On optimal decision-making in brains and social insect colonies

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Presented by

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Overview

- Goals
- Decision making
- Ants and Bees house hunting
- Models
- Discussion

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Goals

- Compare a model of primate decision-making to 3 different models of house hunting by social insect colonies.
- Determine whether such models can implement or approximate the statistically optimal strategy given for primates.
- Make steps towards a common theoretical framework for the study of decision-making in biological systems.

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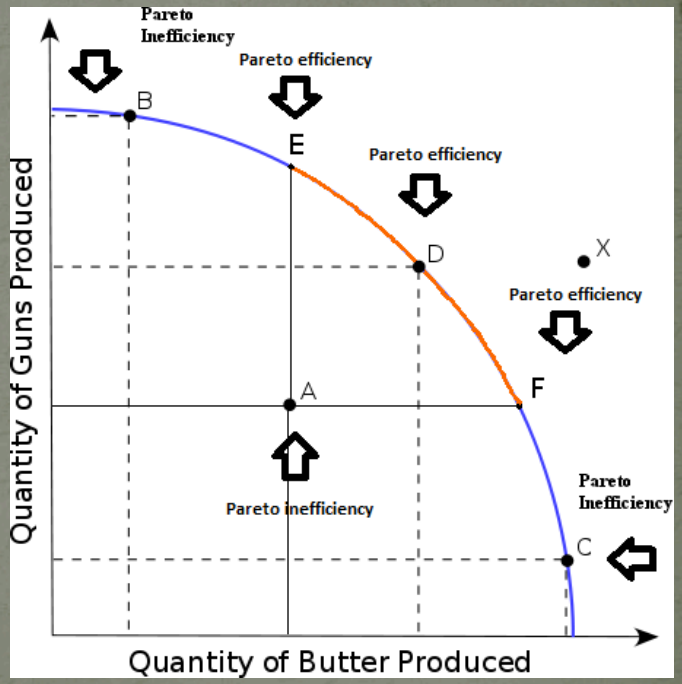
Decision-making

- Decision-making

  A process where uncertain information must be processed to make a choice between two or more alternatives.

- Optimal decision-making



Source: http://upload.wikimedia.org/wikipedia/commons/b/bd/Production_Possibilities_Pareto_Curve.png

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Diffusion Model

- SPRT (sequential probability ratio test)
- Can be represented abstractly as Brownian motion
- 1-d Browning Motion Example
- Drunken walk

