Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Lecture with Computer Exercises:
Modelling and Simulating Social Systems

Project Report

Vector based navigation of desert ants

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Vector based navigation of desert ants

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Contents

1 Abstract

In this project we simulated the behavior of desert ants, as stated by Collett in his report (Collett et al. [1998]). He conducted experiments with real ants and proposed a theory how these ants handle the orientation in the desert. We used his results to simulate an ant, which behaves as Collett stated in his thesis and conducted his experiments again in simulation. With our Simulation we got results which are very close to Collett's own research.

2 Individual contributions

N.Z and J.G set up a basic concept for the simulation, N.Z. and J.G. programmed the simulation, J.G. run the simulation, N.Z and J.G. wrote the report.

3 Introduction and Motivations

3.1 Motivation

Desert ants (*Cataglyphis*) have a difficult task to navigate since their natural habitat has not much landmarks helping to find their way. Different scientific papers (Müller and Wehner [1988]), (Collett et al. [1998]), (Knaden and Wehner [2005]) are postulating that desert ants use path integration as one component of there navigation. Because many technical applications are inspired by nature it is of high interest to have a clear idea how ants navigate in a unrecognizable landscape like desert. We could imagine a technical use in satellite steering or the navigation of evacuation robots in.

3.2 Base Paper

This project is based on the paper "Local and global vectors in desert ant navigation" (Collett et al. [1998]). Through simulating an ant which follows the concepts of local and global vector described by Collett et al. [1998] and comparison with the actual behavior we wanted to find out if the concept postulated is complete or needs adjustments. The goal was to implement the ant following the concepts as accurately as possible, then simulate the same test setup as it was used for the paper and compare the simulated plots with the plots from the experiments.

3.3 Hypothesis

The hypothesis for our simulation is that if we implement all the in the running text of the paper (Collett et al. [1998]) described navigation tools of desert ants in our simulation we would get the same plots than Collett and his collaborators got in there real life experiment. To prevent our simulation to be a self-fulfilling prophecy the basis of implementation are only the described concepts in the running text and not the results of there experiment.

4 Description of the Model

4.1 Behavior of the ant

For our simulation we aimed to implement our model as closely as possible to the postulated model by Collett and his participants (Collett et al. [1998]). Their model splits the navigation of the ant in two parts. First, if there are no known landmarks in sight (which is the usual case in the desert, the ants natural habitat) the ants orient themselves with a process named 'path integration'. An ant leaving their nest to gather food counts each step it takes and measures its direction with aid of the sunlight, which it uses as a sort of compass. Like this it is always aware of its position relative to the nest and is able to find its way home. With this practice it is also less vulnerable to changes in the environment. The integrated value, respectively its negative which is pointing to the nest, is called the `global vector` by Collett and his colleagues. However, this practice becomes unreliable if the sun is not visible or the ant makes a mistake counting its steps. Therefore the ant also uses a different form of finding their way. It uses known landmarks, as for example rocks, bushes or other static objects for his orientation. Collett uses the word `local vector` to describe this form of orientation. Here it is important to say that as Collett says he does not calculate its `local vector` according to the direction of travel, like "after the gray rock go left", but relative to the cardinal direction, like "after the gray rock go south".

4.2 Conducted experiments

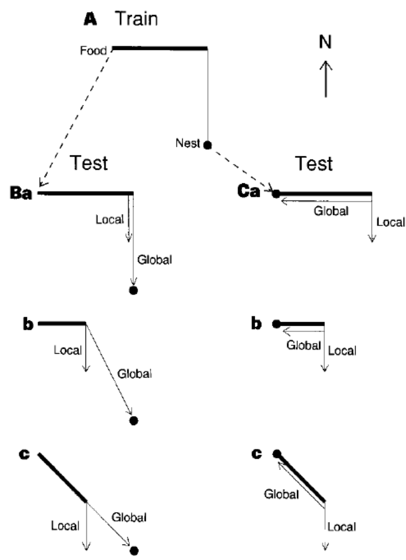

Figure 1: Test setup and some experiments conducted by Colletts. Collett et al. [1998]

