## Abstract

1. Propose a sparse representation of the pheromones using movable beacons.
2. There is no communication between the beacons to propagate pheromones. Robots deploy the beacons throughout the environment, and subsequently move them and update them using a variation of value iteration.
3. Robots make movement and update decisions based entirely on local pheromone values.

## Introduction

1. Challenge – No effective communication
   1. Broadcast communication is unattractive due to environmental factors, limited range and power, lack of global communication infrastructure or congested channels.
   2. Instead, we have to focus on local interaction and forms of indirect communication such as pheromone deposits.
2. Idea
   1. Robots make routing decisions based on the pheromones in nearby beacons. After discovering a trail, the robots may additionally move the beacons in order to optimize it.
   2. Extend the approach taken in to environments with more realistic assumptions.

## Model

1. Environment
   1. 1 nest, 1 food source.
   2. Also contain obstacles through which the ants may not travel.
2. Task - bring as much food back to the nest as possible within a given time frame.
   1. Find the remote food location.
   2. Establish a trail there.
   3. Repeatedly follow the trail to the food location, harvest some food, ferry it back along the trail to the nest and deposit it there.
   4. Ants should optimize the trail, adopting new routes when they are found to be shorter.
3. Three pheromones
   1. Foraging pheromone – used to build a gradient to food
   2. Ferrying pheromone – used to build a gradient to the nest
   3. Wandering pheromone – used to indicate how often a state has been visited
4. Beacons
   1. Beacons within the range of one another, and not occluded by an obstacle are defined as neighbors.
   2. Each ant will associate itself with the nearest beacon. And this beacon is called the ant’s current beacon.
   3. Ants do not directly communicate with each other, and likewise, beacons do not communicate with each other.

## Introduction

1. Examine how automated methods can be applied in the specific case of inferring the social structure of a group of six monkeys given tracking data of their movements over a period of three months.
2. Social structures
   1. Association preference
      1. indicates which members of the group each individual prefers to spend time in close proximity to.
      2. A graph constructed from association preferences can illuminate subgroups, key individuals which connect otherwise disconnected groups.
   2. Dominance hierarchy
      1. Observed displacement and withdrawing behaviors such as chasing and fleeing indicate a dominance relationship.
3. Agent based model – solve two major problems in the experimental study of animal behavior
   1. Firstly, the data collection cost associated with studies done in simulation using high fidelity models is essentially zero, at least compared to the cost of running experiments and collecting data on real animal objects.
   2. Secondly, when inferring model parameters from data, one is faced with the task of validation without access to any “ground truth”. Performing the same inference methods on simulated data can provide crucial insight into how those techniques may perform on data from live animals. Both success and failure can be valuable clues into the capabilities and limitations of the inference methods.
   3. Using ABM, we can measure quantitatively the effectiveness of out methods for recovering social structure.

## Methodology

1. Dominance
   1. Dominance encounters only occur when an individual approaches another within some distance threshold representing an intrusion into personal space.
   2. Each individual is given a dominance weight, and the difference in weights probabilistically determines the winner of any encounter.
2. Association - Grouping behavior
   1. Grouping represents a desire by all individuals in the group to remain within some proximity of other group members.
   2. When an individual finds itself far away from the center of a group, it selects another visible member of the group uniformly randomly to head towards.
   3. Each individual has a list of association preferences, which can be thought of as the distribution over individuals selected for grouping (第i行是i-th individual 会跟其他individual待在一起的概率，每行的总和是1).
   4. The list of association preferences can be combined into a single association preference matrix, with each row corresponding to a single individual’s association preference list.
3. Heuristic behavior recognition
   1. Count the frequency of such event: the ego comes within a threshold distance of another individual, and remains there at low to zero velocity for at least some minimum period of time. Such event indicates the ego’s preference to spend time with that individual.
   2. Detect withdraw event: the ego rapidly moves directly away from the target, which is called fleeing event.

## Experiments

1. Two disconnected subgroups
   1. Association preference set to 1.0 for other members of its subgroup, and 0.0 otherwise. This way there should be no deliberate preference to spend time in proximity of non-subgroup members.
   2. The dominance relationship was a direct linear relationship with rank corresponding to ID. (第一个老大，第6个老小, dominance rate 分别为32,16,8,4,2,1)
2. One individual, which we call hinge, become an articulation point linking the two subgroups.
   1. Modified the association parameters such that the hinge individual preferred everyone equally, but no one has a preference for the hinge.
   2. In the preference matrix: Phj = 1.0, Pih = 0.0
3. Repeated the second experiment, but allow the other individuals to preferentially group with the hinge individual.
   1. Set Pih = 1.0
   2. This model may only recover transitive (A prefers B, B prefers C, then A also prefers C) association preference accurately and may not be able to recover the social structure for non-transitive association preference.
   3. Note that the metric for association preference makes no distinction between individuals which are within proximity because they chose to be, and those that just happen to be nearby. For example, if A and B do not have any preference, but each has a high preference for associating with C, then regardless of C’s preference, A and B will spend a high proportion of time in proximity of each other.
4. Applied the methods to tracking data of live animals
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