

Agent-based and macroscopic modeling of the complex socio-economic systems

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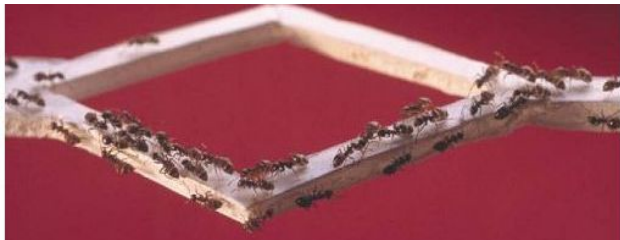
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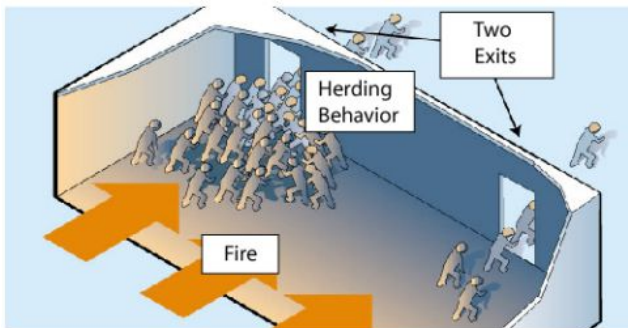
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Herding behavior in social communities

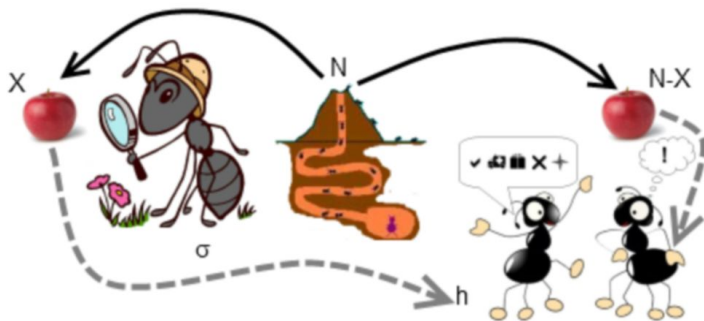
COLONY



FOOD



Kirman's agent-based herding model



Each ant (=agent) at each time step

can switch the food source (=state) probabilistically:

$$\mu_2 = \sigma_1 + hX, \quad \mu_1 = \sigma_2 + h(N - X).$$

One-step, birth-death, process formalism

Let us assume that

the time step, Δt , is small enough for only one switch to be probable:

$$P(X \rightarrow X - 1) = X\mu_1\Delta t, \quad P(X \rightarrow X + 1) = (N - X)\mu_2\Delta t.$$

In this simple case we can derive

a macroscopic, stochastic, model. General form is given by:

$$dx = [(1 - x)\mu_2 - x\mu_1] dt + \sqrt{\frac{(1 - x)\mu_2 + x\mu_1}{N}} dW.$$

While for the Kirman's model the exact form is given by:

$$dx = [(1 - x)\sigma_1 - x\sigma_2] dt + \sqrt{2hx(1 - x)} dW.$$

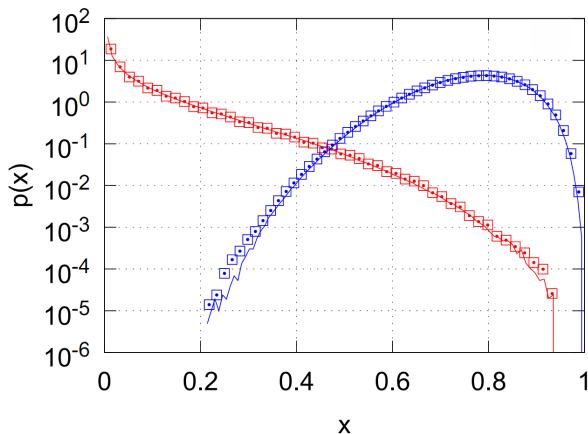


Figure: The probability density functions obtained from the macroscopic (curves) and the agent-based models (boxes) in two distinct cases. Model parameters: $\sigma_1 = 0.2$ and $\sigma_2 = 5$ (red), $\sigma_1 = 16$ and $\sigma_2 = 5$ (blue), $h = 1$ and $N = 1000$ (in all cases).