To prove their theory the four researchers conducted several experiments. They built a training ground for the ants, where they had a nest, a feeding ground and a so called 'channel'. The channel was a tunnel dug in the ground just deeply enough that the ants could not see it form the surface. The ants were left in this training area, where they continuously gathered food and brought it back to the nest. So they got used to the setup and memorized the local landmarks and therefore set up their `local vector`. After a few days training the researchers started to conduct several different experiments, where they changed the setup partly. In some experiments they changed the the length and position of the channel, which disordered the ant's `local vector` and in some other cases they picked up the ant at their nest or on their way home and released it somewhere else, in order to give them a false estimation of their position according to the `global vector`, see Figure 1

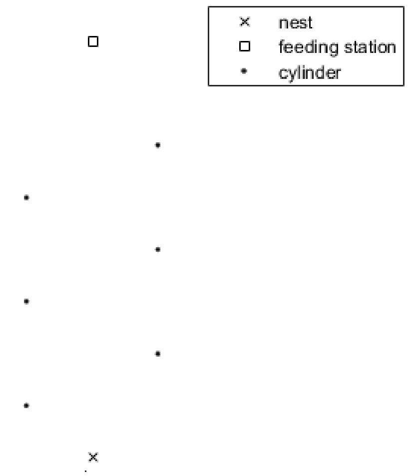

Figure 2: Training ground with cylinders.

Furthermore the group conducted an other kind of experiments, where they used no channel, but six highly visible black cylinders. They formed some kind of alley, where the ants had to get trough in order to reach their food. With this arrangement the ants were trained again, see Figure 2. In the experiment conducted with those ants, they were picked up at the nest and released them at the feeding station.

5 Implementation

5.1 Main Concept

Our goal was to set up a simulation environment which was as general as possible, so we could easy switch between the test cases. The simulation is actually a huge loop, where in every iteration the ant does a step on a grid. It can just move horizontally, vertically and diagonal. This of course limits our ant, but if we simulate it with a big enough resolution it does not really matter. The ant can not reach every point on the map, there are several restrictions. First there is the channel, which can only be entered at specified channel exit or enter points. On the other hand the ant can not leave the map, so we constructed a virtual wall around the whole map, which it can not pass. Finally there is the nest, which we placed in the middle of the map.

In every iteration, the desired direction of the ant gets calculated according to the global and local vector in the `desired_direction` function. Then we calculate all possible directions in the `possible_direction` function. At the end the function `actual_step` lets the ant walk one step and the global vector gets adjusted. If the ant did a certain amount of steps the simulation stops and the path gets plotted.

Our whole simulation environment is highly configurable, in the `conifg.py` file one can import any test file, in which all things like the map configuration, the start position of the ant etc. can be specified.

5.2 Global Vector

The global vector starts with an initial value, which can be edited in the test file. In every iteration of the main loop the step conducted by the ant gets subtracted form the global vector. Additionally to model the imperfectness of the ants 0.1 mg brain we introduced two random factors. One gives credit to the fact, that a normal ant never walks in a straight line but rather zig-zags its way home. For this reason before a step is executed by the ant, the step gets randomly rotated, but with a gaussian distribution around the straight forward direction, see lst 1. The second randomization mirrors the fact that an ant never can memorize exactly how many millimeter it walked north or east. Thus the global vector gets slightly rotated randomly after every step, which means the ant does not exactly remember which way it took to get to its current position.

Listing 1: Randomization of desired step

```
# choose a random angle
sigma = con.sigma
randomAngle = np.random.normal(0, sigma)

# construct rotation matrix
rotationMatrix = [[math.cos(randomAngle), -math.sin(randomAngle)],
        [math.sin(randomAngle), math.cos(randomAngle)]]

# rotate vector
rotated = np.matmul(rotationMatrix, desired)
```

5.3 Local Vector

The local vector gets calculated every iteration and depends on the close surroundings of the ant. The influence and the position of these surroundings can be configured in the test files. The channel exit for example pushes the ant to the south. All these objects have a circular area of influence and the influence lowers quadratically with the ants distance to the object. All influences of all objects get summed up to the local vector and are merged with the global vector to the desired direction with the following formula:

$$desired\_direction = local\_vector * local\_weight + global\_vector * (1 - local\_weight)$$

