Self-Organising Space (SOS): artificial neural network spaces

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Abstract

In the processes of continues functional differentiation the contemporary society increasingly displays the characteristics of complex, distributed systems. In this condition architecture can no longer rely on top-down reductionist methodologies in ignoring the constituting importance of contextual parameters. The present paper describes how Artificial Neural Networks can be employed to design with-in the underlying logic of our society -the logic of distributed systems. In computer simulations the paper explores the capability of ANN to Self-organisation: Neural Networks Architectures absorb and adapt vast amount of urban data in order to adjust their organisation to exterior changes through interior structural reconfiguration, thus producing adaptive spatial formations.

Introduction

In the now emerging 'non-linear' understanding of biological, psychological, social and urban phenomena, the mechanistic conception of architecture is becoming increasingly in need of extension. It no longer performs within the currently changing socio-cultural environment. Rooted in the modernist tradition the architectural discourse of today has only started to come to terms with the dynamic nature of architecture. Informed by the modernist paradigm architecture has been understood as something static, factual and objective with the design of objects enclosing space in the centre of the architect’s pursuit.

In understanding space -the central concept in the architectural discourse- as an emergent quality of action and interaction between individuals and groups with physical environment it can be re-describing as a parallel distributed system, a self-organising entity. These spatial systems are autonomous from their progenitors, people. They built intricate systems and sub systems capable of interaction and inter-communication. These systems are constantly re-building themselves in a process, which is called structural coupling in Luhmann’s Theory of Social Systems.

This paper discussed an attempted to use a distributed connected algorithm base on Kohonen self-organised maps (SOM) as a “perceptual aid” for creating geometric mappings of these spatial systems. In an epistemic shift from the physical delineation of space towards a reading of its dynamic nature the generated mappings are intended to capture the self-organising nature of spatial processes and subsequently provide the informational environment for architectural interventions.

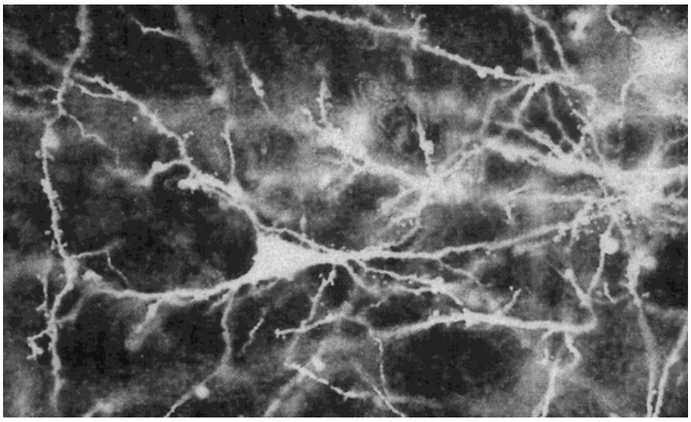

Fig. 1 Cartography (scan) showing pyramid neurons and the network of axons and synapses

Systems

Part of the problem with the traditional static conception of space stems from the way space is perceived as well as the conceptual framework at hand to describe and structure it. In the modernist view Space is seen as the backdrop or container for objects and subjects (us). It can be measured and described in terms of the Cartesian Space; it can be analysed with help of the Descartes analytical method. His method was highly successful in dealing with systems of unorganised complexity, which are understood with statistics, the laws of change, and in the last resort the second law of thermodynamics. It facilitated the development of new types of spaces and structures. But ultimately it is now limiting the development of new kinds of architectures because of it static concept of space. The paper proposes an understanding of space as a system of organised complexity. In that Space carries the characteristics of complex systems such as wholeness, teleology, control, self-regulation, differentiation all of which are difficult to accommodate with the conventional discourse.

Central to the perceptual shift is the term ‘system’. A system always describes a whole, which in contrast to the elementary consists of parts. To understand space as system implies the fact that it has a structure. The term system always refers to the whole in the sense of unity. In the traditional modernist conception an architectural entity is that of a complete whole made of components or parts in some summative manner. The whole is developed or made on the practical basis of putting parts together and making them fit. In this conventional way of working, the whole develops by integration of the parts. It implies a linear sequence: first the parts, then the whole. The implication is that the whole always comes later than its parts.

