Assignment 1
Aggregations Phenomena

Project Collective intelligence

Problem description

The field of Swarm Robotics focuses on employing groups of robots to solve tasks while their behavior is inspired by how swarms act in nature. Nature is full of complex patterns and dynamics, and Self-Organized Aggregations is one of them. Aggregation describes the process whereby agents gather in a common location using only very limited sensing capabilities. More specifically, agents do not have access to global information or any type of centralized knowledge [1]. More specifically, agents sensing abilities are local, and all they can do is estimate the local density of conspecifics (i.e. peers) within a limited sensing range, which can be done by counting the number of neighbors within a given range.

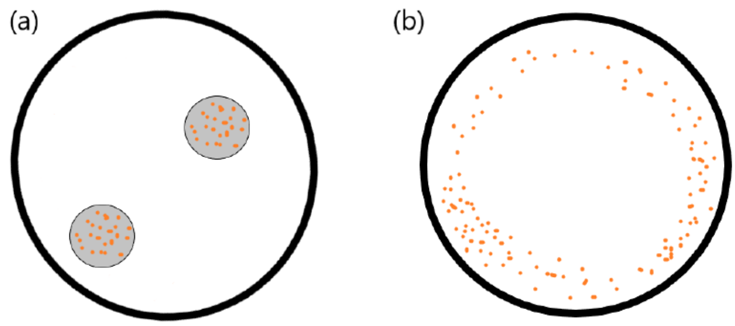

Figure 1: Aggregation Types

There are two extreme types of aggregations [1]. In scenario (a) in Figure 1, a number of environmental cues are assumed to be present in the environment (here represented by circular areas) and can be perceived by the agents. Here, agents are required to aggregate within the circular areas, henceforth called sites. In different, more difficult scenarios such as (b), the environment is uniform and agents are required to aggregate anywhere in the environment, forming an as large as possible aggregate. The latter is very difficult because, due to limited perception, agents joining an aggregate have no clue on whether the current aggregate is the largest or there is a larger one somewhere else in the environment (this problem is similar to the exploration/exploitation problem in machine learning). This assignment aims to target the environment type (a), that is the simplest of the two as the environment presents clue on possible aggregate sites (therefore the total number of possible aggregates is bound by the total number of sites). Here, the main challenge is to have agents aggregating as much as possible towards one among the n potential sites (in this assignment n = 2), instead of splitting in the n aggregates. According to [2] the two main approaches to aggregations are the Probabilistic Finite State Machines (PFSMs) and artificial evolution (through the use of neural networks). Furthermore, in this assignment, we advice you to use the PFSM approach where "the robots explore an environment and, when they find other robots, they decide stochastically whether to join or leave the aggregate [2]".

Implementation

This type of behavior can be characterized by every agent having 4 possible states: **Wandering** (random walk), **Joining** (decided to join an aggregation), **Still** (stop in the aggregate location) and **Leaving** (where the agent decided to start **Wandering**again). Figure 2 illustrates the transitions between the agent's states.

The collective behavior of each agent depends mainly on the rules governing the transitions between each of the different states. Agents start in the **Wandering** state. When the focal agent senses it entered a site, it may transition from **Wandering** to **Joining** according to a probability P_{join}, a probability that takes into account the number of neighbours n in the range of sight of the focal agent. Once in the Joining state, the agents does not stop yet but continues walking in order to avoid stopping always on the edge of the site (potentially blocking other agents). The transition from the **Joining** to the **Still** state is governed by a timer, that once it reaches T_{join}

