TRAINED ARCHITECTONICS

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Abstract. The research presented here tests the capacity of artificial-neural-network (ANN) based multi-agent systems to be implemented in architectural design processes. Artificial Intelligence algorithms allow for a new approach to design, taking advantage of its generic functioning to produce meaningful outcomes. Experimentation within this project is based on Self-Organizing Maps (SOMs) and takes advantage of its behavior in topology to produce architectural geometry. SOMs as full stochastic processes involve randomness, uncertainty and unpredictability as key features to deal with during the design process. Following this behavior, SOMs are used to transmit information, which, instead of being copied, is reproduced after a learning (training) process. Pre-existent architectural objects are taken as learning models as they have been considered masterpieces. In this context, by defining the SOM input set, masterpieces become measurement elements and can be used to set a distance to the new element position in a comparatistic space. The characteristics of masterpieces get embedded within the code and are transmitted to 3D objects. SOM produced objects from a population with shared characteristics where the masterpiece position is its probabilistic center point.

1. Introduction

Trained Architectonics explores design processes relying on the use of nonlinear procedures to produce architectural geometries. Taken from the Artificial Intelligence (AI) field, specifically from Artificial Neural Networks (ANN), Self-Organizing Maps (SOMs) are used in this project to produce specific new geometry according to an input set of geometry.

ANN are use in machine learning processes and SOMs, as part of this group of algorithms present the self-organizing feature that allow the algorithm to develop itself with no external supervision. This characteristic is based on fully stochastic functions that imply an amount of randomness and uncertainty during the process development.

"The SOM may be described formally as a nonlinear, ordered, smooth mapping of high-dimensional input data manifolds onto the elements of a regular, low-dimensional array" (Kohonen, 1982). There are two vector sets involved in the mapping process: the codebook set – which is the actual ANN – and the input set playing the role of the signal space. The model in the original definition of the SOM is associated with a one- or two-dimensional array of nodes, defining a certain topological connectivity between the model vectors according to the node configuration.

SOMs are commonly used for clustering and visualization of high-dimensional data, to support theoretical analysis or as non-human supervised optimization algorithms in machine learning. The aim of this project is to take advantage of SOM behavior and topology-preserving features to produce architectural geometry. Thus, the discussion should not focus on its functioning or optimization.

2. Indices

2.1. INPUT SET QUANTIZATION

The *input set* in a SOM defines the target of the learning process. As in a human learning environment, the input set acts as an example of exceptional craftsmanship to lead the direction the learning moves towards. For the purpose of this project, in the architectural field this role is performed by architectural masterpieces. However it is a pretty much subjective issue whether a building is or is not a masterpiece. What is important here is the ability of masterpieces to stand out with their own architectural characteristics, becoming unique buildings that are worth to use as study cases.

The case of Le Corbusier's Chapel of Notre Dame du Haut in Ronchamp, is used here due to its characteristic geometry. Its iconicity will allow the reader to place a virtual image of the building and establish a certain relationship of proximity with every outcome (index) produced by the SOM. The other selected buildings – Venturi's Vanna Venturi House; Eisenman's Guardiola House; Van Der Rohe's Farnsworth's House – allow the establishment of different positions in an architectural comparatistic space.

The several outcomes produced in this project act as a *resemblance* (Deleuze, 1994; Eisenman *et al.*, 1995) rather than as a *representation* (Deleuze, 1994; Eisenman *et al.*, 1995) of the aforementioned masterpieces. The code transmits information from the masterpieces – as information sources – in an *indexical operation* (Carpo, 2011) to the outcomes that become *indices* (Figure 1) of the previous masterpiece.

