Supporting Information

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SI Text

Individual cell size. We estimated the sand pellet volume and weight by counting the number of ants exiting the nest during a two-hour period and weighting the total amount of excavated sand. We measured that 931 sand pellets (n) had a total weight of m=0.1932 g. The sand density has been estimated as d=1.5 g.cm^{-3}. Considering that each cell of the simulation has a square basis and a height that corresponds to that of the experimental setup (h=0.2 cm), we estimate the surface of each cell (A_{cell}) to be 0.07 mm^2 via the following equation:

$$A_{cell} = \frac{V_{cell}}{h}$$

With

$$V_{cell} = \frac{m}{n \times d}$$

Digging dynamics equation. The excavated area (A) is well fitted by the Eq. **1**:

$$A = \frac{A_M t^\alpha}{\beta^\alpha + t^\alpha}$$

where t is the time elapsed since the start of nest digging, A_M the nest size at the end of digging, α stands for the cooperation level between ants and β is the time at which A=0.5A_M.

The corresponding digging rate is:

$$\frac{dA}{dt} = \frac{A_M \alpha t^{\alpha-1} \beta^\alpha}{(\beta^\alpha + t^\alpha)^2} \qquad \textbf{[S1]}$$

Taking the inverse of Eq. **1**:

$$t = \frac{A^{1/\alpha}\beta}{(A_M - A)^{1/\alpha}} \qquad \textbf{[S2]}$$

and substituting t in Eq. **1** gives an equation in which the digging rate depends only on the excavated area:

$$\frac{dA}{dt} = \frac{\alpha}{\beta} A_M^{1/\alpha} A^{1-1/\alpha} (1 - \frac{A}{A_M})^{1+1/\alpha} \qquad \textbf{[S3]}$$

with $\theta = \frac{\alpha}{\beta} A_M^{1/\alpha}$

β is related to the number of workers and decreases with the group size. Eq. **S3** shows that the digging rate depends on two antagonistic effects: a positive feedback loop ($A^{1-1/a}$) and a negative feedback loop incorporating the limit to growth (1-A/A_M).

If Eq. **1** allows a proper fitting of the phenomenon, then it provides weak insights into the underlying mechanisms that give rise to the change of digging rate with time.
The Eq. **4** that is used for the simulations is a simple form, with two assumptions that can be related to the basic mechanisms. We make the hypothesis that the positive feedback loop is related to the length of the digging front. However, crowding over the digging front (difficulties to dig side by side or to access small anfractuosities), and all over the nest surface (ant traffic among aggregated workers, time of pellets' transportation), are important. The crowding zone is, therefore, much smaller than the real digging front length, and is approximated by the perimeter P of a circle of surface A as $P \approx A^{0.5}$ (Fig. S1). Secondly, we assume that the negative feedback loop is proportional to the difference between the excavated area and A_M(1,2). The area excavated per time step is therefore:

$$\frac{dA}{dt} = \theta A^{0.5}(1 - \frac{A}{A_M}) \qquad \textbf{[S4]}$$

$$A = A_M (\frac{1 - De^{\theta t}}{1 + De^{\theta t}})^2$$

$$D = \frac{A_M^{0.5} + A_0^{0.5}}{A_M^{0.5} - A_0^{0.5}}$$

Eq. **S4** being another notation of Eq. **4**.

Eq. **4** fits well the experimental curve (Fig. S2) and is close to Eq. **1**, despite the fact that they are different from a mathematical point of view.

Random choice of a cell. Each cell i of the N_{reach} cells has an individual probability to be dug $p_{dig\,i}$ computed using Eqs. **7** and **8**. Cumulative probabilities are calculated as

$$p_{cum\,j} = \sum_{i=0}^{j-1} p_{dig\,i} \quad \text{with } j \in [2; N_{reach}] \text{ and } p_{cum\,0} = 0$$

A random number $0 \le rand < 1$ is generated, and the chosen cell j is the one for which $p_{cum\,j} \le rand < p_{cum\,j+1}$. This cell is filled with pheromones and removed from the reachable cells list.