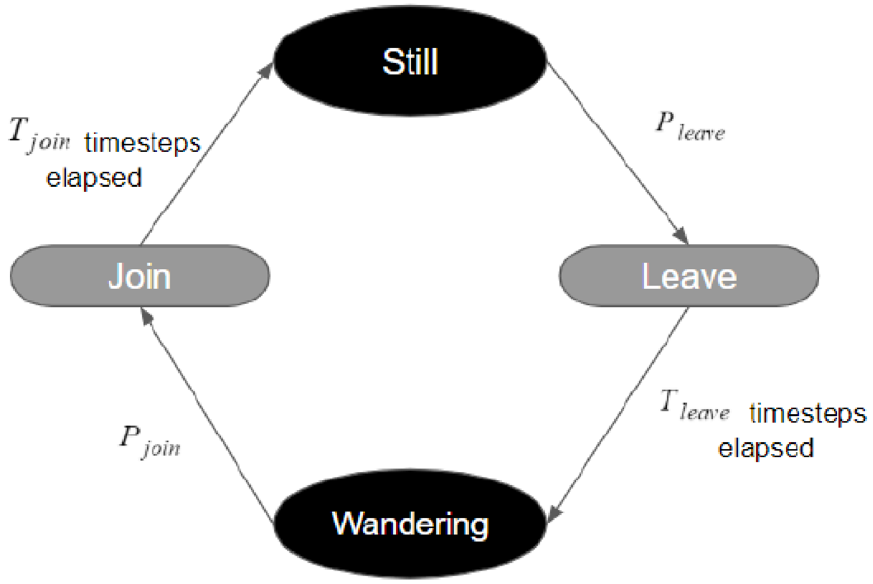

Figure 2: States of the Agent with their transitions

it triggers the transition to the **Still** state. T_{join} can be a static parameter or can be slightly random (e.g. constant plus a small Gaussian noise) in order to have agents stopping in random locations in the aggregate. Once in the **Still** state, the focal agent does not move. However, at a given frequency (e.g. every D time steps), the agent counts the number of neighbours perceived, and samples the probability P_{leave}. The probability P_{leave} controls the transitions to the next state, **Leaving**. Also in this case, the probability P_{leave} takes into account the number of neighbours n in the range of sight of the focal agent. Once in the **Leaving** state, the agent needs to walk without checking the site, without sampling P_{join}, and therefore without stopping again. This state is the "dual analog" of the **Joining** state, and is suggested in order to let agents really leave the site (e.g. they may be in the central part of it) instead of continuously **Joining** it again and again. The transition from the **Leaving** to the **Wandering** state is controlled once again by a timer, that triggers the transition once it reaches value T_{leave}. It is very important to note that T and P parameters are very different: the former are "maximum times", while the latter are probabilities. There could be reasons to consider $T_{join} = T_{leave} = T$ (left to the students to discuss), however in general $P_{join}! = P_{leave}$, as the two need to be set based on diametrically opposite principles (is it better to join/leave aggregates with high or low local density?).

Assignment Description

The assignment contains two stages. The goal of Stage 1 is to ensure you complete the minimum requisites for Stage 2, therefore, you don't need to explain the findings of the former in the Presentation.

Stage 1

Firstly you need to implement the basic structure on the aggregation File, and to define the Cockroach agent's class. The initial scenario to implement is described in Figure 3. The outer shape is not relevant as long as it restricts the movements of the agents inside the area.

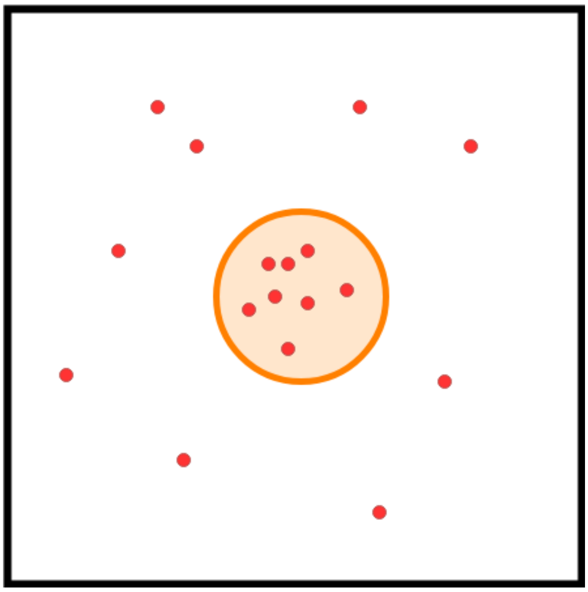

Figure 3: Representation of the initial task

Stage 2

Assuming that the steps from the previous stage are concluded, we can design experiments to test and optimize the collective behavior of the agents. The goal is to document the results of the 2 experiments with the set up as illustrated in Figure 4. The experiments are characterized as follows:

- The experiment (1) is set up containing two aggregate shelters in symmetrical position over the y-axis but with different sizes. The expected behavior should be that after a certain amount of iterations, all agents are in the bigger aggregate shelter.

- The experiment (2), similarly to the previous experiment set up, contains the shelters in symmetrical positions but now with the same size. The goal is to convey a collective behaviour in a way that the agents ended up organized all in a single shelter.

