FROM COMPLEXITY THEORIES TO VALUE CREATION IN CITIES

JUVAL PORTUGALI*
TEL AVIV UNIVERSITY
https://english.tau.ac.il/profile/juval
juval@tauex.tau.ac.il

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ABSTRACT

The last decades have witnessed the emergence of complexity theories of cities (CTC) – a domain of research that applies the various theories of complexity to the study of cities, their dynamics, planning and design. The last decades have further witnessed the 4th industrial revolution that by means of its information and communication technologies (ICT) gave rise to the so-called smart machines and smart cities. Finally, the unprecedented urban growth of the last decades has recently culminated in the "age of cities": as from 2008, for the first time in human history, more than 50% of human population live in cities; according to the UN World Urbanization Prospect by 2050 some 68% of the world's population will live in urban areas. The aim of this one-week seminar is to explore the interrelations between these developments and their implications to value creation in cities.

***K*eywords** Complexity theories · CTC—complexity theories of cities · Complexity, cognition and the city · smartification of cities · Value creation in cities · Cognitive science

1 GENERAL INTRODUCTION–

Complexity theories (CTC) A DOMAIN OF RESEARCH THAT APPLIES THE VARIOUS THEORIES OF COMPLEXITY TO THE STUDY OF CITIES, their dynamics, planning an design.
New industrial revolution by means of its information and communicatin technologies (ICT) gave rise to the so-called smart machines and smart cities.
Age of cities: as from 2008, for the first time in human history, than 50% of population lives in cities.

Erwin Schrodinger
What is life?
Mind and Matter
Entropy: a property of matter
Negative entropy: a property of life (*Negentropy*)
"How would we express the marvellous faculty of a living organism, by which it delays the decay into thermodynamical equilibrium (death)?"
"It feeds upon negative entropy, attracting...a steam of negative entropy upon itself, to compensate the entropy increase it produces by living and thus to maintain itself on a stationary and fairly low entropy level"

Example: Prigogine's entropy certain materials behaive as an organic element as they exchange energy with their environment.

*Use footnote for providing further information about author (webpage, alternative address)—*not* for acknowledging funding agencies.

2 COMPLEXITY THEORIES–

So, complex systems are not a closed systems, as they need to extract negative entropy from another system. Also a complex system behaves with "self-organization", "spontaneously". Ordering that is emerging by itself. So we have two properties: open systems and self organization. The first one related with the interaction of the environment and the second one related with spontaneously taking a sort of order. Emerging property that comes from parts and then it affects the parts of the system *sinergetycs* ("- forces - working together".
Three properties of most complex systems (*Fractals*):

- **Self-similarities:** System is similar at different scales.
- **Simple rule:** A simply set of mathematical relations can produce a very complex dynamics after certain number of iterations. Our reality could be explain by relatively simple mathematical relations. Example, construction of fractal, start with a single triangle and start generating triangles in each of the sides of the prior one. After certain number of iterations of the simple rule the result will be a snowflake shape.
- **Relative rule:** The measurement depends on the measurement scale. Example.- Cost line of England, the length depends on the *zoom* used to measure it. Broken or fractal dimensions $1D \rightarrow 2D$. Another example.- math theory of chaos *sensitivity to initial condition or non-linearity*. Light changes to initial conditions in a dynamic - complex - system generates very distinct equillibrium (final outcomes). One way to look at is the so-called butterfly effect. So, by nature in complex - dynamic - systems it is impossible to predict the final outcome.

Graph theory: For new network studies. Symmetric networks vs random networks. *Small world network* an in between symmetric and random networks. Complex systems are essentially networks. So it is possible to use graph theory to the study of networks. Scale Allometry is - for our purposes - looking for the scales of a system.

A complex self-organizing system is composed of parts, elements, components, units....
Its network of interactions serves for exchange of matter, energy, and information. Language is an example (*human creation*), another is a flower (*natural creation*). Noam Chomsky ones described what he called a natural language versus an artificial creation of language (English, Spanish, French, etc..).

Public opinion creation modeled as a complex system: http://jasss.soc.surrey.ac.uk/11/4/2.html

Network analysis with R: https://www.jessesadler.com/post/network-analysis-with-r/

3 CTC—COMPLEXITY THEORIES OF CITIES–

Accompanied complexity theory from the start. Already in his Nobel lecture Prigogine (1997) says:

"Are most types of 'organizations' around us of this nature?",
- that is, characterized by thermodynamic equilibrium? - the answer is negative. Obviously in a town, in a living system, we have a quite different type of functional order. To obtain a thermodynamic theory for this type of structure we have to show that non-equilibrium may be a source of order.
Each **CTC** emphasizes a different property of the complex system.

