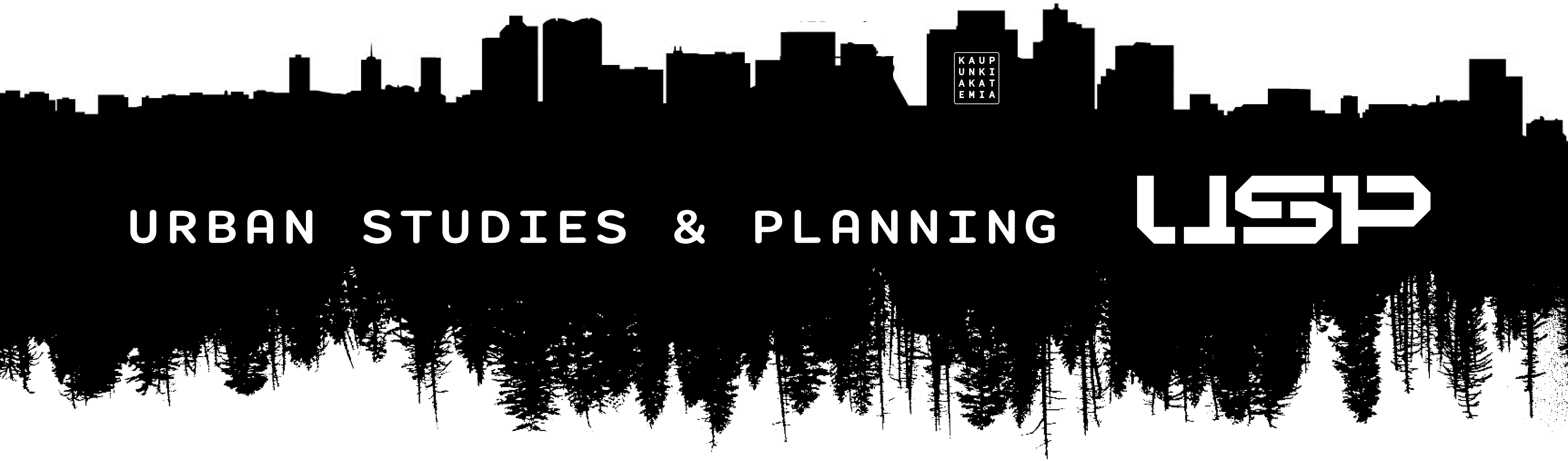


USP-E0361
Complex Adaptive Systems

Lecture 1

19.4.2021 Anssi Joutsiniemi

Course syllabus

Credits: 5
Schedule:
Teacher in charge:
Anssi Joutsiniemi
Teaching Period:
V
Learning Outcomes:

- Understand the principles of systems thinking and the development of systems theory.
- Identify the key characteristics of a complex system and complexity sciences.
- Understand the nature of cities as far-from-equilibrium systems.
- Identify interconnections between key concepts of complex adaptive systems, such as balancing and amplifying feedback loops, self-organization and emergence.
- Get familiar with model-driven exploration and simulation of emergent order.

Content:
Course is built around lecture series on systemic interaction and ontology on urban modelling. Lectures develop the theoretical and historical background of systems thinking in its various forms. The narrative is built on the development General Systems Theory of 1950’s to the most recent trends of systems thinking. Along the course students gets familiar with various families of rule-based modelling connected to cellular automaton, multi-agent systems and network theory. Lectures are supported with hands-on exercises using general purpose modelling and simulation tools like NetLogo and Processing. Theory of systems is rooted to urban planning practice with examples of operational urban modeling tools such as SLEUTH, CityScope and alike.
Assessment Methods and Criteria:

- Lectures
- Class discussions in flipped classroom manner
- Hands-on modelling exercises

Workload:
Total 135 hours. Tutored studies 35 hrs (lectures, class assignments, feedback reviews), independent study 100 hrs (exercises and assignments).
Study Material:

- Gleick, James (1987). Chaos: Making a New Science, Penguin Books.
- Holland, John (1998). Emergence: From Chaos to Order, Helix Books.
- Batty, Michael (2005). Cities and Complexity. The MIT Press.

Prerequisites:
The course UrbanGIS needs to be passed
Grading Scale:
Grading scale 0-5. Course completion is based on successfully accomplished weekly exercises. No exam.

