Eliciting Fairness in Multiplayer Bargaining through Network-based Role Assignment

Extended Abstract

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ABSTRACT

From employment contracts to climate agreements, individuals often engage in groups that must reach decisions with varying levels of fairness. These dilemmas also pervade AI, e.g. in automated negotiation, conflict resolution or resource allocation. As evidenced by the Ultimatum Game, payoff maximization is frequently at odds with fairness. Eliciting equality in populations of self-regarding agents thus requires judicious interventions. Here we use knowledge about agents' social networks to implement fairness mechanisms, in the context of Multiplayer Ultimatum Games. We show that preferentially attributing the role of Proposer to low-connected nodes enhances fairness. We further show that, when high-degree must be the Proposers, stricter voting rules (i.e., requiring consensus for collectives to accept a proposal) reduce unfairness.

KEYWORDS

Evolutionary Game Theory; Group dynamics; Fairness; Networks

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1 INTRODUCTION

Fairness impacts human decision-making and individuals often prefer fair over payoff maximizing outcomes [5], as evidenced in numerous behavioral experiments with the two-person Ultimatum Game (UG) [6]. From human interactions to Distributed AI, however, fairness matters beyond pairwise interactions. Autonomous agents take part in groups that must select outcomes possibly favoring different parts unequally, such as in automated bargaining [7], conflict resolution [10] or multiplayer resource allocation [2]. Some of the fairness dilemmas associated with group interactions are captured in Multiplayer extensions of the UG (MUG) [17] .

Previous studies with the UG [3, 8, 12] and the MUG [15, 17], assume that each agent has the same probability of being selected to play as Proposer or Responder. In real-life, however, being the Proposer or the Responder depends on agents' characteristics. Employers, investors or rich countries, are often in the privileged position of deciding upon which divisions to offer, that is, being the Proposer. This can further potentiate inequality. As predicted by the *sub-game perfect equilibrium* of the UG, Proposers are likely to keep the largest share of the resource being divided. Differences between roles are exacerbated in a multiplayer context as punishing Proposers becomes harder as punishing unfair offers requires a successful collective agreement by Responders.

In the context of the 2-person UG, Wu et al. studied degree-based role assignment, showing that attributing the role of Proposer to high-degree nodes leads to unfairness [21]. Deng et al. concludes that the effect of degree-based role assignment depends on the particular strategy update mechanism considered [4]. Both works focus on pairwise interactions. Considering multiplayer ultimatum games opens space to study the interplay between group characteristics (such as group sizes and voting rules) and network-based criteria to select Proposers in eliciting fairness.

Here we analyze degree-based role assignment in MUGs played in complex networks. We find that selecting low-degree Proposers elicits fairer offers. We further show that stricter voting rules (i.e., imposing an accepting consensus for collectives to accept a proposal) attenuates the unfairness that results from high-degree nodes (hubs) being the natural candidates to play as Proposers.

2 MODEL

In the MUG, proposals are made by one Proposer to the remaining $N-1$ Responders, who must individually reject or accept it [15–17]. Proposers' strategy (offer) is denoted by p and q is the Responders' minimum acceptance threshold. Group acceptance will depend upon M, the minimum fraction of Responders that must accept the offer. Responders individually accept an offer if $p \geq q$. If the fraction of individual acceptances stands above M, the offer

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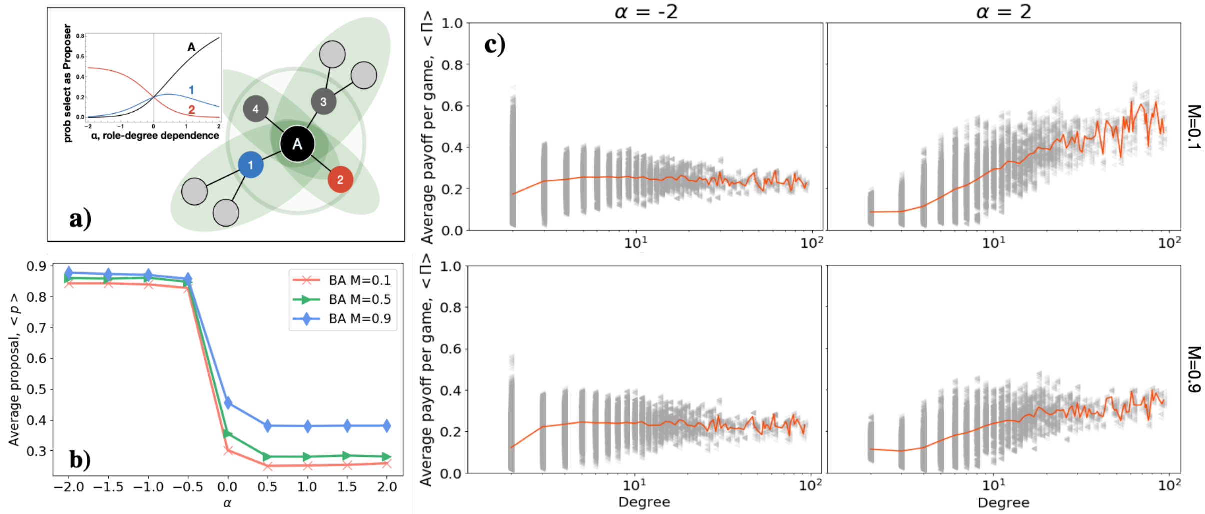

