Variations on Error Strategy of Foraging Ants

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Purpose of this study

To investigate

the Strategy of Errors

in the group forging of ants
Animal behaviour is probabilistic. This is exemplified by the communication behaviour of ants during food-searching. Experimental evidence
Experiments to quantify the following ability of pheromone path by 2 species of Tetramorium (シワアリ)

--- Motivation 1 ---

Table 1

Comparison between recruitment accuracy in two ant species

<table>
<thead>
<tr>
<th></th>
<th>Tetramorium impurum</th>
<th>Tapinoma erraticum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (% of single recruitment trails actually followed by recruit)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>17 (40)</td>
<td>67.7 (47)</td>
</tr>
<tr>
<td>Percentage of recruits reaching the food source</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alone</td>
<td>8.9 (45)</td>
<td>73.6 (216)</td>
</tr>
<tr>
<td>In group</td>
<td>60 (10)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>18.2 (55)</td>
<td>73.6 (216)</td>
</tr>
</tbody>
</table>


“Probabilistic behavior of ants: a strategy of error?”
§3. Computational mode
--- multi-agent model
Setup of Simulation Field

Food $f(t)$

Hexagonal lattice field

Food $f(t)$

Nest

$\theta$, $R$ : Environmental Parameters
Choice of moving direction in each step by Chemo-taxis

- Choose one cell among three frontal cells

\[
P(i) \propto (\rho_i + z)^n \quad (n = 10)
\]

- \(\rho_i\): pheromone density in \(i\)-th cell
- \(\alpha_k\): accuracy of \(k\)-th ant

(normalization \(P(1)+P(2)+P(3)=1\))
1. Exploring mode
   explore food
   following recruit pheromone
2. Homing mode

- Move according to Chemical cues and/or Visual cues
- Put recruit pheromone
- On reaching nest, go back to the exploring mode
Time evolution of Pheromone field

evaporation

diffusion

pheromone

secretion
Parameters characterizing the error strategy of each colony:

\{ \text{Number of normal ants } n \text{ (in totally 500 ants)} \hspace{1cm} & \hspace{1cm} \text{Accuracy of dull ants } \alpha \text{ ( } < \alpha_{\text{normal}} = 50 \text{ )} \}

Normal Ants
\(\alpha = \alpha_{\text{normal}} = 50\)

Dull Ants
\(\alpha < \alpha_{\text{normal}} = 50 \times 10^{-1}, 50 \times 10^{-2}, 50 \times 10^{-3}, 50 \times 10^{-4}, \cdots, 50 \times 10^{-7}\)

number ratio \(n : 500 - n\)
What we simulated

Food $f(t)$

Hexagonal lattice field

θ

R

Nest

Food $f(t)$

Environmental Parameters

θ, R
What we measure

$\rightarrow$ Foraging Efficiency $\quad E(n, \alpha)$

$E$: Total amount of food which a colony of 500 ants carry to the nest per unit time

$E(n, \alpha)$: Foraging Efficiency as the function of Num. of normal ants & Accuracy of dull ants
E: Foraging Efficiency in $n--\alpha$ space

(Total Num. of ants 500)

- **E($n, \alpha$)**
- **All extremely dull ants**
- **Uniform Colony of all intermediately dull ants**
- **Mixture of Two Extremes: Extremely dull & normal ants**

Numerical values:
- $n = 500$
- $50 \times 10^{-7}$
- $50 \times 1$

Axes:
- **$n$**: Num. of normal ants
- **$\alpha$**: Accuracy of dull ants

Legend:
- **mini**
- **max**
Mixture of Two Extremes: Extremely dull & normal ants

Uniform Colony of all intermediately dull ants

$E(n, \alpha)$

$10^{-7}$

$\theta$

$R=50$

Food

Food

nest

Num. of normal ants $n$

Accuracy of dull ants $\alpha$

$0$

$1$

$500$
Result 1  $E(n, \alpha)$:

(tot al number of ants 500)
Optimal colony:

Binary-Mixture of two types of extreme ants

Normal ants & Extremely-dull ants
Result 2 $E(n, \alpha)$:

(total number of ants 500)

Max $E$

Num. of normal ants

$\theta = 10^\circ$

$R = 50$

$E(n, \alpha)$: 

$\frac{1}{10^7}$

Accuracy of dull ants $\alpha$
Optimal colony:

Uniform colony of

All Weakly (Intermediately) Dull Ants
\[ \theta = 80^\circ \]

R = 50 : fixed

\[ \theta = 50^\circ \]

\[ \theta = 30^\circ \]

\[ \theta = 20^\circ \]

\[ \theta = 10^\circ \]

Food

nest
Shift of Optimal Colony According to the change of $\theta$

$E(n, \alpha)$

$\theta = 10^\circ, \ldots, 90^\circ$

$R = 50$ fixed

$n = 10^{-7}$

$\theta = 30^\circ \sim 90^\circ$

$\theta = 10^\circ$

$\theta = 20^\circ$

$\alpha$

Accuracy of dull ants $\alpha$

# of normal ants $n$

500
Summary of simulations

- Including inaccurate (=dull) ants within a colony increase the foraging efficiency of colony

  → Strategy of Errors

- According to the change of foraging environment the optimal binary distribution of inaccurate ants in a colony sharply change between:

  i) a binary mixture of extremely-dull and accurate ants

  ii) the uniform colony of all-weakly dull ants

  → Variations of Strategy of Errors
Remaining Problems

Only numerical results for the model:

- Need proof in the reality (in experiment / field )
- Need some theoretical explanation for the results

Through an more abstract model we extract the essential feature of the above results
= Emergence of the non-uniform of error strategy
§4. Conceptual model
\[ E = (500 - n) (1 - f(\alpha)^\beta(\theta))^{1/\beta(\theta)} \cdot ((500 - n)f(\alpha) + n) \]

\[ f(\alpha) = \frac{\alpha^b}{2^b + \alpha^b} \quad (b=10) \]

\[ \theta = 80^\circ \quad \Leftrightarrow \beta = 0.5 \]

\[ \theta = 10^\circ \quad \Leftrightarrow \beta = 2.0 \]
peak

$f(\alpha)$

Max E

$10^{-7}$

$50 \times 10^{-1}$

Food

nest
5 Conclusion

- Including inefficient (=dull) ants within a colony increase the foraging efficiency of colony.
- According to the change of foraging environment, the optimal binary distribution of inaccurate ants in a colony sharply change between:
  i) a binary mixture of extremely-dull and accurate ants
  ii) the uniform colony of all-weakly dull ants

- A simplified mathematical model indicates that the transition between different strategies of errors is reduced to the change of optimal division of role according to the feeding environment.
§6. Perspectives
Remaining Problems

Only numerical results for the model:

○ Need proof in the reality (in experiment /field)
Experimental study of group strategy of ants (Collaboration with a making company of RFID chips)

RFID chip
Produced by SK-Electronics CO., LTD. (Kyoto, Japan)

- Size 0.4 mm square
- On the RFID chips
- A reading device is set at a gate and is connected to PC
- Then we can automatically record all the data of ants passing through the gate

Camponotus japonicus
Setup

Example of obtained data

- Activity = Number of passages per hour at the gate

- Time (every one hour)

- Corridor (transparent tube)

- Nest

- Sensor

- PC

- Food
Data extraction and analysis using RFID tips is started very recently and still little data has been obtained.

If you are interested in it,

Please come to Poster session
And visit poster  P29

‘Activity statistics of foraging ants’
Osamu Yamanaka, et al