Different Levels of Communications in Multi-Agent System

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Abstract

A multi-agent system consists of multiple interacting intelligent agents within an environment. Among the agents, communication occurs as a way of sharing information. The amount and quality of information shared determines their behaviors. A foraging game is implemented as a platform to figure out the influence of communication on agents' behavior in the system and whether it earns its complexity.

Introduction

In multi-agent system (MAS), there are several agents attempting to jointly solve tasks to maximize the system's performance through their interaction [1]. The amount and quality of information shared among agents would influence their behaviors. As a consequence, different levels of communication could lead to different game difficulties. More information shared would help agents make better decision, but redundant information could also lead to a waste of storage and processing time. This project focuses on measuring the performance of different communication strategy and whether it earns its complexity.

In this project, a game with a multi-agent system is implemented as a platform. With goals and different levels of communication assigned to agents, their behavior would be analyzed to evaluate the performance and complexity of the communication strategies. Specifically, the MAS is designed on foraging problem, which is a representative multi-agent behavior. In this system, the basic tasks for agents include searching the unknown world and transmitting food from food source to home. In addition, there are some goals such as minimum energy efficiency [2].

Game Design

Built on the foraging problem, there are three essential entities in this game: food sources, foragers and hive. For the food source, it would have two basic attributes: location and amount of food. The foragers' jobs basically include searching the food sources, transmitting the food to the hive. In addition to the basic status attributes, they have attributes like capacities, energies etc. Certainly, it should communicate with companions. Hive is the location that forager starts from and collects food.

Two different modes of goals are in the game: Time Mode and Energy Mode. In Time Mode, agents are required to carry as much food back as possible in a limited time. Energy mode assigns energy cost to different behavior (e.g. wander, carrying). With a certain amount of food, the goal is to transmit as much food as possible. The result of game will be used to evaluate the performance of foraging in different levels of communications.

Benefits

In many current games, different difficulties are achieved by adjusting environments attributes, such as enemy's status and resource in world. However, this projects is aimed at changing the difficulty by changing AI team's communication strategies. In multi-agent system, from no information sharing to all information sharing, each agent chooses the action based on the information they owned. This method can be used in many game environments where teamwork and strategy are needed.

Besides, by evaluating the performance of different level of communication, we can find out which level of communication is the most appropriate under certain environments or situations, and what is the advantage and disadvantage of each level respectively. From perspective of foraging, showing how agent behaves in different situation may provide some useful approaches for multi-agent foraging problem.

Tasks and Techniques

World Building

For the most basic, a game world would be designed and built. The basic tasks include distribution of food source, obstacles and terrain. Since world building is a fundamental topic, generative methods would be applied to generate ran-

dom environment so that our experiments could be more diverse. Furthermore, players are allowed to specify the scale of world and distribution type of food.

Movement

Movement is the basic part of the game. In addition to the basic movement behaviors, in the beginning of the game, agents have no information of food source. They should move around to discover food source, which is a kind of wandering behaviors without returning to the place where it has travelled.

In addition, there exist obstacles in the world, agents must avoid them. And after getting information of food, agents should find a path to the food. Since the world would not be too big, A* algorithm would be enough.

Communication

Communication between agents is the most significant part. The communications are classified into four levels of communication in terms of amount and quality of information shared in the communications. In the first level, there is no information shared by the agents. In the second level, agents share useful information such as food locations with each other. In the next level, in addition to the information shared in the second level, agents could know what other is doing, which is a very important information used in decision making. In the last level, all the information is shared among agents, which include status, remaining capacity and so on.

Furthermore, the types of communication would also influence agents' behaviors thus should be considered. There are two types of communication between agents. One is that agents can send or receive information everywhere, i.e. no distance limit. Another type is that communication only occurs between two agents that are within certain distance. In the second type, agents should take whether to communicate with companion into consideration. For example, if a companion appears in the sight of an agent, it could occur that the agent stops doing other things and tries to get close to the company to share information.

Level 1

Agents have no information of the environment except its current surrounding and memories. Thus, an agent could be either in searching state or collecting state. When agent is in searching state, agent wanders in the environment gathering information until food source is found. Then it goes into collecting state. After its collect enough food (e.g. capacity is full) or the food source runs out, it tries to transmit food home or search the next food source.

Level 2

Besides the features in level 1, agents are aware of other agents and the useful information other agents have gathered. A naive approach would be to treat environmental information as its own. A more complex approach would be to try to infer what other agents might do based on information gathered by them. For example, if agent A knows two food source, now a new agent B joins in. Because of sharing information, agent B will also know the two food sources and agent A will know that B joins in. If agent A is closer to one of the food source and agent B is closer to the other. Agent A will infer that agent B will try to collect from that food source and therefore won't try to collect food there.

