eCAADe 2010, Zürich. September 15-18, 2010.

SOMcity: Networks, Probability, the City, and its Context

Klaus Wassermann[1]

[1]*Laboratory for Noosynthesis, ETH Zurich, Computer-Aided Architectural Design – Institute for Technology in Architecture*

[1]*wassermann@arch.ethz.ch*

Abstract. Cities have always been locations of densified collections of various kinds of networks. While usually networks are conceived as a kind of immaterial logistic devices, we emphasize another quality of networks, their capabilities for associative learning. We propose autonomous associative networks in their probabilistic flavor, such as so-called Self-Organizing Maps, as abstract candidate structures for simulation experiments and as actualized structures of real cities as well. The properties of Self-Organizing Maps allow to introduce a whole new area of analytical procedures to conceive of the city and its properties. It also makes it possible to operationalize the attractivity of cities or the success of the implementation of urban planning.

Keywords. urban theory; participation, self-organizing maps (SOM); associativity; network-based metric;

Introduction

Ever since the first cities in Mesopotamia, people have been enchanted by the particular quality of these dense, manifold, overlapping and mutually interfusing communities, even as that very density has always created more or less serious problems and frictions. Whether they have been founded as a consequence of conditions ultimately to be characterized as economic (cf. Eaton 2003), whether they came into existence more by cosmic reasonings like the cities of the ancient meso-american cultures (Mumford 1961), whether they have been intentionally planned or randomly grown by accretion, they have always developed a status as an entity capable for storing (Fassler 2006) and processing materials, immaterials (like information), and the glue between them (money) at an accelerated rate. Actually, it is this increased rate of turnover which has been responsible for the comparable wealth of cities and their inhabitants.

It is thus not surprising to find reasonings about the city and its structure since its inception, even as a part of urban life. The people of ancient Athen for instance have discussed the structure and the size of their small city at least since Platon (2003). From our perspective it is somehow funny that they seeked to determine the optimum size of a city as approximately 10’000 inhabitants. Today, we can understand that the structure of the political organization has been a particular constraint on such ideas as well as on the development of the city itself. What we can learn from that, and its historical relativization, is that it might be somewhat problematic to refer to the concept of optimization when discussing the phenomenon of the city.

Despite all the discourses and discussions about urban development, quite likely spurred by the constantly increasing proportion of people living in cities, we still do not completely understand the phenomenon of cities, its qualities and specific dynamics. To draw onto the saying of “complexity” obviously does not help much. As a consequence, there are still no convincing arguments about the reasons for failing or succeeding of larger scale urban planning (cf. Hillier et al., 1983, Schlüter [1], Koolhaas 1997). This brings the question about an appropriate level of theorizing about urban planning to the fore, or in a Deleuzean term, the way of theory-practicing (Deleuze 1986).

It might proof not to be sufficient to build extensive cartographies about the material effects and the engraved trails of the activities of people, that is, to follow the representationalist illusion of describing things as they are. The dynamics of the immaterial, predominantly the openness and indeterminacy of making use of buildings or any grouping of buildings, seem to be at least equally important, as it has been demonstrated by Koolhaas and his co-editors (Koolhaas et al., 2001). If we accept that the immaterials of a city are rooted in the activity of its inhabitants, and in the dynamic change of the buildings and the infrastructure itself, we find a different direction for our investigations. The form of housing estates, the geographical distribution of real estate values, or the layout of traffic systems, they all form networks (Baccini and Oswald, 2003, Cullen and Godson, 1975), as we are used to say today.

Neither of these three publications, however, refer to the networks and its properties in its own right, which holds even for rather abstract analysis oriented on topology (Hillier 2007), specifically devised on a structural and empiric understanding of human inhabiting of buildings and cities. The concept of "network" all too often remains in the status of being a means for geometric descriptions, it has not been recognized as an abstract structure beyond logistics and topology, and thus the specific dynamic properties of certain types of networks as an active part of the city.

This neglects two important aspects, which are so-to-speak located inside the network. The first aspect concerns mediality and the emergence of new media in any milieu of densified communication (Bühlmann 2009). Everything can turn into a media, if there is some routine and regularity in the flows of immaterials which matches density. New media in turn allow for new means and new ways of getting connected. In that way, urban surrounds are a fertile substrate for a particular self-sustaining process of creating immaterial networks. This leads us to the second aspect which usually remains unnoticed: Some kinds of networks start to develop a certain degree of autonomy, a capability to learn, to associate and to sort out bits of arbitrary information. Noteworthy, the type of stored and processed information is completely independent from the (im-) material conditions of the respective network.