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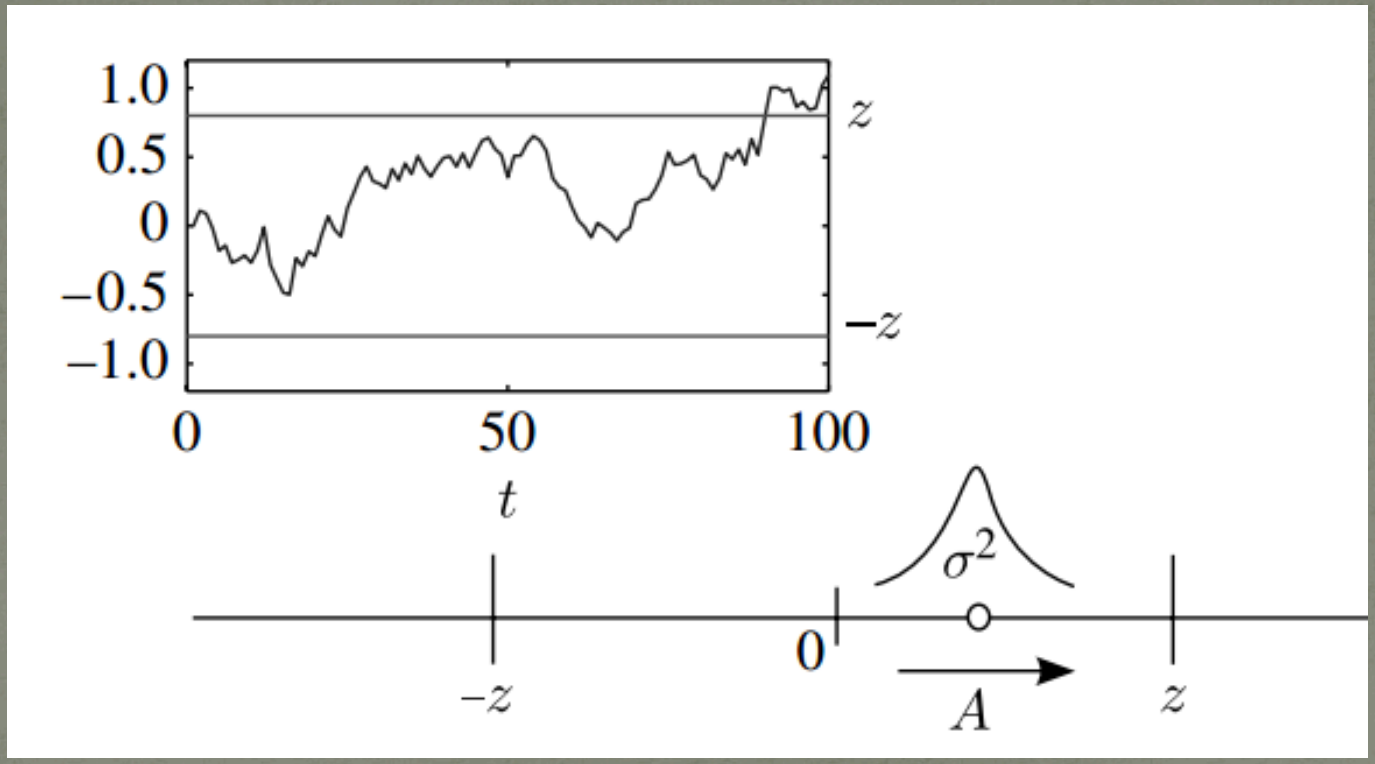
Diffusion Model

Binary Diffusion Model



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Usher-McClelland Model

- Represents decision making using neural populations.
- Leaky.

Source: http://www.brainlesstales.com/images/2010/Mar/forgot-remember.jpg

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Usher-McClelland Model

- Inhibitory.

Source: http://2.bp.blogspot.com/_walYVfGceg4/TEDpw1pQ_tI/AAAAAAAAAIs/1iU84iqIcxg/s1600/Sumo+074.JPG

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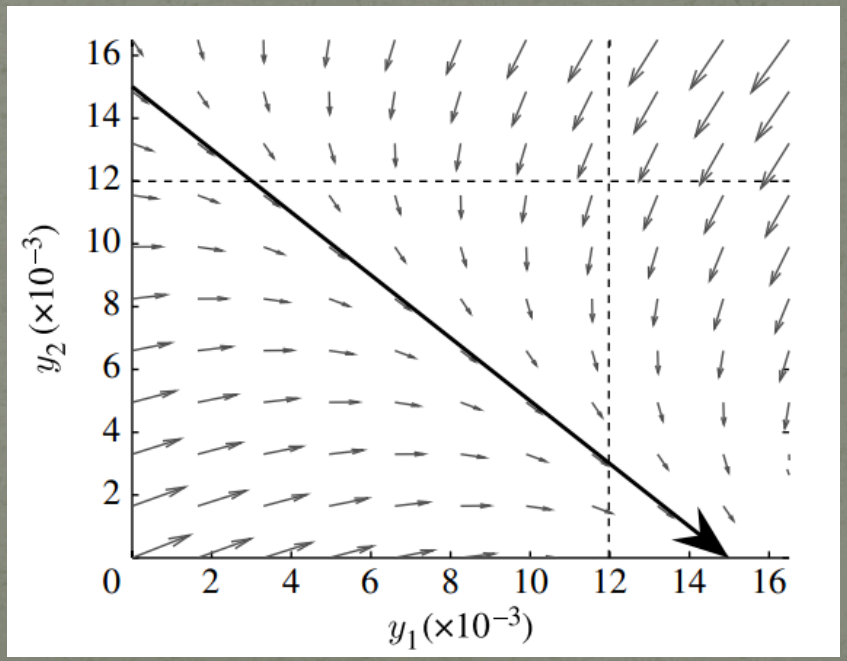
Usher-McClelland Model