Preliminary concepts

MODEL

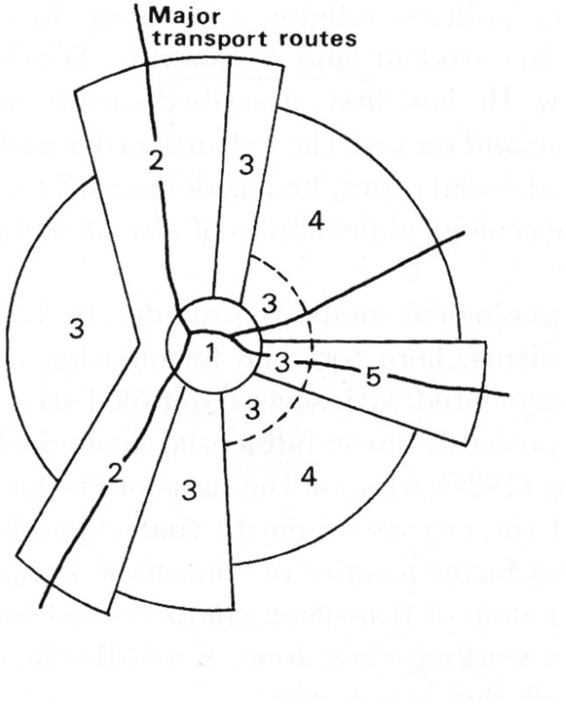
" ~ simplified representation"

- Mathematical theories can sometimes applied to technical and natural sciences via modelling. By this we mean that reality may be represented with concepts and equations of mathematic based theory.
- The axioms are chosen in a way that they meet the requirements of perceived phenomenon under interest.
- The axioms of model may then be understood as representations of this phenomenon and further explained as predictions of these assumed isomorphic systems.

…On the other hand, due to necessary translation process, it is necessary to understand that in case of false prediction the model is not incomplete, but instead that it really represents the reality with mock agreement of similarity.

MODEL

" ~ simplified representation"

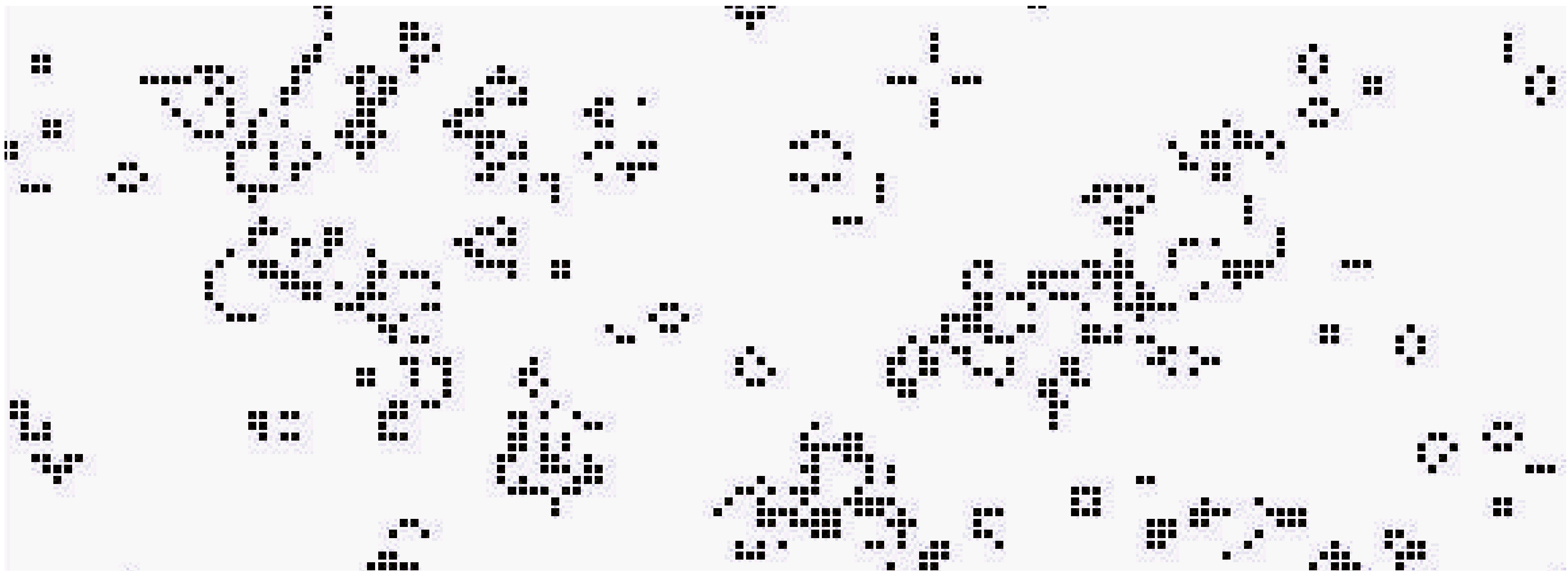


$$A_i = \sum_{j=1}^{n} d_{ij}^{-k}$$

Sipmlicity in science

- Occam’s razor

… line of reasoning that says the simplest answer is often correct.

