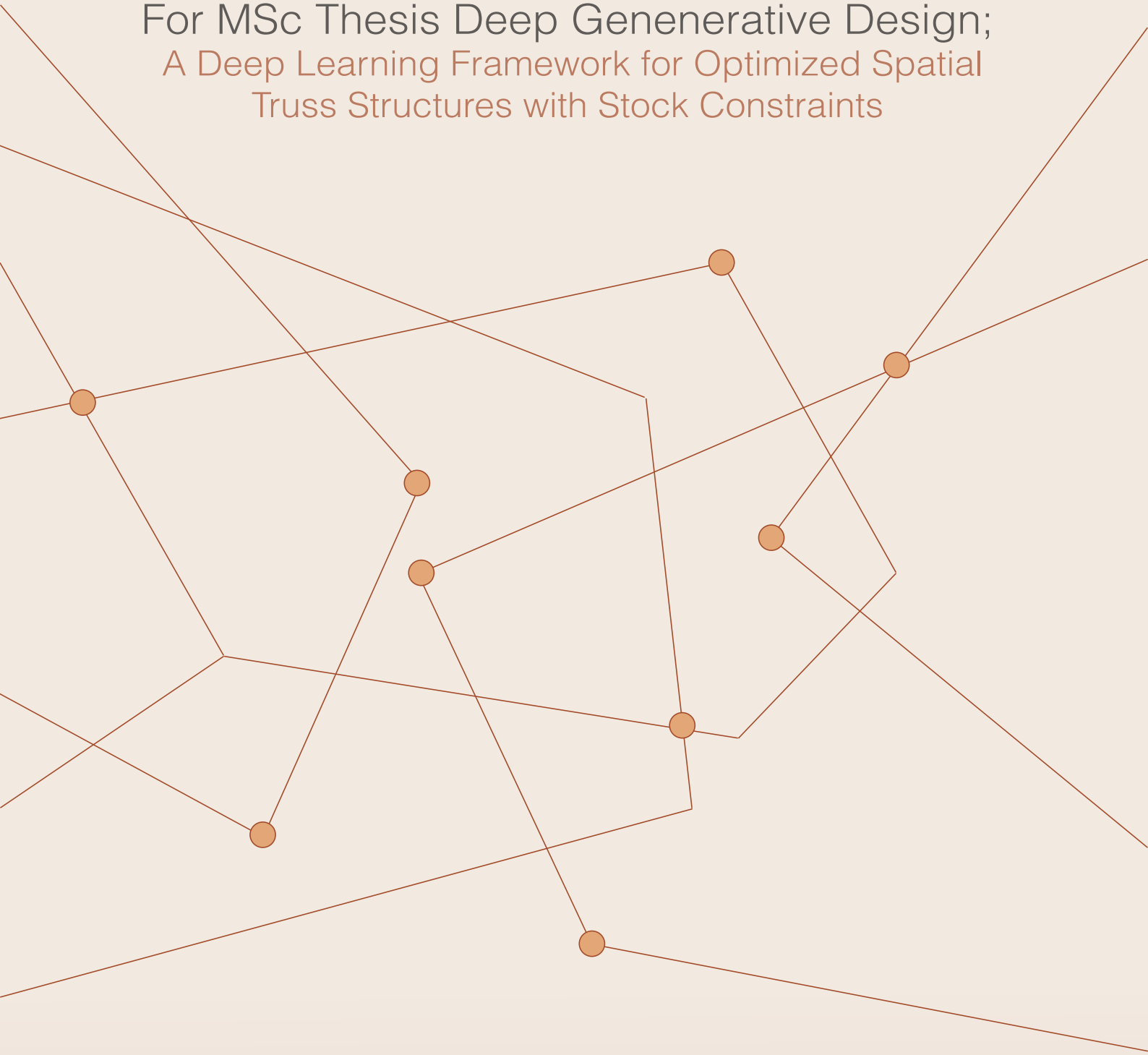
Reflection Report

For MSc Thesis Deep Genenerative Design;
A Deep Learning Framework for Optimized Spatial Truss Structures with Stock Constraints



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Student: Amy Sterrenberg
Mentors: Charalampos Andriotis
& Michela Turrin

TU Delft
MSc Architecture, Urbanism & Building Sciences
Building Technology Track
Sustainable Structures Theme

Student: Amy Sterrenberg
Student number: 4593057

Mentors:
Charalampos Andriotis (Sustainable Structures/Sustainable Design)
Michela Turrin (Computational Design/Design Informatics)

Delegate of the Board of Examiners:
Seyran Khademi

0 Reflection

INTRODUCTION

In this reflection, the approach to the posed problem and the translation of the feedback given during the thesis is evaluated. Additionally, the knowledge and experienced gained in this process is reflected on and the relevance and value of the thesis work are discussed.