Level 3

Agents are aware of other agents' current action or state. This is like level 2 approach, except now agent doesn't have to infer what the others are doing and just get it. In the example in level 2, if A knows B is collecting one source, it would avoid collecting the same one, which is determined by the strategies.

Level 4

What has changed is the scope of an agent's knowledge. Instead of knowing just the local information, now agents know about the global information. How this will be implemented is the same as level 3, except now we have much more information to process. There would be redundant information which should be avoided.

Information Structure and Storage

Information is a set of data stored in the agent. To decide its structure, which data are should be in what form contained in the information should be considered. Basically, a piece of information should include the description of food (location and amount, etc.) and the agents' status. Furthermore, agents should store information shared by others. If possible, the information should include where there exists no food by sampling.

In the no-limit communication, all the agents share the same information storage. As the communication with limitation, each agent has its own information storage. When they communicate, they share the information in their storage.

State Machine

In this game, each agent could have many states, such as searching state and collecting state mentioned above. Switching among different states and more detail about when to trigger the switch are going to be considered before implementation.

Decision Making

In this game, agents should make decisions in many aspects. Since an agent could have information of food in different positions, it should decide which to collect food from. In this case, the criteria are the distance and remaining amount of

food. In addition, if agents should positively communicate with other agents, it has to decide whether to stop current work to communicate. To solve this problem, we would assign a set of priorities to actions. Thus, if agents have many choices, he would select the most important one.

It can be expected that with more information owned by the agents, the decision making would be more complicated.

Evaluation

Evaluation Environment

The famous game engine Unity might be adopted in this project. This engine is extremely popular, and many successful commercial and indie products used it, like Assassin's Creed and Temple Run. Unity also has nice features such as being a cross-platform software and allowing export to multiple platforms. With the popularity of Unity, there will be large amount of resources online that can help us through development, debugging and testing.

With Unity engine, various two-dimension environments would be created using generative methods, in which we can implement and test out our algorithms. Also, in order to draw convincing conclusions, we would like to have more realistic environments with obstacles and terrains. To answer our question on whether environment plays an important role in performance of strategies, we want to have different scales of environments: small, medium and large.

Questions Identified

Several questions that need answering have been identified in this system:

1. How efficient is the algorithms in terms of collected food (per minutes)?
2. Does environment affect the performance of each strategy?
3. Does sharing more information necessarily produce better result?
4. Where is the balance between sharing too much information and too little information?

Evaluation Metrics

As mentioned in Game design section, the result of game will be the main value to evaluate the performance of foraging in different information-sharing level.

Time efficiency

In time mode, which aims to carry more food home in a limited time, the final amount of food in the hive is a criterion to compare the time efficiency, which could be defined as:

time efficiency = amount of food / time

Energy efficiency

In energy mode, which aims to carry certain amount of food in less energy, the final energy cost will be used to evaluate the energy efficiency. First, a table should be created to assign different energy cost to different behaviors, in the form shown below. And the energy efficiency could be defined as:

Energy efficiency = amount of food / total energy cost

Behaviors	wander	collection
Cost	10/distance unit	12/food unit

Table 1: example

Weighted Sum

In an unlimited mode, agents would collect all the food in the world back. In this situation, the performance should be evaluated by a weighted sum of energy cost and time cost. The more the cost is, the less efficient the method is. This could be defined as:

$$Efficiency = k / (m*time + n*energy)$$

Number of Agents

Different number of agents will also be used as a variable for test. We will use around 10 agents as small test case, 100 agents as medium test case and 500 agents as large test case to evaluate the influence result from the number of agents.

We will use level one (no communication) as the baseline of evaluation and look at other levels' behavior.

Expectation

Communication is expensive in practice and reducing the amount of communication is often desirable. In our expectation, the level with best performance is level 2 or 3. In level 1 the information doesn't allow cooperation, an agent has to find food itself. Although, it is useful in other cooperation like cooperative construction [3]. As level 4, there might be too much information to process and affect operating time.

Conclusion

Swarm intelligence, the collective behavior of decentralized and self-organized system, has been an interesting topic for many years. Based on foraging problem, which is an attractive subject for studying multi-agent cooperation, we have come up with different information-sharing strategies for agents we want to implement and compare. In the process of doing this project, we seek to gain insights about multi-agent system and maybe implement other interesting approaches.

Compared with the informal proposal, we switched to focusing on comparing different levels of communication in multi-agent system. One important reason is that it is hard to conclude that whether decentralized system or centralized has better performance. With different method and different strategies, both would behave different. Focusing on the communication allows us into deep study of the filed.

References

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