Emerging Spaces

As discussed by Bortoft (Bortoft, 1996) in detail the whole of a system is neither the result nor superior ordering principle of subservient part. Systems constitute a whole made from parts, which are related in a reflexive and non-linear manner. But a part is a part only inasmuch it serves to let the whole come forth, as a material thing it is unimportant. A part is only a part according to the emergence of the whole, which it serves. At the same time, the whole does not dominate, for the whole cannot emerge without the part. The whole as whole is neither earlier nor later. Such is the relation between the people as progenitors and the spatial systems the emerge from their interaction. One particularity in this complex is the fact that the ‘parts’ are intelligent, conscious being. And despite of this fact that they give rise to these emerging spatial systems they are not aware of them. We are not equipped with the necessary sensory apparatus for the detection of such systems.

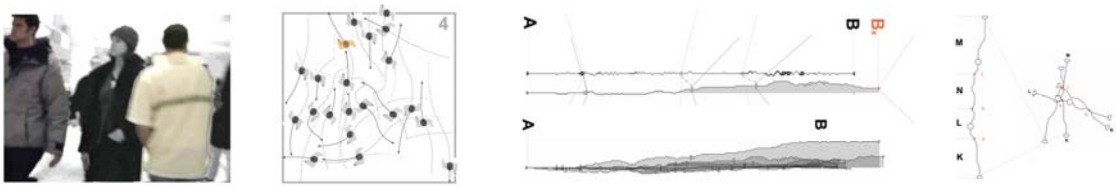

Fig. 1 Mapping Occupants: systematic diagrams of encounters and movements describing emergent spaces

Spatial System - Closed System

Closed systems are in reality impossible to find. They exist only as very useful abstractions of the real world. It is a theoretical position formalised by the founders of modernism such as Galileo Galilee and Rene Descartes particularly in his book 'discourse de la methode...' Closed systems do not maintain any exchange with their environment like physics experiments in the laboratory problems are considered in separation to their surrounding. In the modernist urbanism of the 1920s, for example the models proposed by Hilberseimer, the representation of the problem of housing was taken out of its context and reduced to variables such as circulation and the provision of sunlight and fresh air. As a consequence the proposal became rigid and repetitive. By default these kind of closed systems do not respond to their environment and do not allow for some form of organised complexity. They exist, scientifically speaking, thermodynamically closed in a state of stable equilibrium.

In contrast open systems are thermodynamically and materially open. They are able to extract or dissipate entropy and matter into and from their environment. Because of these possible exchange processes the system is able to develop an inner dynamic, which allow it to settle into a stationary stable state far away from thermodynamic equilibrium. On one side the continuous material and energetic exchange with the environment makes the open system only possible in its context. On the other side as a result of its inner dynamic, the open system is able to maintain is organisation, which constitutes its identity despite environmental changes. It becomes autonomous stable and independent of its environment.

In this organisational closure (Maturana79) the system selects that 'information' from its environment required for the maintenance of its organisation. The environment, i.e. everything which is not part of the system, on the other hand is not able to influence the system in a linear causal manner. Spatial systems are dependent on their environment, which are the individuals and groups that interact. In this relation we as progenitors can only trigger temporal structural changes of the system’s inner organisation and not determine the system’s behaviour directly. The spatial system has the ability to respond to perturbation by its environment but this is achieved only by structural changes within the system itself. This ability of open systems is summarised in the term self-organisation thus the systems capacity to rearrange its internal organisation in case of environmental changes. Consequently it is from outside that spatial systems are not linearly causally determinable. They have a life on their own.

SOS - Communicative Interaction

Different self-organized spaces enter a relationship of interactions. Mutual perturbation develops into a relation of structural coupling. Each spatial subsystem response as consequences to the structural coupling with a systemic re-structuring of its own order to maintain their organization (homeostasis). In the autonomous relation to the pro-generating ‘parts’ spatial systems have the ability to communicate between themselves.   Furthermore the spatial systems enter a process of functionally differentiated. Those subsystems act as close autopoietic systems. They create environmental perturbation, since they are mutually environments for each other, that generate inner structural adaptation, which stems from a process of structural coupling mentioned above. Again these potential 'structural couplings' of spatial subsystems are invisible to the human observer, because he is locked in his own closed, system with an independent structural coupling for which specific semantic is available.

The human differentiation of space/ environment has been generated communicating in language. In contrast object/ field of space/ environment will be differentiated through the self-organising activities of spatial systems. Therefore, unconsciously we are occupying 'spatial differences' that are not detected by our communication and that can only be traced by simulating or modeling spatial systems.