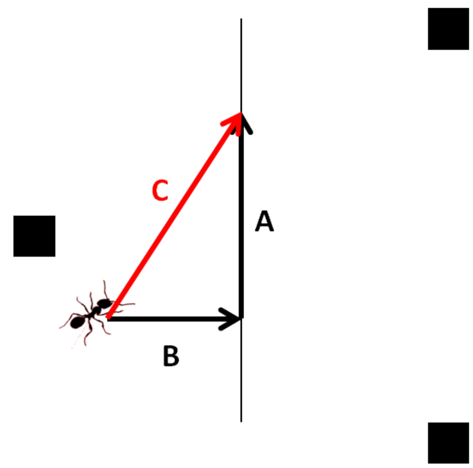

Figure 3: Calculation local vector in the influence region of objects. **A:** weighted vector in path direction. B: vertical distance from the ant to its familiar path. **C:** calculated local vector at the ants position

To calculate the local vector in the area of a familiar path the path is represented by a straight line with start and end point. Mathematically the straight is a linear function $y(x) = m \times x + q$ and the vertical slope n is calculated by $n = \frac{-1}{m}$. This implementation leads to errors for familiar paths with slope 0 or ∞. Since the familiar path does not have to be a such exact defined line we can use this simple implementation for adjusting the local vector in the region of objects. In the influence region of the objects the local vector for the ant is calculated as represented in Figure 3 . The local vector is the sum of a weighted direction vector and a weighted distance vector vertical to the path.

6 Simulation Results and Discussion

6.1 Simulation Results

Due to our simulation setup the results are plots of traced ant paths on a square map. To compare them with the experiments conducted by Collett et al. [1998] we take e look on there plots and define some critical characteristics in the plots, that we would like to recognize in the simulation.

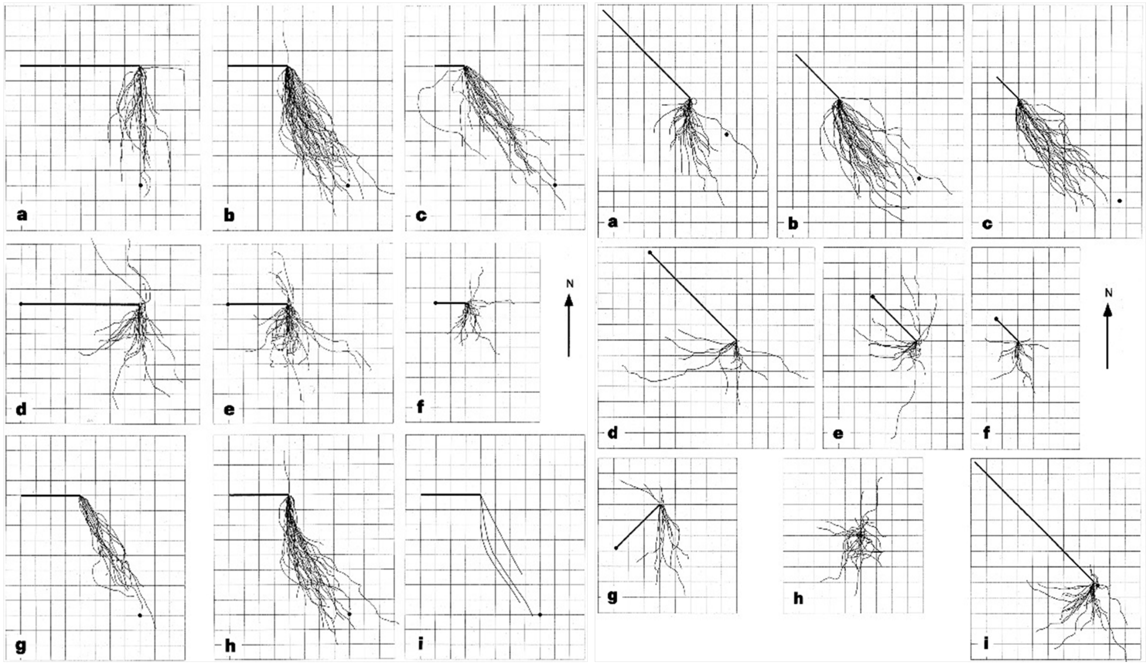

Figure 4: Trajectories of ants 'homing' on the test area. **left a)** results of test setup Ba. **left b)** results of test setup Bb. **left d)** results of test setup Ca. **left e)** results of test setup Cb. **right b)** results of test setup Bc. **right e)** results of test setup Cc. Experiments conducted by Colletts (Collett et al. [1998])