1. Rasse P, Deneubourg JL (2001) Dynamics of Nest Excavation and Nest Size Regulation of *Lasius niger* (Hymenoptera: Formicidae). *J Insect Behav* **14**:433–449.
2. Buhl J, Deneubourg JL, Grimal A, Theraulaz G (2005) Self-organized digging activity in ant colonies. *Behav Ecol Sociobiol* 58:9–17

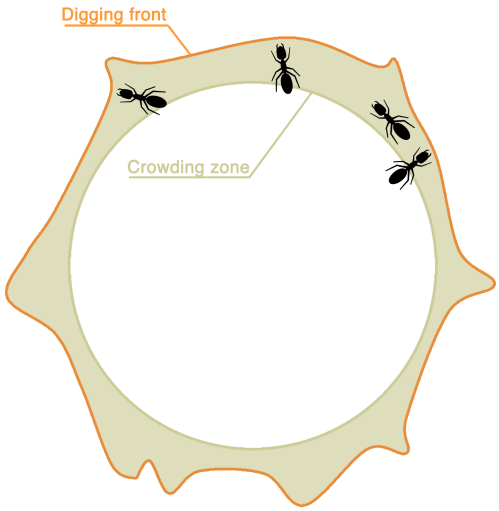


Fig. S1. Crowding zone during the nest excavation

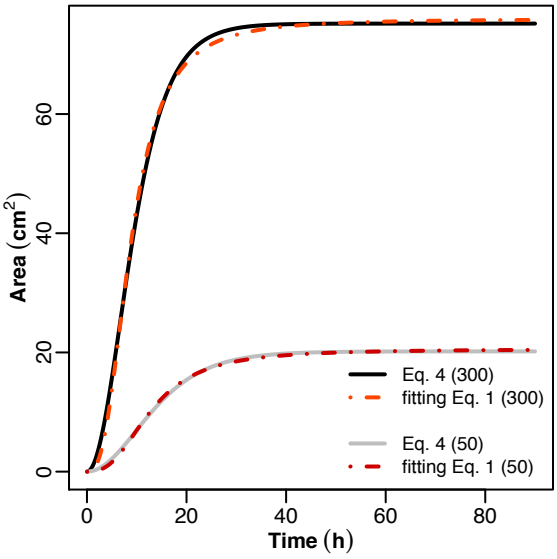


Fig. S2. The Eq. **4** used in the simulations to generate the digging dynamics and its fitting by Eq. **1** (estimated parameters value of fitted curve – 300 ants: α=2.70, β=8.76 h, A_M=75.93 cm^2, r^2=0.99; 50 ants: α=2.61, β=12.93 h, A_M=20.55 cm^2, r^2=0.99).