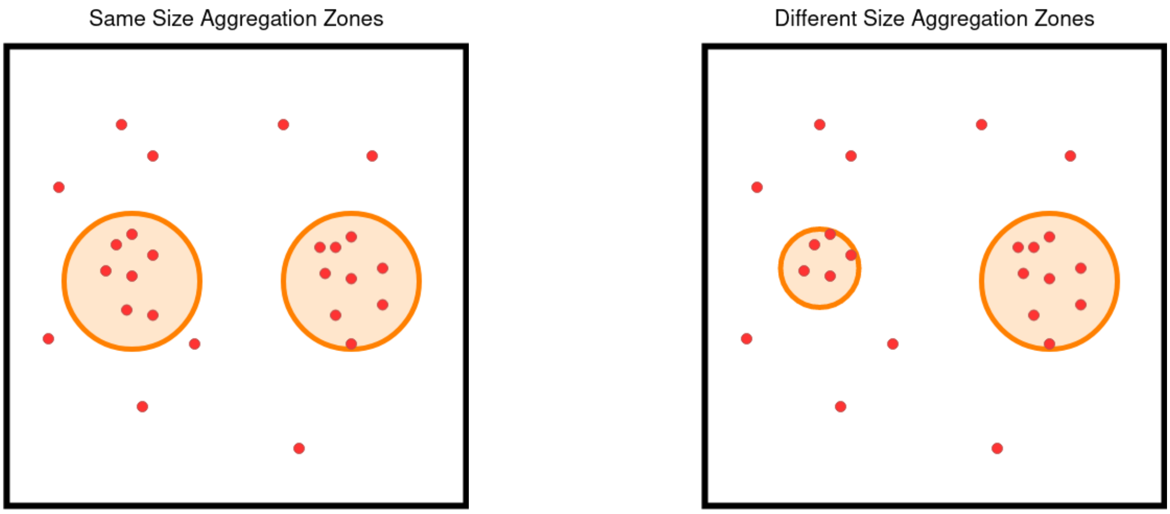

Figure 4: Task Environments for Stage 2

Bonus

In a further note, if the behavior was achieved successfully in both the experiments of this section there is an extra experiment you can explore. It consists of experimenting in an environment with no aggregation shelters. The experimentation and analysis in this environment will be considered as bonus points in the grade but be aware you should only attempt it when you finalized both experiments in Section 2. Feel free to explore other aspects of your experiments that are not covered by these sections but be aware that they should be extras and the evaluators are expecting the main developments in the sections above.

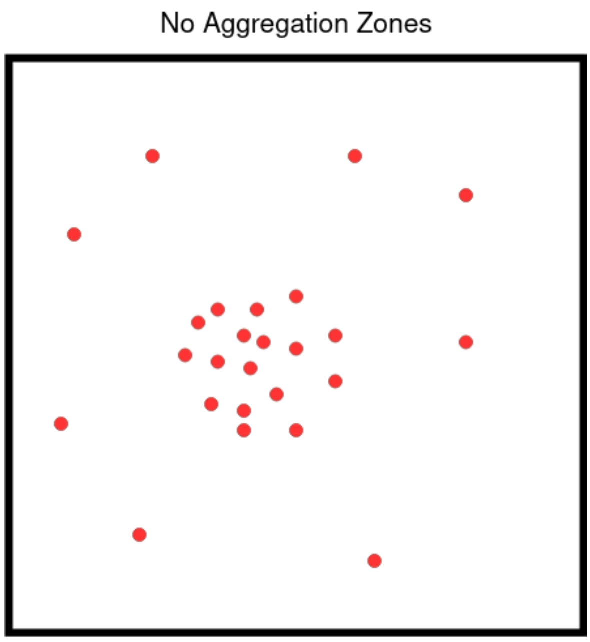

Figure 5: Aggregation without shelters

Presentation and Demo

Given that the previous week was for preparation and reversal of the evaluation methods, in this week both the Presentation and the Demo will be graded. The presentation should last max 15 min (including showcasing the created simulation and excluding 5 minutes for questions), and the structure should be as follows:

Introduction	Briefly introduce the report: purpose of the simulation, type of analysis being done, questions that will be answered with the simulation.
Methodology	Present how agents are modeled. How is their interaction implemented? Try to explain the main idea behind the code without showing the actual code (e.g. use finite state machines, formulas, or pseudo-code if everything else fails).
Results	Present the result, in the form of images and videos of the simulations, trajectories of the agents, and simple plots. It is important to show here how different parameters affect the collective behavior, especially parameters that have a connection on the idea of embodiment and physical interactions (between agents and between agents and the environment).
Conclusion	Conclude stating what you have learned. How do different choices concerning the embodiment affect the collective behavior/intelligence of the population?

Table 1: Presentation Sections

Deadlines

Deadlines assignment 1	
Presentation/Demo	Friday 16-06-2023
Hand in slides on canvas	Friday 16-06-2023

References

[1] N. Cambier, Bio-inspired collective exploration and cultural organisation. PhD thesis, 2019. Thèse de doctorat dirigée par Frémont, Vincent Informatique : Unité de recherche Heudyasic (UMR-7253) Compiègne 2019.
[2] M. Brambilla, E. Ferrante, M. Birattari, and M. Dorigo, “Swarm robotics: A review from the swarm engineering perspective,” Swarm Intelligence, vol. 7, pp. 1–41, 03 2013.