The following questions are answered in this reflection:

1. What is the relation between your graduation project topic, your master track (Ar, Ur, BT, LA, MBE), and your master programme (MSc AUBS)?
2. How did your research influence your design/recommendations and how did the design/recommendations influence your research?
3. How do you assess the value of your way of working (your approach, your used methods, used methodology)?
4. How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?
5. How do you assess the value of the transferability of your project results?
6. In what ways has the thesis project attributed to your personal and academic development?
7. In what ways could the AI-related approach be improved, were the thesis to be repeated?

RELATION BETWEEN YOUR GRADUATION PROJECT TOPIC AND MSC EDUCATION

The graduation topic of 'Deep Generative Design', as described in the original documentation of BT track graduation topics, combines aspects of architectural design, engineering and design informatics. These topics are all strongly related to the MSc Architecture, Urbanism and Building Sciences (AUBS) programme and, especially, the Building Technology (BT) track. The final design product and application of this thesis project consist of a computational framework and a design for a sustainable architectural structure. Sustainability is addressed through reuse, which is a major aspect of a circular economy. This choice is in line with the future-oriented approach to building design and technology of the MSc programme. Moreover, the focus of this graduation thesis is on the integration and application of technological innovations such as AI/Deep Learning within the design process, demonstrating a strong link to innovative aspects of the MSc programme. Even though some of these topics and technologies are not (yet) explicitly part of the BT track courses, they are a logical extension of the (computational) principles explored during the MSc track courses. Additionally, this thesis provides an interesting challenge for me, as it required and encouraged personal academic development and growth. The work allowed further development of my skills within the fields of structural design and design informatics. Furthermore, if offered a unique chance to gain insight into the innovations that AI-based generative models can bring about, especially since these techniques are not yet widely applied in the fields of AUBS.

In conclusion, the thesis project topic demonstrates a relation to the BT master track and AUBS MSc programme through its aspects regarding innovation, sustainability (reuse & circularity), architectural design, structural design and design informatics.

APPROACH AND METHODOLOGY

The approach of the thesis work started with a literature review. This greatly helped me familiarize myself with the use of generative AI models in general and, more specifically, the Keras library in Python; both topics I was unfamiliar with before starting this process. This way, I obtained essential knowledge in the field of deep learning, which allowed me to make informed choices on the neural network architectures and inputs used in the AI framework. This research directly influenced the design of the framework.

After learning about the most essential aspects of the posed problem, I started formulating the problem statement and methodology. During the development of the framework, I continued to follow this methodology. However, during this process, I constantly critically evaluated the approach. This attitude was for example present during the training of the deep learning models. Originally, I only considered using vertex coordinates as input data type, as this was concluded in my literature review to be suitable for training the deep learning models and allowed for easy conversion between numerical data matrices and 3D mesh structure visualisation. Additionally, this data type is easy to retrieve from the mesh geometry and has a small computational cost (comparatively low storage usage). While designing the surrogate model and variational autoencoder (VAE) however, I found that more exploration into input data types was required. As alternative input data types were already researched during the literature review, it was relatively simple to implement new strategies. Here I retrieved the adjacency matrices and edge-vertex matrices based on a fine mesh, as described in the thesis report. These input types proved to be more effective, as discussed in Chapter 6 of the thesis report.

