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Activity in ant colonies

C. Noda, J. Fernández. C. Pérez-Penichet, E. Atshuler

Facultad de Física, Universidad de La Habana, Cuba; Cátedra de Sistemas Complejos:“Henrí Poincaré”;
noda@complexperiments.net†, javier@complexperiments.net, cpp@complexperiments.net, ea@infomed.sld.cu.

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Sumario. Los insectos sociales, y las hormigas en particular, son un ejemplo recurrente de optimización, basado en la autorganización. A pesar de la simplicidad de cada individuo, la colonia presenta inteligencia collectiva: la organización de las filas de hormigas para buscar comida es un ejemplo de ello. Pero la observación directa no es suficiente para recolectar la cantidad de datos necesarios para entender la autorganización de las colonias en su medio natural. Aquí presentamos un sistema de medición para monitorear la actividad de la colonia de forma contínua y con alta sensibilidad. El rol protagónico corresponde a un sensor de actividad infrarojo diseñado específicamente para medir actividad de las hormigas a través de la boca del nido, aunque son utilizados otros sensores para medir temperatura e iluminación. Se estudian las características del sensor de actividad y su comportamiento en el terreno y, finalmente, se presentan las mediciones en una boca de un nido de Atta Insularis, una hormiga endémica de Cuba, para ilustrar el potencial de nuestro sistema de medición.

Abstract. Ants, as paradigm of social insects, have become a recurrent example of efficient problem solvers via self-organization. In spite of the simple behaviour of each individual, the colony as a whole displays “swarm intelligence:” the organization of ant trails for foraging is a typical output of it. But conventional techniques of observation can hardly record the amount of data needed to get a detailed understanding of self-organization of ant swarms in the wild. Here we are presenting a measurement system intended to monitor ant activity in the field comprising massive data acquisition and high sensitivity. A central role is played by an infrared sensor devised specifically to monitor relevant parameters to the activity of ants through the exits of the nest, although other sensors detecting temperature and luminosity are added to the system. We study the characteristics of the activity sensor and its performance in the field. Finally, we present data measured at one exit of a nest of *Atta insularis*, an ant endemic to Cuba, to illustrate the potential of our system.

Keywords: Social Insects 87.23.Ge, Complexity 89.75.-k, Instrumentation 87.61.Ff, Sensors 07.07.Df.

1 Introduction

Social insects have become a paradigm to describe a number of properties of complex systems, such as self-organization[1]: in spite of the extremely simple behavior of each individual, an ant colony as a whole exhibits amazing properties ranging from activity oscillations[2] to optimization in foraging trails[3,4]. Moreover, such “swarm intelligence” is being seriously considered by engineers as a model to design “herds of robots”[5].

However, conventional biological techniques—mainly direct visual observation—still dominate the measurement of insect activity in the wild. In the last decades, other approaches such as quantitative image analysis have been applied only in controlled laboratory conditions[6].

In this article, we report the design, construction, and test of a data collecting system, including an infrared sensor to quantify the activity of ant nests at their entries/exits, during prolonged periods of time.

2 System Description

At the core of our data acquisition system is the simple network application platform SNAP^{TM} from Imsys AB (http://www.imsys.se), an open JAVA reference platform based on the Cjip microprocessor for Networked, JAVA-based control, running at 66 Mhz. The SNAP module includes several hardware input-output I/O options. We use the 1-Wire^{TM} net (http://www.maxim-ic.com/AN1796) as a convenient interface to our sensors.

It is intended to collect data in the field in an uninterrupted fashion. It collects a data stream from the sensors, wired across the field, processes it, and later transfers it to a server in campus using a wireless fidelity Wi-Fi network. The small power requirements of the system permit to operate it, for over 30 h, off a 12 V – 7 Ah lead-acid cell. In the experiments we reported here, it is powered from the grid and the battery remained as a backup.

Our in-field system collects, filters, and aggregates a datastream from the ant nest sensors and then uploads it to the server. The output file contains information about local temperature distribution, daylight intensity, and activity at the nests exits, along with a time stamp for every sample taken.

Activity in this case is defined as the number of counts the sensor generates when ants enter or leave the nest during a given time interval. For the experiments made so far, the time resolution was set to 2 samples/min.

Over ten sensor nodes could be easily deployed in the field. Typical required lengths to cover the entries of one nest extended up to a few tens of meters.

3 Activity Sensor

In order to measure the ant activity at nest entries—our fundamental parameter—we have devised an ad hoc infrared sensor. The principle of the activity sensor is very simple yet effective. A light beam is reflected in the inner surface of a cylindrical mirror build from a thin metallic band. The reflective band is open at one point where a tiny IR lightemitting diode LED and phototransistor are stacked back to back and positioned close to the mirror surface. Thus the light beam experiences multiple reflections confined within a radial distance of 1 – 2 mm above the inner surface of the mirror, only interrupted by trespassing ants.

