Living in Living Cities

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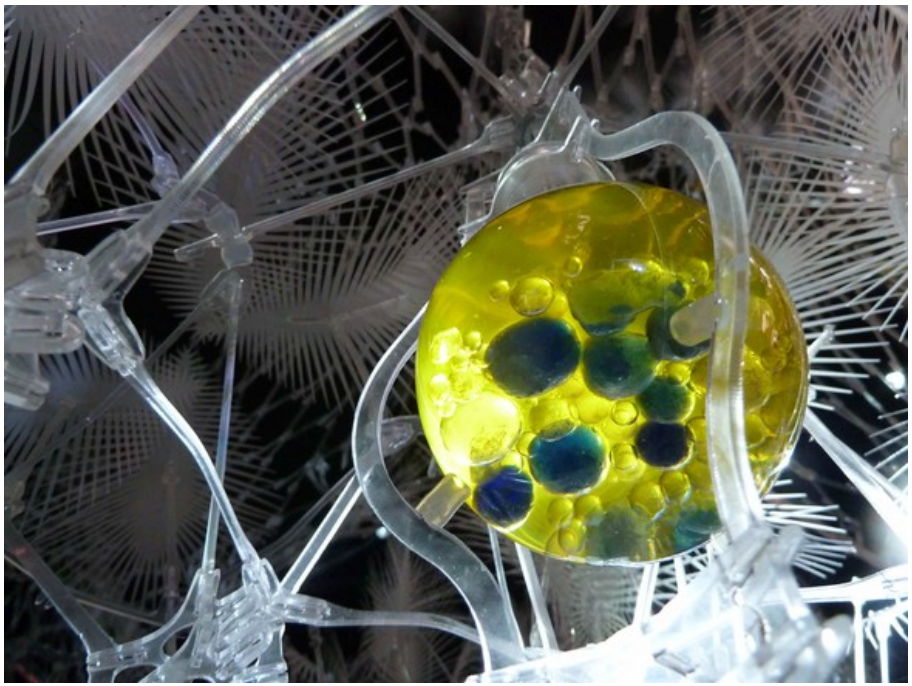
Outline

Cities...

- Half of people live in cities, 70% by 2050.
- Advantages and disadvantages, i.e. problems.
- Complexity limits traditional techniques.
  - Non-stationary problems.

Living Technology

- *Technology that is based on the core features of living systems* [Bedau et al., 2009].
- Living technology is adaptive, learning, evolving, robust, autonomous, self-repairing, and self-reproducing.
- Primary & secondary living technologies.



