Multiagent Interactive World

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1 Introduction

The project we are working on is a multi-agent game in which the agents can move in a simulated world where they need to gather food in order to survive. Our main goal is to get a better understanding of how altruistic behavior emerges. For this purpose, we use Unity game engine for simulating the world in which the agents live. In addition, we use real-time Neat for training the agents.

2 Progress

After research we made some change to agents sensors. Mainly, we replace the large number of raycast with fewer number of pie slice sensors as it is shown in Figure 2. Each agent now has three pie slices to detect food and other agents. The inputs value of those pie slices are the distance to the closest detected target. The number of pie slices is limited to three for the time being and could be increased depending on how well the experiments proceed. Each agent also has a number of raycasts to detect wall. The number of raycasts is set to three for now but we plan to increase depending on agents performance on maze-like map. Other inputs that agent will receive are its own food level, and the food level of the agent detected.

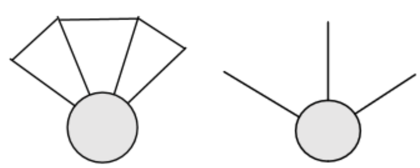

Figure 1: (Left) agent with three pie slices sensor that detect food and agent. (Right) agent with three range sensors to detect wall

Both the pie slice sensor and raycast sensor return the distance to the detected target. These data will then be normalized to inversely proportional to the input, which mean the smaller distance will have higher input. After the change of input from raycasting to pie slice sensor. An experiment was conducted to test the agents new sensors and verify outputs from agent sensors. In Unity, the agent was able to correctly detect food and other agents. The distance data were also successfully normalized to desired input data.

This shows We also change the outputs format of the neural network. The move forward and move backward were merge together. The turn left and turn right actions were also merge together. The move right and move left actions were considered unnecessary and removed.

There will be three outputs for the neural network:

- Movement amount (forward/backward)
- Turn amount to right or left
- Should agent give foods to the agent detected

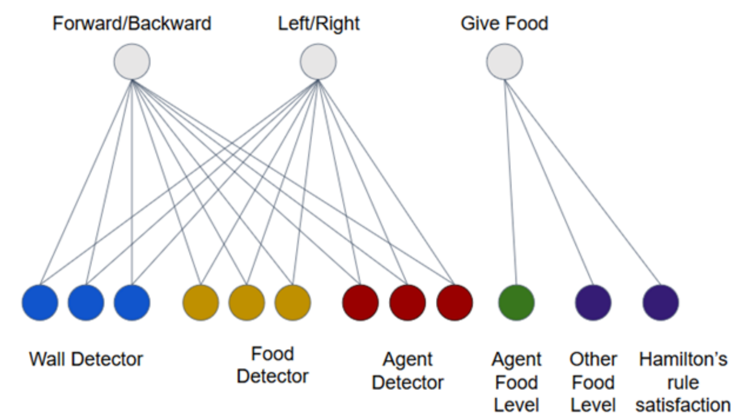

Figure 2: The illustration of the Start genes, detectors are wired to movement outputs. Food levels are wired to give food output.

The start genes, input and the output of the neural network is shown in Figure 2. At the beginning of the simulation, the pie slices and range sensors will be wired with movement outputs. The agents food level and detected agents food level will be wired with give-food output. The Hamiltons rule will be calculated explicitly and feed to the neural network where 1 mean the Hamiltons rule is satisfied and 0 mean otherwise.

Each agent is an organism in real-time NEAT and has a corresponding ID in the Unity. The Unity sends the information to the rtNeat and waits for the rtNeat to decide what action the agent should take. After a fixed number of time-steps, when rtNeat has gathered enough information about the behavior of the agent, it evaluates all the agents in the game. The worst agent will be replaced with a new offspring.

The communication between the rtNeat and Unity is through file communication. There is a file for each agent which shows the current observation of the agent. rtNeat reads this file at each time-step and uses it as the input to the neural network of the agent. The rtNeat reads all of the input files from each agent and calculates the output of each agent's neural network. This output, which contains the actions that the agents should do, will be written in individual file for each agent. The filename contains the ID of the agent, so the Unity can decide which agent should take that action. The Unity continuously checks for the update from the rtNeat each 10ms. As soon as the action is ready to be performed, the Unity takes that action and writes the current observation to the files for the rtNeat. This loop continues until the experiment is terminated.