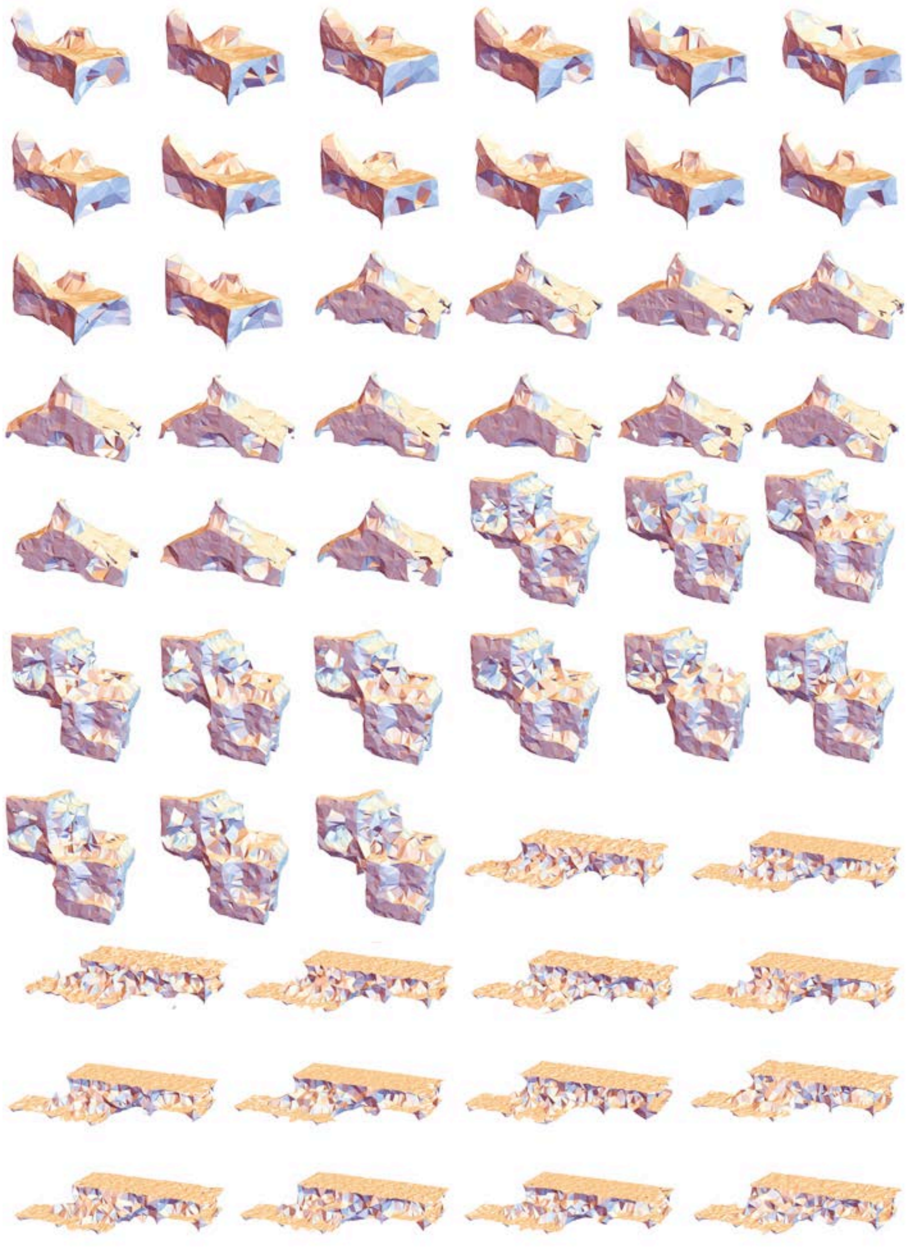

Figure 1. Indices of Le Corbusier's Chapel of Notre Dame du Haut in Ronchamp; Robert Venturi's Vanna's House; unbuilt Peter Eisenman's Guardiola House; Mies Van Der Rohe's Farnswoth's House, produced by stochastic SOMs.

Architectonics are transmitted from geometrical inputs to geometrical outputs through topology, producing a population of individuals that resemble one another, and where the masterpiece becomes the probabilistic center point as the model of learning.

The masterpiece architectural geometry determines the SOM input space. Two operations are required to bring geometry to topology. The first operation consists of modeling a mesh model of the building. This mesh becomes a three-dimensional continuous region in Euclidean space (Figure 2a) acting as the information signal space. The second operation quantizes the previous region into a finite collection of three-dimensional vectors (Figure 2b) rendered as a point cloud and performing as the input sample set. The input set then is defined by quantization of a continuous signal.

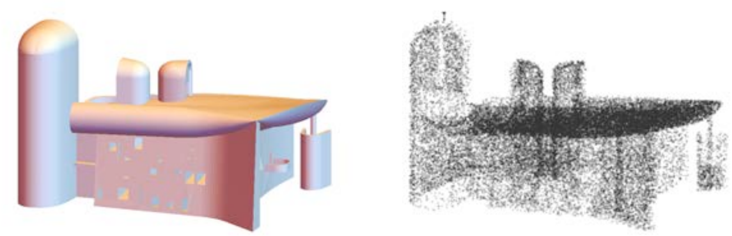

Figure 2. (a) 3D region as continuous domain in Euclidean space, (b) vector quantization of the region. The 3D region must be modeled as an error-free closed three-dimensional mesh.

2.2. CODEBOOK MAPPING

The initial codebook set values have been defined by random initialization as a uniform random distribution of three-dimensional vectors spanning within the domain of the input vectors, adapting the codebook point-cloud size to the input point-cloud size.

The way the codebook vector set adapts to the input set is widely described in mathematics and computer science publications in papers. It is not the intention of this project to offer further details on the SOM functioning. Generally, the SOM produces the codebook vector set adaptation to the input vector set by mapping the input values to the codebook values or neurons. Both codebook and inputs are defined as points in a Euclidean space. In the pure form, the SOM defines an "elastic net" of points – neurons – (or model set or codebook) that are fitted to the input signal space to approximate its density in an ordered fashion (Kohonen, 1982). The SOM maps the input values to the codebook producing the adaptation. The code parses the codebook for every input vector in several iterations. The accuracy of the adaptation depends upon the number of iteration but mainly upon the number of input samples (Figure 3).