The Bass diffusion model

Let us now use the following one-agent switching probabilities:

$$\mu_2 = \sigma + \frac{h}{N}X, \quad \mu_1 = 0, \quad \Rightarrow \quad \frac{dX}{dt} = (N - X) \left(\sigma + \frac{h}{N}X \right).$$

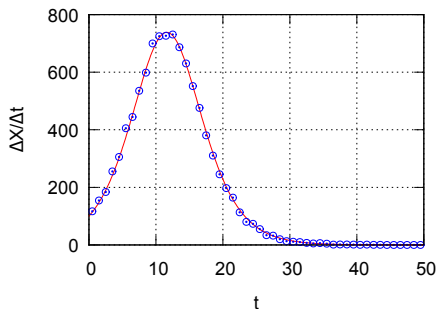


Figure: The agent-based model (circles) vs the Bass diffusion model (curve).

Global vs local interactions

Previously we have used

$$\mu_2 = \sigma_1 + hX, \quad \mu_1 = \sigma_2 + h(N - X), \quad (\text{red})$$

$$\mu_2 = \sigma_1 + \frac{h}{N}X, \quad \mu_1 = \sigma_2 + \frac{h}{N}(N - X). \quad (\text{blue})$$

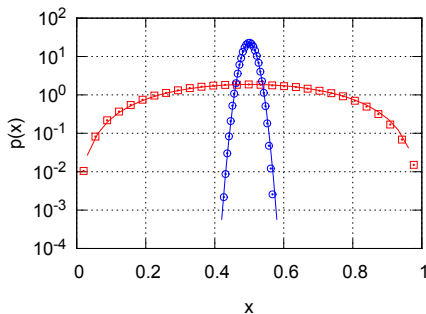


Figure: Implications of the global (red) and local (blue) interactions.

Leadership in social communities

Let us now use the following one-agent switching probabilities:

$$\mu_2 = \sigma_1 + h(M + X), \quad \mu_1 = \sigma_2 + h(N - X).$$

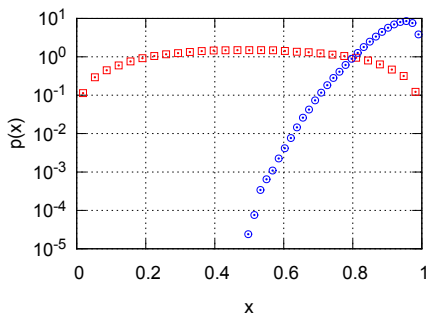


Figure: No leaders, $M = 0$, (red) and small fraction (2%) of leaders, $M = 20$, (blue).

Agent-based herding model and predator-prey model

Predator-prey model is given by

$$\frac{dX_i}{dt} = \left[a_i X_i - X_i \sum_j c_{ij} X_j \right], \quad \forall i.$$

The key differences are:

- the herding behavior is asymmetric in the predator-prey model,
- system size might not be fixed in the predator-prey model.

The comparison leads to:

$$dx = [(n-x)\sigma_1 - x\sigma_2 + cx(n-x) + T_1(x,n)] dt + \sqrt{2hx(n-x)} dW,$$
$$dn = [T_1(x,n) + T_2(x,n)] dt.$$

In the simplest case $T_i(x,n) = T_i = a_i$. In predator-prey case $T_i = a_i x_i$.



We can assume that

agents follow chartist trading strategy,

$$D_c = r_0 N_c(t) \xi(t),$$

or a fundamentalist approach,

$$D_f = N_f(t) [\ln P_f - \ln P(t)].$$

The Walrassian scenario provides us with the absolute return, y ,

$$\frac{1}{P} \frac{dP}{dt} = \beta [D_c + D_f], \quad p = \ln \left(\frac{P}{P_f} \right) = r_0 \frac{x}{1-x} \xi = r_0 y \xi,$$

$$r_\tau(t) = p(t) - p(t - \tau) \approx r_0 y \eta, \quad \eta = \xi(t) - \xi(t - \tau).$$

The macroscopic model for y is given by

$$dy = [\varepsilon_1 + (2 - \varepsilon_2)y^{1+\alpha}] (1 + y)dt_s + \sqrt{2y^{1+\alpha}}(1 + y)dW_s.$$

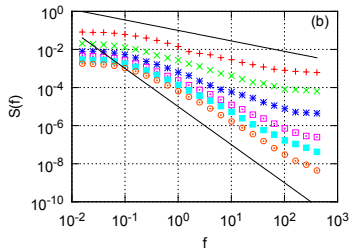
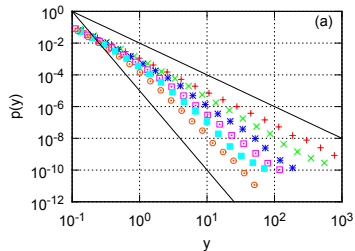


Figure: Wide spectra of obtainable probability (a) and spectral (b) density functions of absolute return, y .

Thank you!



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