Networks

While only a few decades ago the term was almost unused, nowadays it is a common term, not only in everyday language. Literally everybody seems to have a clear picture about it. This should not be surprising since we are all experiencing several giant technical explications of the concept of network today. Without any doubt, we have started to make our living in the dispositive of the network explicit. The internet with all the necessary cableworks beneath, the WWW and all the social and virtual networks on top of it have developed into an essential infrastructure. That infrastructure of networks is continuously expanding and strengthening, not just by a kind of blind evolution, but rather as a goal-directed enterprise. All the more it is astonishing, that there is comparatively little cross-disciplinary, urbanistic or even philosophical reflection on them, and the existing ones tend to focus more on the political aspects of networks (Shaviro 2003, Galloway and Thacker, 2007).

When referring to or using the concept of networks itself, and also when speaking about networks, most people think of the geometrico-graphical aspects of them. In other words, the static aspects of their topology dominate, literally, their "layout," or their transduction or transport capabilities and capacities. While it is true that "being connected" means that I can send something from point A to point B, it is equally true that it is not the whole story. Thinking in this way about networks we immediately find ourselves in the domain of logistics, trying to optimize time, energy, material, needed for setting them up and throughput capacity. The necessity for a flexible routing between arbitrary points A and B usually lead to a cell-structure of hubs and terminals, which we can observe for air traffic networks, mobile communication networks or the hardware of the internet. As interesting and powerful as these structures are, they are highly deterministic machines for organizing flows. As a matter of fact, they have to work deterministic because they are essential infrastructural elements for our contemporary life form.

Nevertheless, there is a completely different type of networks showing drastically different phenomena, namely associative capacities and structural learning. Astonishingly, even in dedicated state-of-the-art anthologies about networks this very property of associative capabilities remains completely unnoticed (e.g. Mitchell 2004, Fassler 2001, Castells 1996). It is very important to understand that associative networks are so different from logistic networks as stones are when compared to air. "Being connected" cannot be reduced to the logistic aspects of real-time availability and mutual accessibility (Shaviro 2003). Before we can develop this further, we first have to discuss the possible ways to describe the morphology and the dynamics of networks.

Network Morphology

Networks can be thought of consisting from nodes and edges, as it happens in mathematical graph theory. Nodes are locations where different edges meet. Both, nodes and edges can have dedicated properties, even varying from location to location. Even a binary hierarchy is a network from the formal perspective. Nodes, or edges, may have a small storage capacity, e.g. causing delays in the transmission. Edges can have different weights, that is, different capacities for transmission. Nodes and edges, however, are not the only building blocks, or modules, which can be used to describe a network.

Beyond this more classical or usual way to conceive of a network one can think about how to reflect the form of the network as a whole, i.e. as a figure. If we want to draw upon the form of a network we have to operationalize it somehow, we have to make the form measurable. Hillier (2007), and drawing on his results, Benjamin Dillenburger (2010), have used various connectivity measures of city layouts or floor plans. Inevitably, we loose some aspects of that "wholeness" in doing so. For that reason we always have to use several such measures and operationalization procedures, the relevancy of which then have to be related to a chosen purpose.

Nodes may be conceived as partially or completely free-ranging entities, exchanging partially or completely number and types of relations and properties at a new place. Obviously, this introduces further possibilities. In a probabilistic framework like the one we are proposing here, there is, however, no need to explicitly specify such capabilities for ranging around at all. Usually, we think of nodes and edges as crisp, well-identifiable entities. This is firstly unnecessary and secondly they pose a serious limitation of the overall capacity of the concept of networks. Both, edges and nodes can be formulated in a probabilistic manner. That means, any of the parameters describing a node or an edge do not “have” just one well-defined value. Quite differently, parameters can take any value weighted between 0 and 1. Instead of identifiable relations we find randomized relations, or, as a neologism, "randolations." Our concept of “randolations” is related to the quantum-mechanic notions of waves of probabilities, a track which we cannot develop further here. In extreme cases it is even possible that the whole node or edge, or, dependent on the complexity of the network, even the parameters might vanish for a particular period of time. Naturally, one can think of such volatile parameters as results of a further level of regulation, which also could be dependent on the overall behavior of the whole network itself. This element of self-referentiality is by no means empirically exotic or forbidden for formal reasons. Quite to the contrast, it is the common case for (but only for) associative networks. Concerning formal aspects one could point to a still developing branch in mathematics, the so-called non-standard model theory and non-standard analysis.