- **Progigine** *The END OF CERTAINTY, 1997, 62*: " A crystal.. can be maintained in a vacuum, but if we isolate the town, it would die.."If you put a city in a vacuum it will disintegrate. A city is an open system, we call it maintainance, for example for keeping a building functional we must acquire building material from the environment. This leads to the idea that we humans create the link between the artifact and the environment, what would happen if we - humans - disappeared from the earth? (a world without us - youtube video-)
- **TIME, STRUCTURE AND FLUCTUATIONS:** Order through fluctuations. Fluctuations over the steady state. In cities, these changes happen very rapidly, for example 1st, 2nd, 3rd, 4th industrial revolutions. Fluctuations give rise to new steady states.
- **Synergetic cities:** Bottom up emergence, top-down slaving. In cities, equilibrium emerges bottom up and it comes back circularly to the parts. People creates cities and cities creation citizens (people of the city). Psychological development, morphological development of a baby born in a certain city, a boy from that specific city at a very short age can identify morphological aspects of the city where he was born - i.e. car brands -. Closely related with the idea that the total is not just the sum of the parts.
- **The play between control parameter and order parameter**.- Finger movement paradigm (Haken, Kelso Buntz). Experiments with body parts moving while a metronome is working (after a while they get sync).

Collective behavior of this aspect of human reality. A single person walking along a crowed street gets their paced syncronized - *millenium bridge* -. **Crowed behavior** at a certain level single personalities gets synced with a collective personality.

- **Chaos (math notion)**.- Time evolution of segregation in a city with two cultural groups. **Game of life:** they used two types of initial groups, with groups of wanting to live in their own neighborhood. Boundaries of the segregations are always moving on a chaotic - non predictively - manner. Public Opinion as synergetics a complex system.
- **Chaotic cities:** Example early urban societies in middel east (3,000 BC). Fractal cities (Michael Batty & Paul Longley). Fractal theory to the domain of cities. Infrastructures are often self-similar with specific fractal dimension. Paris metro (+suburban net) is a fractal.

  Fractal Geometry in cities: Apply fractal theory to the study of growth of cities. Compare the fractal dimensions of cities: FRACTAL CARTOGRAPHY OF URBAN AREAS. Reminder – Christopher Alexander: "A city is not a tree". A city should be model as a network not a tree (there is an equivalence between fractal system and a network). Thing the present world as a network of cities, where global cities are the mayor connectors to the network.
- **SCALE:** Allometry cities

$$Y(t) = Y_0(t)N(t)^{\beta}$$

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Where $Y(t)$ stands for a given urban indicator, $N(t)$ is the population size of a city at time t, and $Y_0(t)$ is a time-dependent normalization constant. β that characterizes the various urban indicators, can take three universal forms: $\beta < 1$, sub-linear regime $\beta \equiv 1$, a linear regime and $\beta > 1$, a super-linear regime associated with outcomes from social interactions

Table 1: CTC - Cognitive Theories of Cities

Single Frame to Theoretically Unify			
Jane Jacobs	Central place theories	Rank-size power	Cultural Segregation
(Batty)	(Allen)	(Iaw Pumain)	(Portugali e al)

4 COMPLEXITY, COGNITION AND THE CITY.–

4.1 WHY COGNITION–

Complexity Cognition and the City

Because human systems differ from both material and organic systems, that is, they differ from natural systems:

Natural organic systems are subject to one evolutionary process - Darwinian evolution
Humans are subject to two evolutionary processes - Darwinian and cultural
Cities are dually complex systems=They are HYBRID CS The Quark, the jaguar and the City:
The Jaguar contributed - with - adaptation; what has the city to contribute? **Hybridity!**
CAS: Complex Adapting Systems, the examples that can be found in nature are just natural entities. That is not the case with cities. Cities are **HCAS:** Hybrid Complex Adapting Systems. Are a mixed of two type of systems, single systems or artifacts (automata machines) and humans. Humans create the city and control the relation between these two. **What can the city add to Complexity theory?**

To understand human behavior in cities we need to make a link to cognitive science

- **Cognitive Maps:** People behavior in the city is determined by their (often systematically distorted) cognitive map of the city

