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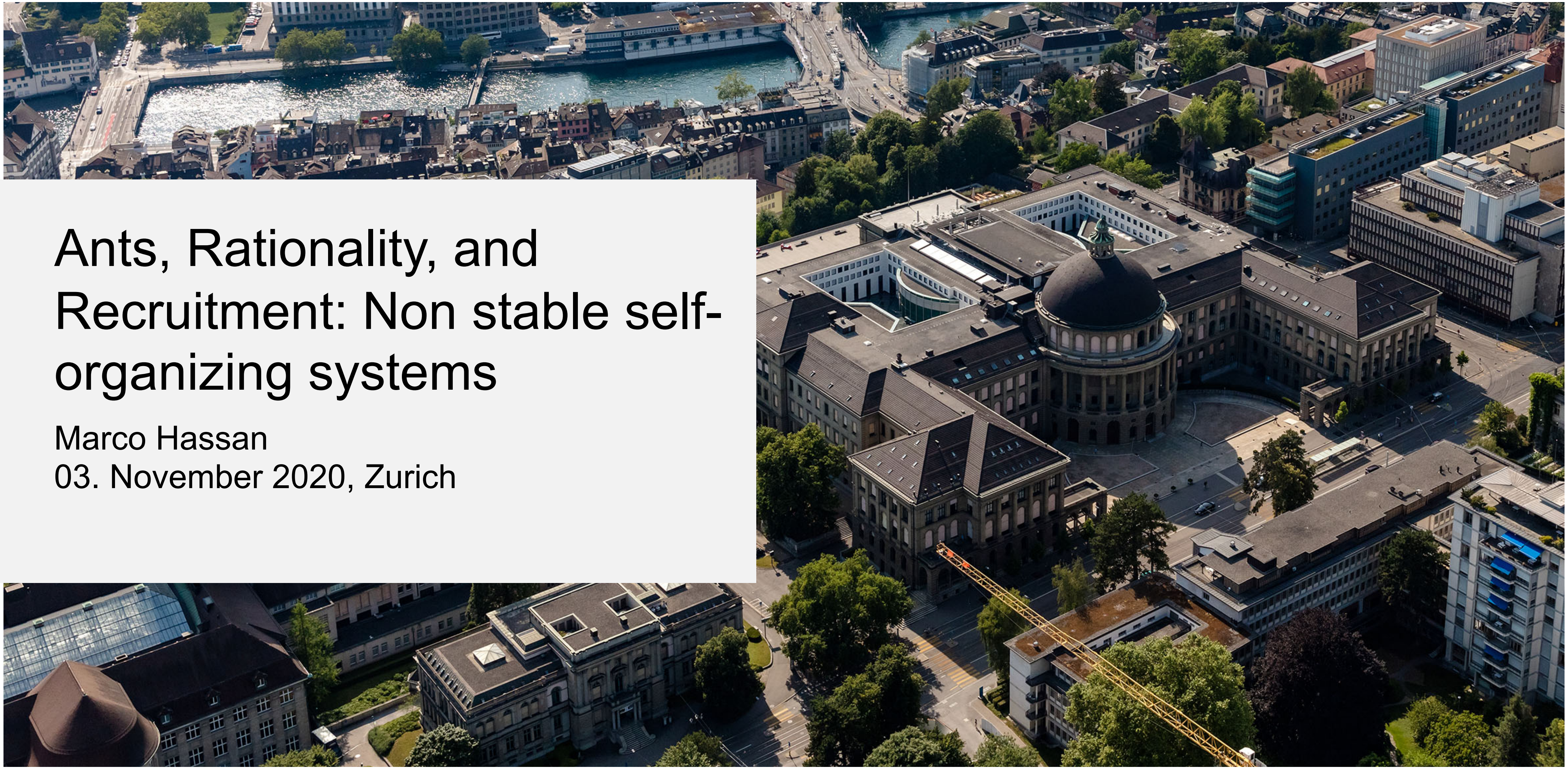

Ants, Rationality, and Recruitment: Non stable self-organizing systems

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Agenda

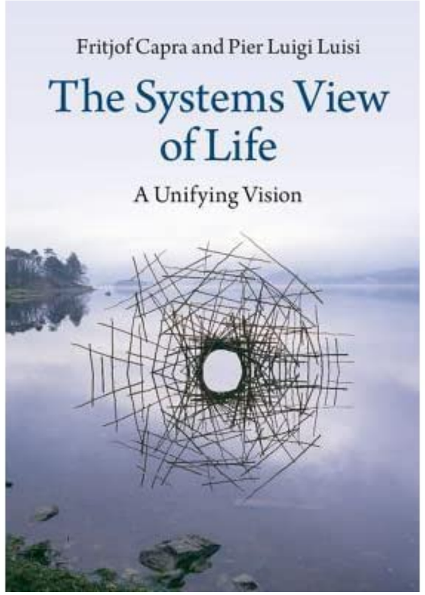
- Background and Motivation
- Research Question/Puzzle
- Methodological Approach
- Key Formulas, Findings & Interpretation
- Key Insights/Lessons Learned
- Summary and Outlook