- When the leak rate and inhibitory rate are equal this model reduces to the diffusion model and is optimal.



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Temnothorax albipennis

- Colony size ~100
- Live in Rock crevices

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Apis mellifera

- Western honey bee
- <50000 workers
- Nest in tree cavities

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Emigration

- When nest degrades or is destroyed, the colony must emigrate
- Send out scouts
- Quality-dependent requirement
  - Leading to a collective decision

Temnothorax albipennis

- Scouter recruit nest-mates
- Recruiters recruit others after approving of a site
- This leads to positive feedback
- When quorum is reached switch to carrying nest-mates
- Size of quorum affects quality of site

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Apis mellifera

- Scouts recruit using waggle dance
- Positive feedback happens when recruits become recruiters
- When a decision is made by quorum the whole swarm moves.

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Decision Making in House Hunting

- Individuals use only local information
- The best site can be selected even if information of it come late in the decision making process
- In bees the decision making is separated from the execution of the decision.

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Modeling Temnothorax albipennis

- Model only decision making up to quorum not execution
- Ants switch from uncommitted to committed

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Modeling Temnothorax albipennis

- Optimal decision making can only be achieved if individuals have global knowledge about alternatives.

- Therefore optimal parameterization of the model for house hunting is biologically unrealistic.

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Modeling House-Hunting with Indirect Switching in A. Mellifera

$$\begin{cases} \dot{y}_1 = (n-y_1-y_2)(q_1+c\eta_{q1}) - y_1(k_1+c\eta_{k_1}) \\ \qquad +y_1(n-y_1-y_2)(r_1'+c\eta_{r_1'}), \\ \dot{y}_2 = (n-y_1-y_2)(q_2+c\eta_{q2}) - y_2(k_2+c\eta_{k_2}) \\ \qquad +y_2(n-y_1-y_2)(r_2'+c\eta_{r_2'}). \end{cases} \tag{6.3}$$

- ***y***: population of recruiters for the two sites.
- ***q***: rate of spontaneous discovery of alternative sites by uncommitted scouts.
- ***r***: recruitment rate.
- ***k***: rate of scouts to become uncommitted.
- ***cn***: noise that the rates are subject to.

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Indirect Switching in A. Mellifera

- This model cannot be made exactly or approximately equivalent to the diffusion model of decision-making.

- A. Mellifera house-hunting with indirect switching is not a statistically optimal decision-making strategy.

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Modeling House-Hunting with Direct Switching in A. Mellifera

$$\begin{cases} \dot{y}_1 = (n-y_1-y_2)(q_1+c\eta_{q1}) + y_1(n-y_1-y_2) \\ \qquad \times(r_1'+c\eta_{r_1'}) - y_1 k + y_1 y_2(r_1-r_2+c\eta_{r1}-c\eta_{r2}), \\ \dot{y}_2 = (n-y_1-y_2)(q_2+c\eta_{q2}) + y_2(n-y_1-y_2) \\ \qquad \times(r_2'+c\eta_{r_2'}) - y_2 k - y_1 y_2(r_1-r_2+c\eta_{r1}-c\eta_{r2}). \end{cases}$$

- Similarly, this model cannot be reduced to two independent random processes.
- However x_1's behavior can be analyzed in the limit when x_2 converges.