- **Image of the city:** Urban morphology affects legibility/*imageability*
- **Mental maps studies:** People perception of the environment depends on (determined by) their location in space
- **Embodied cognition:** People perceive environmental affordances
- **Brain studies/neurology:** The hippocampus as a cognitiv map;
  Brain plasticity: memorizing a city affects human brain
  Place cells, grid cells, edge/border cells, head direction cells
  How much the environment affect the mental structure and ultimately the way we humans think
- **Human memory is chronesthetic:** capable of mental time travel (MTT)

THE BRAIN IS THE ULTIMATE COMPLEX SYSTEM
But cognitive science disregards artifacts, and a city is at least in part an artifact!!

4.2 COGNITIVE MAPS

Tolman (1948) Cognitive maps in rats and men

Experiments with rats in mid XIX century to learned that they were creating a mental map of mazes. Mind learned the morphology of the space (in this case the maze). Humans have the same type of creations in mind.

$$Environment \Rightarrow \textit{Cognitive Maps} \Rightarrow Behavior$$

Black box approach for the **Cognitive Maps** it's something that can not be seen. So, behaviorist postulate that it is possible to correlate stimulus with behavior, even if there is a black box happening in the middle (Cognitive Map). Economic theory for example, can be seen as a behavioral approach. **WARP** postulates rationale for preferences of agents. So independently of the mental process of agents the decision can be predicted by the stimulus.

Systematic distortions in cognitive maps. For example, central localization of your country home (B. Tvetsky). The cognitive maps differs from the cartographic map of the world. The behavior is not determined directly by the stimulus but by our perception of it.

4.3 THE EXTERNAL WOLRD

The image of the city (Kevin Lynch). What are the architecture elements of a city that make the city convenient for their inhabitants? Elements such as: Paths, Edges, Districts, Nodes and Landmarks. His study took place in three north american cities: Boston, Jersey, and Los Angeles.

What does the external world - in the city - would create a nice cognitive map?

4.4 EMBODIED COGNITION

The mind/brain, the body and the environment form a single interacting system. **Noam Choamsky** suggested that human babies comes to the world with something that could be called **Universal Language**. A type of potential for language. From this potential language every - all most - learn an specific language.

In seventh's Gibson suggested that the classical model of cognition, that assumes a split between body (hardware) and cognition (software) is not sufficient. He suggested that when a person is looking at the world is looking what the body let him to see. He called this concept *affordances*. Gibson (1986) ecological approach to visual perception: organisms perceive environmental *affordances*

Donald Norman 1992/2002, **The Design of Everyday Things / The psychology of every day things**: Gibsonian *affordances* are part of nature. **Artifact's affordances** are part of culture = specifically designed to fit (adapt to) humans' body and cognitive capabilities.

Cognitive approach versus Behavioral approach?

The hippocampus as a cognitive map (John O'Keefe and Lynn Nadel). Hippocampus as one of the oldest elements of the brain. Hippocampus is responsible for spatial recognition. Brain **plasticity** experiment can be seen when O'Keefe measured the average size of the hippocampus for a group of London taxi drivers. Also it is possible to identify **plasticity** when animals remember a place or thing that when close to them make their hormones to *fire*. **Place cells, Grid Cells,**

4.5 COMPLEXITY, SELF-ORGANIZATION AND COGNITION

The brain with its about 100 billion (10^11) neurons each with about 10^4 connections is the ultimate complex system. **Chronesthesia** or mental time travel (MTT). The brain's ability to think about the past, present, and future. Certain regions in the left lateral parietal cortex, left frontal cortex, and cerebellum, as well as the thalamus, were activated differently when the subjects though about the past an future compare with the present. Notably, grain activity was very similar for thinking about all of the non-present times (the imagines past, real past, and imagined future.

Form of Chronesthesia/MTT: Prospective memory (Cue dependent and time dependent) and Cognitive planning

Our brain works the same way when we remember the past that it works when we *remember* the future, prospective memory. Another example is cognitive planning, we humans are always planning, in that sense planning is basic to human cognition. That is a natural characteristic of human condition, plan and design are basic properties of human cognition. Every human being is essentially a planner. One is behaving and acting in response to a plan or design, that is, in response to a reality that doesn't yet exist and might never exist.

4.6 URBAN DYNAMICS IMPLICATIONS

Urban planning implications: Every person or urban agent is a planner at a certain scale. In the city we therefor have two form of planning.