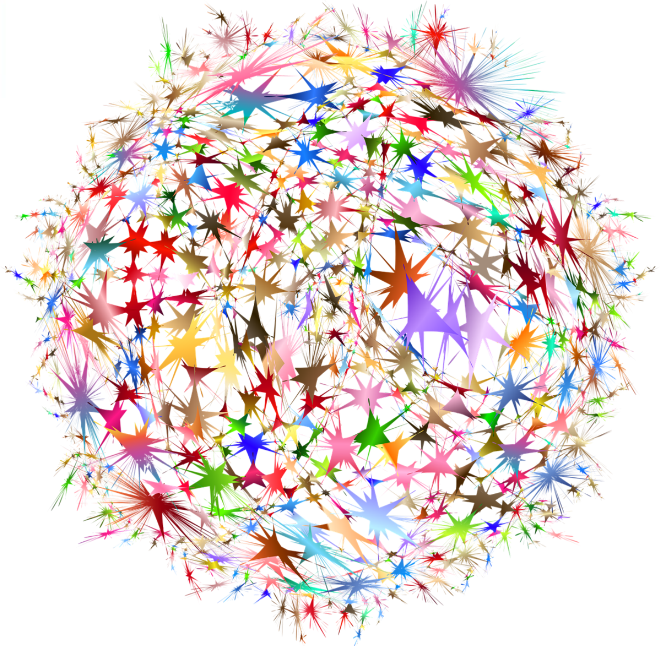
Background and Motivation

- One year since I discovered the book *The Systems View of Life (Capra and Luisi).*

- The authors pledge for stopping to try to model the world with the cartesian methodological approach of decomposing a problem into its smallest components, but rather start to map and ***analyze systems/networks***. New ***patterns*** will emerge that are ***bigger than the sum of the smallest elements***.

- ***Historically*** that was impossible, we had to rely on ***simplified models*** and ***analytical solutions***.

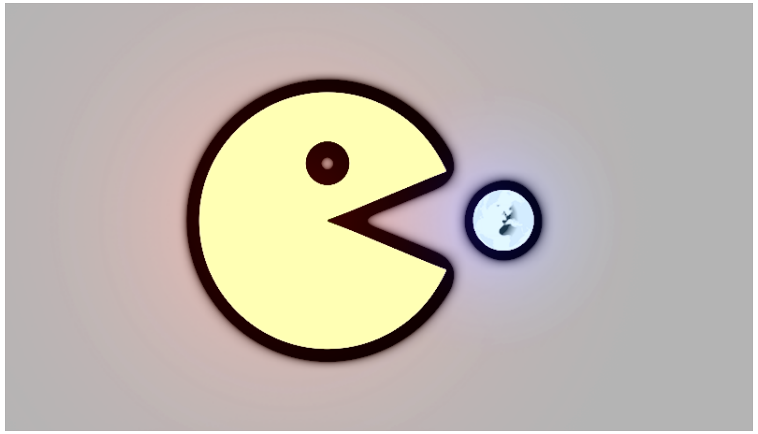


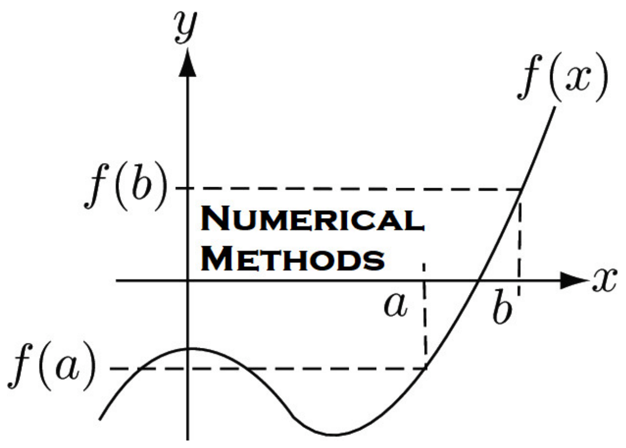


Background and Motivation

- ***Software is eating the world*** - we live in a historical moment where we first have the chance to map and analyze complex systems.