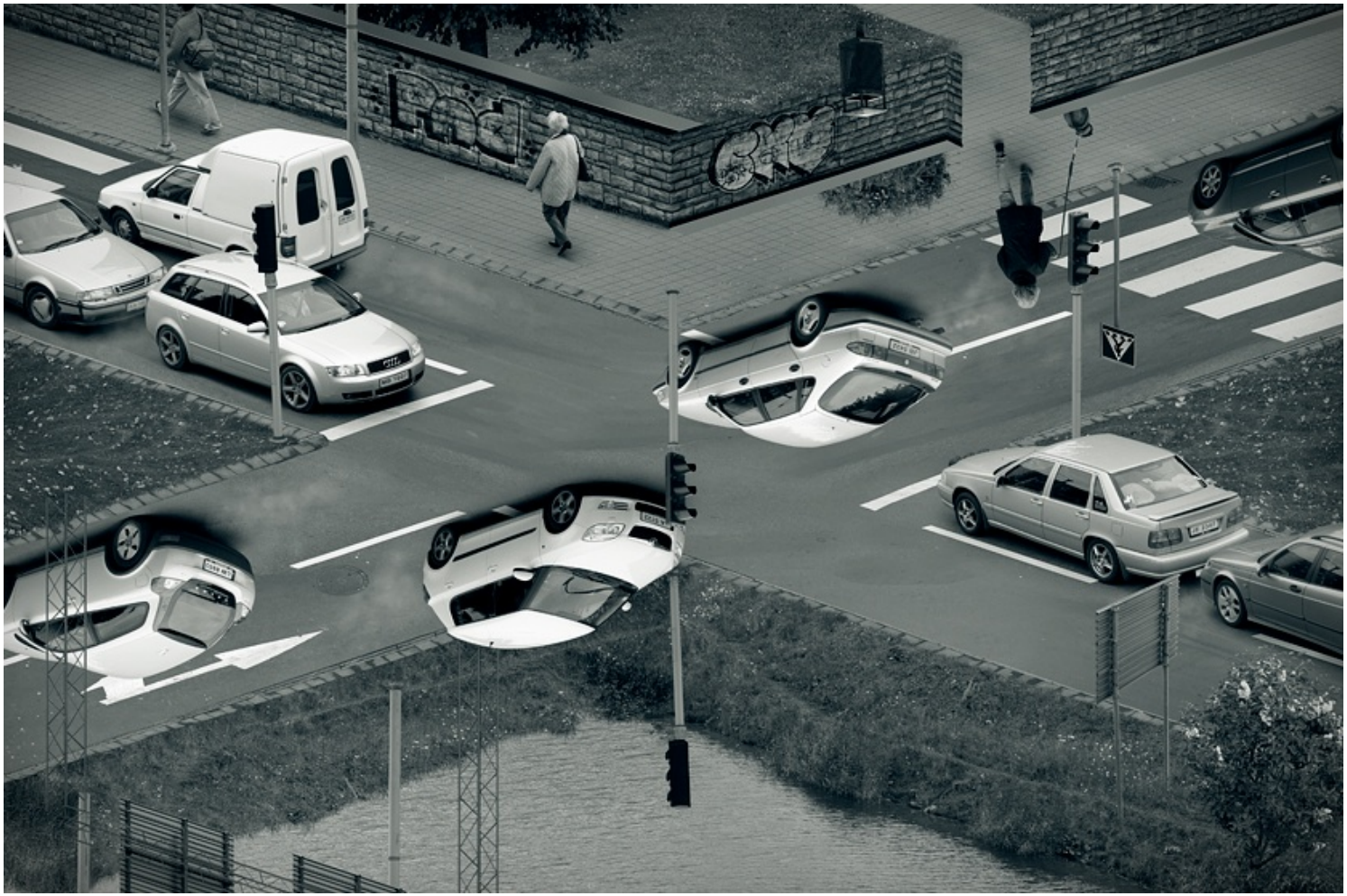
Cities as organisms

- Cities metaphorically as organisms, e.g. [Dawson, 1926, Spilhaus, 1969]: growth, metabolism, internal organization, transportation networks of matter, energy, and information, telecommunications as "nervous systems".
- Scientific study of cities is transitioning "from thinking of 'cities as machines' to 'cities as organisms'" [Batty et al., 2012].
- Some properties of cities in different universality classes [Bettencourt et al., 2007], but cities constantly adapting [Bettencourt and West, 2010].
- Most urban problems are *non-stationary* [Gershenson, 2012a]
- Living technology as potential solution.

IT on its way...

