

Adaptation in Unknown Environment: Emergence due to Individual Complexity

ARKADY ZGONNIKOV

UNIVERSITY OF AIZU, JAPAN

“...more mental complexity must be modelled to understand what are the specific mental properties allowing social complexity to be managed and simplified”

Conte, R. et al.: Manifesto of computational social science
The European Physical Journal Special Topics, 2012, **214**, p.338

Non-equilibrium game theory

CANONICAL GAME THEORY

- Focus on Nash equilibrium
- Agents are perfectly rational
- Predicts what is the best way to play the game

LEARNING APPROACH TO GAMES

- Focus on game dynamics
- Agents are boundedly rational
- Predicts how players may play the game in real life

Nash, J. F., PNAS, **36(1)**, 48-49 (1950).

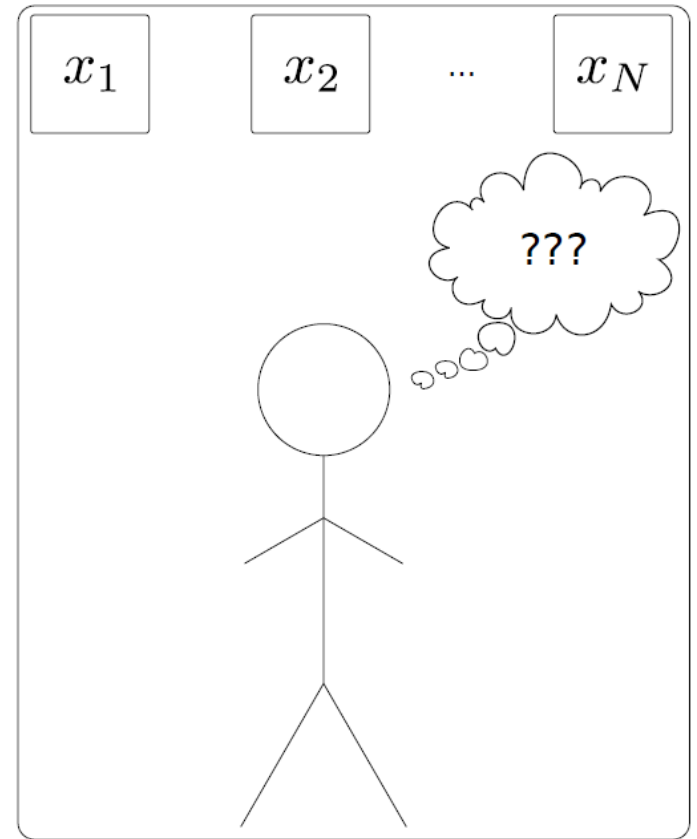
Fudenberg, D., and Levine, D. K. , *The Theory of Learning in Games* (MIT Press, 1998).

Erev, I., and Roth, A. E., Am. Econ. Rev., 848-881 (1998).

Reinforcement learning

- r_i - reward for choosing x_i
- p_i - probability of choosing x_i
- q_i - estimate of “quality” of x_i formed by the agent in the course of adaptation

$$q_i \longrightarrow p_i$$
$$\dot{q}_i = f(r, p, q)$$

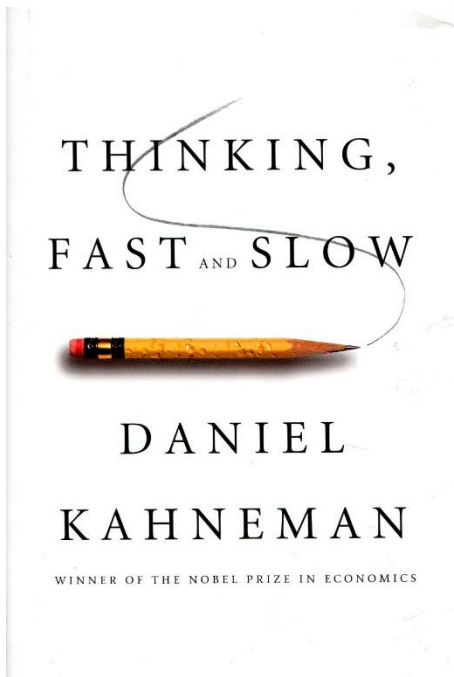


Ultimate goal

A psychologically plausible model that...

1. ...captures more behaviors of an individual
2. ...leads to emergence of more diverse phenomena on macro-level

Dual-system theory of mind



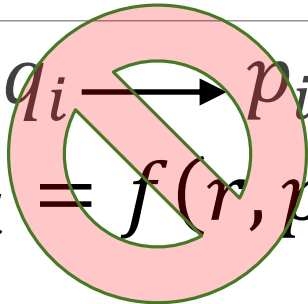
System 1

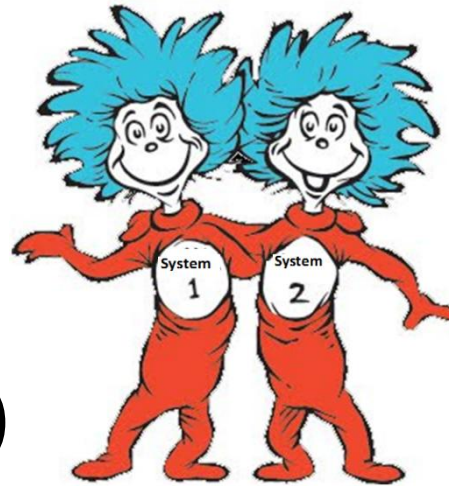
automatic
unintentional
unconscious
emotion-affected
fast
intuitive
effortless
affective

System 2

conscious
analytic
critical
deliberative
slow
intentional
controlled
logical

Dual-system reinforcement learning

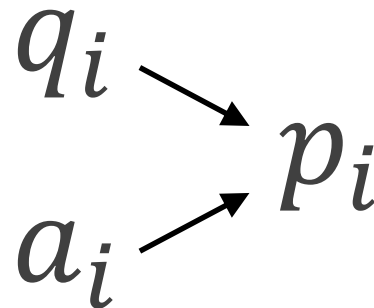
$$q_i \rightarrow p_i$$
$$\dot{q}_i = f(r, p, q)$$




$$\dot{a}_i = g(p, a)$$

$$\dot{q}_i = f(r, p, q)$$

source: <http://www.culturalcognition.net>



Intrinsic motivation

“... is inherent tendency to seek out novelty and challenges <...>, to explore, and to learn.”

Ryan, R.M., and Deci, E.L., Amer. Psych., **214**, p.68 (2000)

Some equations, sorry...

$$\dot{q}_i = r_i p_i^{1-\gamma} - q_i / T_q$$

$$\dot{a}_i = \phi p_i - a_i / T_a$$

$$p_i = \frac{e^{q_i - a_i}}{\sum e^{q_j - a_j}}$$

Canonical model is restored for $\gamma = 1, \phi = 0$

Dual-system model: results

Non-optimal agent behavior is possible

Interplay between System 1 and System 2 may lead to unstable dynamics of adaptation

In some situations relying on feelings (in addition to objective information) may lead to better adaptation

Relying mainly on feelings may lead to completely random choice

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Next steps

How does intrinsic motivation affect the collective adaptation dynamics?

What other effects of System 1 may have an impact on learning?

Thank you!