While training variations of the deep learning models and gradient descent (GD)

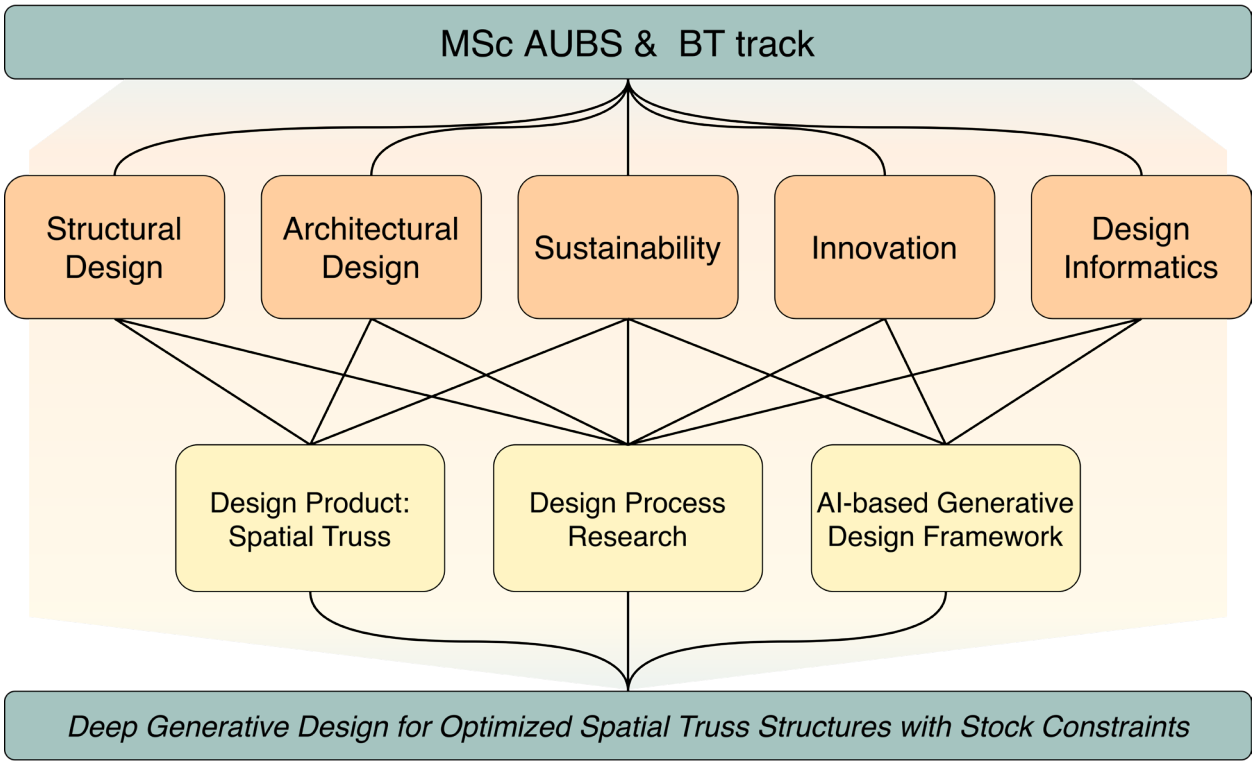

Figure REF-1. Schematic showing the connections between the MSc AUBS Programme and the thesis topic
Own work.

optimization, however, I found that constant in-depth evaluation of the results was essential. Problems were encountered that could not be solved solely with information found during the literature study process. Therefore, further exploration was done through Keras documentation, tutorials and comparison of my own results, which I have found to be a very effective way of increasing my skill as well as the quality of the work, as I learned to intuitively solve issues and bugs in the algorithms. Each attempt in training the network required careful evaluation and, in some cases, further research to solve errors and improve the accuracy of the models. In this way, the design of the network influenced my research.

MENTOR FEEDBACK AND PERSONAL EVALUATION

During the graduation process, I received plenty of helpful feedback from my mentors. This feedback was very valuable to me, as it helped me keep a critical view of my work. It also prompted some new ideas, which kept me highly motivated during my work. During the design of the VAE, for example, I encountered some obstacles and setbacks that I felt were impossible to overcome. The results were not accurate enough, disallowing me from taking the next steps in the framework design, including the gradient descent optimization. However, during a feedback session, some new ideas were brought up that motivated me and ultimately, I managed to create various successful VAE architectures, which I am proud of. The feedback I received during these meetings also included a request for a more in-depth study into the limits and assumptions that were a part of this thesis. This prompted me to add sections to my report to explore this. As a result, I found that outlining the limits of the study made me more aware of the current practical applications of my work and its potential future developments. This, in turn, encouraged me during my work.