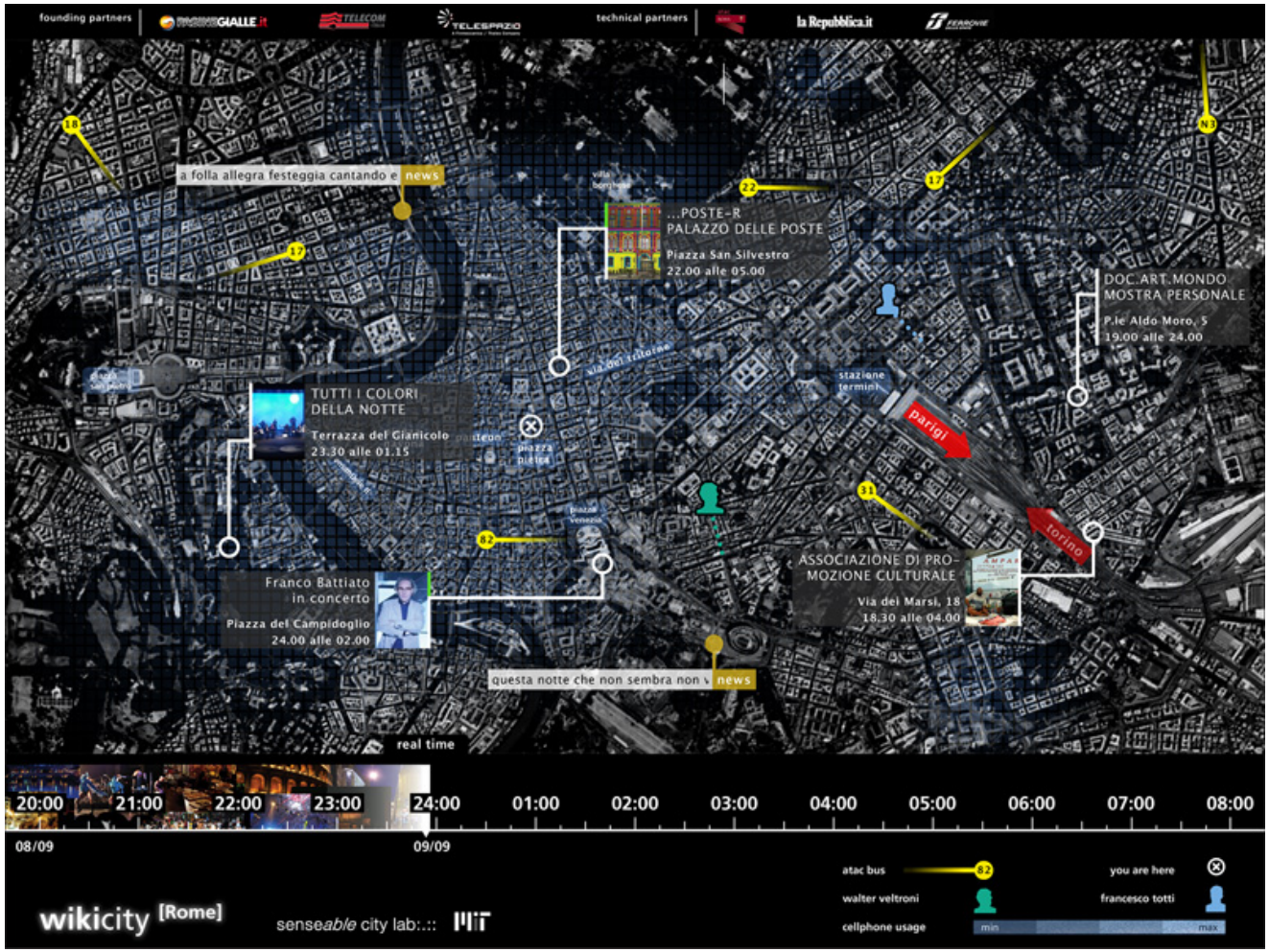
- Cybersyn [Miller Medina, 2005].
- IBM's smart cities [Dodgson and Gann, 2011, Harrison and Donnelly, 2011].
- FuturICT flagship project [Helbing, 2011].
- Earth 2.0 project.
- Organic computing [Müller-Schloer et al., 2011].

