Deep Generative Design

A Deep Learning Framework for Optimized Shell Structures

REFLECTION

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How is your graduation topic positioned in the studio?

The “Building Technology” Master Track covers topics linked to both to architectural design and engineering. It encourages students to follow a wide range of courses; structural design, generative design, climate design, construction detailing, computational design, all approached in relation to sustainability, efficiency and interrelationship. This is because interdisciplinary thinking is key to creating innovative solutions to real-time problems.

Over the last years, computational design has enabled new possibilities of design exploration, with respect to qualitive and quantitative criteria. The integration of generative computational tools in the early stages of design was a breakthrough for the architectural community, allowing designers to find the ideal cross-section where architectural concept, engineering requirements, sustainability and efficiency are met.

The current graduation thesis attempts to broaden the possibilities of generative design through Artificial Intelligence (AI) for a common design task: topology exploration and optimization. In this direction computer science, generative design and structural optimization are combined through a generative workflow, to test if AI can contribute to assisting efficiently designers and engineers in the early decision-making stage of topology exploration.

What is the methodical line of approach of the graduation studio and your chosen method and how ?

The Building Technology Master Track encourages students to think multidisciplinary in relation to real design and construction problems. AI is changing the way scientific problems are solved nowadays and is rapidly emerging in the design and engineering field.

This was one of the first AI-related topics for the Building Technology Master Track, therefore experimentation with tools associated with AI was also needed. The first phase of the literature review involved following a series of tutorials related to AI and research for application of AI workflows for topology optimization, under the guidance and supervision of my mentors. Following these steps an AI workflow for a designing problem that I was engaged with during my master's was proposed.

How is research and design related and how did the research approach work out?

The Building Technology graduation studio approaches design though research to propose innovative solutions for current problems related to the construction field. There are significant indications of how the contribution of AI can be beneficial in problem solving, generation of solutions and optimization, in many scientific fields.This thesis topic is also an experiment to test the possibilities of AI in the field of generative design and optimization.

The case of topology optimization is explored to evaluate the hypothesis that AI can also be an assisting tool for designers and engineers for an optimization task. There are multiple criteria that have to be taken into account, however this thesis focuses only on structural performance. The findings of this research are encouraging and suggest that indeed AI can be used as a generative assistant in optimizing design-related tasks.

Did you encounter moral/ ethical issues or dilemmas during this process? How did you deal with these?

A moral issue that can arise is how AI will impact the role of designers and engineers. In 2022 an AI generated artwork won the Colorado state fair prize bringing forward a lot a negative criticism.

AI models can generate novel designs but they always refer to the dataset that was used for training. This means that AI generative models can be used to optimize structures but they will also respect the boundary conditions of the training dataset. The role of proposed workflow is to act as an assisting tool that will respect the qualitive and quantitative criteria of the designer or engineer and facilitate topology exploration during the first stages of design.

To what extent are the results applicable in practice?

The conclusions of this graduation thesis can be used as a guide to develop AI workflows for optimized structural systems based on mesh tessellations. The boundary conditions of the dataset can expanded to fit more generative tasks. The proposed workflow could be integrated as part of an extended AI framework that will generate optimum solutions for mesh tessellations with respect to one or more criteria (such as structural performance).

To what extent has the projected innovation been achieved?

The generated dataset representing shell structures was successfully used in training AI models. Moreover, it can be used as a base to create even more pattern variations. The proposed workflow was also able to generate novel and optimized designs that performed better, in terms of structural performance, compared to the training dataset. The conclusions of this research can contribute to further improvement of the workflow.

Does the project contribute to sustainable development and what is the impact on sustainability?

The built environment industry accounts for massive amounts of energy usage and employ millions. Sustainable design and construction is a necessity. Early stage decisions affect significantly the final outcome with respect to cost, structural performance, assembly time, etc.

Generative tools that allow a deeper exploration of the design space are desirable. This project proposes a generative assistant for optimum shell structures with respect to structural performance. The workflow allows the minimization of the variables that describe a structural network that occurs from mesh tessellations, in order to solve effectively an optimization problem.

What is the socio-cultural and ethical impact and what is the relation between the project and the wider social context?

In an urban context facing population growth and displacement, while existing and aging infrastructure must be adapted to climate change, the construction industry faces the need to take immediate action. Designing workflows that allow fast and easy exploration of the design space, but also make no compromises regarding the quality of the result with respect to qualitative and quantitative criteria, is the key to addressing current design challenges.

How does the project affect architecture/built environment?

The topology exploration for shell structures that occur from mesh tessellations is a time consuming process operated in the early stages of design. To generate solutions initial parameters have to be specified and there are countless variables on which the structure's outcome depends. This projects suggests an AI workflow able to minimize the variables that describe a shell structure, predicts its structural performance and search for structural optimum solutions. The results of the research are encouraging for expanding the capabilities of generative design though AI integration, easing the decision making process and improving an optimization workflow.