If I could restart the process with my current knowledge, I would make sure to focus on an even simpler, or smaller structure, as this would allow me to perform even more in-depth research on representation methods and their effectivity as training data for the various deep learning models. Although this would have limited the complexity of the final structural product, it would add higher value regarding research into the uses and potentials of generative AI frameworks overall, which I found to be what is currently most essential to the development of this framework. Here, I would have chosen to give priority to AI-related research over the sustainability and reuse aspects of my work, though I also acknowledge the unique value and perspective that these topics have brought to my thesis. Still, I am satisfied and proud of the direction I have chosen to take my work in, the things I have learnt from it and the value it holds in the sector.

ACADEMIC AND SOCIETAL VALUE, SCOPE AND IMPLICATION

Various countries, including the Netherlands, are currently facing a shortage of housing. Quicker project realisation, as can be done by decreasing the time required in the architectural design process, could help mitigate this problem. Besides, the continuously increasing importance of sustainability in the building industry requires re-evaluation of material sourcing. The circular economy and reuse specifically have been shown to be effective in this regard. Unfortunately, the integration of sustainable aspects such as reuse lengthens the design process even further. As deep learning models are promising tools for acceleration and automation of parts of the architectural and structural design processes, they can result in faster project realisation with integration of sustainable aspects, therefore fighting the posed issues. In practice, however, these methods are currently rarely used and barriers exist, as

shown in the introductory chapters of the thesis. Further research and development of methods that eliminate or bypass these obstacles are therefore valuable. So, the academic value of this work lies in the extension of AI-related computational tools in architectural and structural design. As stated, these tools are all relatively new to these fields but have proven to be promising in other fields, such as computer science and industrial/product design (Cui & Tang, 2017, Jiang et al., 2022, Oh et al., 2018, Qian et al., 2022). Therefore, studying these tools and transforming/adjusting them to further fit within the architectural design process has great relevance to the scientific framework of architecture, building technology and engineering. Furthermore, learning the limits of current AI applications in these sectors holds value as well.

In conclusion, the computational, AI generative workflow developed during this project provides insight into ways to incorporate AI into the architectural design process to achieve goals through new and (more) effective methods. This work describes a case that, if successful, can directly improve the feasibility of circular, sustainable design, which is currently limited. Additionally, the results of this thesis can serve as a valuable stepping stone towards the use of AI in the field of building technology in general.

PERSONAL AND ACADEMIC DEVELOPMENT

This thesis project has been extremely valuable to me. It has introduced me to the potential and practical applications of deep learning in the field of Building Technology. Before starting this thesis, I was familiar with AI as a concept and had a vague idea of the types of applications it has been used for, including text and image generation and data prediction based on pattern recognition. I had considered its use within the field of architecture before, but this seemed far beyond my skill set. So, when the opportunity for an AI-related graduation topic presented itself I was immediately interested, though admittedly also slightly nervous. In the last months I have been able to learn many valuable skills, such as communicating with Delftblue through Linux, which I had no prior experience with, and increasing my computational and programming skills in Rhinoceros Grasshopper and Python, including becoming proficient in Keras (Python Library) to develop deep learning models. When I started this thesis project I set it as my main personal goal to expand and deepen my knowledge of parametric and computational design skills and I feel that I have achieved this beyond my expectations. I hope to apply and expand these skills even further in future projects.

Additionally, I have improved essential soft skills in individual work, such as organisation, planning and time management. During my graduation, I learned that the process of training a framework such as the one designed in this thesis can be time-consuming and sometimes frustrating. Therefore, I had to plan for unexpected and unpredictable outcomes. Even though this resulted in some time pressure and stress, my obtained skills helped me to maintain a productive and healthy working style overall. I have also gained confidence, communication skills and skills in presenting, especially through my communication with my supervisors. I found that I am now able to communicate new ideas and articulate problems more effectively than before. For all their help and feedback during this graduation process, I would like to express my gratitude for the help my mentors, Charalampos Andriotis and Michela Turrin, have offered me. Their expertise and feedback helped me greatly improve my work.