From our perspective we distinguish, as said before, two large classes of networks, logistic networks and associative networks. Logistic networks minimize distances, connections, and redundancy, thus time of transmission, often under the constraint of a maximized coverage. In two dimensions, the result often looks like leaf veins, or trees. Logistic networks often are described as being scale-free (Barabasi and Bonabeau, 2003) or self-similar. Associative networks, in contrast, not only often show a considerable redundancy concerning the connections between their nodes, they are also characterized by a high overall connectedness. Most of the nodes are directly connected to most of the nodes in their vicinity. Such dense networks not only develop memory, here understood as a reconstructive capacity for inputs from equivalence classes, which is called pattern recognition. They are also able to separate dissimilar inputs, or observations, into different groups or classes, which are more “pure” than any globally calculated average. This class-building could be called projective or constructive pattern detection.

Associative networks differ from their logistic siblings in a further remarkable manner. Dense networks with associative capacity are pure informal entities, for which it does not make much sense to apply the concept of causality. Logistic networks, on the one hand, are seriously expected to behave linearly and perfectly predictable like Newton’s apple. Any event therein can be reduced to a formula, and so everything is predetermined in advance. Associative networks are creative instead. They may not change their structure even on a large or strong input or disturbance, while, dependent on their historical development, they may change their structure drastically for some rather small inputs. In other words, it is not possible to dissect a situation into causes and noises anymore, to separate inputs, operators and outputs. Associative networks not only learn and associate different bits of information, they associate also what is generally labeled as “object” and “subject” as well. As a consequence, these dynamic aspects of associative networks can’t be recognized from their topological description alone.

Before we will advance in applying the concept of associative networks to the concept of city (and the realm of cities), we first have to briefly introduce a well-known representative of this class of networks, namely the so-called Self-Organizing Map. Usually, they are used in the task of data analysis in a wide range of domains. Here, we abstract from that usage by re-interpreting the structure of Self-Organizing Maps in a ways that they become applicable for questions in urbanism.

Self-Organizing Map (SOM)

Initially, the Self-Organizing Map has been developed in research about statistical data analysis. It was Teuvo Kohonen who recognized a particular associative capability of certain correlation matrices very early (Kohonen 1972). While working on conditions of that associativity, he eventually succeeded in finding the appropriate level of abstraction when referring to the brain as the very prototype of associative structures. Kohonen did not simulate neural networks by simulating a hive of artificial neurons, which has been the major stream of research led by psychologists (McClelland and Rumelhart, 1985) or physicists. Instead, he took the probabilistic approach. The SOM is a probabilistic representation of populations of interconnected items, which results in a remarkable capability to learn and to associate. Any of the nodes of a SOM can be conceived as an instance of local memory with an additional capability to perform a simple rule of selection which is applied on the information it collects. Usually, nodes of SOMs are thought to collect somehow similar bits of information, but the exact body of rules performing these similarity considerations may vary to a large extent. A central design property of SOMs, however, is the structure of arrangement of nodes. All members of the whole population of nodes are interconnected in a topological way, i.e. they are all members of a large number of overlapping neighborhoods of different ranges.

A SOM typically implements a nonlinear projection of a probability density function p(x) from a high dimensional input data space $R^{\mathbb{N}}$ onto a two-dimensional grid of simulated neurons such that topology is preserved within the limits of the reduction of dimensionality (Kohonen 1995). A compressed representation of the basic idea is given by the following formula, which expresses the development of the representation held by one node of the SOM between two time steps, from t to t+1, of the learning process:

$$m_i(t+1)=[1-h(t)]m_i(t)-h(t)x(t), \text{ with } 0<h(t)<1 \text{ and } h(t_i)>h(t_i+1) \qquad (1)$$

where $m_i(t) \in R^{\mathbb{N}}$ is a weight vector of node i, $x(t) \in R^{\mathbb{N}}$ is an input (stimulation) vector, and h(t) is the neighbourhood function (Walter and Ritter, 1996).

Described in everyday language, observations are introduced into the SOM-network just by adding them one after another into the most similar node of the network, thereby adapting that node's visible surface (the weight vector) and, radially decreasing, also its neighbourhood. As time progresses, the neighbourhood may shrink and the influence of new observations decrease. When applied in a data analysis task, these changes are monotonic, i.e. they change continuously in the same direction. This is, however, mostly a technical trick to accelerate learning and convergence. It is not a necessary condition for the realization of the properties of segregating bits of information.

This process whereby additional information is introduced into an ever changing topological population of "nodes" leads to a self-organized sorting of the observations across the grid which reflects the manifold of possible sortings, i.e. the topology of the data. To achieve that, the SOM-process does not need a target criterion, albeit in data analysis it can be helpful to introduce such a criterion. SOM learning is competitive, and can be either unsupervised or supervised. Its inherently probabilistic and non-representationalist approach renders it into a very general structure, which can actually learn anything. Not only data coming in as structured vectors of property values can be learned by it, but also data which cannot be structured before learning, like language

(Kohonen et al., 2000) or images. Compared with standard neuronal networks or artificial swarms, SOMs are both more powerful and more general, although it is possible to create hybrids between all of them.