Modeling Self-Organizing Spaces

The SOS is an artificial neural network, modeled on the basis of the Kohonen algorithm. The Kohonen self-organising map as a neural network has no hierarchical structure of input layer, output layer and hidden layers, but consists solely of one layer, containing a matrix of vectors. Since the distinction between input and output layer is missing, no aims can be set of what the outcome of the learning should be, making the SOM a unsupervised network.

Essentially, the matrix vectors are being compared to a vector space. Each vector's direction of the vector space is compared to each vector of the matrix. The matrix vector that has the smallest Euclidean distance is being declared the winner. The distance between the winner and the vector of the vector space will then be decreased to a small margin over an undefined number of generations. The winner excites the matrix vectors in a pre-established surrounding, which then will be assimilated to the vector of the vector space as well; however, less rigorously. Matrix vectors outside of the winner's neighborhood will be inhibited, thus making increasing their distance to the vector space. The functions of excitation, inhibition and neighborhood are proportionally tied to each other via a time function that is decreasing monotonously, exponentially, etc. until the minimum distance of difference between the winner and the vector of the vector space is reached. This competitive process of learning is called Hebb's learning rule and is repeated until the matrix of the SOM has learned all vectors of the vector space.

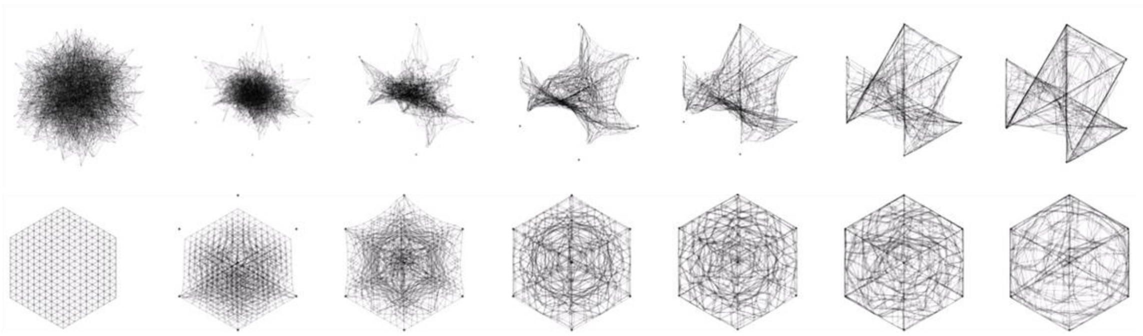

Fig. 3 SOM learning same vector space from different initial conditions, resulting in distinct interpretations

The Kohonen algorithm for neural networks translated into a spatial systems bears close associations to salient qualities of complex systems. The recursive feedback between all nodes of the matrix avoids an iconographic representation of the environment. Environmental perturbations are adapted by and distributed over all matrix nodes de-localising meaning.

Meaning therefore can only be established through differences of node constellations, which are supported by the neighborhood function (Mexican hat function).

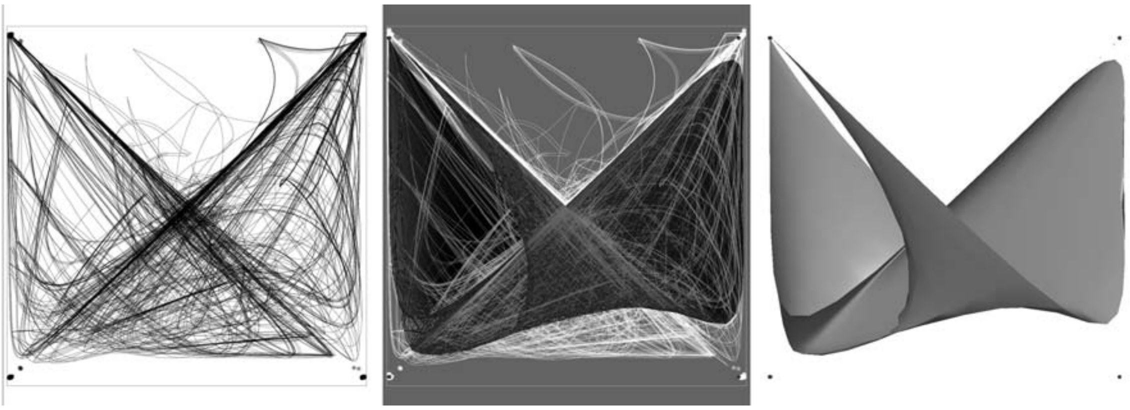

Fig. 4 Network history of topology adapting to changing input space (left); it's visualized current state(right)