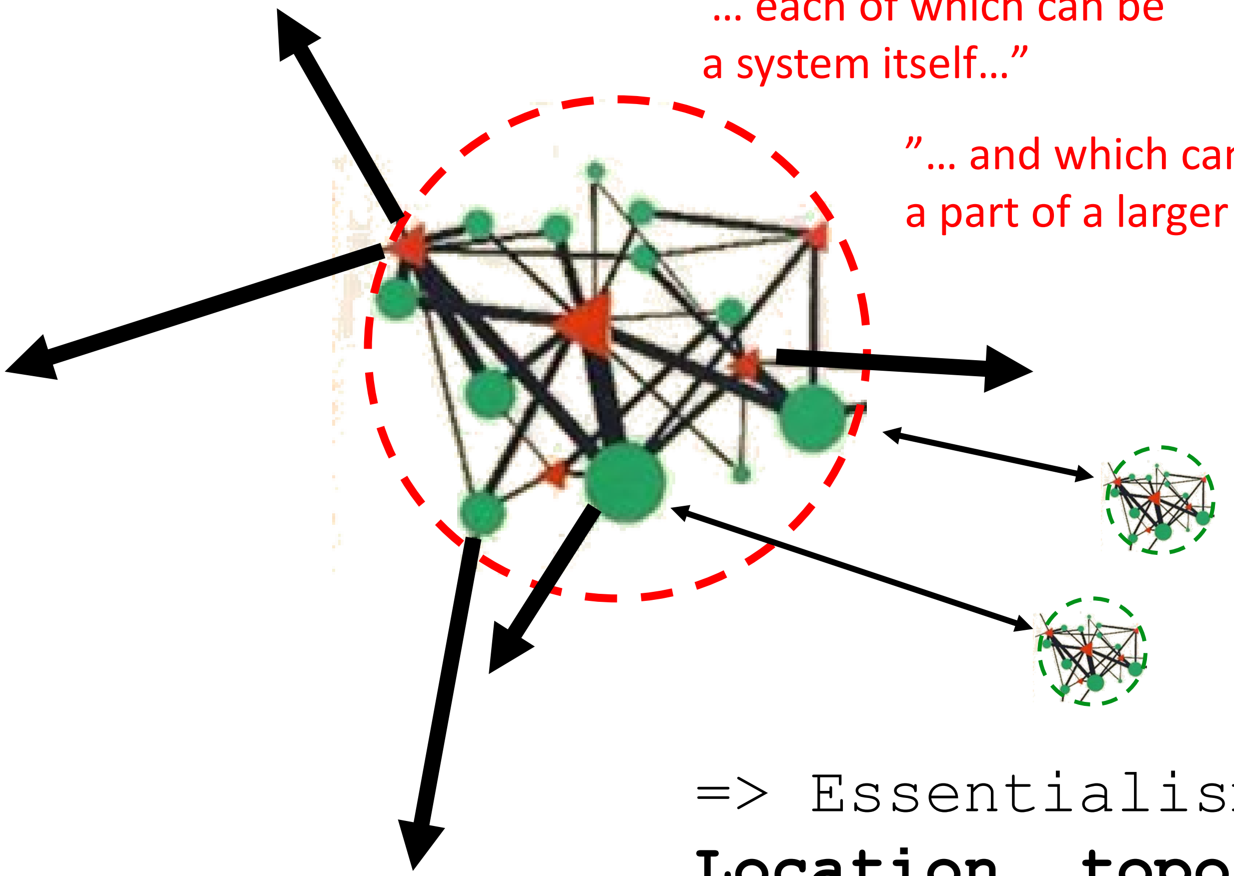


Spatial systems

"System is a set of interconnected parts…"

"… each of which can be a system itself…"

"… and which can be a part of a larger system



=> Essentialism on:

Location, topology and mereology

Preliminary concepts

"**Emergence** refers to how collective properties arise from the properties of parts, how behavior at a larger scale arises from the detailed structure, behavior and relationships at a finer scale. "

"If earnest scholars do not find it dignifying to compare an introduction of a science to a travel guide, be they kindly reminded that 'where to travel' and 'what is worth seeing there' is nothing but a way of saying in plain English what is usually said under the pompous Greek name of **'method'** or, even worse, 'methodology'." (Latour 2005, 17)

