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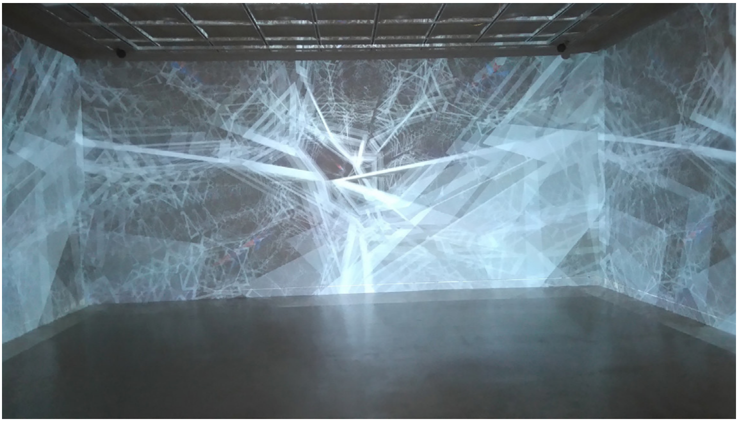

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Suprasymmetry

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Suprasymmetry is a project that deals with AI and dynamic immersive environments. I use neural networks to explore non-euclidean geometries and sound spatialization. I have developed machine learning methods that extend granular and pulsar synthesis in composing and new methods of building and transforming virtual environments. I was particularly interested in the problem of presence and flow in virtual environments. The project proposes a new strategy for creating evolving structures based on the idea of adaptation to a dynamically changing environment and with the use of advanced machine learning and AI methods. The evolving architecture uses physical and virtual processes that are transformed and assembled into structures based on environmental properties and capabilities. The project investigates a living dynamic system as a complex set of natural and cultural sub-processes in which each of the interacting entities and systems creates complex aggregates. It deals with natural processes, communication flows, information networks, resource distribution, dense noise masses, a large group of agents and their spatial interactions in the environment. By significantly expanding existing research, the project creates a meta-learning model useful for testing various aspects of adaptation to a complex dynamic environment. This refers to the difficulty of designing artificial agents that can intelligently respond to evolving complex processes.

Description

The article is organised as follows. The first part focuses on the concept of a dynamic environment. Then the concept of an evolutionary architecture is introduced based on the ideas of adaptation to environmental changes. Popular machine learning algorithms and neural networks have a limited range because they deal with individual tasks and are not sufficient for modelling complex adaptation processes. Therefore, we propose an approach based on advanced methods such as meta-learning, in which the knowledge gained to solve one task can be generalized and applied to many other tasks. We present the applications of meta-learning to analyse and create architecture and art. We test our framework in the form of an immersive installation.

Dynamic Environments

In our view, urban and architectural structures are complex multi-dimensional structures in which natural processes and interactions of large groups of agents, communication flows, information networks, and others are intertwined. The above structures undergo continuous transformations. A dynamic environment is any space that surrounds us and the structure of which changes over time or is modified by groups of agents. There are closed spaces with relatively well-defined boundaries and others that do not have well-defined boundaries, which we can call open spaces. These environments are usually rich, complex, unpredictable, and can generate significant "noisy" data, unstructured and sometimes very dynamic changes.

Adaptation

Evolving Architecture uses the features of natural design processes and relies on dynamic adaptation to environmental changes (Frazer 1995). The analogies of evolving architecture should be understood not only in terms of the applied natural processes of development of forms through natural selection, but also in the restless tendencies towards optimization and self-organisation that significantly improve the efficiency and power of diverse prototyping. Architecture is designing for survival, designing for life, and emphasizes the need for a responsible approach to the transformation and formation of energy and materials. The solution to dynamic environmental problems is to link architecture with a contextual understanding of the structure of nature. At the same time, in computer science, methods inspired by the process of natural selection such as genetic algorithms have been developed widely, e.g. design, games, image processing and robotics. Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by relying on biologically inspired operators such as mutation, crossover and selection. A particular example is Hyper-NEAT (Stanley 2009), which we used to transform 3D objects. The principle of the algorithm is the simple weight evolution in a topologically static neural network (CNE) or the evolutionary adaptation of the covariance matrix (CMA-ES) strategy, to the weight and topology evolution (NEAT) and intermediate weight coding (HyperNEAT). All algorithms encode artificial neural networks (ANNs), which are represented by weights and connectivity (also called topology). The first two algorithms only search the ANS weights, while the last two can also modify the topology.