Since this project involved multi-agent interactive, with relative complex inputs, we decided to limited the population to thirty. Thus, for this project we have conducted experiment in which we spawn thirty agents and observed no significant drop in performance. Therefore we concluded that file communication is sufficiently fast enough for this project. To improve the synchronization between Unity and rtNEAT, we set the minimum time for each tick of the game to be 20ms. We expected that amount of time would be sufficient to make sure that the new observation is ready to be reported and . However, this waiting time is the bottleneck in our application. If we could reduce this waiting time in the future, we will think about using another communication method to speed up the training process.

3 Altruism

There are abundant observations of altruistic behaviors in nature. For instance, in the field of animal communication, many primates and birds warn their conspecifics about approaching predators. This behavior known as alarm calls has been studied in many species such as ground squirrels. In this kind of species, there are two specific alarm calls, one call known as trill, warns about less immediate danger and the other one known as Whistle is made in response to immediate threats, more often aerial ones [1].

The word, altruism is derived from the Latin *alteri*, meaning "other people" or "somebody else" [2]. Altruistic behavior refers to an action, which results in a cost for the altruist but in reverse, benefits another individual who is the recipient of altruistic behavior. In this sense, it is different from cooperation which is based on mutual benefits.

Much debate exists about the existence of true altruism among human. Psychological egoism, suggests that there is no act of true altruism, as the actor may receive some level of personal gratification [3].

3.1 Evolution of Altruism

Is altruism against natural selection? If natural selection acts in individual level, then it seems that altruism would never evolve because behaving altruistically endangers one's reproduction and is disadvantageous for the organism, itself. In 1994, David Sloan Wilson and Sober proposed a mechanism of evolution known as group selection in which natural selection acts at the level of group instead of level of individuals.

3.1.1 Group Selection and Altruism

Altruism can be explained through group selection, in a sense that a group containing a greater number of altruists who are ready to help for the sake of group, has more chance of survival over a group containing less such number. Consequently, natural selection favors a group composed of altruists which results in evolution of altruism among the groups. However, within each group, individuals with altruistic behavior are in state of selective disadvantage in comparison to the selfish individuals. Group selection is able to justify between-group selection but fails to evolve altruism within each group. Darwin in his book, "On the origin of species", discussed that "a tribe including many members who...were always ready to give aid to each other and sacrifice themselves for the common good, would be victorious over most other tribes; and this would be natural selection"[4]. He further argued, however, that it is unlikely that the number of altruists could be increased through natural selection.

If the group selection is not an accurate explanation for the evolution of altruism, then what is? Through the years of 1960 and 1970, a new theorem, known as Kin Selection has been emerged.

3.1.2 Kin Selection and Altruism

In 1964, Hamilton popularized the idea of kin selection. Kin selection, refers to an evolutionary behavior which favors the reproductive success of an organism's relatives, at a cost for the donor. Also in human, altruism is more likely to occur and on a larger scale among kin rather than to unrelated people. Kin selection is able to better explain the evolution of altruism. In nature, social shrimp protects highly related colonies.

The involvement of relatedness between the altruist and receipt permits altruism to evolve. According to this theory, altruists are discriminating in who they help when behaving altruistically and consider the degree of relatedness. It is possible for the altruism to evolve as a trait as long as the benefits of altruistic action fell on individuals that are genetically related to the actor. For instance, it would be beneficial for an animal to give an alarm call, and place itself in danger and warn a group of relatives, since its relatives also carry copies of its genes. Hamilton showed the general importance of relatedness in evolution by introducing the Hamilton's rule [5]. This rule predicts when one individual will likely behave altruistically.

