Distributed Course Allocation with Asymmetric Friendships

JAAMAS Track

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ABSTRACT

Students' decisions about course enrollment are affected by whether their friends plan to take the same class. In some cases, a student may prefer to enroll in a less desirable course to study with friends rather than take a more preferred course alone. Prior research has shown that taking classes with friends can improve academic performance. This paper studies course allocation mechanisms that explicitly account for students' friendship relations in a distributed setting. We formulate the problem as an asymmetric distributed constraint optimization problem and introduce a dedicated algorithm tailored to this formulation. The evaluation includes both simulated data and a user study involving 177 students, based on reported preferences over courses and friendships. The results indicate that the proposed algorithm commonly finds feasible allocations with high social welfare, while maintaining fairness and respecting course seat capacity constraints.

KEYWORDS

Course allocation, Multi-unit allocation, ADCOP, Friendships

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1 INTRODUCTION

Allocating students to courses poses a challenging problem. To do so, we need to consider student preferences — i.e., which classes they like and which they don't — as well as university requirements, such as seat limits. Course allocation mechanisms must account for these constraints, while also ensuring that the resulting allocation satisfies fairness, equality, and welfare goals.

Course allocation deals with indivisible items (courses). Allocation of indivisible items is a well-studied problem with applications in various domains. In this problem, a set of *agents* needs to be assigned a set of indivisible *items*. The agents have *subjective utilities* over the items they receive. We focus on dependencies between agents, i.e., agents' preferences over items also depend on the assignments of other agents. Relevant settings with agent dependencies include potential neighbors in land allocation and shift allocation problems (of nurses, waiters, etc.), where workers are assigned shifts with their preferred colleagues. This property has been largely overlooked in research and practice to date. Course allocation serves as a fitting illustration of this context: The agents are university students, and the items are class seats. One student might choose Introduction to Algorithms, whereas another might select Machine Learning. However, if students prefer to take classes with their friends, the intrinsic desirability of a class seat depends on how other class seats are assigned.

For students, being allocated to courses with their friends may be a top priority. Students might prefer to be assigned to a less-preferred course if it means being with their friends, rather than taking a more preferred class alone. Taking classes with friends has a positive effect on academic performance [4–7]. Our definition of friendship is asymmetric: a student is considered friends with another student if they wish to be assigned to courses with them, regardless of the other student's wishes. Unlike other parameters in this problem, information about friendships may be sensitive, especially because preferences can be asymmetric and students' social status can be inferred from them. Thus, students may wish to refrain from reporting their friendship to a central authority (such as the administrative office).

In this research, we formulate students' course allocations, taking into account not only their course preferences but also their preferences for classmates. Our inspiration for this research was a recent study by Elkind et al. [2] that addressed land allocation among friends. Nevertheless, it is important to note that the aforementioned paper primarily focuses on single-unit allocation, in which each agent is assigned a single piece of land, and proposes a bidding mechanism. In contrast, our work extends this concept to a multi-unit scenario, incorporating the dimension of friendships, and frames the problem as an Asymmetric Distributed Constraint Optimization Problem (ADCOP) [3]. Furthermore, we introduce an innovative DCOP algorithm tailored to the specific requirements of the course allocation problem.

Method Contributions: (1) **Multi-unit allocation with friendships** – explicitly incorporates friendship relations among agents. (2) **Decentralization** – operates in a fully decentralized setting, with agent preferences not revealed to a central coordinator. (3) **Welfare** – produces solutions with high aggregate utility. (4) **Fairness** – maintains low dispersion in agents' utilities.

2 MODEL

We consider a one-sided multi-unit assignment problem in which each student must be assigned to a fixed number of courses. Each course has a strict capacity limit that cannot be exceeded. Students express preferences for courses and for studying with specific

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friends. These friendship preferences are potentially asymmetric: one student may value studying with another more than the other student does.

Each student is modeled as an autonomous agent that privately holds its own preferences. Agents do not reveal their full preference information to a central coordinator. Effective communication among all agents is imperative for two key reasons: (a) The presence of a global constraint to enforce the course capacity limit (b) the asymmetry in friendship relations, leading to scenarios where agents may lack knowledge of which other agents consider them as friends. This necessitates the establishment of a communication clique. Given the potentially large number of students involved in course allocation problems, we opt for an incomplete lightweight algorithm to address these communication challenges effectively.