Generally, it is important to see that a SOM-like network represents an autonomous memory and classification capacity, which are largely independent of the materiality of the nodes or the edges. Else, the constructive separation and the recall of a particular class is usually dependent on the other classes stored in a SOM network. A SOM-network is able to create an assortative 2-dimensional arrangement of items, which may be initially described by hundreds, or even (tens of) thousands of properties. It projects a high-dimensional multiplicity into an area. Within the total area of a SOM you will then find sub-areas, which collect "similar" cases and thereby represent groups of resembling items, easily falling into resonance due to their similar setup. If applied within an evolutionary setting, the SOM is further able to reduce the number of descriptive properties as far as possible for a given sorting task. Quite interestingly, even the kind of similarity evolved at a particular location within the SOM may be dependent on the overall "experience" stored in the SOM. Since a SOM is a memory as a whole and at the same time it consists from items itself stuffed with a comparably "small" memory, SOM can be stacked or nested. Without loss of generality, one can start with an arbitrary layer.

For these reasons, the SOM may be regarded as the most general structure able to learn, memorize and sort. It is just this generality which allows the application of the SOM framework to our context, which remarkably enough, as it seems, could not be achieved by any other method.

The Mapping

In the previous section we have introduced Self-Organizing Maps (SOM) as an abstract associative structure showing a lot of remarkable properties. Its generality, which is mainly a result of its probabilistic approach, allows to map any kind of network from the "real world" onto it.

The nodes of a SOM may be conceived as an "actor" in the sense of Bruno Latour's Actor-Network-Theory (ANT) (Latour 2005). However, the only definite properties we need to assign them is a small and simple memory, the capacity to filter bits of information before accepting it and/or the capability of transmitting information to its neighbours. An "actor" in the sense of the ANT comprises any distinguishable entity, like buildings, streets, building rules, administrative procedures, cars, trams, cable cars and other vehicles, deterministic networks, and of course humans and their information-technological devices like smart-phones or computers. We do not need to make any assumptions about the movement of the nodes, which not only would render them explicitly into agents, it would also cause a lot of troubles in the then necessary fixation of the parameters for the simulation. Quite to the contrast, nodes are related simply by their capability of passing information to at least one of their neighbours. In this way, we could take the nodes as the medium for the information passing through the network, a perspective first proposed by Vilém Flusser (1997, p.178).

Our experiments with SOMs in this context indicate that the associative and memorizing capability of a city, or even of a quarter within a city, is strongly dependent on the spatial layout of it and the parameters following from that, like the distribution of traveling speed of the inhabitants. It is, however, not the spatial layout which is the "cause" for a particular urban culture. On the basis of experiments on a large number of city layouts we hope to develop a SOM-based metric, which could serve as a basis for comparing existent city layouts or planned changes of layouts without loosing the important aspects and without being trapped by reductionist statistics. This then could be used to explain the dynamics of the attractivity of cities, or to find an answer to the question of how to drive the networks of a "city" to either forget or to recall the right things. This would result in a much more integrative and less directivist way of implementing planned changes in the urban context.

SOMcity

As we have seen, the random processes of a city can be mapped onto a SOM, regarding things like human actors, device actors (Latour 2005), buildings or traffic. Taking a rather abstract perspective before this background provided by the SOM, a city can be conceived as consisting from a unorderly set of networks, each of which sets up a particular active memory. As said before, associative networks are built from items of which each owns some memory capacity. Here we could build a bridge to the philosophy of Bergson (Bergson 1990), and his search for the relations between matter and memory. Different networks form different, presumably overlapping and/or nested layers of different kinds of memories, differing from one another by their duration and capacity. Some of the networks have very little capacity to learn, like the road map or the telephone network, but on the other hand, they preserve the tiny amount of stored information very well. Other networks are able to store and recall much more information, but those are more volatile at the same time. One may think here of the local traditions of building styles, of ways to organize public transportation, or the general attitudes towards screen-based media facades.

It is feasible to assume that dense networks, with a lot of redundant interconnections between their "nodes," become able to learn and to associate, i.e. to process information. As the examples of biological neurons and the artificial neural networks proof, the information stored and processed by a network is completely independent from its materiality. The same obviously holds also for the networks a city is built from. What's going on inside those networks is invisible, but it influences the behavior of the nodes irrespective to their own capabilities of storing and processing information. Quite obviously then the hypothesis claiming that a city is just two things, a physical and a social one, as it has been proposed in (Vaughan 2007), can not be kept any longer. We have to reflect the realm of the information as well.