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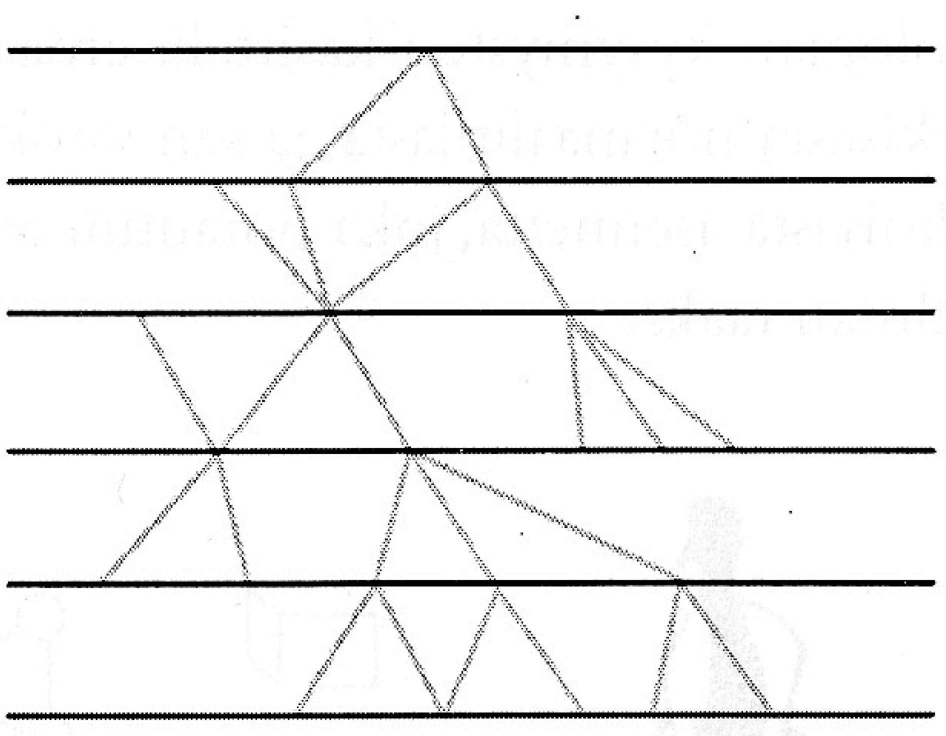
Emergence

- Cultural
- Social
- Psychological
- Biological
- Chemical
- Physical



First law of geography

- "…The global distribution of population could now be approximated by an equation with a modest number of coefficients. Alternately, the world population potential [29] could serve as a single surrogate for the 1.6 x 104 variables. Instead of using this approach I invoke *the first law of geography: everything is related to everything else, but near things are more related than distant things*. The specific model used is thus very parochial, and ignores most of the world."

Waldo R. Tobler (1970): "A Computer Movie Simulating Urban Growth in the Detroit Region", *Economic Geography*, 46, 2 (1970), pp. 234-240

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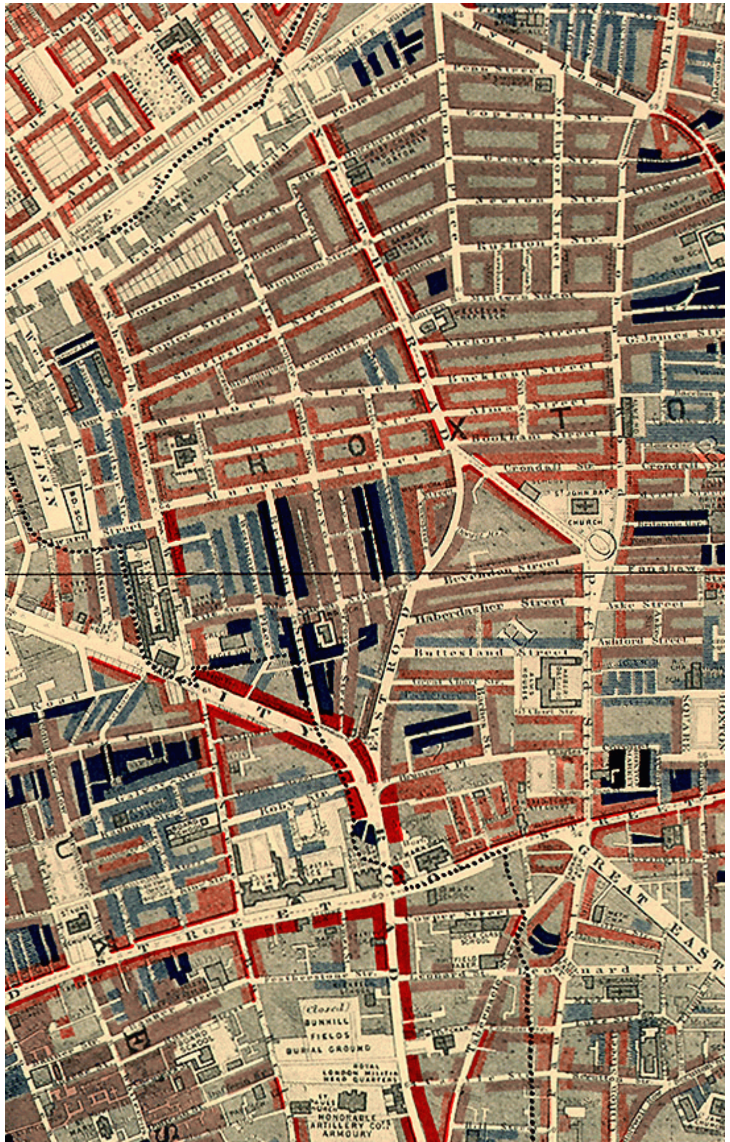
Planning and order