Evolutionary Strategies and Meta-learning

Deep artificial neural networks (DNNs) are multilayers networks of nodes and connections between nodes (weights) typically trained via gradient-based learning algorithms, namely backpropagation (LeCun 2015). The next step was to research and implement Evolutionary Strategies, which means transformation of architectural objects in time. This can be done by modifying selected layers in the neural network or by using the population-based genetic algorithm (GA). We evolve the weights of a Deep Neural Network by applying additive Gaussian noise in such a way that the general features of the training class of 3D objects are kept, but its evolution is possible. We created a mechanism for controlling hyperparameters of the neural network and ipso facto for controlling generated output numbers that represent new geometry. In this way it is possible to create a fully universal 3D object generator, and propose a new method of designing complex original art and architectures. Evolution strategy described above is a step toward research focused on the self-organization of complex structures from random elements. This method is general enough to become the starting point for meta-learning research and creating universal toolkit that supports artists, architects and designers.

Working with large data sets obtained from a changing environment requires advanced machine learning methods. We tested various AI methods for modelling and generating new architectural forms. In particular, we use Transformers that work by using convolutional neural networks together with attention models, making them much more efficient than previous models. We have previously tested recurrent neural networks RNN, long short-term memory networks LSTM and VAE variational autoencoders (Lisek 2020). The transformer model is a seq2seq model which uses attention in the encoder as well as the decoder.

Transformers have been used for many (conditional) sequence generation tasks, such as machine translation, constituency parsing, protein sequence generation and can be used for architecture design. Transformer models consist of an Encoder and a Decoder. The Encoder takes the input sequence and maps it into a higher dimensional space (n-dimensional vector). That abstract vector is fed into the Decoder which turns it into an output sequence. The output sequence can be in any sequence of numbers, symbols, etc. The attention-mechanism looks at an input sequence and decides at each step which other parts of the sequence are important. Self-attention, is an attention mechanism relating different positions of a single sequence in order to compute a representation of the sequence. Self-attention can be intuitively explained using a text example, when reading this text, you are temporarily focusing on the word being read, but at the same time your mind still keeps the important keywords of the text to provide context. In our research we worked with sequences of numbers that represent 3D object as positions of its particles/elements and velocity (Vaswami 2017).

Our approach for analysing and creating evolving architecture is based on meta-learning. Meta-learning is the next generation of artificial intelligence systems. Meta-learning goes by many different names: learning to learn, multitask learning, transfer learning, zero shot learning, etc. People easily transfer knowledge acquired in solving one task to another more general task. This means that we naturally recognize and apply previously acquired knowledge to new tasks. The more the new task is related to our previous experience, the easier we can master it. In contrast, popular machine learning algorithms deal with individual tasks and problems. Transfer learning attempts to change this by developing methods to transfer knowledge acquired in one or more source tasks and using them to improve learning in a related target task. The goal of transfer learning is to improve learning in the target task by using knowledge from the source task. Techniques enabling knowledge transfer will constitute significant progress in AI and art.

We have developed a learning strategy for a set of neural network modules that can be combined in various ways. We train different modular structures on a set of related tasks and generalize to new tasks, composing the learned architectural modules in a new way. For composing, we use concatenation, addition and product operators. We quickly learn something about a new task based on previous tasks without training our model from scratch. Our system finds two or more suitable modules that can be combined as optimal solution for a new task.

Fig. 1. Evolutionary strategies.

