Artificial Intelligence For
Complex Problem Solving (CP3064)

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Project Title:
Emergent pathway creation based upon pheromone trailing, and its impact upon the population.

Introduction

I have decided to look into the application of building pathways within communities, using the concepts of stigmergy which occur within ant colonies. By applying the usage of pheromones to dictate movement patterns, I hope to be able to create semi-permanent pathways which provide the agents in the simulation with information on where to acquire food when they are in low supply.

I'm predicting that by using long lasting pheromone trails, I can emulate the creation of interconnecting artificial paths. These paths, once connected, will prove a network to which agents may travel different parts of the map area, while also reproducing offspring, locating food supplies, and avoiding death by starvation. In order to achieve this, I hope to set a series of rules for each agent, and individually each agent will be able to react to two types of pheromone trail.

Therefore, my research questions are as follows:

1. Is it possible to link a series of emergent pheromones trails into a network of complex, interconnecting pathways?
2. In answering my first question, can I achieve this when the agents are also expected to reproduce and acquire food supplies?
3. Can I create a visual representation which will bare similar characteristics to path and road layouts which exist in society today?

My strategy will consist of firstly researching into subjects which could potentially help create the foundations for answering my research questions. This research will involve reading information regarding existing research on the topic I've chosen, looking into ant colonies and analysing the different information available to me, and finally visually analysing examples of societies which I can base my outcome results upon.

Using the research, I'll first create a model using agents, which will adhere to a series of rules. These models will be placed in an environment containing food, and the simulation will be run. The results acquired will then allow me to answer my research questions with more clarity. There will be two different types of pheromone, the first for creating "popular" paths between agents, and the second for signifying the origins of nearby food. In order to abstract from the more detailed reasoning's of food supply, the model will consist of a series of "unlimited" food supplies which can only be accessed when the agents' current food supplies are low.

The outcome I hope to achieve consists of a series of small outcomes. The first is that I would like the result to be visually similar to examples existing in society. This is important, as it allows the research to perhaps be applied to further, practical applications (such for simulation and pathway design). Another outcome I hope to achieve is that the population of agents is self sustaining within their environment. This will help prove that the model is a practical example of a working economy, and that emergent behaviour can result in a self balancing society.

Research

To begin the research, I investigated into the usage of pheromones within ant colonies. From here, I would be able to find key information on how ants interact through of usage of pheromones, and also find any information regarding the scenarios in which they would react to different pheromone levels. After searching various sites, I found a lot of information regarding not only trail pheromones in ant colonies, but also different types of pheromones in both ants and many other different species.

In the information provided on a website I located (Kimball, J W. (1994).) I found that ant trail pheromones are laid once the ant has found food and is returning to the nest, and that it is continually renewed as the ants return to the nest. The pheromone also evaporates over time, meaning that unless the supply is continual, then the trail will only exist until there is no longer any trace of food left at the original source. In certain ant species, a repellent pheromone is also used, although I feel that adding such a thing in such a constrained environment would yield non-complimentary results based on my research questions. These different aspects will help underpin a series of basic rules which will be developed later in the design.

The next thing I immediately noticed in the same article was that there also pheromones I other species for mating. The application of mating does exist within what I'm trying to accomplish, and this information will need to be considered in the design stages.

After looking into the usage of trail pheromone, I decided to research into the currently existing path making methods. I realised that there are a large number of examples where paths are created yet aren't done so as a planned consensus. For example I realised that at car-boot sales, although the entire event I usually carried out in a large field, the pathways between where each stand is placed is created entirely based on the preference of the people walking on them. The field would start off fresh, however once people had walked over certain routes enough times, paths would form from the treading down and eventual dying of the grass. As a result, only dry dirt paths would remain, and eventually people would indentify them as paths and use them accordingly. This observational knowledge that I'd acquired made me wonder as to whether or not similar methods were used in human history in perhaps the creation of roads and walkways. Despite a large amount of searching, I was unable to find any information regarding the creation of paths and walkways using emergent behaviour or decentralized group behaviour. This in fact seemed very unusual, as I could think of what was seemingly a good example myself (car-boot), but could not find any articles which explained the subject in a similar way. None the less I at least have the information on pheromones to work on. I did however manage to find a site which uses an algorithm to create city-like maps (j.tarbell (2003)). The problem however was that the theory behind it was far too complex for what I needed. I also couldn't extract any data relating to path generation from it, as I wasn't sure whether the algorithm developed road intentionally or not. I then discovered on the same site an interesting application called the "city traveller". It appeared to create very artistic images by making a series of travellers move between cities while leaving a pixel behind them. The application however didn't provide any research notes which I could apply to designing my proposed model.

Methodology

The model itself will consist of the following:

Agents

Agents will each have a series of different rules governing their behavior within the allocated environment:

1. by default, move forward by 1, and randomly change heading by a set number of degrees left or right each tick.
2. after each tick, a proportion of food will be subtracted from the total food.

