Introduction to Multi-Agent Systems

Garbage Collector problem: Analysis of the cooperation mechanisms between agents

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December 12th, 2016

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Cooperation, Negotiation and Coordination Mechanisms

Partial Global Planning (PGP)

In the case that Partial Global Planning (PGP) would be applied to scouts and scout coordinator, the scout could make a plan to sweep an area with the scout in the center, and then submit the plan to the scout coordinator. The scout coordinator can create a solution for the whole garbage detection problem in case the areas submitted by each of the scout do not overlap each other. Now, let's suppose that two scouts have defined overlapped areas, in that case, the scout coordinator could ask one of them to move to a certain position and redefine the area based on its new current position. This is a case of conflict detection by the scout coordinator.

We cannot apply this particular coordination mechanism as described because of the definition of the architecture we made for delivery 1; all the scouts were defined as reactive agents.

For the harvesters and harvester coordinator, PGP can be implemented if each harvester (with a prior knowledge of the location of a particular type and amount of garbage) makes a plan to collect the garbage and informs the harvester coordinator. Then the harvester coordinator can create a solution base on the partial plans of each agent always taking in consideration a possible task reordering, task reallocation, conflict avoidance, etc.

Advantages

- All plans could be adapted to dynamic changes in the environments. Scouts could avoid going to some areas which have been recently visited, or there is up-to-date information about it. Harvester could avoid going to harvest the same piece of garbage.

Disadvantages

- Changing a local plan could trigger modifications on several agent's plans, in the Scout case, for re-routing its trajectory.
- Complex management of data structures and reasoning capabilities (algorithms) should be used to keep up-to-date maps among all the agents.

Coalition

We found out some ways to establish coalitions in this problem, the ones we are going to explore are among the scout agents and among the harvester agents; and also between both the scout agents and harvester agents. The only task that Scouts do is to scan the city and look for garbage; we considered scout agents as reactive and thus we won't implement any coalition mechanism between them.

- **Scout Agents and Scout Agents:** They could make a coalition to scan all the city and divide it in areas to be swept.

- **Scout Agents and Harvester Agents:** They could make a coalition to keep harvesters close to the scouts in order to make it easy to collect the garbage when the scout founds it.
- **Harvester Agents and Harvester Agents:** They could make a coalition to collect all the garbage of a specific building, when the capacity of an agent it is not enough.

Advantages

- Efficient solutions.
- Decentralised mechanism.
- Less redundancy in done a task.
- Collecting garbage could be done faster than doing by an only one harvester agent.

Disadvantages

- It is necessary to send many messages between agents.

Contract Net

Contract Net coordination mechanism can be view as a one-to-one relation (in this case it should be consider like a direct contract), one-to-many or many-to-many. In the latter case, the roles (manager - contractors) can be exchange according to the needs of each agent. We are going to implement this mechanism, therefore the description of its use is in the implementation part of the document.

Advantages

- The most common application for this mechanism is when subtasks are large enough and it's worthwhile to spend effort to distribute them wisely. This could be the case of the harvester coordinator, which has to be sure that all the garbage is harvest, and therefore must divide the multiple unit to collect in a variable number of contracts.

Disadvantages

- Some stages are non-trivial, like the problem decomposition, solution synthesis and some of the task related with the bid analysis. All this is applied to the harvester coordinator which has to decide how to decompose the problem and how to unify the solution.

Auctions

Auction has an explicit communication in negotiation of tasks or goods. If this mechanism would be implemented, then the harvester coordinator could make an auction for each group of garbage, where the winner of each auction has to collect it.

This considers that the harvesters are rational, and they are self-interested and they want to maximize their profits. Each agent will seek the most suitable garbage to collect, by considering the current position, garbage position, and/or its current state.

The auctions could be considered a multi-unit auction by considering a parallel auction of the single tasks for each garbage-type collection. Also, it can be considered a combinatorial multi-unit auction, which is an auction in parallel this considers offering some combos of tasks i.e. in terms of tasks auction in agents collecting garbage type 1 and type 2.