- ***We have to be thoughtful*** when mapping such complex systems – do not always focus on stationary, one shot pics (➔ focus of the paper and presentation)





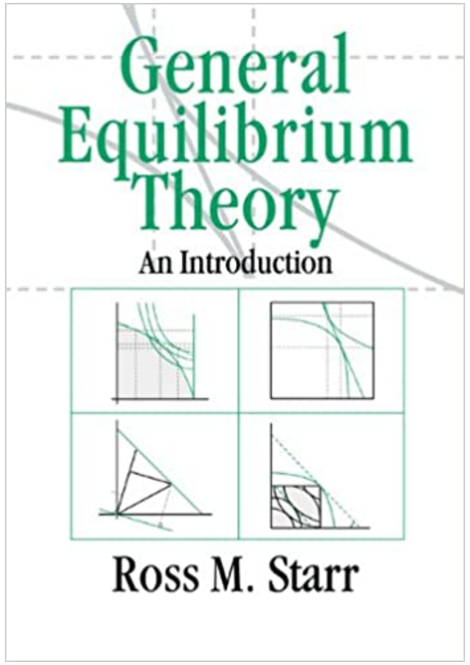
Research Question/Puzzle

The Artifact – Equilibrium Theory

In order to model complex social sciences problems we rely on the notion of equilibria.

*Many models are developed with the specific intention of finding a **steady state** to which an economy or market will finally **converge** or of defining a static equilibrium.*

(Kirman 1993*)*



We often assume equilibria and try to model them

- What if the very notion of general equilibria is flawed?

- What if instead of thinking in terms of abstract markets – or abstract collectivities – striving to reach a steady state we would model dynamical systems and interaction patterns?

- What if even trivial non-coordinated agent behaviour would give rise to complex dynamical patterns?

The Setting

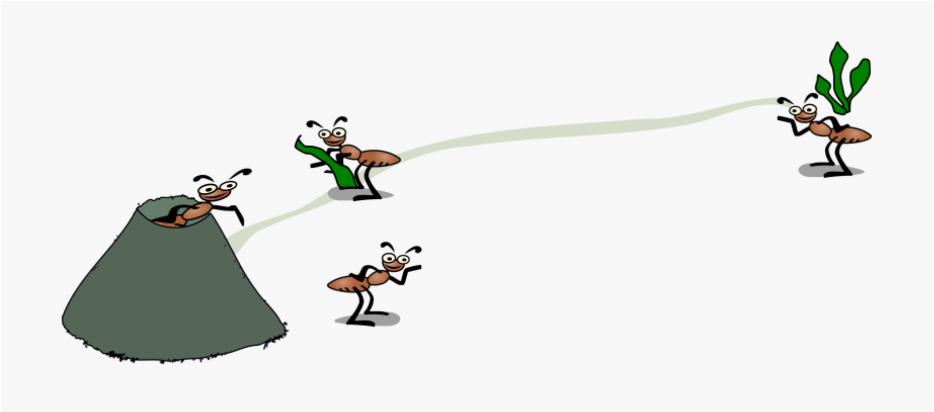
Two trails with identical, constantly replenished, food sources and ants.

The Ants

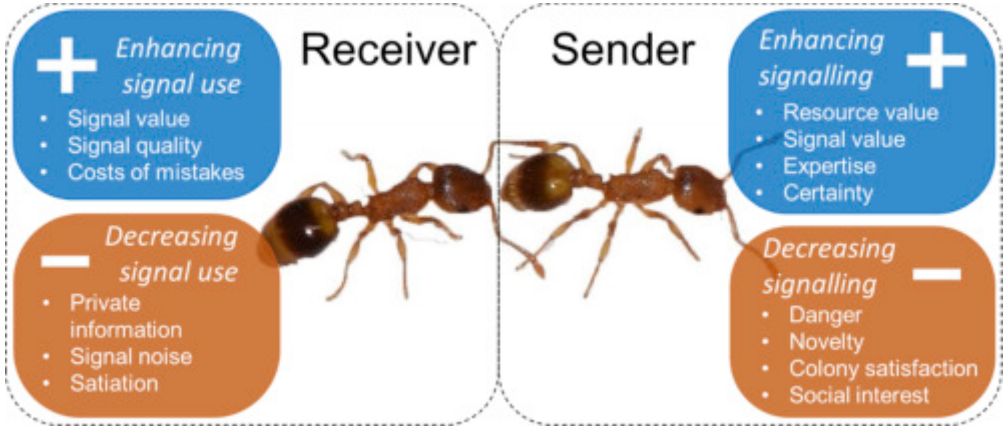
- Different Ants Families with different recruitment models
  - Trail Recruitment
  - Group Recruitment
  - Tandem Recruitment

- All of the families were tested in the experiment

Geocentric – Pherormone Trail



Sociocentric – Social Interaction



Puzzle

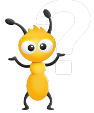
In a series of experiments entomologists [Deneubourg et al., 1987a; Pasteels et al., 1987a] observed that ants in an apparently symmetric situation behaved, collectively, in an asymmetric way.