Emergence of urban orders (Webster & Lai 2004)

- **Public domain order**
  - (patterns of rights imposed upon common resources)
- **Organizatorial order**
  - (patterns of planned co-operation)
- **Institutional order**
  - (patterns of rules and sanctions)
- **Proprietary order**
  - (patterns of exclusive property rights)
- **Spatial order**
  - (patterns of activities over space)



(Charles Booth 1889)

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Two examples

Cellular Automaton (CA)

Multi-Agent Systems (MAS)

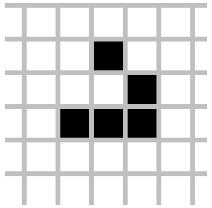
Cellular Automaton (CA)

- John von Neumann:
  ”Problem of self-reproduction” (1948 =>1957)

  - Cell division
  - Finite
  - Determinism
  - Homogenity
  - Local rules

- Lisää esim: http://atlas.wolfram.com/

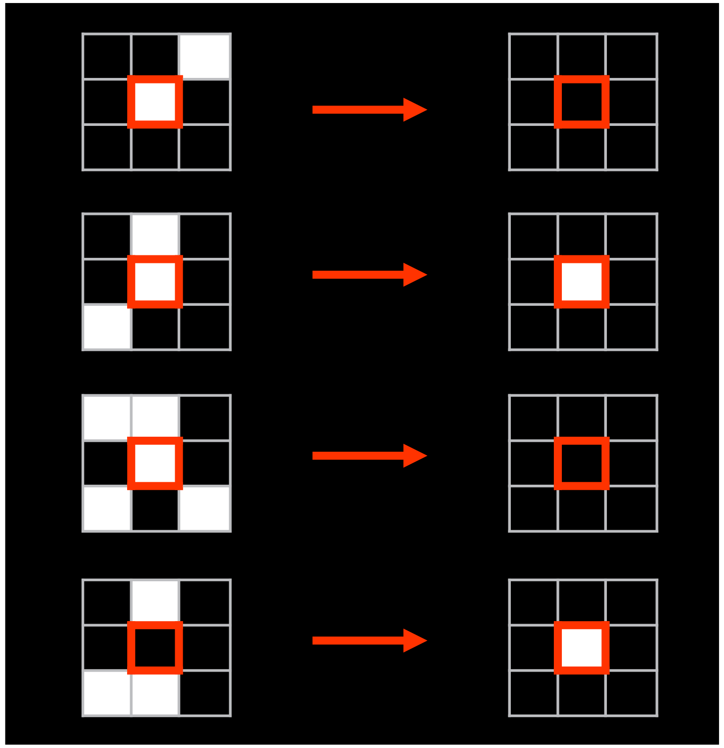
Emergence



- Emergence as system level phenomenon
- John H. Conway: Game of Life (1970)

