

Royal Academy of Engineering International Travel Grant Report

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**Research trip to Brazil
14th January – 28th February, 2005**

Purpose of trip

I am currently studying complex adaptive systems, which are of vital importance to human society. The organisation of the multitude of systems on which our society relies is an ever increasing problem. Ants continually face dynamic organisational problems and have been evolving to manage these problems for 80 million years. One type of organisation frequently used by ants is self-organisation. Here organisation emerges from local interactions of individual components which occur without reference to the global pattern and without centralised control. This has many potential computational applications.

I had previously been studying foraging behaviour of laboratory ant populations. This research trip to Brazil was made in order to study the organisation of complex systems in their natural dynamic environment. Brazil is an ideal country for the study social insects, with thousands of species of ants from army ants to tiny scavengers. Studying ant organisation in the field has complemented valuably the lab work I have carried out so far and may lead to a deeper understanding of the processes of self-organisation.

Sao Paulo: university

The trip commenced with a period of orientation at the University of São Paulo. We were made welcome by the Brazilian scientists working on social insects. They demonstrated techniques appropriate to the climate and fauna. I was able to familiarise myself with the range of ant species and their activity patterns. I carried out some preliminary experiments on the organisation of soil excavation which allowed me to design full experiments for our time at the field site. I also began to realise the impact rain would have on my work, and built a margin into me schedule to allow for the time lost during heavy rainstorms.

Sao Simão: field research

After four days at the University of São Paulo we travelled to the conservation farm near the village of São Simão which would be our field site. This farm is owned by Dr. Paulo Nogueira-Neto, an eminent Brazilian academic and former Secretary of the Environment who has a special interest in stingless bees. This farm houses hives of 50 stingless bee species, but the number of ant species living wild on the site was even greater so I had plenty of scope for study.

During the first two weeks at the field site, the weather was extremely wet, so initially I put into action the plans I had developed in São Paulo to investigate soil excavation, which occurs particularly after rain. Ants dump soil out of their underground nest, forming an annular ridge round the entrance. They tend to drop their load of soil only when they have passed the summit of this ridge, thus preventing the soil falling back down the slope into their entrance. This is a highly simple but effective method of organising waste disposal. For nest entrances on slopes the problem is slightly different and piles of waste soil here are often closer to crescent shaped. The heavy rain often washed soil away unevenly, changing the slope which the ants had to work on.

I investigated the cues used by the ants for when to drop their load, by artificially altering the tilt of the slope on which they were dumping. The experiments were all video recorded, and I carried out preliminary data analysis on two tapes. These data suggested that the ants responded to the change in slope by dropping the soil close to the nest entrance on the downhill side where there was no danger of it rolling back in. This shows that the cue for dropping is based on the slope, not on the distance from the nest.

While carrying out these experiments, I was also investigating other species of ants to find a suitable network system to study. I found colonies of an ant which have several nests linked by trails and started investigating food retrieval. This was a truly dynamic system, where the network of nests was extended in the direction of good resources and moved away from threatening competitors. As the weather had now become more favourable, we decided to extend our stay in Brazil to six weeks. This allowed me to focus on this dynamic network, having completed the study on organisation of waste dumping.

The decision of which nest in the network to take a food item to is a difficult one as it depends not just on the relative distances to the two nests but on the relative needs of these nests and the quality of the routes between them in terms both of terrain and of trail traffic. I found one important factor in food retrieval was that if food was placed on a trail linking two nests, ants frequently wasted time carrying the food item backwards and forwards between the two nests before choosing which one to enter. A second important factor was theft of food by ants of other species. This was most common with food items not on trails, and therefore not well defended. The ants seemed to be making a trade-off between retrieving food via well defended trails and wasting energy in on-trail-conflicts about which nest to choose. I carried out a range of experiments to understand what simple rules the ants were using to retrieve food effectively in a multi-nest system. This has clear analogies communication networks if for example there are packets of information with alternative potential destination nodes.

São Paulo: review of projects

The last few days of the trip were spent back at the University of São Paulo. There I discussed the possibility of future projects based on understanding the network architecture of these ants and how it responds to change. We discussed the opportunities

for future collaborations with scientists at the University of São Paulo. A return trip next year to extend the work carried out so far was proposed by several of the Brazilian scientists. Such a return trip would be very productive as I would have the background knowledge of the sites, species and techniques in advance, so would be able to focus on data collection quickly and efficiently.

During this research trip I learnt a lot about field work in unfamiliar situations and about how to find and focus on an experimental system, how to refine my techniques and how to check the experiments are working. I made a detailed list of what equipment was most useful and what else we would have liked to have used; this information will be invaluable in planning future trips.

I also learnt the importance of making a range of plans suitable to the possible weather conditions, so that projects are not dramatically set back by events out of our control. One unexpected benefit of the trip was that I acquired conversational Portuguese, a skill which is sure to come in useful in the future.

Future

In the short term, the next step for me is to complete the extraction of data from videos and to analyse all the data. I will then consider what modelling of the results will be appropriate and useful, and put this into action. The work will be written up and submitted for publication.

In the medium term what I have learnt from this trip about organisation and dynamic networks will help to shape my thesis. Future work will be planned in the light of what I found out in Brazil about systems facing changing environments.

In the long term the experience gained during this research trip will inform plans I make for future field work.

Thank-you to the Royal Academy of Engineering for contributing funds to make this very productive trip possible.