Chapter 1

Introduction

1.1 Optimal Coalition Structure

Computing optimal coalition structures in multi-agent systems is an important research problem both from theoretical and practical perspectives. Generally speaking, a coalition is a group of agents who have agreed to jointly work towards a common objective. Coalitions may be formed for a specific task (then disband after the completion of the task) or persist over long durations and over several tasks. The utility of such a coalition is described by the coalition value, e.g. profit accruing from the coalition, saved cost gained from the coalition, etc. The optimal coalition structure problem seeks to identify the global way of how agents should be formed such that the sum of all the coalition values is maximal. The optimal coalition structure problem can be applied in many real world settings, including logistics and supply chains, virtual organizations, team formation, etc. This problem is proved to be NP-Hard.

The number of all coalition structures can be determined by Bell Number, B_n. Since the value of B_n can be very large for a small value of n, existing algorithms tend to divide the search space into small portions. There are two approaches to achieving this: lexicographic-based algorithm and value-oriented algorithm. In the first approach, coalition structures can be categorized by the number of coalitions within each coalition structure. The set of all coalitions structures containing exactly i coalitions, where $1 \leq i \leq n$, is is referred to as a layer. The number of coalition structures in each layer is given by the Stirling Number of the Second Kind. Alternatively, we can categorize coalition structures by the integer partition of n that describes the number of coalitions (in a coalition structure) and their cardinalities. Each instance j of such a partition is known as a pattern or a configuration, which extends the former approach by further categorize each layer into smaller parts based on the cardinalities of coalitions within the layer. In contrast to lexicographic-based algorithms, the value-oriented algorithm generates coalition structures based on coalition values rather than their coalition members. The algorithm generates coalition structures as a process of repeatedly choosing the best coalition (i.e., one that contributes the best value to the coalition structure) from available candidates such that for each generated coalition structure the exhaustiveness and the disjointness conditions are met.

1.2 Motivation and Research Question

In the following, we will discuss the motivation of this research. We then raise research questions that we address in later chapters.

1.2.1 Motivation

While recent research in optimal coalition structure has gone a long way from where it originated, most of the research is focused on theoretical aspect and consider centralized environment. However, multiagent systems, by nature, are distributed and heterogeneous ones. Therefore, we just feel that the research in the area should turn its direction to these environments, which are more realistic and more useful in applying research work to real world application. Let us consider the real world examples that reflects the need for optimal coalition structure research in distributed and heterogeneous environment.

In the last several years, we have witnessed all kinds of changes in the world's climate. These changes have affected mankind's lives profoundly. The catastrophic 2011 flood in Thailand, for example, was one of the worst in that country's and the world's history. There were 12.8 million affected people, hundreds of thousands lived their lives under water for more than a quarter of the year, while many others were homeless. The flood also struck Thailand's economy heavily. Most of the industrial estates in central Thailand were under water, and, as a consequence, hundreds of thousands of jobs were floated away. The World Bank estimated that the economic loss was 1.44 trillion Baht—more than half of the country's annual budget. Of course, Thailand is not the only victim of this kind of catastrophe as we have seen that the trend of catastrophic consequences of climate change has been consistent or even worse in 2012.

Dealing with the consequences of climate change is an extreme challenge (leaving alone the highly complex character of climatic phenomena, which requires extreme computational power to model, understand and, hopefully, prevent its catastrophic consequences) because there are several complex tasks to deal with. During the 2011 flood in Thailand, there were a lot of donated resources gathered from people around the country. The problem here is how these resources be distributed efficiently to the victims. Given this single task here, there are several research questions that challenge researchers in multiagent systems. Since the victims, the volunteers and the donators were geographically dispersed, it was very difficult to synchronize the collections of the donated resources and their logistics, i.e. storing distributing, etc. Furthermore, the distributions of resources, the search for victims (dead, alive or disappeared), evacuation, etc. were conducted in extreme environment, where communication was sporadic. Most of the times, the operational teams had to make their own decision on the scene. We believe that this a good environment for optimal coalition structure research.

1.2.2 Research Questions

Given the aforementioned example which raises several research opportunities, we choose to tackle the optimal coalition structure in distributed environment, where communication among agents is sporadic. Having set this objective, there are two research questions, which are the main contribution of this project, to tackle:

1. to develop the algorithm to efficiently partition the search space among agents. This is not just a simple division of coalitions among agents and let them search for optimal coalition structure. It has been proved that doing so is not possible for the agents to mutual-exclusively cover all the coalition structures. Furthermore, since the communication among agents is sporadic, this partitioning approach has to balance between the workload among agents and the final solution.

2. to enhance the capability of the value-oriented algorithm for optimal coalition structure. The existing algorithm follows the depth first search, i.e. it branches its search at the lower nodes when it finds that there are no ways to improve. This leads to the poor termination time although the time to reach optimality is relatively short.