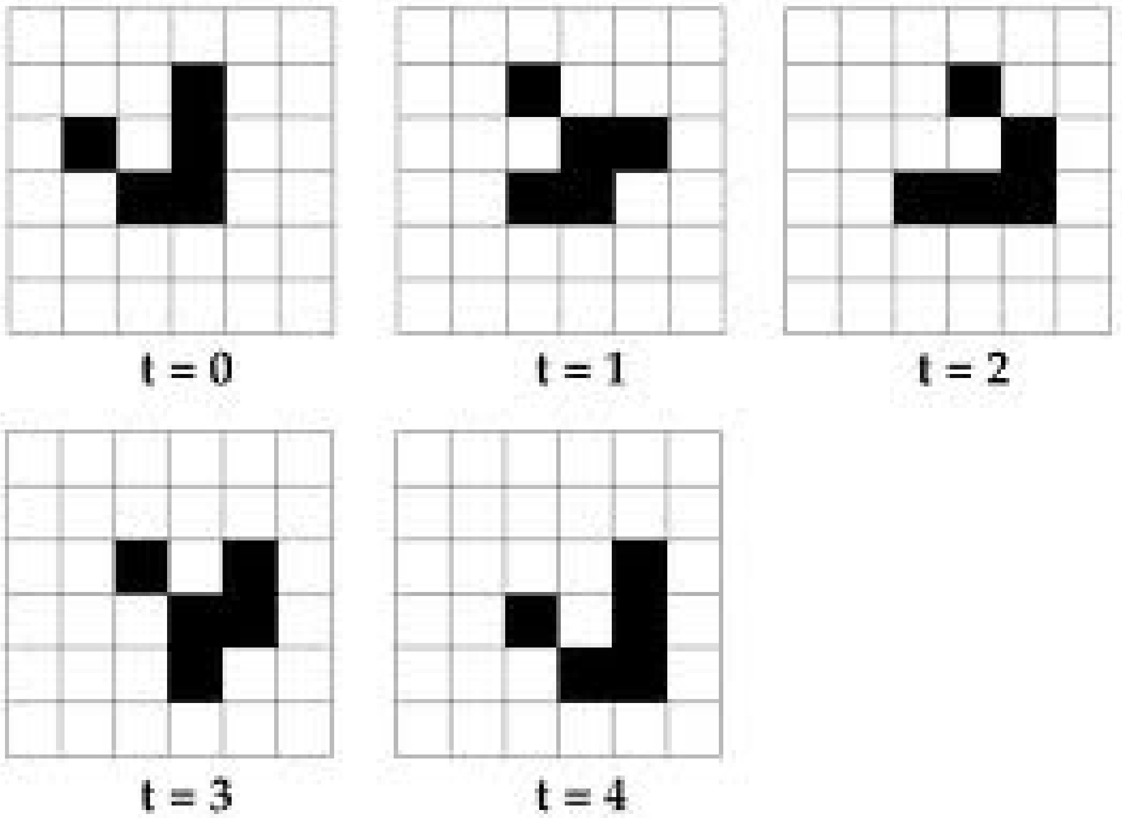
Transition rules of automaton:

- Any live cell with fewer than two neighbours dies, as if by loneliness.
- Any live cell with two or three neighbours lives, unchanged, to the next generation.
- Any live cell with more than three neighbours dies, as if by overcrowding.
- Any dead cell with exactly three neighbours comes to life.



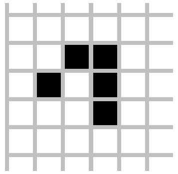
Game of Life (John H. Conway 1970)

- Stages of "glider"

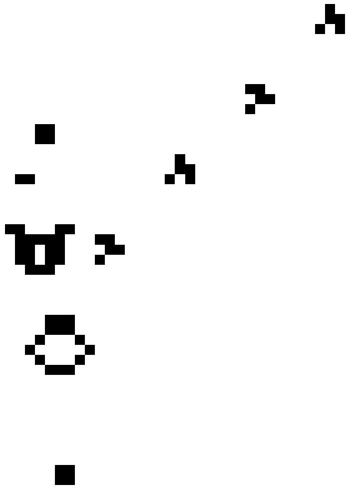


Game of Life (John H. Conway 1970)

Emergence or ”organisms”:



- 1.gen. Glider
- 2.gen. Glidergun
- 3.gen Breeder



Check also: Dylan Beattie - The Art of Code (From 4:26 onwards)
https://www.youtube.com/watch?v=6avJHaC3C2U