The standard Distributed Stochastic Algorithm (DSA) [8], while effective for symmetric DCOPs, does not account for constraints arising from asymmetry, specifically those perceived by peer agents. To address this limitation, the Asymmetric Coordinated Local Search (ACLS) algorithm was introduced [3]. ACLS focuses on coordinating efforts among agents sharing a constraint to achieve more efficient and stable solutions. However, it operates under the assumption that asymmetry pertains solely to the costs/utilities associated with the constraint's sides. In contrast, our model considers a broader sense of asymmetry, where even the mere existence of a constraint can be asymmetric. Consequently, the coordination mechanism of ACLS can reveal critical private information about friendships when applied to our model.

Our model introduces an additional challenge that is not addressed by general-purpose algorithms such as DSA and ACLS, namely the handling of course capacity constraints. These constraints have two defining properties: they are *global*, in that they involve all agents, and *hard*, in that every feasible solution must satisfy them. Accommodating these properties motivated the development of a dedicated algorithm, DSA_RC, specifically designed to handle such *resource capacity* constraints.

Herein, we introduce DSA_RC, a dedicated DCOP algorithm designed for course allocation with friendships under resource capacity constraints. The algorithm operates in a distributed manner, searching for assignments that satisfy all course capacity constraints while achieving high overall utility. In this extended abstract, we present DSA_RC at a high level only; full technical details and formal analysis are provided in the journal version [1].

3 EVALUATION

We evaluate DSA_RC using data from a user study involving 177 students. In the study, students reported their preferences for available courses and for studying with specific friends. These data were used to construct course-allocation instances that reflect both capacity constraints and social preferences. Figure 1 presents the friendship network in the user study as a directed graph $s.t.$ each vertex is an agent, and a directed arc from A to B indicates that agent A considers agent B a friend. The number of incoming arcs determines the size of a vertex.

The evaluation focuses on three aspects: feasibility, social welfare, and fairness. Feasibility refers to satisfying all course capacity constraints; social welfare is measured as aggregate utility across agents; and fairness is examined through the distribution of utilities, reflecting fairness in order as a natural outcome of the algorithm's operation. As the problem is NP-hard, exact methods such as linear programming are impractical for realistic settings with tens to hundreds of students. Accordingly, we focus on scalable solutions; further details appear in the full paper.

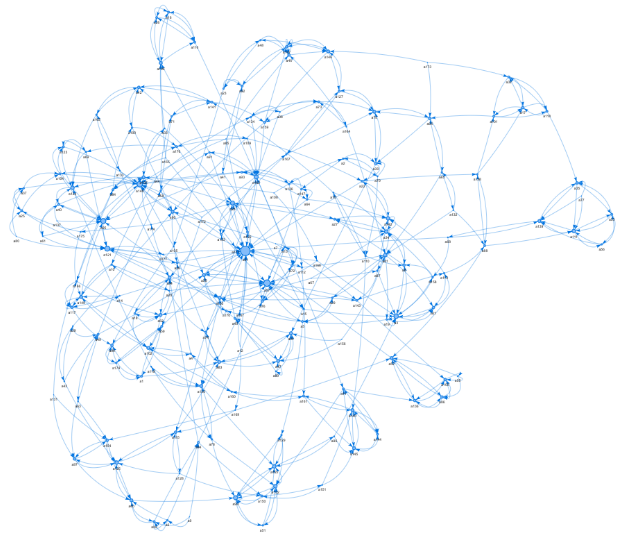

Figure 1: The friendship network reported in the user study.

Across the evaluated instances, DSA_RC commonly finds valid allocations that respect all course capacity constraints. The resulting solutions achieve high social welfare, and the utilities obtained by agents are distributed in a manner that reflects fairness across different positions in the allocation process. In addition to the user study, we conducted experiments on simulated data to examine scalability and robustness under varying conditions. Results are consistent with the trends observed in the user study.

4 DISCUSSION

The results indicate that course allocation problems that incorporate friendship relations can be addressed within a distributed optimization framework while respecting course capacity constraints. Modeling students as autonomous agents and representing friendships through asymmetric utilities enables the allocation process to capture interdependent preferences that standard formulations do not accommodate. The resulting mechanism preserves a fully distributed structure, in which preference information remains local to individual agents and is not centrally aggregated. Despite this decentralization, the resulting allocations exhibit desirable properties in terms of social welfare and fairness. More broadly, this study demonstrates the applicability of DCOP techniques to social decision-making problems in educational contexts, where preferences are both interdependent and partially private.

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