When faced with two identical food sources, the ants exploited one more intensively than the other.

Furthermore, from time to time they switched their attention to the source that they had previously neglected.

Methodological Approach

Model Parameters and Recruitment

 = *N*

"*black*"  = *k*

<u>Algo 1 – Recruitment</u>

round = 0

while true:

round += 1

if two  *meet:*

$1 - \delta$ *probability of being converted into other group*

elif:

ε *probability of being spontaneously converted into the other group*

Dynamic System Evolution

= prob white * prob black,
i.e. the two must meet

The dynamic evolution of the process is then given by

(1) k

$k + 1$ with probability $p_1 = P(k,k+1)$

$$= \left(1 - \frac{k}{N}\right)\left(\epsilon + (1-\delta)\frac{k}{N-1}\right)$$

Conversion into black

$k - 1$ with probability $p_2 = P(k,k-1)$

$$= \frac{k}{N}\left(\epsilon + (1-\delta)\frac{N-k}{N-1}\right).$$

Conversion into white

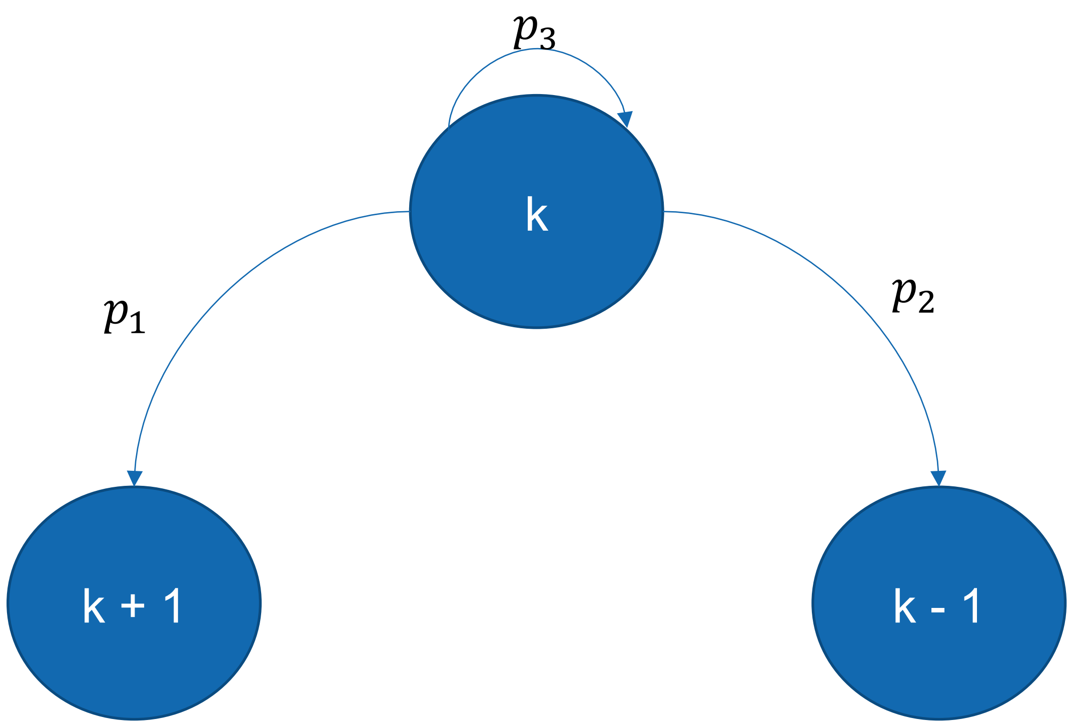
$p_3 = 1 - p_2 - p_3$

Status Quo

Markov Chain Evolution

We are interested in the ***equilibrium probability distribution μ(k)****, k = (0,1, . . . , N) of the Markov chain defined in the previous slide*

It is easy to see that the chain is ***irresistible***, that is – unformally - we can reach any state from any state.

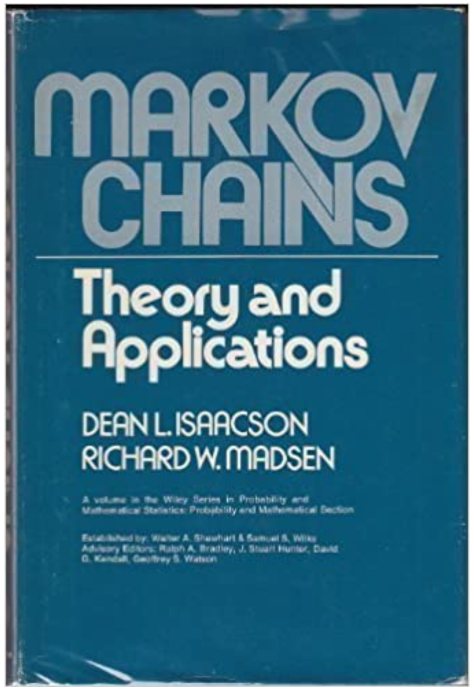


You can then solve the Markov Chain for its steady state

- Given the irresistible property we know that a steady state equilibrium with $\mu * P = \mu$:

