Expandable search networks

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A teacher's guide and instructional video will be posted on this website in March 2014, when the data from the ISS experiment have been analysed, and when the weather is warmer so ants will be easy to collect outside.

The searching problem

What's amazing about ant colonies is that there is no one in charge. All ant species live in colonies, consisting of one or more female reproductives who are called queens although they have no authority; they just lay the eggs. The ants you see walking around are sterile female workers. No ant makes a plan or tells any other ant what to do. So an ant colony has to solve its problems by working collectively, using only local interactions between ants.

Searching is one of the important problems that ant colonies have to solve. Ants need to find food, water, nest sites, and to detect threats. Since most ants can't see, but operate by smell, an ant detects something only when it is nearby. What is the best way to explore a space, to ensure that if there is something there, some ant will find it? This is also a problem that humans have to solve sometimes. For example, in robotics, efforts are underway to design methods for groups of robots to search a burning building collectively, without having to maintain any central control.

The best way to search collectively depends on the number of searchers and the size of the space to be explored. There's a tradeoff between thoroughness and covering ground. To search thoroughly it is necessary to spend a lot of time in a small area. To cover ground it is necessary to travel. How best to do this depends on density, the number of searchers in a certain area.

Suppose you lost something small and valuable – say, a contact lens, or a diamond ring - on a football field. If you are on your own or with a few other people you would make a plan to walk up and down the field, looking at the ground as you go. If you had a thousand people to look, you would make a plan to assign each person to look carefully in a small area of the field.

Ant colonies have to solve this problem without a plan. In some species, the ants can change the way they search according to density. Many invasive species, the ones that show up in our kitchens, are especially good at thorough search while still covering a lot of ground.

When there are many ants, the group can achieve thoroughness without having to worry about covering ground, because there are so many ants that if one ant doesn't find something, another one will. An ant can search thoroughly by using a convoluted path, such as a random walk. A random walk tends to turn round and round in the same place, since the direction of each successive step is random relative to the direction of the last step.

If there are few ants in a large area, so that density is low, the ants have to lose some thoroughness, in order to cover more ground. Then they use straighter paths. The least random possible walk is a straight line: each step is in the same direction as the last one.

So the paths of all the searching ants form a network. It is like a network made of tight elastic bands, which is contracted when density is high, but stretches out to cover ground when density is low. [Similar experiment with Argentine ants, pdf for Gordon DM Anim Behav1995 Gordon lab website].

Ants can evaluate their current density, so as to adjust their paths accordingly. How? They can use the rate at which they meet each other. When they meet they touch antennae and that's how they smell each other. When there are many ants in a small space, and density is high, they meet each other often. When there are fewer ants in a large space, and density is low, they don't meet as often.

The experiment

A detailed guide for how to do the experiment will be posted on Gordon lab website.
A video showing how to do the experiment will be posted on Gordon lab website.

The Expandable Search Networks experiment tests how ants search a novel area, first at at high, then at low density. It lets the ants search a small space, when density is high, and then gives the same number of ants the opportunity to search a larger space, when there are fewer ants in a larger space, so density is lower.

If the ants are using the expandable network strategy, then when density is high, they will search using more convoluted, random paths. When density is low, their paths will stretch out to cover more ground.

In microgravity, because the way the ants move around the arena will be different, their interactions might be interrupted, or more difficult. This means that they do not have perfect information about density. The experiment tests how expandable search networks operate without perfect information.

Getting the results of the experiment

To learn the results of this experiment, we evaluate how thoroughly the ants search and how much ground they cover. To evaluate how thoroughly the ants search, we need to measure how convoluted and circuitous are their paths. To measure how much ground they cover, we need to measure how much of the area was ever visited by at least one ant. We can then ask whether path shape and the amount of ground the ants covered changed when the density changed from high, in the smaller area, to low, in the larger area.

One very way to ask how thoroughly the ants search is to trace their paths. This can be done by placing a sheet of transparent plastic, like an overhead transparency, over the arena and following some ants with a pen. To get a value for how random the path is, you divide it up into steps of equal length, and measure the angle between successive paths. (The shorter the step length, the more precisely this measures path shape). The more that angle changes, for example the higher its variance, and so the more random is the path.

One very basic way to ask how much ground the ants cover is to make a grid on a sheet of transparent plastic, and put a dot in every square that an ant enters. The more ground that the ants cover, the more squares will have dots. The finer the grid, the more precisely this measures the amount of ground covered.

Then to ask whether the ants' behavior changed at the two densities (high in the first area, low when the second area is added to the fist), compare the values for either measure (path shape or ground covered). If the values are different, then the ants changed their searching behavior according to density.

Comparing species

There are more than 12,000 species of ants in every conceivable habitat on earth. Different species use different resources, and so they have different searching strategies. This means that different ant species will behave differently in this experiment. For example, the ants we tend to find in our kitchens and in our cities are often invasive species that have been successful in many parts of the world because they are very effective searchers. Those species might be especially good at adjusting their searching behavior to local ant density.

If people try this experiment in different places, with different ant species, we can put the results together and see what we can learn from coming up with such a global guide to ant searching!