3.1.3 Hamilton's Rule

The rule predicts that an altruistic organism will be favored by natural selection when a certain condition is satisfied:

$$B > \frac{C}{R}, \tag{1}$$

where C is the cost incurred by the altruist, B is the benefit received by the recipient of altruistic action and R is the degree of relatedness between the donor and recipient. Aside from the notion of relatedness, This formula is rational; the benefit of recipient should be greater than the cost for the altruist scaled by the relatedness. As an example, it is observed that ground squirrel, when escaping from immediate danger call while running because others need to be alarmed as soon as possible (higher value of B), but when escaping from less immediate threat, they don't call until they make it to safety (higher value of C).

3.2 Altruism in Our Game

In our game, we follow the kin selection theory in order to spread altruism in the population. In NEAT, organism with similar topologies reside in the same species. Therefor we restrict the agents in a sense that they are just able to behave altruistically within their own species. Therefore, we expect to observe that a species with more number of altruists will be favored by natural selection. Besides, in order to increase the altruistic behavior within each species, we try to enforce Hamilton's rule. As stated before, the input of neural network for organism o_1 also includes the o_1's level of food, the food level of sensed organism and a single bit indicating whether the Hamilton's rule is satisfied (zero for not satisfying). In our game, upon an altruistic action the amount of food given to the recipient is fixed. Therefore the satisfiability of Hamilton's rule is investigated and is passed to the neural network as an input.

Hamilton's rule is enforced by penalizing agent who do not follow it. The penalty is calculated as below:

$$\text{Penalty(Organism O)} = \begin{cases} 0 & \text{if } B > \frac{C}{R} \\ (\frac{C}{R} - B) \times \text{Hamilton-rate} & \text{Otherwise} \end{cases}$$

where the parameter Hamilton-rate, will be initialized experimentally.

3.2.1 Degree of Relatedness

We determine, R as the degree of relatedness to fell in interval (0,1) in such a way that the higher value of R corresponds to more relatedness of the recipient to the actor. Assume there is an edge between two organism if they have parental-offspring relationship. Then the degree of relatedness in such a graph is $\frac{1}{2^{\omega}}$, where ω is the minimum number of edges between two organisms. Therefore, value of R for a parent and its offspring is equal to 1, between two siblings is equal to $\frac{1}{2}$, and so on.

3.2.2 Fitness Function

Fitness function implemented in our game depends on the food level, age and Hamilton's satisfiability of the organism (The longer an organism has lived, the more qualified it is, since it has learned the secret of survival):

$$\text{Fitness(Organism O)} = \alpha \times \text{food-level} + \beta \times \text{age} - \text{penalty(organism)}, \quad (2)$$

where α and β will be tuned experimentally. This function has already been implement but if the altruism behavior does not begin (the evolution is guaranteed but we doubt about its beginning), it will be altered to the inclusive fitness which is also a part of kin selection's theory. Inclusive fitness is the summation of direct fitness plus the effect on fitness of relatives. In other words, the Hamilton's rule try to increase the organism's inclusive fitness. Given this definition, natural selection will act to maximize the inclusive fitness of individuals in the population[6]. The reason is inclusive fitness consists of direct fitness due to personal reproduction and indirect fitness due to additional reproduction by relatives:

$$\begin{aligned} \text{Inclusive-Fitness(Organism O)} = \text{Fitness(O)}+ \\ \frac{R \times \sum_{O_2 \in \text{Species}} \text{Fitness}(O_2)}{\sum_{O_2 \in \text{Population}} \text{Fitness}(O_2)} \end{aligned} \quad (3)$$

4 Future Plan

We plan to do different experiments in this domain to see how altruistic behavior emerges. Hung will work on improving the simulation in Unity and add some features if necessary. He will also try to reduce the time of executing an action by the agent and make sure the new observation will be ready for rtNeat to process as soon as possible. Rouhollah and Elham will work on the rtNeat part by implementing the relatedness of organism and executing the experiments and trying various fitness functions. If necessary, we will improve the file communication method to increase the training speed. We also need to closely monitor the process of training and see what is being learned, first. Finally, we will record a video of the trained agents working together to survive and behaving altruistically, towards each other.

References

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