  - must be unique

  - LLN applies



- Moreover, noticing that given the transition matrix P the chain of the unique equlibrium is symmetric and thus ***reversible,*** we can solve for the steady state distribution in an efficient way, where it must hold

$$\mu(l) * P(l,k) = \mu(k) * P(k,l)$$

Key Formulas, Findings & Interpretation

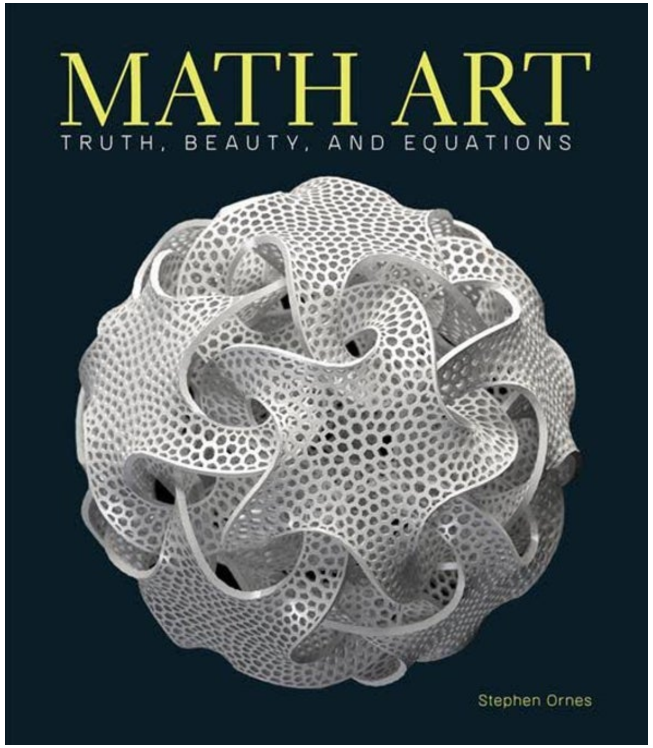
Solution for the steady state Markov Chain Distribution

- Solving for the Markov Chain equilibrium we would then get

$$\mu(k) = \frac{(\mu(1)/\mu(0)) \ldots (\mu(k)/\mu(k-1))}{1 + \Sigma_{l=1}^{N} (\mu(1)/\mu(0)) \ldots (\mu(l)/\mu(l-1))}$$

where, given the reversibility condition, we have that:

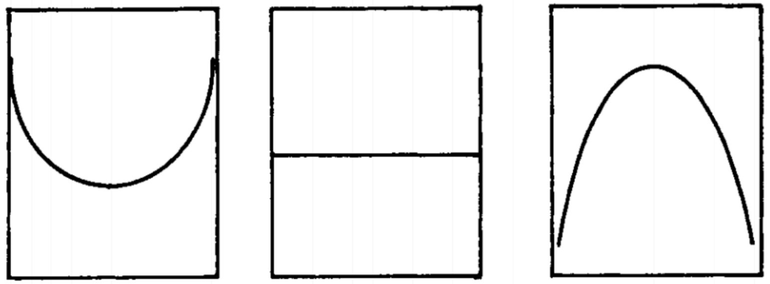
$$\begin{aligned}\frac{\mu(k+1)}{\mu(k)} &= \frac{P(k,k+1)}{P(k+1,k)} \\ &= \frac{(1-(k/N))(\epsilon + (1-\delta)(k/(N-1))}{((k+1)/N)(\epsilon + (1-\delta))(1-(k/(N-1))}\,.\end{aligned}$$



Bottom Line

- The steady state equilibrium depends on the self-conversion parameter ϵ and the conversion factor $1 - \delta$ **relative power (not absolute values!!)**

- They showed that in the limit case, the steady state probability converges to a symmetric beta distribution.