6.1.1 Test setup Ba

The setup Ba is a horizontal channel starting at the feeder/launching position in the northwest and has its exit exactly in the north of the nest. In this run the launched ants had been picked up at the feeder on the test ground therefore they have the correct global vector pointing form there position to the nest.
In the plot of the experiment it can be seen that all the ants leaving the channel in south direction and then loose the direct path in a kind of cone shape. Comparing the simulation with the experiment the simulated ants leave the channel collectively in south direction and spread later than the real ants.

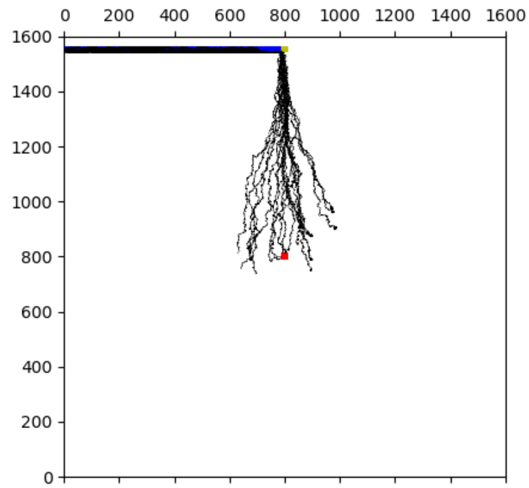

Figure 5: Simulation setup Ba

6.1.2 Test setup Ca

The setup Ca is almost the same than Ba but the launched ants had been picked up at there nest. That means they do not have a global vector at there launching position/feeder and allocate this position as the origin to calculate the global vector. In the experiment the ants leave the channel mostly in south direction as trained but then do a kind of searching walk. The ants in the simulation heading back to the feeder but outside of the channel, because after leaving the channel in south direction the the local vector is missing and the global vector takes control of navigation. The global vector is total is useless since the ants do not know there position compared to the nest and just walk back to there launching position. In this simulation it can be seen, that Collett et al. [1998] did not describe the ant navigation if the global vector is disturbed by different pick up and launching position. We did not implement a searching walk since there is no idea mentioned in the paper how the ants do that.

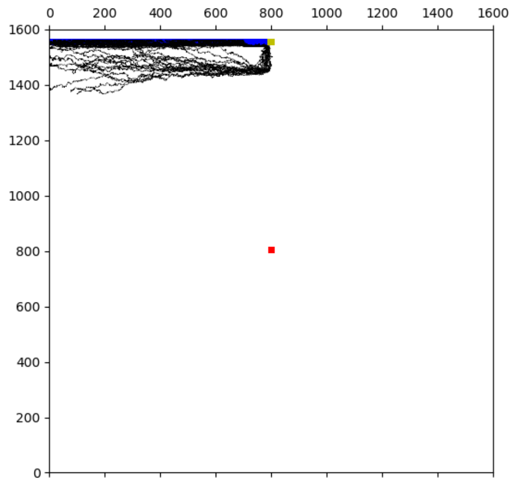

Figure 6: Simulation setup Ca

6.1.3 Test setup Bb

In the setup Bb the horizontal channel from the feeder ends at half horizontal distance to the nest. The training ground for the ant is the the same than before.
In the experiment the ants walked from the exit to the nest in a slightly south curved diagonal. This can be seen better in the experiments plots **left g-i** there are the ants "segregated according to whether ants went to the left (**g**) or to the right (**h**) of a point 2m south and 0.5m east of the channel exit." (Collett et al. [1998] Figure 2) All the ants walking to the right (**h**) did the same as they trained actually heading south after the exit just when the local vector ends the global vector leads the ants home. In the simulation this behavior is stronger but similar.