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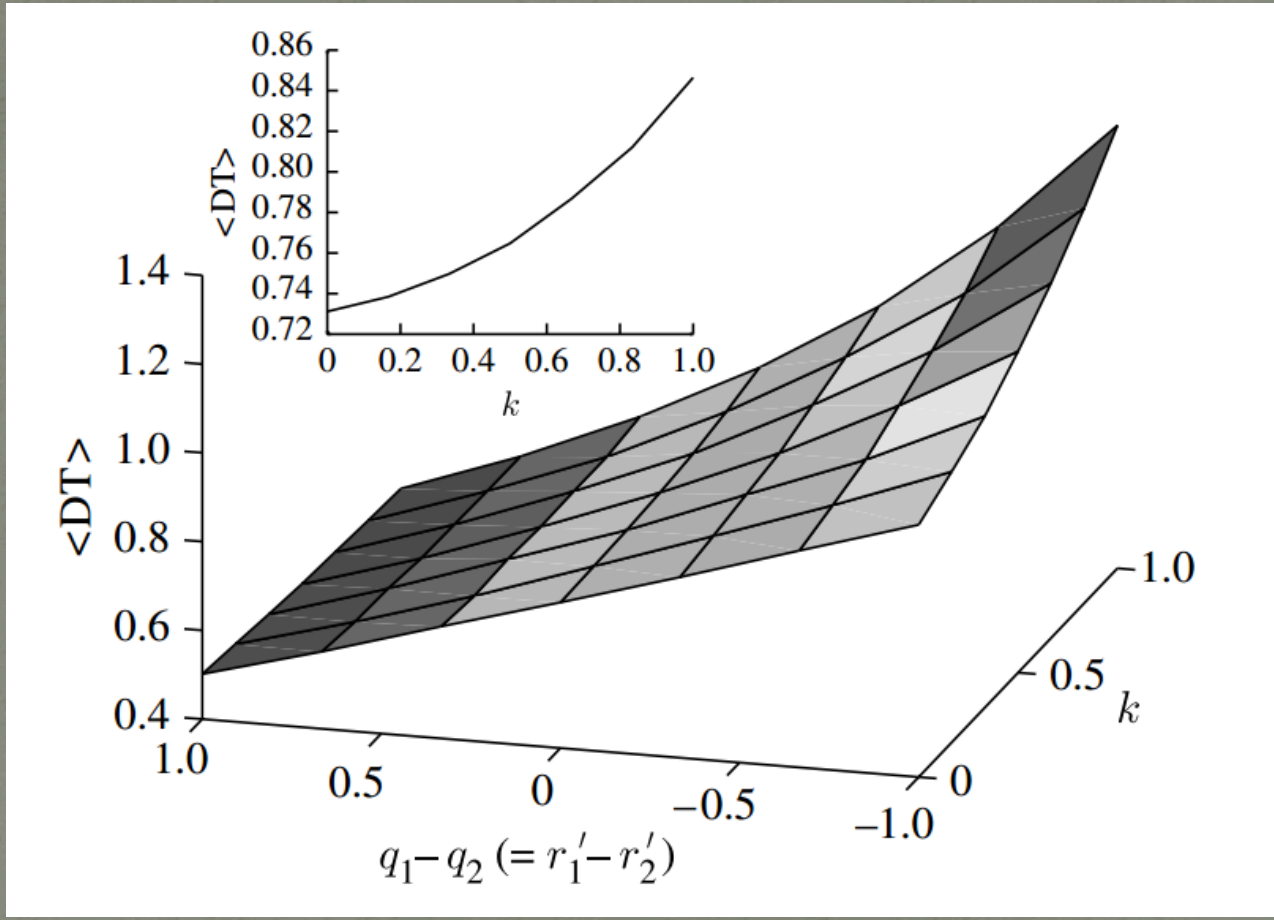
House-Hunting with Direct Switching Numerical Simulation



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Discussion

- Do you think a standard model of decision making for all biological systems is possible?
- Thoughts on the primate study, confidence?