$\varepsilon < \frac{(1 - \delta)}{(N-1)}$ $\varepsilon = \frac{(1 - \delta)}{(N-1)}$ $\varepsilon > \frac{(1 - \delta)}{(N-1)}$

a b c

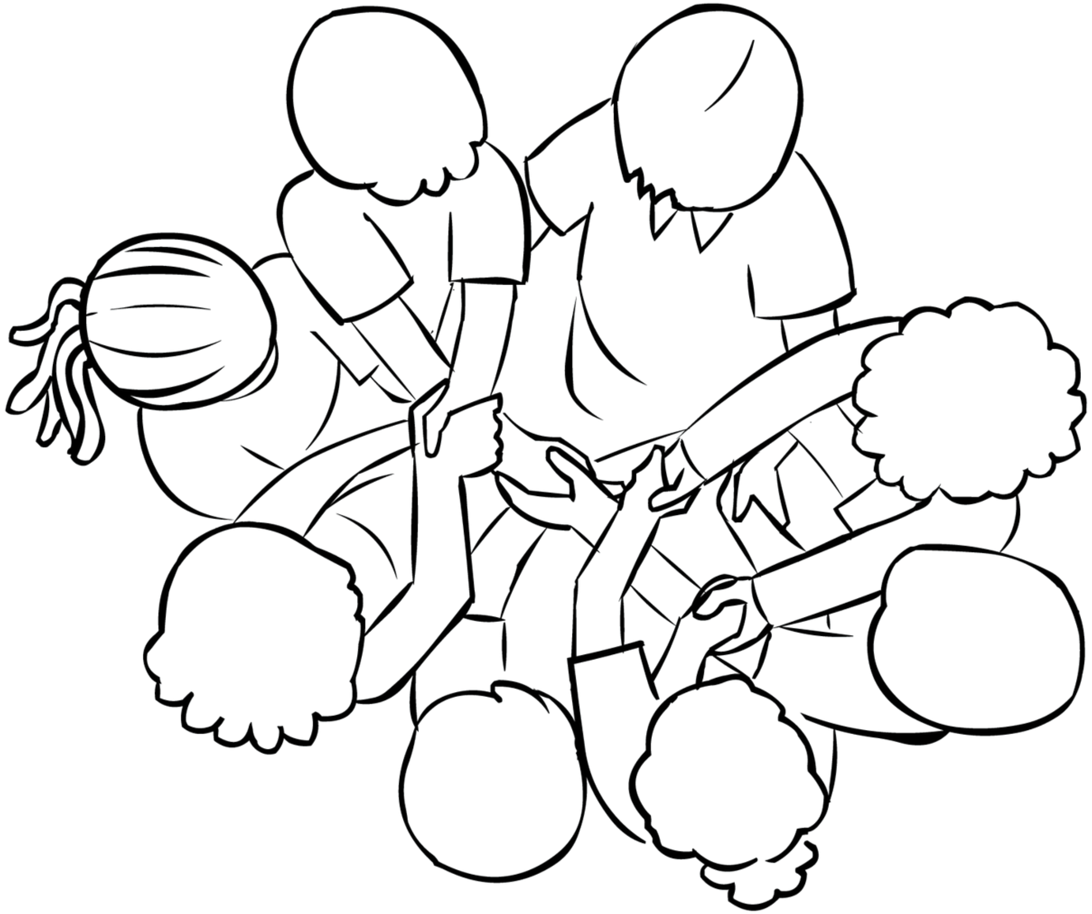
FIGURE I
Equilibrium Distributions for the Model with State Space $\{0,1, \ldots, N\}$ with Three Different Values of ϵ and δ and $N = 100$