3. If the total food reaches 0, the agent will die.
4. If a there is a stronger pheromone smell ahead, left or right of current position, change to face the direction of the stronger signal.
5. If current food is below the value of 2, and a stronger food pheromone is found ahead, left or right of current position, change to face the direction of the stronger signal.
6. If food is found, current food value is set to 10, and change direction to face opposite of current facing direction. Also set to emit food pheromone for a number of turns

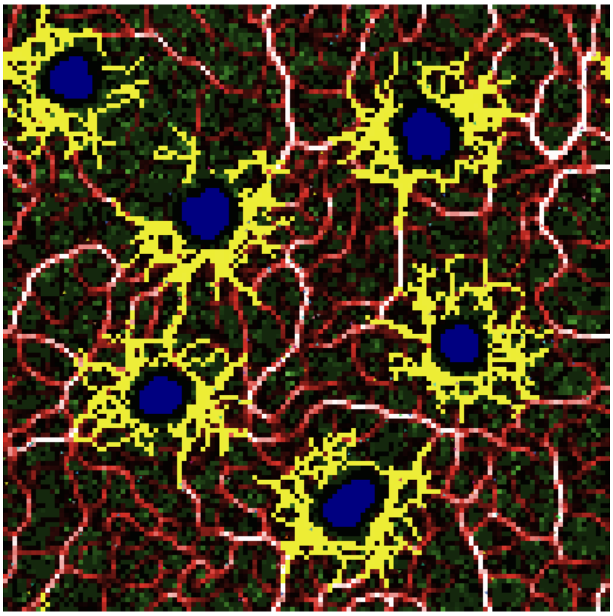
Patches
Patches consist of the ground where pheromones are present, and also where food sources can be found. Paths (standard trail pheromone) will be coloured red, food will be coloured blue, unused patches will be coloured green, and food pheromone trails will be coloured yellow. The path pheromone shade will vary based on the amount of popularity of each patch. The rules are as follows:

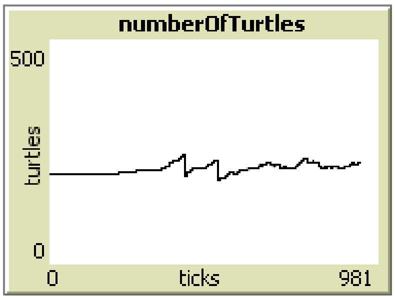
1. If an agent steps on a segment of patch, increment a "popularity" pheromone for that patch
2. If an agent is not present on the patch, slowly evaporate any pheromone present on that patch
3. If an agent who has just received food steps on a segment of patch, and the patch does not have food pheromone applied, apply it to the patch
4. If a patch has been left unoccupied for a certain amount of time, begin turning it green to signify lack of use
5. if two agents meet on a patch who each have more than half of their max food allowance, create offspring, and decrease their food

These rules should allow for the emerging of an ecosystem that maintains a steady number of agents. Hopefully using these rules will result in the desired behaviour required to meet my research questions.

Results and Analysis

The resulting behaviour of the combined agents has successfully yielded some very satisfactory results:





The image above, as well of the statistical representation alongside it, detail that despite a few fluctuations in the population it manages to stay even, without increasing or decreasing. The visual results show many similarities to how road structures exist within interconnecting towns. The blue could represent the town itself, bright white/red paths could represent major roads, and the darker red paths could represent more minor roads:

Google Maps 2010

The environment is first created when agents begin to detect the pheromone trails of each other, while also leaving their own. Eventually the agents disperse into many sub-groups, which each create a segment of what eventually will become a main pathway (these how on the image as almost white). Once agents require food, they begin to search for food pheromone. By chance, some agents appear to find the food without pheromone, and as a result take some and leave a trail of food pheromone behind them. This pheromone is then detected by other hungry agents, and as a result they follow the pheromone to the food and create their own trail as they leave. Eventually it seems that the popular pathways are interconnected with the food via a continuous food pheromone link, and the unused pathways slowly fade away. Sometimes when the model is run, the population will very gradually decrease over a long period of time, while other the opposite will occur.

Conclusion

The model answers all of the research questions posed in the original brief and the model itself works better then could be expected. The creation of pathways is clearly evident, however I couldn't have expected the creation of smaller lightly used pathways in addition. The main pathways displayed as almost white are visually similar to A-roads found in the UK today. The red, more lightly used roads, are distinguishably more akin to B-roads, and even connect together more tightly, forming small cul-de-sacs and groves.

Returning to my research questions, it seems evident that:

1. A network of interconnecting pathways can be successfully created using pheromone trails.
2. A balance in the society can be achieved when both food and the ability to reproduce are applied to the model.
3. The visual representation is defiantly very similar to how roads exist in the UK today. The additional creation of apparent "A" and "B" type roads means that this model can effectively create realistic models of road development and growth.

Overall I feel that this model has successfully displayed traits of emergent behaviour. By applying simple rules to a number of different agents, all of whom interact only for the purpose of reproduction, I've managed to develop a realistic looking road map and a relatively stable eco-system.

An improvement which I would have made if there was time would be to create food sources which diminished, and also areas where food would "grow". Due to time restrictions, and other project work, this functionality was not implemented; however I still feel that the result I've produced contain many different strengths, which perhaps cover the omission of such functionality.

Another thing which perhaps will be an issue is that I carried out a project to which I couldn't find much research about. The research into ant colonies was very useful, however it seemed a large proportion of my model was created to theorise the potential strengths/weakness of applying an existing concept to work in a different way to what has previously been done. I chose the topic believe I could find a lot a research, but unfortunately found that in the end I had to create chances using my own observational work.