Mobility



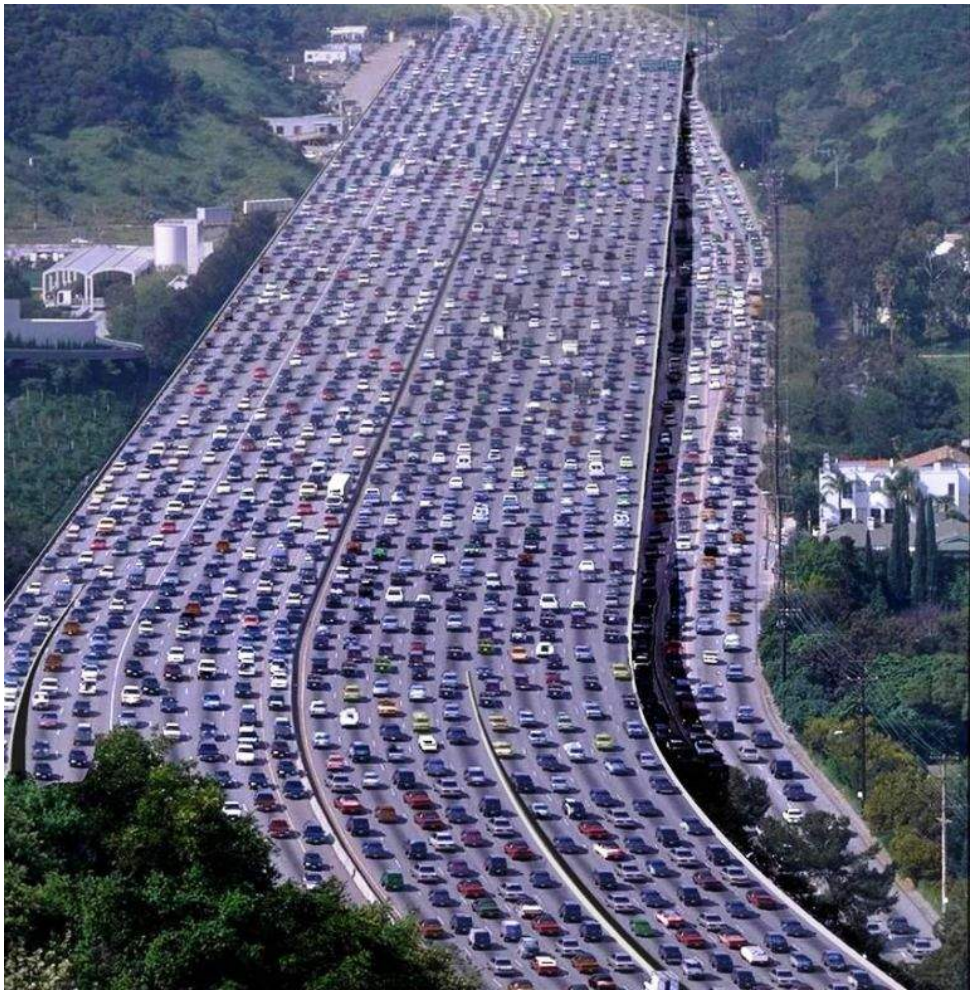
8 Factors of Urban Mobility

1. Transportation Requirements



2. Schedule Distribution

3. Quantity



4. Capacity

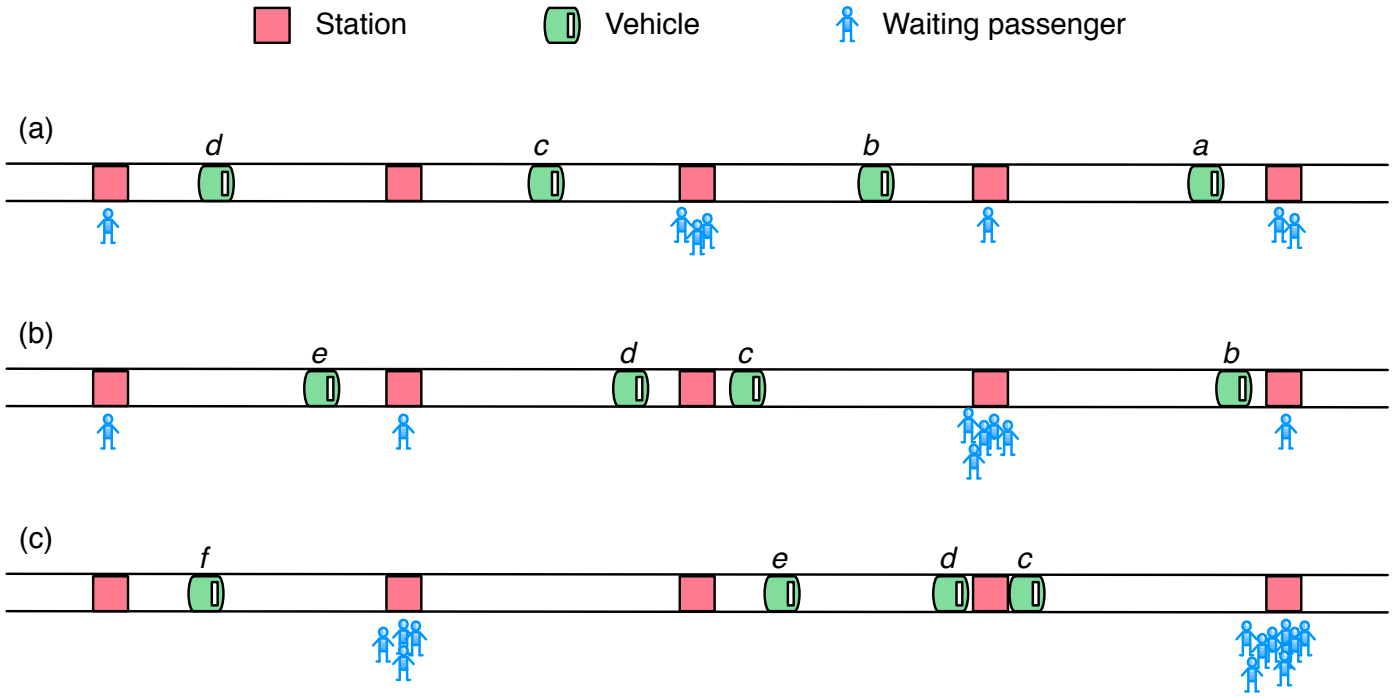
5. Behavior

6. Infrastructure and Technology

7. Social Contagion

8. Planning and Regulation

Public Transportation



Gershenson, C. & Pineda, L. A. (2009). Why does public transport not arrive on time? The pervasiveness of equal headway instability. *PLoS ONE* (10): e7292. doi:10.1371/journal.pone.0007292.

An "antipheromone"-based solution

- Current theory focuses on waiting times at stations.
- 'Slower-is-faster' effect leads to supraoptimal performance.
