Multiagent Systems

11. Coalition Formation (continued)

B. Nebel, C. Becker-Asano, S. Wölfl

Albert-Ludwigs-Universität Freiburg

July 4, 2014

Multiagent Systems

July 4, 2014 — 11. Coalition Formation (continued)

11.1 Motivation

11.2 Coalition games with Goals

11.3 Coalition Structure Formation

11.4 Summary

11.1 Motivation

What we've learned so far

Last time we learned about:

- Coalition formation
- The core of a coalition game
- The Shapley value
- Different representations for different types of games
  - General coalition games: induced subgraphs & marginal contribution nets
  - Simple games: (k-)weighted voting games
- The Shapley-Shubic power index of simple games

Today:

Coalition Games with Goals & Coalition Structure Formation

11.2 Coalition games with Goals

Coalition Games with Goals

So far, **utility** in coalition games was represented as some **numeric value**:

$$\nu : 2^{Ag} \rightarrow \mathbb{R}$$

In BDI systems (such as Jason) this is inappropriate. System designers want their agents to achieve some **goal(s)**.

$\Rightarrow$ **Qualitative coalition games** (QCG)

- Each agent has set of goals and wants one of them to be achieved, but does not care which one
- Agents cooperate to **achieve mutually satisfying sets of goals**

Qualitative coalition games

Formal model:

- every coalition C has a **set of choices** $V(C)$, i.e. different ways the coalition C could chose to cooperate
- characteristic function of QCG has signature $V : \mathbf{2}^{Ag} \to \mathbf{2}^{\mathbf{2}^{G}}$

Suppose set of goals $G' \subseteq G$ is achieved:

- G' **satisfies** an agent i if $G_i \cap G' \neq \emptyset$,
  i.e. at least one of its goals is achieved
- G' is **feasible** for a coalition C, if $G' \in V(C)$,
  i.e. G' is one of the choices available to C
- Coalition C is **successful**, if C can cooperate in such a way that G' satisfies every member of C

Propositional logic representation is complete, but not guaranteed to be succinct.

Coalition resource game

QCGs say nothing about where the characteristic function comes form, or how it is derived for a given scenario.

⇒ The **coalition resource game** framework (Wooldridge & Dunne, 2006):

- Simple idea: To achieve a goal requires **consumption of resources** and each agent is **endowed** with a profile of resources
- Coalitions form to **pool resources** and achieve mutually satisfactory set of goals

Interesting questions:

- Theoretical: Can a pair of coalitions achieve their goals whilst staying within their respective resource bounds?
- Real world: Can some countries achieve their economic objectives without consuming too many pollution-producing resources?

11.3 Coalition Structure Formation

Coalition Structure Formation

So far, every agent acts strategically just as in non-cooperative games, attempting maximization of own utility.

⇒ What if one designer owns all agents?

- Performance of single agents perhaps not as important
- Better **maximize social welfare** of the system
- Maximizing social welfare ⇒ maximizing the **sum of the values of individual coalitions**

Coalition Structure

A **coalition structure** is a **partition** of the overall set of agents Ag into **mutually disjoint coalitions**.

Example, with $Ag = \{1, 2, 3\}$:

- Seven possible coalitions:

$$\{1\}, \{2\}, \{3\}, \{1, 2\}, \{2, 3\}, \{3, 1\}, \{1, 2, 3\}$$

- Five possible coalition structures:

$$\{\{1\}, \{2\}, \{3\}\}, \{\{1\}, \{2, 3\}\}, \{\{2\}, \{1, 3\}\},$$

$$\{\{3\}, \{1, 2\}\}, \{\{1, 2, 3\}\}$$

Coalition Structure Formation

Given game $G = \langle Ag, \nu \rangle$, the **socially optimal coalition structure** CS^* is defined as:

$$CS^* = \underset{CS \in \text{ partitions of } Ag}{\arg\max} V(CS)$$

where

$$V(CS) = \sum_{C \in CS} \nu(C)$$

Unfortunately, there are **exponentially more** coalition structures over the sets of agents Ag then there will be coalitions over Ag
$\Rightarrow$ **Exhaustive search is infeasible** (in the worst case)!

Sandholm et al. (1999) developed a technique that guarantees to find a coalition structure that is within some provable bound from the optimal one.

11.4 Summary

- Thanks

Summary

What we have learned today:

- Coalition Games with Goals
  - Goals, not numeric utilities, as targets for agents
  - Qualitative coalition games
  - Coalition resource game
- Coalition Structure Formation
  - Maximizing social welfare, instead of individual agent's utility
  - Number of coalition structures exponential in the number of coalitions

Next (on Wednesday): Allocating Scarce Resources

Acknowledgments

These lecture slides are based on the following resources:

- Michael Wooldridge: **An Introduction to MultiAgent Systems**, John Wiley & Sons, 2nd edition 2009.