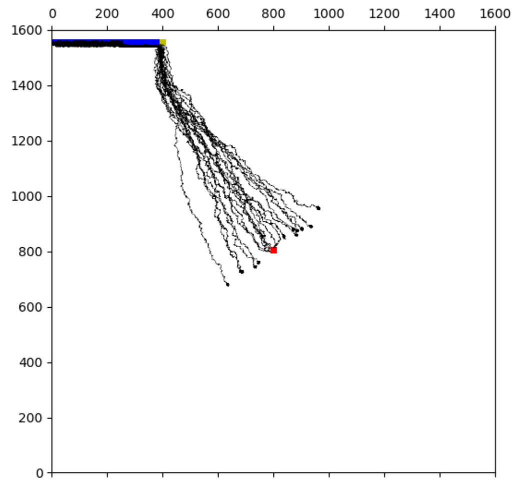

Figure 7: Simulation setup Bb

6.1.4 Test setup Bc

The setup Bc is a diagonal channel of half the distance from feeder to the nest.
In this experiment plot a similar behavior as in Bb can be recognized, the slightly south curved diagonal, but much less clear. In the simulation just one ant does not perform this behavior.

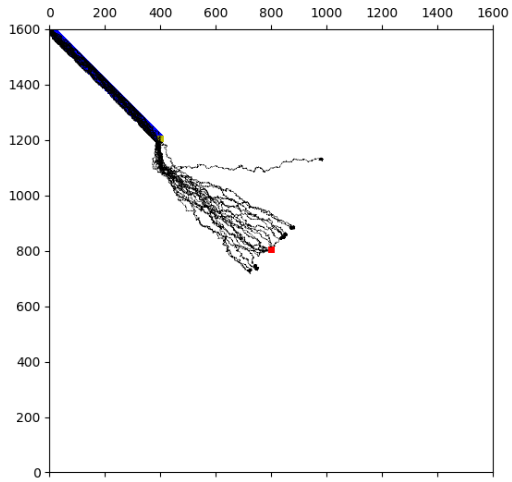

Figure 8: Simulation setup Bc

6.1.5 Familiar path near objects

The setup for the familiar path experiment as it is described in the section 4.2 leads to a local vector allocation in the circular influence area around the objects. The paper (Collett et al. [1998]) does not say anything how the objects lead to a orientation along the familiar path. So it is our assumption that the ants see the objects from a certain distance (influence radius) and then tend to walk on there path.

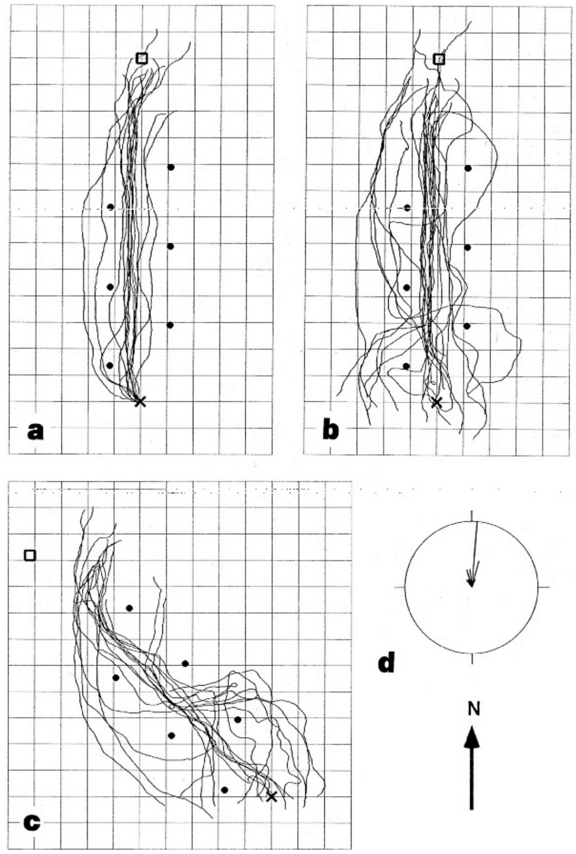

Figure 9: **Figure 4** form Collett et al. [1998]. **a, b,** Test with landmarks arranged in training situation. Ants were caught ether at the feeding site (**a**) or at the nest (b)

6.1.6 Test set up 2a

In the experiment the when the ants were picked up at the feeder and lounged at the feeder the find there way pretty straight. The same behavior can be observed in the simulation. The reason why there are no ants walking around the objects could be that the local vector tents stronger to the middle with increasing distance of the ant to the path.