Considering the auctions protocol for scouts, the scout coordinator could make an auction for each area of the map that has to be explored. The winner of each auction will collect it. Considering that the scouts are rational, and they are self-interested and they want to maximize their profit; they would seek for the most suitable garbage to collect, considering the distance of the agent. Consequently, the agent is going to bid the amount in an inverse proportion to the euclidean distance between the agent and the area or building to be explored.

Advantages

- Create competition; enhances the seller's bargaining power. So, in our particular case scenario, the most qualified scouts and harvesters will probably win the bid.
- Multiple parallel transactions. Many garbages units-types could be auctioned at the same time.

Disadvantages

- The decision is based only in one criteria, in terms of complex environments will be weak decision protocol i.e. selecting the appropriate bidding in terms of contracting agents to perform certain task. Maybe not the best harvester will get the more suitable number - type of garbage to collect.

Voting

Voting is a mechanism that chooses the outcome of a negotiation based on the votes given by all agents to a set of competing options; there are also some protocols based on linear orders where each voter gives a full list of the options, ordered according to its preferences.

In the case that this mechanism would be applied, we need to establish a simple voting mechanism, in this case, we would use a plurality mechanism. Between the harvesters and the harvester coordinator, the coordinator would start a voting, where it asks the harvester agents which garbage it would collect the garbage, each agent would cast a vote. The decision each harvester would make depends on the amount of garbage in a building, the amount of garbage an agent can carry, the type of garbage, the state of the agent and how close an agent is to the building; each one of the harvester would decide depending on the all previous criteria. Once all votes are counted, the agents that voted to collect the same garbage can establish a coalition.

Advantage

- Advantageous when voters' preferences have a common preferential independence structure.
- Produces collective decisions. The majority of the harvesters could choose which harvester is going to collect each type-number of garbage.
- Voting system achieves the 'optimal' outcome, which reflects the 'popular vote'.

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- Plurality: Harvester agents can vote the option that suits them the best based on a certain criteria of their own; after which they can make a coalition if needed.

Disadvantage

- Arrow's Theorem, states that there is no 'ideal' election method, indicates that all methods of winner determination can be manipulated by strategic voting (Arrow, 1970). In our particular case communication between harvesters do not exist, so the harvesters cannot implement any strategy in order to manipulate the voting system.
- Self-interested agents can benefit from insincerely declaring their preferences. Agents could have a preference; this can make that a certain garbage is neglected and left aside.

Project Implementation

After discussing the previous mechanism, we came to the conclusion that we will implement contract net between coordinator agent and harvester coordinator; also for harvester coordinator and harvester agent. Among harvester agents we will implement coalition. The rest of the communication will be done using FIPA-ACL message informs. The following section discusses in detail the proposed implementation.

Coordinator Agent and Harvester Coordinator

Contract Net

Coordinator agent has a list of garbage that needs to be picked up that is why it is necessary to establish a communication between them. The coordinator agent needs to know when was the garbage collected, because it needs to inform the system agent, so it updates the information of the garbage in the map. Contract net protocol gives you precisely this. Contract net has five steps; the final step, expediting, consists of the contractor communicating the manager that the task has been done; in this case the harvester coordinator informs the coordinator agent that the garbage was collected.

Harvester Coordinator and Harvester Agent

Contract Net

The harvester coordinator once it knows the amount and kind of garbage to be collected, it starts a contract net protocol. The contract is divided by type of garbage; any agent can bid for the contract depending on the type of garbage it collects. The contract is won by the nearest agent to the garbage. The contract ends when the harvester informs the coordinator that the garbage has been collected successfully.

Harvester Agent and Harvester Agent

Coalition

When a harvester has been assigned to a contract. In the case that the agent can perform the task, it forms a coalition of just one; if it cannot perform the task by itself then the agent forms a coalition depending on the amount of garbage it needs to collect. Once the task has been completed, the coalition ends. If an agent is in a coalition, then it cannot bid for a contract.

Bibliography

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