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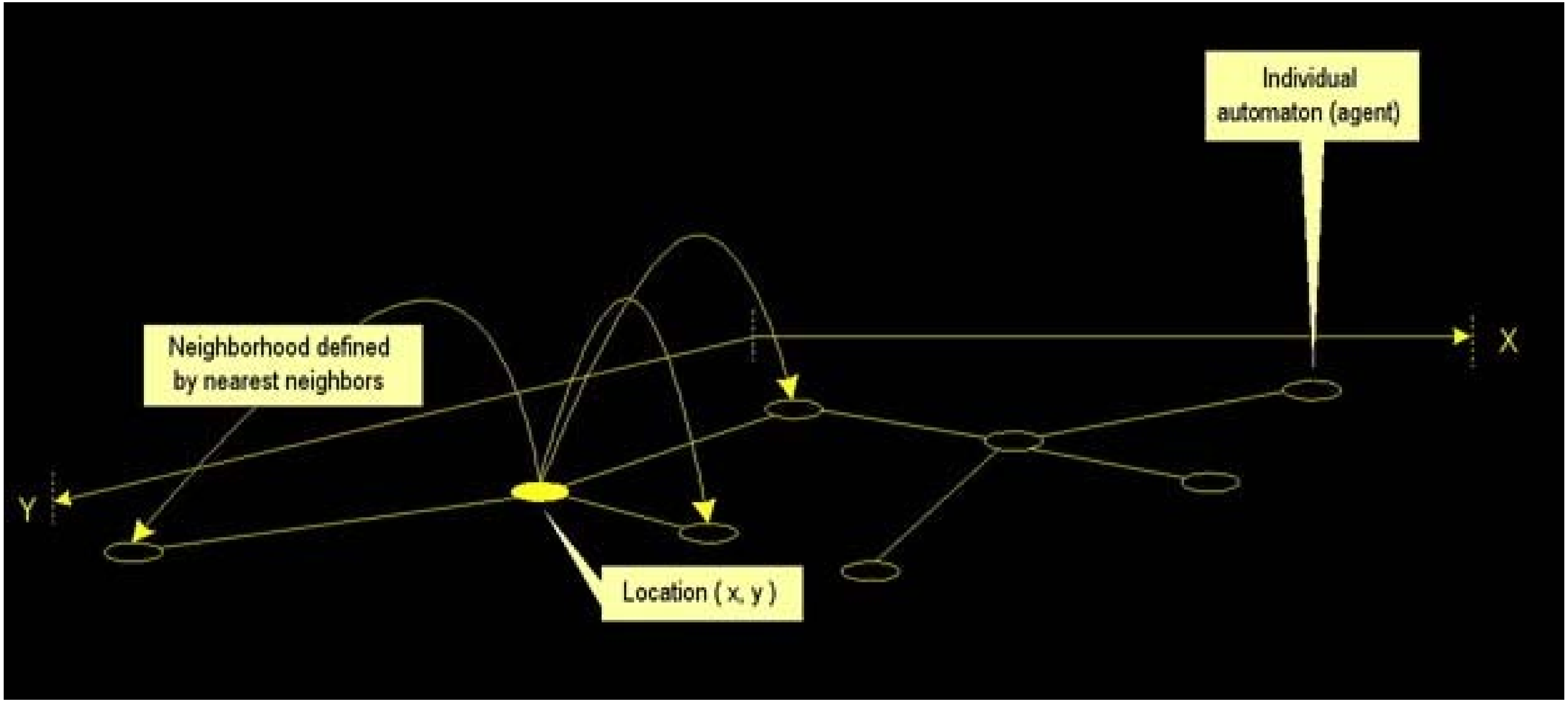
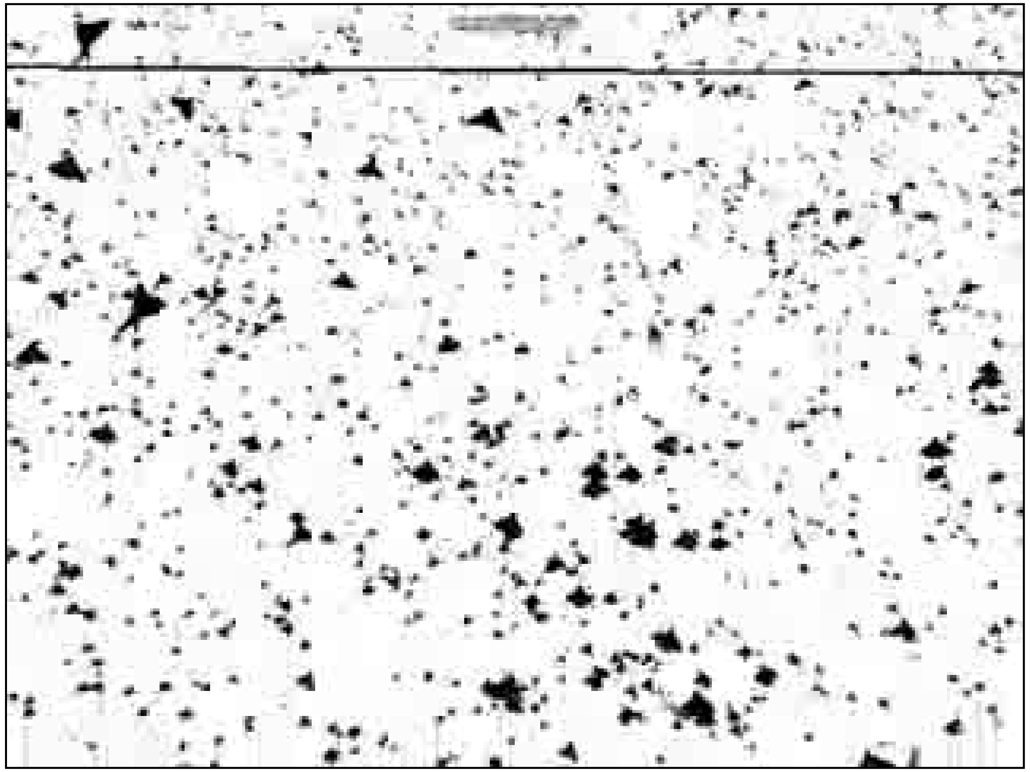
Multi-Agent System (MAS)