- Solution is not predefined, adapts locally to the current situation.
- Adaptation matches timescale of system change.

Gershenson, C. (2011). Self-Organization Leads to Supraoptimal Performance in Public Transportation Systems.. *PLoS ONE* 6(6): e21469. doi:10.1371/journal.pone.0021469.

Self-organizing Traffic Lights

- Independent intersections respond to actual traffic state and coordinate via vehicles to orchestrate efficient traffic flow.

Gershenson, C. (2005). Self-organizing traffic lights. *Complex Systems*, 16(1):29–53.

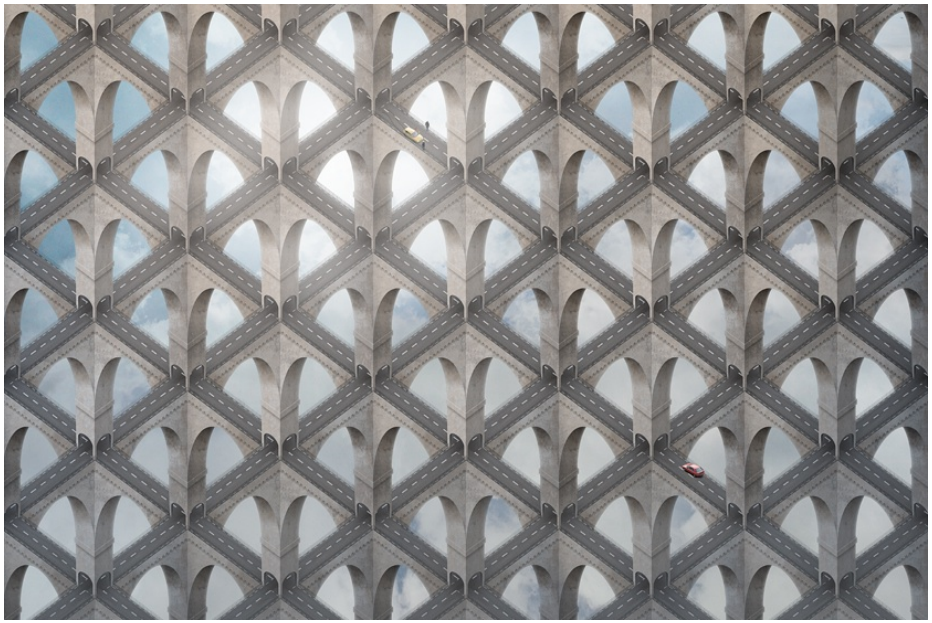
Gershenson, C. & D. A. Rosenblueth (2012). Self-organizing traffic lights at multiple-street intersections. *Complexity* 17(4):23–39. doi:10.1002/cplx.20395