1. **Institutional planning**
2. **Cognitive planning**

Herbert A. Simon "The Sciences of the Artificial". The link to cognitive science thus tells us a lot about human behavior in cities but it also created a problem: A methodological barrier between cognition and the city. The reason: Cognitive science disregards artifacts. Humans live in two worlds at once, and our ongoin visual experience is a dialogue between the two: the outside world that enters through the fovea and is elaborated in a bottom-up manner, and the internal world of the brain's perceptual, cognitive and emotional models that influences information from the fovea in a top-down manner. **ARTIFACTS ARE INTEGRAL PART OF COGNITION!**

4.7 SYNERGETIC INTER-REPRESENTATION NETWORKS

A theory that starts from the notion that artifacts are integral part of cognition process.

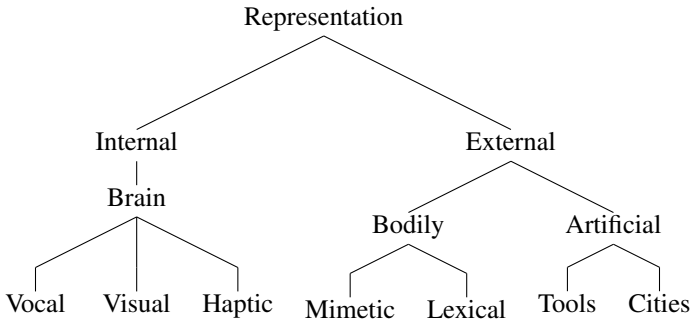
Synergetic: Circular Causality **Inter-Representation:**

Cognition theories Classical Perception Embodied Perception action SIR Perception Action Production

Table 2: Cognition Theories

(Stages and characteristics)			
Theory	Feature (1)	Feature (2)	Feature (3)
Classical	Perception		
Embodied	Perception $\Rightarrow$	Action	
Inter-Representation	Perception $\Leftrightarrow$	Action $\Leftrightarrow$	Production

Humans come to the world with two kinds of representation capabilites:



Inter representation networks (IRN): Many cognitive processes evolve as an ongoing interaction between internal representations created in the mind/brain and external representations created in the world.
In this process we can identify two kinds of **IRN** processes:
Technical processes such as the multiplication we make external representation. *Creative processes* such as painting, sculpturing, developing an idea by means of writing.

In **SIRN** (**Synergetic Inter-Representation**), there exists three types of processes: intra-personal, inter-personal and collective.

1. **Intra-personal** SIRN processes evolving by a single person.
2. **Inter-personal** refers to a sequential SIRN interaction between several persons.
3. **Collective** refers to a collective SIRN process in which several persons are acting simultaneously and interact via a collective (emerging) medium, for example a city

4.8 INFORMATION THEORY

Information theory as develped by C.Shannon Information bits $I = logZ$ Z is a positive number meaning the number of states that can occure.

$$s = -\sum_j p_j log_2 p_j$$

Information theory and it's applications to cognition theory (Attnive 1958, 186). Information is a function not of what the stimulus is, but rather of what it might have been Example of information to cognition relative degree of information Circle i is Low (High redundancy, high certainty). Little information L-shape lines i is high (low redundancy, low certainty). Higher information

To apply Shannon Information measure it is necessary to create semantic categorize for the elements of a city. In the book: Information Adaptation: The interplay Between Shannon Information and Semantic Information and Cognition the presenter made a study linking this two concepts for the study of cities urban design. Natural language processing mechanisms can be used to the studies of cities. What natural language processing can add to the study of the way people in the city lives? Is people leaving in cities with higher or lower information measurements actually living better? Is there a correlation between Shanon's Information measure and quality of life in a city.

Fluctuation in information when an individual agent starts seeing from another point of view characteristics of the city. Relatively poorer life conditions (within the city) we should see when this fluctuations periods appear.

$$SS_0(QL_A) \rightarrow F_0(QL_0) \rightarrow SS_1(QL_B)$$

Betancourt Allometry growth of certain variables of the city.

5 CONCLUSIONS–

At the end of the seminar participants were asked to present how we can incorporate the newly learned concepts in our field of study.

Full project link (includes original presentation from teacher Portugali and participants list) is :

`https://github.com/EduardoHidalgoGarcia/SummerSeminarNOVAIMS2019.git%20Friday.ipynb`

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