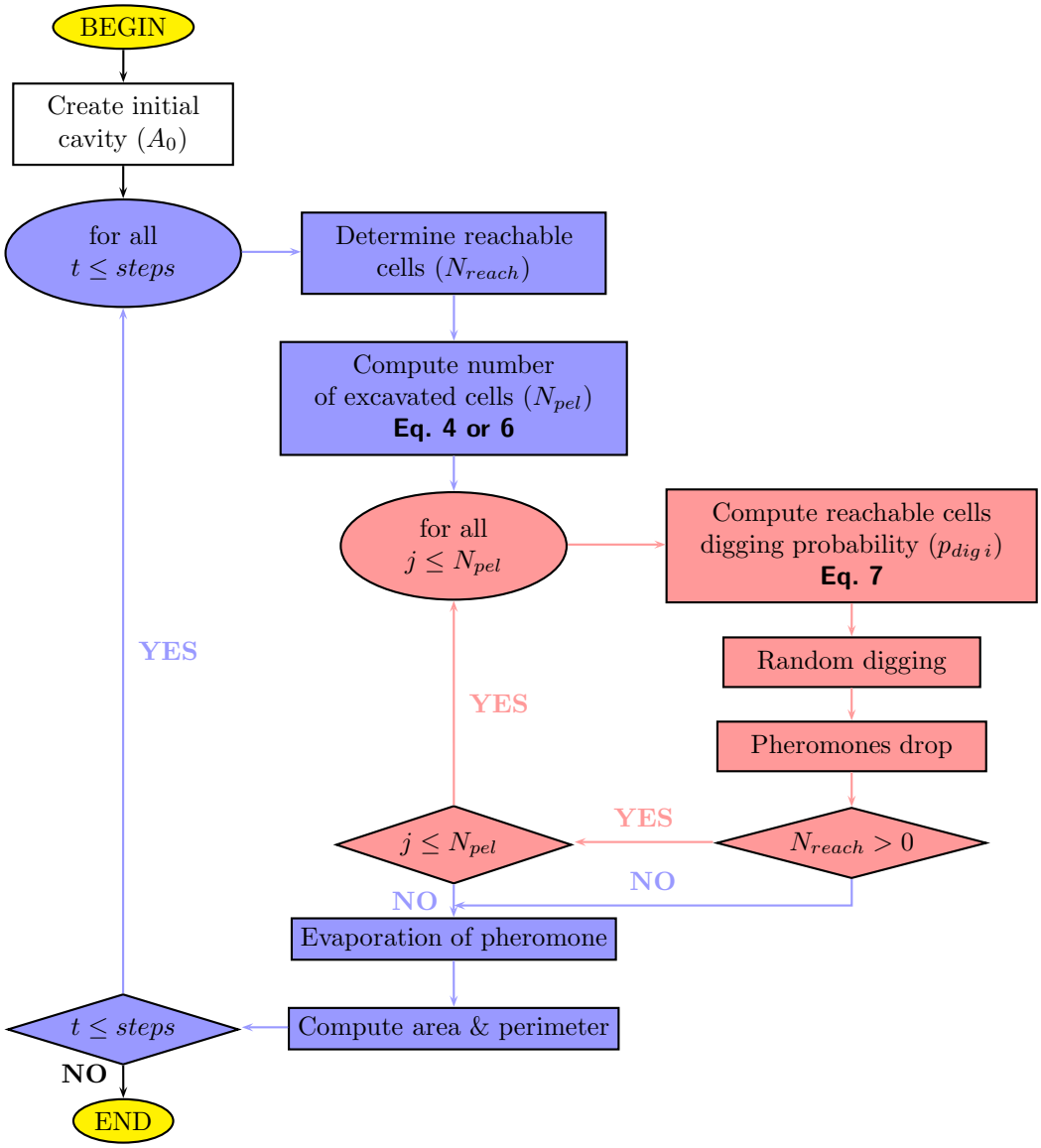
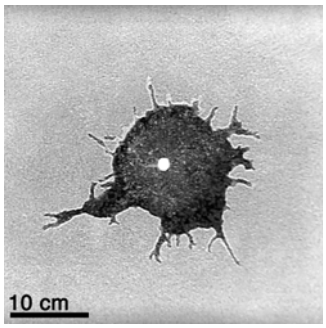
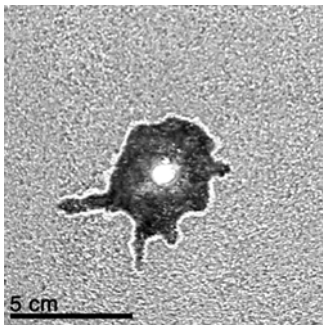


Fig. S3. Flowchart of the digging model.



Movie S1. 2D-horizontal digging by a group of 300 ants. The white disc corresponds to the tunnel by which ants access the digging area. The video covers the 90 hours of the experiment and is taken from the bottom of the digging area.



Movie S2. 2D-horizontal digging by a group of 50 ants. The white disc corresponds to the tunnel by which ants access the digging area. The video covers the 90 hours of the experiment and is taken from the bottom of the digging area.