Real-time Information Systems

- Relevant information on demand for better decisions.
- Sensors, sensor integration [Qi et al., 2001].
- Intervehicle communication [Kesting et al., 2008].
- For public transport [Gershenson and Pineda, 2009].
- For logistics.

Logistics

- Biologistics [Helbing et al., 2009]: living systems also have material flows.
- Bioinspired logistic systems that adapt to demand changes.
- Adapt at multiple timescales [Gershenson, 2010].
- E.g. swarm intelligence [Svenson et al., 2004].

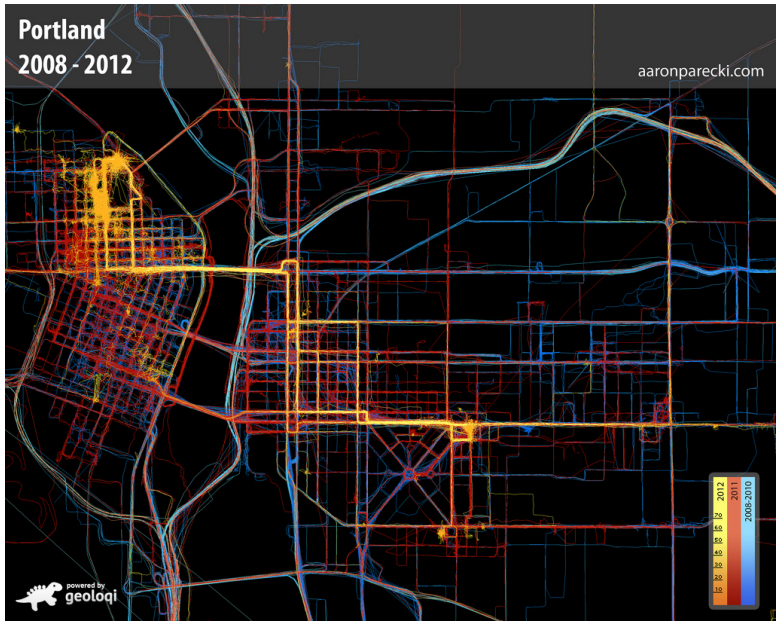


Telecommunications

- IT has reduced communication delays.
- Relevant, timely information for better decisions.
- Not only for citizens, also for devices [Resch et al., 2011].
- High speeds and high complexity.

Governance

- Sensors and effectors to provide timely, adaptive governance [Gershenson, 2008].
- Collective decision-making [Rodriguez et al., 2007].
- Open data.
- Increased citizen participation.



Safety

- Adaptive response to catastrophes.
- Urban sensors to increase safety and accountability.
- E.g. artificial immune sys. [Hofmeyr and Forrest, 1999].
- Safety has increased with technology [Pinker, 2011].

Sustainability

- Capacity to endure.
- Environmental, social, economical.
- Pollution, efficiency.
- Smart grid.
- Rainwater collection.
- Economy: production $>$ consumption.
- Adaptive organizations.
- Cooperation.