Figure 1: a) Example of group formation and degree-based role assignment. b) Average p for different degree-based assignment probabilities (α). c) Distribution of average payoff for different α and group voting rules (M). Other parameters: $Z = 1000$, $\langle k \rangle = 4$.

will be accepted. In a group with size N composed of 1 Proposer with strategy $p \in [0, 1]$ and $N - 1$ Responders with strategies $(q_1, ..., q_{N-1}) \in [0, 1]^{N-1}$ the payoff of the Proposer is given by

$$\Pi_P(p, q_1, ..., q_{N-1}) = \begin{cases} 1 - p, \text{if } \sum_{i=1}^{N-1} \Theta\left(\frac{p}{N-1} - q_i\right)/(N-1) \geq M, \\ 0, \text{otherwise,} \end{cases}$$

where $\Theta(x)$ is the Heaviside step function, $\Theta(x) = 1$ when $x \geq 0$ and $\Theta(x) = 0$ when $x < 0$. The payoff of any Responder yields,

$$\Pi_R(p, q_1, ..., q_{N-1}) = \begin{cases} \frac{p}{N-1}, \text{if } \sum_{i=1}^{N-1} \Theta\left(\frac{p}{N-1} - q_i\right)/(N-1) \geq M, \\ 0, \text{otherwise.} \end{cases}$$

Here, MUG is played on complex networks, in which individuals are nodes and links define who can interact with whom. We consider heterogeneous (scale-free) networks generated with the Barabasi-Albert (BA) algorithm of growth and preferential attachment [1].

We assume that nodes play as Proposers based on their degree [4, 21]. In a group with N individuals, where each individual i has degree k_i, the probability that j is selected as Proposer is given by $\rho_j(\alpha) = \frac{e^{\alpha k_j}}{\sum_i e^{\alpha k_i}}$, where α controls the dependence of degree on role selection.

We simulate the evolution of p and q in a population of size Z. Initially, each individual has values of p and q drawn from a uniform probability distribution in the interval $[0, 1]$. Following [13, 14], the fitness f_i of an individual i of degree k is determined by the payoffs resulting from the game instances occurring in $k + 1$ groups: one centered on her neighborhood plus k others centered on each of her k neighbors (see Figure 1a). Values of p and q evolve as individuals tend to imitate (i.e., copy p and q) the neighbors that obtain higher fitness values [20].

3 RESULTS

We run the proposed model and record the average strategies played by the agents over time and over different runs (starting from different initial conditions). We find that attributing the role of Proposer to low-degree nodes (or *low-degree Proposer assignment*) increases the average level of proposal, p, adopted in the population of adaptive agents (Figure 1b). We also confirm that high-degree Proposer assignment leads to unequal (unfair) results within a population. As Fig. 1c) depicts, for $\alpha = 2$, high-degree nodes obtain higher average values of payoff than low-degree nodes. This situation is ameliorated if individuals with lower degree are given a higher chance of becoming Proposers (lower α) and, to a lower extent, if more Responders are required to accept a proposal in order for it to be accepted (higher M, bottom panels in Figure 1c).

4 CONCLUSION

We find that preferentially attributing the role of Proposer to low-connected nodes increases fairness in a population. We also show that stricter voting rules (high M) attenuate the unfairness that results from high-degree nodes (hubs) being the natural candidates to play as Proposers. The fact that network-based role assignment elicits fairness in rather complicated scenarios — as multiplayer bargaining games — suggests that such approach could also be used within the broader context of active interventions aiming at fostering fairness in hybrid populations comprising humans and machines [9, 11, 15, 18, 19]. In this context, it would be relevant to assess — both experimentally and through numerical simulations — the impact on human decision-making of having virtual regulators dynamically deciding the role to adopt by their group peers, depending on their position in the interaction structure.

Despite these open questions, our present work already suggests that carefully selecting the role of agents — depending on their network position and without limiting their available options — can offer long-term social benefit in terms of fair resource distributions.

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