Key Insights/Lessons Learned

Group dynamics matter

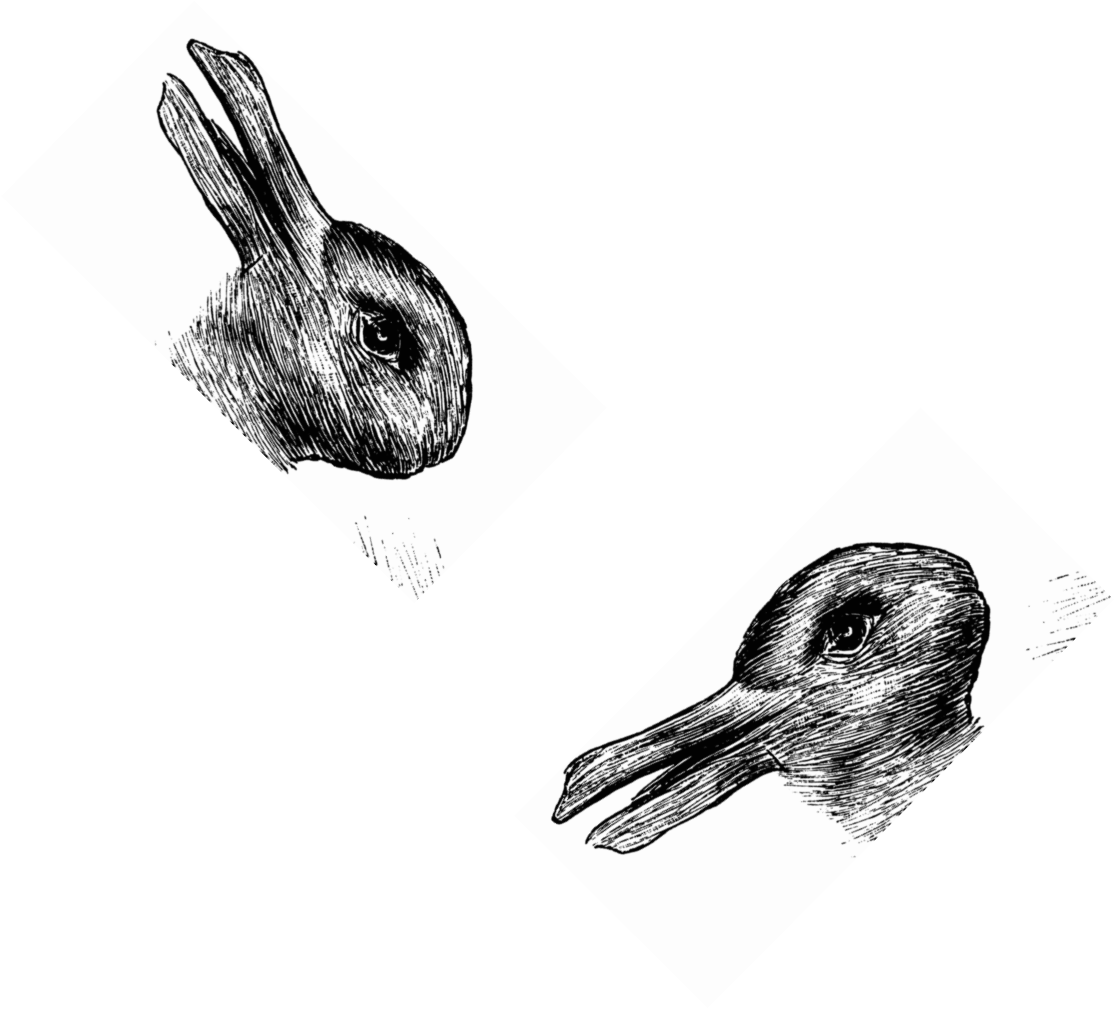
Without taking explicit account of the interaction between individuals, the group behavior observed cannot be explained.

I.e. cannot reconstruct group dynamic by looking at individual person.



No predictive power about the time at which equilibria shift

The process explored was *markov*, still at some point change occurs



Open Mind and Independence matter in order to avoid extrema/polarization!

It is all about the relative power of self-conversion and recruitment conversion!

Think carefully when investing energy in terms of human and machine computational power in order to model dynamic equilibria!

When mapping systems in the new era, when does it make sense to create a supervised dataset?

How long will it apply before the equilibrium changes? Will our trained model still apply? How big is the burden of obtaining a new supervised dataset?

How do I model such a dynamical pattern in my model?