Special care is required during the installation to maximize the fraction of light that reaches the phototransistor. Figures 1 a and 1 b show diagrams that illustrate the functioning of the sensor. The diameters of the mirrors were chosen so that the assembly can fit conveniently, given different sizes of nest entries in the range of 10–25 mm.

Very low power and low noise analog electronics has been used for conditioning the signal and detecting the changes of intensity in the reflected beam arriving at the phototransistor due to the ants interrupting the infrared light ring. In order to isolate the signal level shifts produced by the trespassing ants, from those created by the environment light changes, a filter has been implemented. We exploit the temporal differences of these events and compare a voltage, proportional to the intensity of the reflected beam, to a low pass filtered sample of the same signal. The last one accounts mostly for the dynamic threshold imposed by the infrared component of the daylight biasing the phototransistor. The filter was tuned resulting in a time constant of about 10 s.

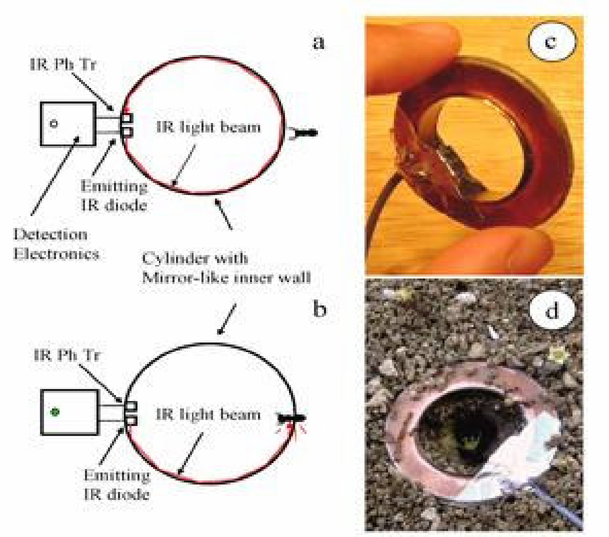

Figure 1. Diagram showing the functioning of the sensor. (a) and (b) illustrate the functioning principle, (c) and (d) show the sensor in the lab and in the field, installed in a nest.

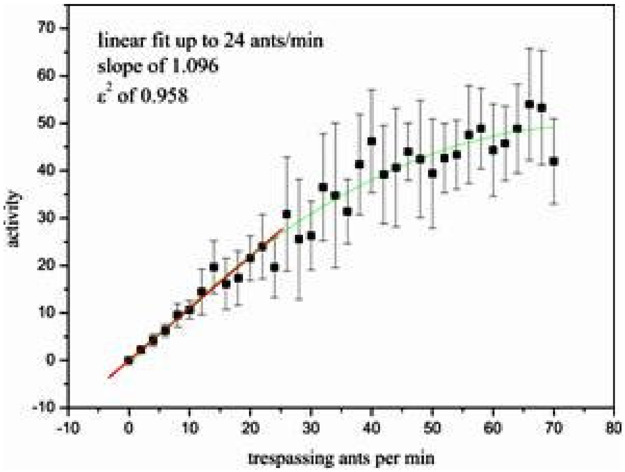

Figure 2. Graph showing the dependece of the activity measured by the sensor and the observed traffic density at the nest entry as it was recorded in the video.

When ants enter the nest, they step through the 4 mm wide metal band and the thin light curtain over this mirror is interrupted, which leads the comparator to trigger the counter. Figures 1 c and 1 d show pictures of the sensor in the laboratory and installed on a nest exit, respectively.

To our surprise, ants consistently show undisturbed by the presence of the setup. However, due to the overlapping of ants trespassing the entry which happens often beyond certain traffic density, one can expect missing ants in the counting and therefore a nonlinear performance of the activity sensor.

In order to characterize this effect, we have calibrated the sensor by videotaping it, carefully quantifying real activity from the resulting images, and then comparing it with theactivity given by the sensor. The video was made with the sensor installed at several nest entries, with different traffic levels, while the system was performing a time-synchronized measurement. Then we watched the video with great care and counted ants entering the nest at regular time intervals, obtaining a variety of traffic density values that span from null when the activity is very poor to over 60 ants/ min (when the activity is well organized and intense, typically very late at night).

Confronting this result with the simultaneous measurement carried out by the system, we analyze the nonlinearity of the sensor and its accuracy and establish the range of traffic densities for which it remains accurate. We have found that the sensor remains linear up to traffic levels of more than 20 ants/ min. Ants' activity was plotted versus the number of trespassing ants as shown in Fig. 2.

It is interesting to notice the larger the traffic, the greater the uncertainty of the measurement. This is indeed related to the increase of the probability that the sensor double counts a "struggling" ant at the entry point, carrying a piece of a leaf, or it might miss several ants entering or exiting simultaneously.

