Chapter III
Coalition Formation Among Agents in Complex Problems Based on a Combinational Auction Perspective

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ABSTRACT

This chapter focuses on a scheduling problem that considers various constraints as a complex real-world problem. Constraints on scheduling can be expressed as combinations of items (time slots) in a combinatorial auction. Agents bid for necessary combinations of time slots to satisfy users’ preferences. We formalize a combinatorial auction for scheduling as an MIP (mixed integer programming) problem, which integrates the constraints on items and bids to express complex problems. This integration solves the trade-off between the computation time to find the solution and the expressiveness to represent a scheduling problem. This chapter presents a new formalization of a combinatorial auction with constraints. We have experimentally confirmed that our method can obtain a socially preferable schedule in practical time.
Auctions have been studied in the field of electronic commerce (EC). Various studies on auctions have already been made, and many protocols and methods have been developed (Ito, Yokoo, Matsubara, & Iwasaki, 2005; Parkes & Kalagnanam, 2005; Sakurai, Yokoo, & Kamei, 2000). An auction also can be a promising method for coalition formation among agents. The purpose of our work is to apply auction protocols and methods developed in EC studies to a coalition formation.

We focus on a scheduling problem considering various constraints as a complex problem. This is because the scheduling problem is a kind of resource allocation problem, and combinatorial auction is compatible with kinds of resource allocation problem. We are currently attempting to construct a scheduling system based on multi-agents. In our system, each agent makes bids based on users’ preferences on events. Agents must determine a consistent schedule by resolving conflicts among agents. To construct the system, we must propose appropriate problem formalization and methods for finding an optimal solution. In this chapter, we formalize a scheduling problem as a combinatorial auction. An appropriate schedule can be obtained by solving the winner determination problem in a combinatorial auction. The winner determination problem is one of determining the optimal allocation of items that can maximize the auctioneer’s revenue. The winner determination problem is a complicated optimization problem, so it can be re-defined as a scheduling problem. When a scheduling problem is formalized as a constraint satisfaction problem (CSP), like in some existing studies (Tsuruta & Shintani, 2000), we need particular methods to relax over-constrained problems. On the other hand, because of the formalization as a combinatorial auction, we can obtain a socially preferable solution according to an economical rationality without having to use such particular methods.

The basic idea behind our formalization is that a scheduling is compared to an auction for winning time slots. This perspective is intuitively and easily understandable for users. In our formalization, a schedule can be represented as combinations of items (time slots) in a combinatorial auction. Agents bid for necessary combinations of time slots to satisfy users’ preferences. In this chapter, we try to deal with various constraints, for example, the date and time, participants, the order of events, and the interval of events. The greater the variations of bids considering some constraints becomes, the more time-consuming the computation time for finding a solution becomes. Nevertheless, decreasing the number of bids reduces the expressiveness of representing a scheduling problem. Therefore, we formalize a combinatorial auction for scheduling as an MIP (mixed integer programming) problem, which integrates the constraints on items and bids to express complex problems. This integration solves the trade-off between the computation time to find a solution for a combinatorial auction and the expressiveness to represent a scheduling problem. We conducted experiments with limited discrepancy search (LDS) and MIP solver to confirm that our method is useful to obtain a semi-optimal schedule within practical time.

A combinatorial auction is appropriate for adjustment of time slots. Considering each time slot as an item, we can use a combinatorial auction protocol to effectively deal with events, each of which needs sequential multiple time slots. Without the dealing with combination of items, an agent might obtain multiple time slots that do not increase his/her utility by obtaining them simultaneously. For example, Rassenti, Smith, and Bulfin (1982) use a combinatorial auction protocol to determine arrival and departure times of airplanes. In this work, each time needs sequential multiple time slots. Because a combinatorial
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