Society and Culture

- Increase "carrying capacity" of cities.
- Innovation acceleration.
- Urban benefits propagate across cities with technology.
- "Social moods" [Bollen et al., 2011].
- Steering of social behavior [Gershenson, 2011]

How to do it? Self-organization as a Method

When building a self-organizing system, elements are designed to *dynamically* and *autonomously* solve a problem or perform a function at the system level.

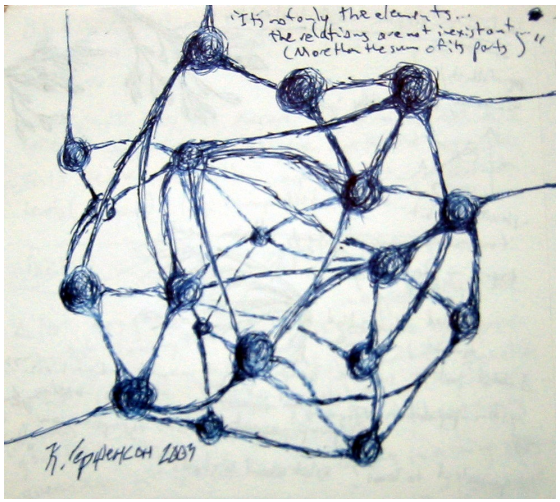
- Useful when solution is not reducible (complex interactions), not known beforehand, or changes constantly.
  - Non-stationary problem domains.
- As problem changes, elements adjust their behavior, adapting to the new situation and finding new solutions.

A Methodology (Gershenson, 2007)

- An *agent* is a description of an entity that *acts* on its environment
- An observer can describe the *goals* of an agent
- The "fulfillment" of goals can be measured with a variable $\sigma \in [0, 1]$, representing *satisfaction*
- Agents *interact*, affecting each other (and their goals and satisfactions) positively, negatively, or neutrally
- *If we minimize "friction" (negative interactions) and maximize "synergy" (positive interactions), global "satisfaction"* σ_{sys} *will increase*
- Use *mediators* to promote and constrain behaviors that reduce friction and maximize synergy.
- Focus on interactions, not only on elements.

Beyond the Metaphor

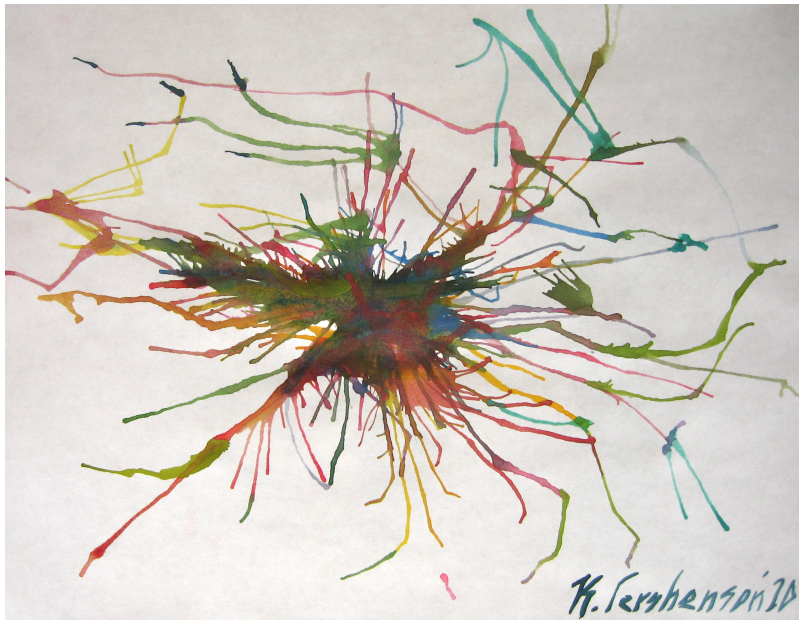
- Cities will offer a higher quality of life if they exhibit the properties of livings systems.
- Cities have not only to be smart, but also to adapt, learn and evolve robustly.
- Can measure in terms of information [Gershenson, 2012b].
- Living cities as integration of technology & living systems.



Complexity Digest

http://comdig.unam.mx

twitter: @cxdig



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