The recursive feedback creates an unpredictable, historic dynamic of the network; one can not anticipate what effect the action of one node/ group of nodes will have upon the others. Seemingly contingently, the controller becomes controlled; center becomes milieu, and so forth, hinting at H Haken's synergetic second order cybernetic "slave system". Further, equilibrium is avoided by Hebb's learning rule by not eliminating the Euclidean distance entirely between matrix and vector space, for as Derrida stated: "interactions are only possible if there is some 'space' between the signs. … The meaning of a sign is the result of the 'play' in the space between signs."

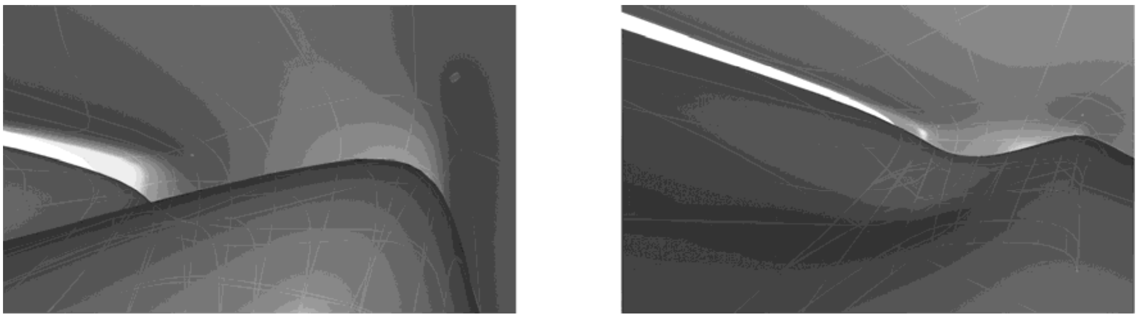

Fig. 5 Shift Space: transition between adaptive vector spaces, showing emergent spaces from interaction

Conclusion

Space is not the unstructured hollowness that surrounds us. On the contrary space is a complex entity. It is highly structured, a fact which is not perceivable due to the lack of the right sensory equipment. But, as we have demonstrated, these systems can be uncovered using SOS modeling techniques. This paper can only be a starting point. More work needs to be done about the precise working of structural coupling process as well as the development of functional differentiation of space into sub-systems. Self-organising spatial systems, we believe are a powerful concept which can help us to learn more about as and our environment. It will provide architects with a tool for design new kind of spaces; spaces that are truly dynamic.

Reference:

Benedikt M L, “To take hold of space, Isovists & Isovist fields” *Environment & Planning B* Volume 6 pp 47-65 1979

Bertalanffy L.Von, *General system theory fouhndation development application*, London Allen Lane 1971

Boden M The philosophy of Artificial Life (Oxford 1996)

Bortoft H *The wholeness of Nature* (Lindisfarne 1996)

Broughton, T. ,Tan, A. ,Coates, P.S. (1997). The Use of Genetic Programming in Exploring 3d Design Worlds. In CAAD Futtures 1997, R. Junge (ed), Kluwer Academic Publishers

Paul Coates, Dimitrios Makris Genetic Programming and Spatial Morphogenesis Proc. AISB conference Edinburgh 1999

P.Coates & H.Jackson Evolutionary models of space Proc. Eurographics UK 1998 Leeds 1998

Descartes, Réné. *Discours de la méthode* (Manchester University Press 1961)

Hillier W. and Hanson *The Social Logic of Space*, (Cambridge University Press 1982.)

Hillier W, *Space is the Machine* (Cambridge University Press 1996)

Langton C. G. (ed.) *Artificial Life II*. Proceedings of the workshop on Artificial Life. Santa Fe. Feb (Addison-Wesley. 1990).

Lyotard, Jean-François. *The post modern condition: a report on knowledge.* Tr. Bennington & Massumi (Manchester University Press 1984)

Maturana H.R & Varela *Autopoeisis and Cognition: The realisation of the living*, Boston : (Reidel 1979)

Pask, G. *An approach to Cybernetics* London (Radius Books 1968)

Pask ,G. *Conversation Theory , applications education & epistemology* (Elsevier 1976)