergence of fairness have been identified. We note that we align our definition of fairness with these previous works, where generous proposers are deemed as fair, regardless of their behaviour when acting in the role of the responder.

2 MODELS AND METHODS

Agents' interaction is modelled using the one-shot Ultimatum Game (UG) [18, 20]. In the UG, two players are offered a chance to win a certain sum of money, normalised to 1, which they must divide between each other. One player is elected proposer, and suggests how to split the sum, while the other, the receiver can accept or reject the deal. If the deal is rejected, both players receive zero. As in [18, 20], we assume that a player is equally likely to perform in one of the roles. As we focus in this paper on the effect of having multiple roles on interference decision making, we consider a minimal UG model where proposers have two possible strategic offers, a low (L, with $p = l$) and a high (fair) (H, with $p = h$) one, where $l < h \in [0, 1]$. On the other hand, receivers have two options, a low threshold (L, with $q = l$) and a high threshold (H, with $q = h$). Thus, overall, there are four possible strategies HH, HL, LH and LL. For example, HL would denote proposing high and accepting any offers.

We consider a population of agents on a square lattice of size $Z = L \times L$ with periodic boundary conditions— a widely adopted population structure in evolutionary games [24]. For a full description, see [4].

We aim to study how one can efficiently interfere in a structured population to achieve high levels of fairness while minimising the cost of interference. Naturally, the level of fairness is measured by the fraction of fair offers in the population [21], which is the total of HH and HL frequencies. An investment decision consists of a

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Table 1: Most cost-efficient scheme to reach a minimum fairness of proposals for different mutation rates (population-based, stochastic update). There exists no schemes which satisfy the higher minimum fairness requirements in the case of very high mutation rate, written as '–' in the table.

Mut. rate	Min. fairness	Target	Threshold	θ	Cost
10^{-4}	75%	HH	0.3	0.1	530
10^{-4}	90%	HH	0.3	0.1	530
10^{-4}	99%	HH	0.3	0.4	999
10^{-2}	75%	HH	0.3	0.3	750
10^{-2}	90%	HH	0.3	0.7	1747
10^{-2}	99%	HH	1	0.1	487514
0.2	75%	HH	0.6	0.2	358089
0.2	90%	–	–	–	–
0.2	99%	–	–	–	–

cost $\theta > 0$ to the external decision maker and this value θ is added as surplus to the payoff of each suitable candidate [3, 14].

We examine and compare different approaches of interference to induce fairness, based on ensuring fairness for either role or both roles, leading to different desirable behaviours to be targeted

- **(i)** ensure all proposals are fair, thus investing in HH and HL (**Target: HH, HL**);
- **(ii)** ensure only fair offers are accepted, thus investing in HH and LH (**Target: HH, LH**);
- **(iii)** ensure both (i) and (ii), i.e. investing in HH only (**Target: HH**).

In the *population-based* approach, a decision to invest is based on the current composition of the population. We denote x_f the fraction of individuals in the population with a desirable behaviour, given a targeting approach at hand, i.e. (i), (ii) or (iii) as defined above. Namely, investment is made if x_f is less or at most equal to a threshold p_f (i.e. $x_f \le p_f$), for $0 \le p_f \le 1$. They do not invest otherwise (i.e. $x_f > p_f$). The value p_f describes how rare the desirable behaviours should be to trigger external support.

3 RESULTS AND CONCLUSION

An external agent must consider several factors when investing in a population of individuals in an effort to ensure some form of desirable outcome. Among these, we consider and aim to resolve the questions regarding what sort of behaviour they should invest in, how large the individual endowment must be, but also what an investor can do when information about the population is incomplete, or even unknown. As such, we consider that the simplest form of information gathering measures fairness on average, as opposed to fine-grained observations on individual neighbourhoods. Likewise, we consider that ensuring all proposals are fair (i.e. investing in HH or HL) is less demanding on an external decision maker than ensuring that only fair offers are accepted (i.e. investing in HH and LH), which is, in turn, a simpler endeavour than for both the former and latter to be strictly enforced (choosing to invest in HH only). In this way, we can conceptualise a hierarchy of investment strategies in terms of complexity, some of which may simply be impossible for an investor to follow, merely due to lack of information, funding, or a combination of the two.

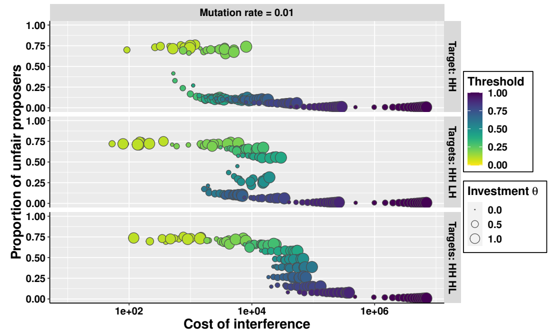

Figure 1: Proportion of unfair proposers as a function of average cost of interference for different targeting scheme (population-based, $\mu = 0.01$, stochastic update). The size and colour of the circles correspond to investment amount and threshold of investment, respectively. We note that the most desirable outcomes are closest to the origin.

We consider that there exists a *minimal level of fairness* which the external decision maker aims to enforce [3, 14]. We determine the least expensive investment strategies for different targeted levels of acceptable fairness. Table 1 highlights the least costly targets for investment for varying mutation (or behavioural exploration) rates [23], showing that the strictest target (HH) consistently produces the most cost-effective outcome, regardless of the mutation rates, when considering population-level information. A full analysis of several investment strategies including those based on local neighbourhood information, is provided in [4].

If the requirements, in terms of cost-effectiveness, are relaxed, an external investor might choose to invest in other roles with positive results, as well. In Figure 1, we present the Pareto efficiency of all the investment targets for varying individual investment amount, as well as the threshold for investment. Invariably, the fairest outcomes are achieved by selecting a high threshold for interference (i.e. never allowing the frequency of the investment targets to drop below a specific amount, typically a high threshold). Correspondingly, we show that fairness does not emerge when the threshold is low, regardless of endowment size.

To conclude, we have shown that when an external decision maker is limited to the macroscopic metrics associated with population-based interference, interference is characterised by its strictness. To elaborate, information gathering should be the main goal for the investor, as ensuring that proposals and responses are simultaneously fair (i.e. targeting HH) is the optimal outcome. Moreover, the individual investment amount can be reduced which, coupled with a high enough threshold for investment, reduces overall accumulated costs. This finding is pervasive regardless of the frequency of behavioural exploration.

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