4 Measurements

Atta insularis common name bibijaguas, a leaf cutter endemic to Cuba, has been chosen for the preliminary study we are presenting as a field test of our system. Each individual measures from 3 to 9 mm in length. Experiments for the probe of concept took place at the park "Quinta de los Molinos" in Havana, where there is a sizable population of bibijaguas. A good nest entry with abundant flow was chosen to install the sensor. Figure 3 shows a typical run of the experiment at one exit of a nest. Temperature upper panel and accumulated activity lower panel are presented as a function of time, within a period of nearly two weeks.

The high resolution of the activity graph—which comprises more than 20 000 experimental points—becomes evident in the inset of the lower panel, which contains approximately half an hour of activity.

Although the full activity range present in our measurements exceeds the linear zone of the sensor, the most relevant parts of it remain well below the nonlinear threshold. In normal conditions, the activity of a nest is typically periodic, with a very high, steady activity during night hours and nearly zero activity during daytime. The most interesting intervals are, however, those where this steady activity "builds up" and where it "slows down." These data subsets provide the valuable information on how the nest self-organizes and their global integrity and accuracy are not compromised by any of the above effects.

Some global features of ants activity immediately become apparent. One is the correlation between temperature and activity cycles, with a period of approximately 24 h: as the temperature starts to decrease each day, the activity starts to increase.

A second observation is the net decrease in the use of the door under study as days pass by, due to "long-term" self-organization process probably modulated by availability of food. While the general features of this pattern are well known, our data probes them with an unprecedented level of detail, to our knowledge.

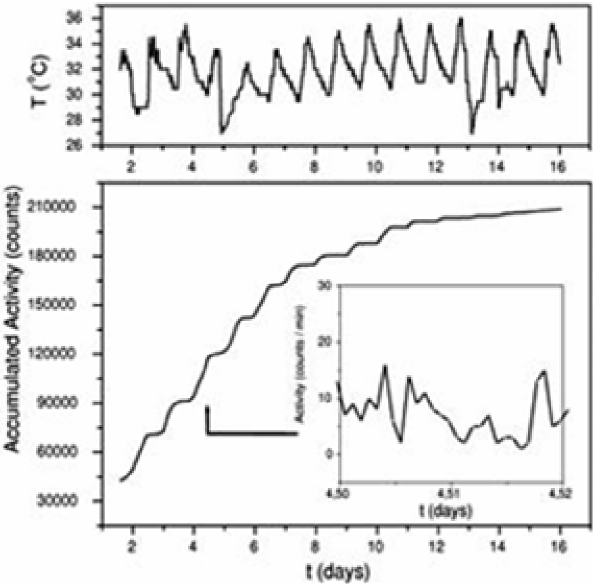

Figure 3. Dateset from a typical run of the experiment. The upper panel shows temperature near the nest exit and the lower panel reports cumulative activity.

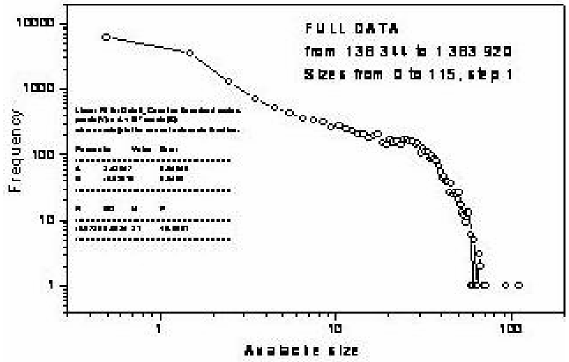

Figure 4. Activity burst size distribution. An avalanche is considered as the number of ants moving within a measurement interval of 1 minute.

It allows, for example, the calculation of the statistical distribution of activity variations, shown in Fig. 4. Notice that, although one decade of linear behaviour in the avalanche size is not enough to consider a power law distribution, some basic arrangements of the avalanche time scale would drastically affect this. For example, choosing a bigger time windows in which one observes an avalanches will lead to an extended range of avalanches sizes. We will study this in more detail as more data becomes available.

5 Conclusions

We have described our system to measure ant activity and shown the infrared activity sensor performance in the field. We are able to collect massive data from ant activity in the nest along with other relevant magnitudes like temperature and daylight intensity.

As a future prospect, we plan to deploy activity sensors at different exits of the same nest and, given the temporal series of activity, calculate correlation functions among them, in order to penetrate further in the details of the self organization mechanisms of the ant society.

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References

1. R. Badii, Complexity: Hierarchical Structures and Scaling in Physics. (Cambridge University Press, Cambridge, 1997) .
2. R. V. Sole, O. Miramontes, and B. C. Goodwin, J. Theor. Biol. 161, 343 (1993).
3. F. R. Adler and D. M. Gordon, Am. Nat. 162, 529 2003.
4. D. E. Jackson, M. Holcombe, and F. L. Ratkiens, Nature London 432, 907 (2004).
5. E. Bonabeau, M. Dorigo, and G. Theraulaz, Swarm Intelligence: From Natural to Artificial Systems (Oxford University Press, New York, 1999).
6. N. R. Franks and S. Bryant, in Chemistry and Biology of Social Insects, (edited by J. Eder and H. Rembold Peperny, Munich, p. 122 1990).