Immersive Installation

An interesting direction of research on contemporary art and architecture is related to the problem of immersion, creating virtual environments and sound spatialization. Virtual environments also provide an excellent space for testing machine learning methods. Restrictions introduced during the pandemic motivated me to research potential of AI and virtual architecture for the evolution of society. Our research was focused on a role of Presence, Flow, Immersion, and Interactivity. We were particularly interested in the problem of presence and flow in VE. Presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another. Presence is a normal awareness phenomenon that requires directed attention and is based in the interaction between sensory stimulation, environmental factors that encourage and enable immersion. Flow is a state of experience where someone is completely absorbed and immersed in an activity. We researched relations between presence, adaptation and interactivity, e.g., how interactivity and adaptation improve the experience of presence. We tested our meta-learning approach as immersive installation and VR. We studied how various new methods of operation in virtual architecture can influence future social structures. We created immersive architectural installations that were presented during *Siggraph Asia 2020* and at Institute of Electronic Arts.

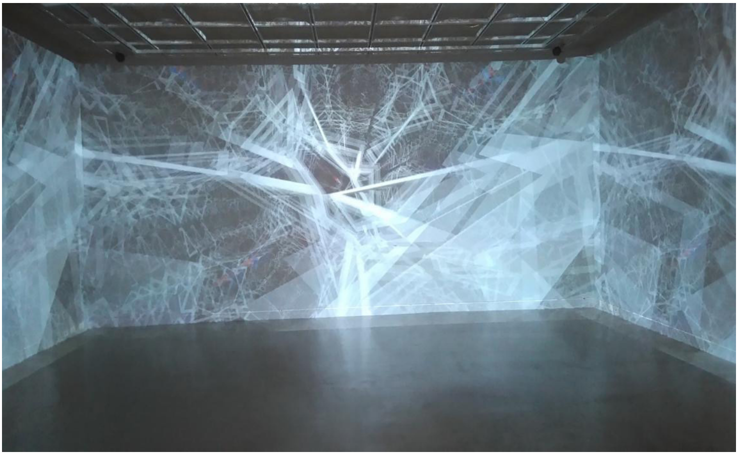

Fig. 1. Suprasymetry, immersive installation, detail
http://fundamental.art.pl/SUPRASYMMETRY.html

Space-time Synthesis

The project focuses also on synthesis of time and space. Breaking symmetry creates new time and space. A space created in the project is never static and is constantly changing. Space is never something given, but rather the result of an empirical body that determines the timing of its actions. Space emerges from the unpredictability of becoming as a series of potential expressions of pure movements, defined as differentiations. It is a process of becoming, that is, not a unity of predetermined systems or a crystallised structure, but a constantly evolving assembling and unfolding mechanism. There is no division between the performer and the environment. The "inner" space is topologically in contact with the "outer" space. The flow from the outside to the inside, in various scales and dynamics. The external is not a fixed boundary, but a moving, vibrating matter. Pulsar quantisation of time and space, mass of pulsating particles and sound events transform the performance space. The performer now begins chasing vibes, causing a new series of interactions and shifts. Spatial transformability. It is a transforming and transmuting system that is constantly evolving. Everything is involved in the continual process of transforming into something else – everything is opened up and put together. Multidimensionality. Composing events and spaces into other spaces. A hyper-dimensional space in which the horizon or axis system does not exist. Performances and installations conceptualise an experiential, living, vital body. The body is a multiple pattern that tries to gain stability through action. Bodies transcend time by acting, entering time, and connecting with other bodies and their activities. The space is revealed only as a result of synchronisation and connection.

Future Research

The goal is to create new support tools in the form of software for researching and developing adaptive architecture and art. The above research is fundamental to an art and architecture of the future that will be well adapted, in particular a flexible safe architecture that accommodates mass migrations and crisis situations such as pandemics. It is also necessary to create large groups of researchers, architects and urban planners that change and adapt the architecture of our cities and suburban to the new needs of their inhabitants. I research more flexible and general algorithms that adopt to many tasks (Liquid Time-constant Networks). Usually, a neural network's parameters are locked into place after training. In contrast, in a liquid neural network LTCN, the parameters are allowed to continue changing over time and with experience. The resulting models represent dynamical systems with varying time-constants coupled to their hidden state, with outputs being computed by numerical differential equation solvers.

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