Symmetry breaking in escaping ants and other experiments in self organization

E. Altshuler
In collaboration with
J. Fernández
Y. Núñez
O. Ramos
C. Noda

“Henri Poincaré”
Group of Complex Systems
University of Havana
Self-propelled particles: Modeling emergent features of “escape panic”

The model

\[ m_i \frac{d \vec{v}_i}{dt} = m_i \frac{v_i^0(t) \vec{e}_i^0(t) - \vec{v}_i(t)}{\tau_i} + \sum_{j \neq i} \vec{f}_{ij} + \sum_w \vec{f}_{iw} \]

Individual movement
(includes the desire to “follow the crowd”)

Person-person interaction
(may include repulsion, tangential interaction, etc.)

Wall-person interaction
(may include repulsion, tangential friction, etc.)
"People" escaping under panic: Emergence of symmetry breaking as a theoretical prediction

"Henri Poincaré"
Group of Complex Systems
University of Havana
Our proposal: using ants as model pedestrians

Atta insularis: BIBIJAGUA

“Henri Poincaré”
Group of Complex Systems
University of Havana
Ants escape under panic: a simple experimental setup

Video camera

Covering glass

Hole (in covering glass)

Acrylic cell

Filter paper

1 cm

0.5 cm

4 cm

“Henri Poincaré”
Group of Complex Systems
University of Havana
Ants in moderate panic:

Statistics for several experiments:

12 ± 3 % difference
Ants in panic: how to produce panic?
Ants in panic:
Using a repellent fluid

Statistics for several experiments:
51 ± 7 % difference
Ants in moderate panic:
A simulation inspired in Helbin et al.’s

Cell shape: circular

Initial conditions:
1) Ants size distribution: Gaussian
2) Ants positions into the cell: random
3) Ants initial velocities: Gaussian distribution of speeds, random directions

Rules:
1) Ant-wall interaction: simple reflection
2) Ant-ant interaction: just delays the will to follow a given direction
3) Ant escape: ant within a distance $D < R_e$ from exit
Simulations vs. experiments: moderate panic

Simulation parameters

\( n = 60 \)
\( R_{\text{cell}} = 4 \text{ cm} \)
\( d_{\text{exit}} = 1 \text{ cm} \)
\( v_0 = 0.5 \text{ cm/s}, \sigma_v = 0.25 \text{ cm/s} \)
\( \langle d_{\text{ant}} \rangle = 4.2 \text{ mm}, \sigma_d = 0.7 \text{ mm} \)
\( R_e = 5 \text{ mm} \)

Statistics for several experiments: \( 12 \pm 3 \% \) difference
Statistics on 300 simulations \( 10.4 \pm 0.09 \% \)
NEW Rules:

1) Ant-poison interaction: If direction points to poison area, it changes at random.

2) Ant direction: given by

\[
\overrightarrow{e}_k = \text{Norm} \left[ (1 - p)\overrightarrow{e}_{k-1} + p \langle \overrightarrow{e}^{\text{herdspeed}}_{k-1} \rangle \right]
\]

where \( p \) is a panic parameter, and \( \overrightarrow{e}^{\text{herdspeed}}_{k-1} \) has been calculated within \( R_{\text{herd}} \)

\[ a \text{ Vicsek et al. PRL 75: 1226 (1995)} \]
Simulations & experiments: ants in panic

Simulation parameters

\[
\begin{align*}
    n &= 60 \\
    R_{cell} &= 4 \text{ cm} \\
    d_{exit} &= 1 \text{ cm} \\
    v_0 &= 1 \text{ cm/s}, \sigma_v = 0.5 \text{ cm/s} \\
    \left\langle d_{ant} \right\rangle &= 4.2 \text{ mm}, \sigma_d = 0.7 \text{ mm} \\
    R_e &= 5 \text{ mm} \\
    R_{herd} &= 3.75 \text{ mm} \\
    p &= 0.8
\end{align*}
\]

Statistics for several experiments: 51 ± 7 % difference
Statistics on 300 simulations: 50 ± 4 %
Modifying the herding rule:

Ant direction: given by

\[ \vec{e}_k = \text{Norm} \left[ (1 - p) \vec{e}_{k-1} + p \vec{e}_{\text{herdCM}}^{k-1} \right] \]

where \( p \) is a panic parameter, and \( \vec{e}_{\text{herdCM}}^{k-1} \) has been calculated within \( R_{\text{herd}} \)

RESULTS

Statistics for several experiments: 51 \pm 7 \% difference
Statistics on 300 simulations, same parameters as Helbing’s inspired model: 49.5 \pm 3 \%

"Henri Poincaré"
Group of Complex Systems
University of Havana
Authors in panic:
The effect of Biological Reviewers

"Henri Poincaré"
Group of Complex Systems
University of Havana
We have demonstrated in a real experiment the possibility of the emergence of symmetry breaking when ants escape from a room under panic.

The phenomenon can be modelled in a simple fashion, if appropriate “herd-following rules” are applied.

If Helbing et al.’s model really applies to humans, we are forced to conclude that, at least partially, people can behave like ants in a situation of escape induced by panic!
Symmetry breaking in escaping ants and other experiments in self organization

"Henri Poincaré"
Group of Complex Systems
University of Havana

Under construction
One experimental idea

“Henri Poincaré”
Group of Complex Systems
University of Havana

Bigger than you think!

Activity A

time

Bigger than you think!
Around limits of the daily cycle: How the colony “wakes up” and “goes to bed”?

CA simulations
Dynamics during “work hours”

**Pheromone trails:**
http://www.melotti.com/EngHome/Computing/AntsSim/AntBoxSimulator.pdf

**Panic simulations**

**Contamination Dynamical Networks**
Sospedra, Noda & Altshuler...somewhere...sometime
Contamination dynamical network

“Henri Poincaré”
Group of Complex Systems
University of Havana

Door detection radius
Contamination radius
Contamination dynamical network

Door detection radius
Contamination radius

Step k

Step k+1
Further experimental ideas

Activity A

“Henri Poincaré”
Group of Complex Systems
University of Havana
Further experimental ideas

Bigger than you think!
Measuring correlations

\[ C_{ab}(t') = k \frac{\langle A_a(t)A_b(t+t') \rangle - \langle A_a(t) \rangle \langle A_b(t) \rangle}{\sqrt{\sum [A_a(t) - \langle A_a(t) \rangle]^2} \sum [A_a(t) - \langle A_b(t) \rangle]^2} \]

Further experimental ideas
But how such biologist’s dream would come true?

Let me tell ya’ about distributed sensors