Already Wiener emphasized, that "information is information not matter or energy" (1948). Information can neither be reduced to the social nor to matter or energy. Somehow the physical and the social both "contain" information, they are "in-formed" as the media philosopher V. Flusser expressed it (1997, p.14). After all, we know also from Latour's work on his Actor-Network-Theory (2005), that we can not maintain a clear-bounded distinction between non-living agency and living, social agency in the narrow sense. Thus we propose to introduce the informational as a third component into the conception of cities. The informational we understand as a very basic onto-epistemological class. For instance, it is forming associative networks, from which we have to expect that they are largely autonomous, unfolding their own dynamics, sorting out the different and acting against the statistical mixture on the level of the processed information.

It is this capability for regular selection which introduces semantics to the concept of associative networks. While logistic networks are equal to deterministic machines and thus devoid of any internal meaning or semantic aspect, the opposite is true for associative networks. Insofar we can not avoid using the concept of associative networks in thinking about the city, we have first to conclude, that cities generate their own semantic content. From this follows secondly, that the hypotheses of urban segregation being a syntactical phenomenon (Vaughan 2007) can not be appropriate. Such, urban form of life including segregation phenomena would be based on a few simple or even formal rules, the city would be literally a space machine, an cybernetic phantasm rooted in the era of first computers (Zuse 1999). Sorting and selection, however, can not be done without accounting for semantics. That semantics, however, which shapes the city, has also nothing to do with human knowledge, as it has been sometimes proposed (Hillier 2003). The city develops its own semantics via the invisible networks, a phenomenon probably closely related to Foucaults fields of statement (Foucault 2002).

Albeit the concept of SOMcity deals with effects which emerge from a population, it should be also clear, that SOMcity is not about concepts of so-called “collective intelligence” of swarm-like entities (Levy and Bononno, 1999). A city is not a swarm, which lacks deep organization and thus historicity. The epistemological effects we focused here are a-human (Galloway and Thacker, 2007), i.e. beyond the sphere of human cognition, although it concerns human culture seriously. The city is an epistemological subject in its own right.

SOMcity, the Second

It is clear that cities with a strong and stable culture equipped with a bounded creativity are more attractive than their overly volatile, static or even declining competing relatives, and it is equally clear that it is not just the spatial layout of the street network which as such determines the attractivity of a city. It is quite important to understand that there is no such thing like a “genetic code” of a city (Hillier 2009), as this seriously neglects the role of associative networks and their semantic activity. At the same time such a notion naively inverts the relation of genes and the phenotype as it is known in biology.

The probabilistic urban networks as we conceive them here by using the formal template of the SOM have a further quite appealing property. If we think of the nodes not as stable and inert entities, but rather as modulated ones, whose capacities and preferences are dependent on the overall “field” and the local neighborhood, we find the possibility of a transition between reaction-diffusion-mechanisms (Turing 1952) and associative networks. While the first are highly creative und productive, the latter are preserving and able to learn. We find the possibility of a phase transition along a very small number of parameters, built-in right into the life form of the “city” itself.

It seems quite reasonable to expect that the cities itself develop a culture of expanding their associative networks of which it is made from as well as the respective logistic networks which are needed as infrastructure for them. Public artwork, focusing on the participatory aspects in a playful manner (e.g. [2], [3]), can represent an important contribution to the healthiness of urban networks, as such activities may be able to seed additional associative networks in a city by push-starting new symbolization processes. A possible further step of that evolution would probably be to make the associativity of the immaterial networks directly visible by some kind of semi-virtual simulation, which would act as a bridge between the simulated virtual and the social reality. It is intriguing to think about such an environment which itself would be able to learn and to adapt to the conditions and processes of the "real world." In such a setup, both the real world and the virtual world would function as a distributed reference in a mutual way. The associativity of an urban network itself would be rendered visible, thus possibly becoming a subject of socio-informational behavior. In fact, a student project at our chair called "AvaGarden" already demonstrated the feasibility of the approach on a small scale [4].

Taken together, we can clearly see that based on the perspective of associative networks we not only can rework the way we contextualize what usually is supposed to be a "city," this spatial layout of living together which is so typical for human culture since its first historical traces. Equipped with a new conceptual tool in urbanism, we even can start to think proactively about further development of a city in a new way, both unspecific and concrete at the same time, exerting control without control, by taking into account the special quality of invisible urban networks.

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