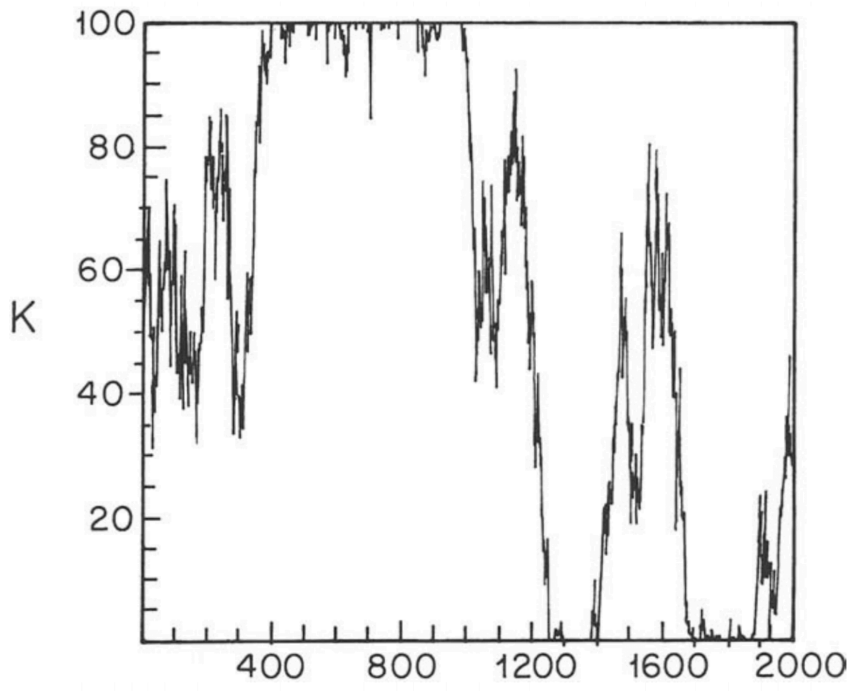
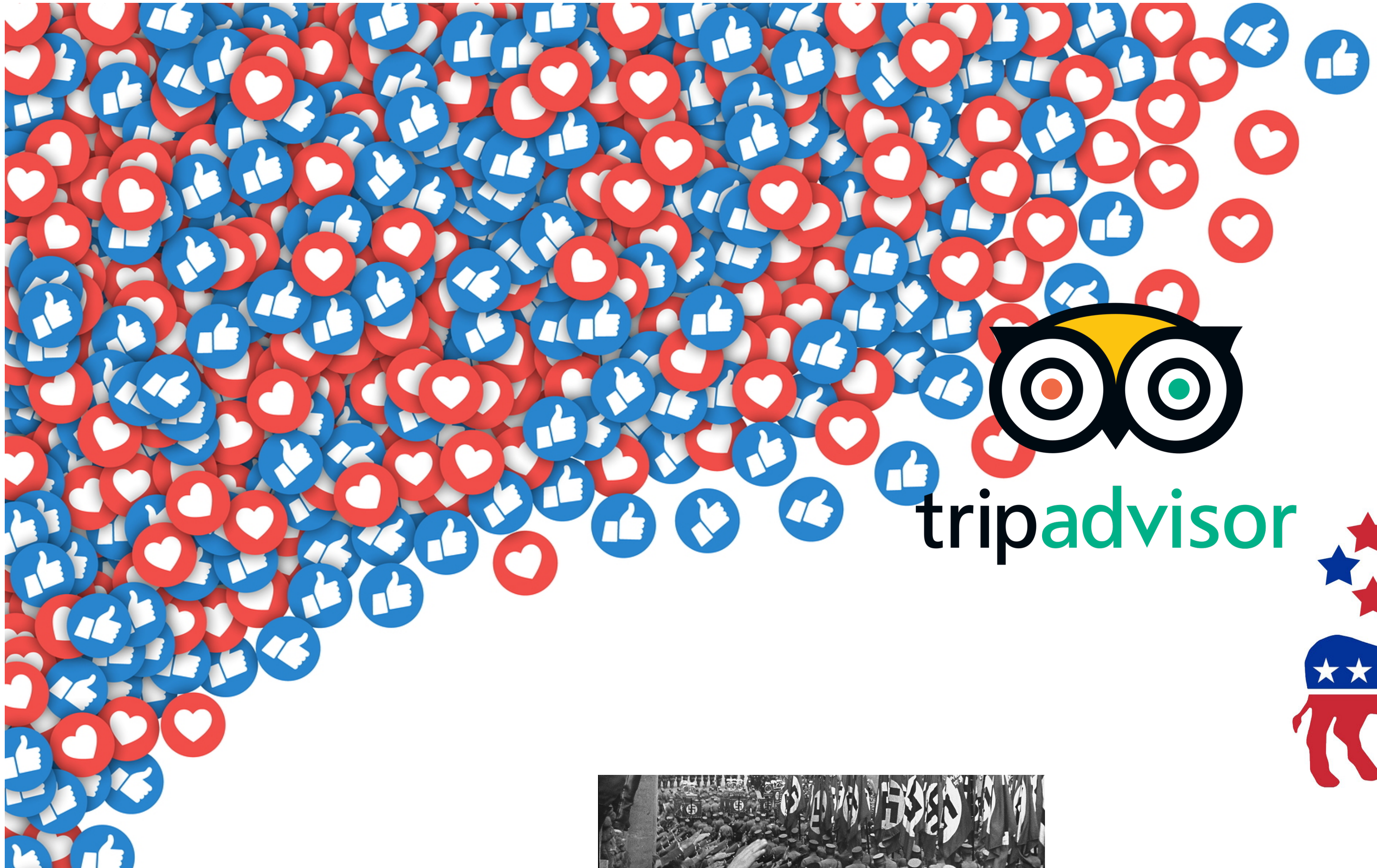
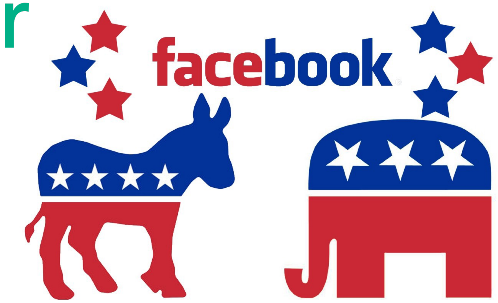


FIGURE IIb
100,000 meetings, every fiftieth plotted, $\epsilon = 0.002$, $\delta = 0.01$.

Summary/Conclusion

Some Thoughts on Recruitment





Open Questions

What if strong ideas recruit stronger?

Are we bounded in history to experience rough extremes while dreaming of moderation?

Can me measure self-conversion through time given some metric about average time of preference changes?