Rule set

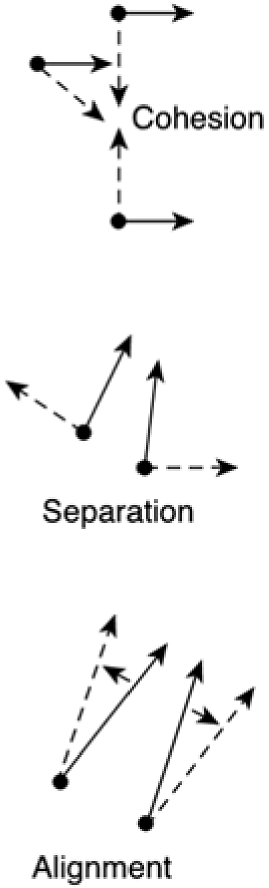
- …is also the base for Craig Raynolds Boids "game"



http://www.youtube.com/watch?v=xM9DHHBqBCk

Boids Rules

- ***Cohesion*** *(Keskeisyys)*
  (”head toward the centre”)
- ***Separation*** *(Etäisyys)*
  (”keep personal distance”)
- ***Alignment*** *(Menosuunta)*
  (”delineate with others”)



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Inspirations

Examples in NetLogo

- **CHAOS IN A BOX** https://ccl.northwestern.edu/netlogo/models/ChaosinaBox
- **FLOCKING** https://ccl.northwestern.edu/netlogo/models/Flocking
- **SLIME** https://ccl.northwestern.edu/netlogo/models/Slime
- **ANTS** https://ccl.northwestern.edu/netlogo/models/Ants
- **FIRE** https://ccl.northwestern.edu/netlogo/models/Fire
- **FRACTALS**, several models, e.g. https://ccl.northwestern.edu/netlogo/models/KochCurve
- **SANDPILE** https://ccl.northwestern.edu/netlogo/models/Sandpile3D
- **SEGRATION** https://ccl.northwestern.edu/netlogo/models/Segregation
- **FIREFLIES** https://ccl.northwestern.edu/netlogo/models/Fireflies
- **CELLULAR AUTOMATA 1D Elementary** https://ccl.northwestern.edu/netlogo/models/CA1DElementary

Examples in NetLogo

- **CHAOS IN A BOX** https://ccl.northwestern.edu/netlogo/models/ChaosinaBox
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- **ANTS** https://ccl.northwestern.edu/netlogo/models/Ants
- **FIRE** https://ccl.northwestern.edu/netlogo/models/Fire
- **FRACTALS**, several models, e.g. https://ccl.northwestern.edu/netlogo/models/KochCurve
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- **FIREFLIES** https://ccl.northwestern.edu/netlogo/models/Fireflies
- **CELLULAR AUTOMATA 1D Elementary** https://ccl.northwestern.edu/netlogo/models/CA1DElementary

Flipped classroom task on Mon 26.4.2021

Prepare a 10-15 minute talk on Chapter you chose from the James Gleick's book Chaos.

You may use slides + material beyond the book to explain the main leaning from your chapter. The idea of this task is to give everyone in the class an overview of the features on this new science of unpredictability.

After presentations we have a brief talk how and what features you find most relevant for planners to digest and what features would be nice to test out in a model.

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