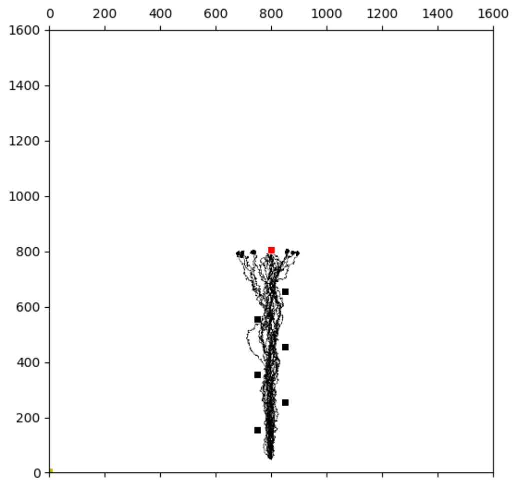

Figure 10: Simulation setup 2a

6.1.7 Test set up 2b

The plot of the experiment shows that most of the ants find there way to the nest without a global vector, but there are more random walks. In our simulation instead the ants do not move at all since there global vector holds them back to the position of the feeder. Here a random search walk could be necessary for an natural behavior of the ants.

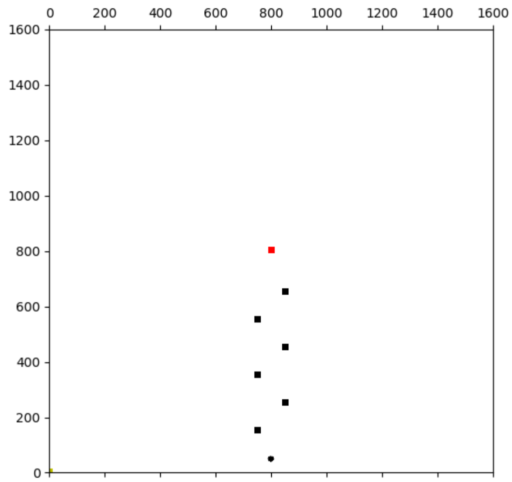

Figure 11: Simulation setup 2b

6.2 Discussion

The most obvious difference between simulation and experiment is that natural ants walk as well when they do not know where there nest is. We cold that a search walk. How ants do that is not covered by Collett et al. [1998] but would be a very interesting research topic. We expect that they does not mention it because it is still unknown. The second point our simulation can not compete the nature is the fact that ants probably have preferences where they walk due to there experience. For example they do not walk back along the channel despite there global vector point in this direction.

7 Summary and Outlook

7.1 Summary

The results of our Simulation correlate quite well to the results Collett received with real ants. This leads to the conclusion that his model mirrors the behavior of the ants really precisely in the case there global vector is not disturbed. The greatest difference between their experiments and our simulation is the behavior of the ants if they have no global vector, which means they have been caught at their nest. The real ants started to walk around randomly and tried to find a familiar landmark or something which helped them to get back their orientation. In the simulation if there was no global vector and also no landmarks in sight, therefore also no local vector the ants just stood still. So there must be also some random element in their orientation if the have no other help. This was not described in Colletts paper Collett et al. [1998], but it could also be argued that this kind of behavior was quite obvious and therefore they did not describe it.

7.2 Outlook

The subject of desert ant orientation is really interesting, but does not really fit in our studies plan. So we will probably not continue our research in this topic. But generally the subject will surely be investigated more, because learning of nature is always promising and can lead to major technological discoveries.

8 References

M. Collett, T. S. Collett, S. Bisch, and R. Wehner. Local and global vectors in desert ant navigation. *Nature Magazin*, 394, July 1998.

Martin Müller and Rüdiger Wehner. Path integration in desert ants, *Catglyphis fortis*. *Proc. Natl. Acad. Sci. USA*, 85, July 1988.

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