The input set defines the information to be transmitted, hence to be instructed. The codebook conforms to the neural network itself. It is initially defined as a set of random vectors in a specific topology. Its initial state is generic by definition, thus it is considered as *pre-specific* (Bühlmann, 2008). The masterpiece input set provides specificity to the outcomes that no longer remain generic and become architectural by acquiring architectonic features. The process of learning consists of the approximation of the neurons to the input set values by stochastic algorithms.

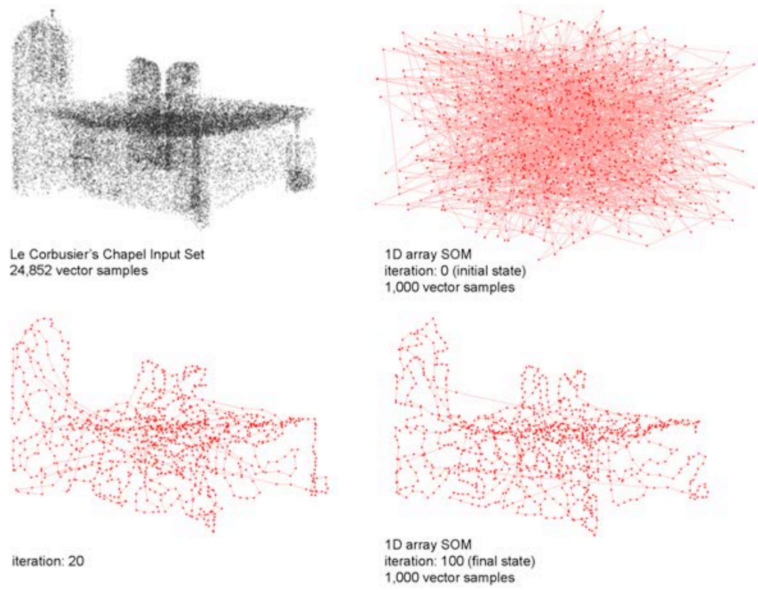

Figure 3. Selected iterations of a one-dimensional array codebook (red) adaptation to the input set (black).

3. Conclusions and Results

SOMs as stochastic procedures differ essentially from deterministic procedures. The production of indices by SOMs allows for the creation of a population of fully independent individuals by always using the same function and keeping exactly the same parameters. Differentiation becomes an intrinsic value of the production system where, in these cases, allows for the transference of form information without the reproduction of structural components. Every produced object is able to perform to a certain degree as the original object, due to their relationship of proximity.

Design in this research is not taken as a process of final shapes definition but as a process of instruction. The final output is not the product or the result of a design or fabrication procedure. It is not linked to any material system. The produced form lacks structure or else, it is provided with an amorphous structure, and still it results in a meaningful object. The role of the designer here is the role of an instructor of learning machines.

Due to the lack of structure, 3D printing is a natural fabrication process able to produce structureless objects. However, 3D printing methods (laser sintering in this case as in Figure 4) still based on post-processed printing must be developed in order to achieve real-time processes, fitting the stochastic SOM behavior.

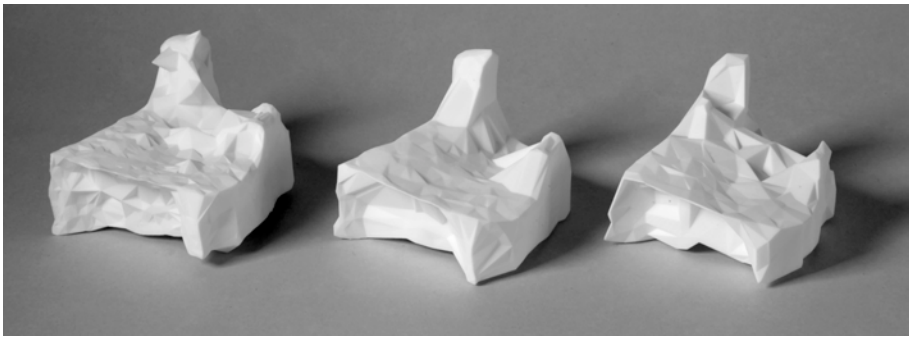

Figure 4. Printed meshes on Le Corbusier's chapel generated by α-shapes from one, two and three-dimensional array SOMs (from left to right).

Acknowledgements

I would like to thank Prof. Ludger Hovestadt and Prof. Vera Bühlmann for their support and the rich background provided within the framework of the MAS in Architecture and Information at the Chair of CAAD at ETH Zürich, starting point of this research. Thanks also to Despoina Pippa for giving me a title.

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