Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences
Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

**Personal information**
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**Studio**
- **Name / Theme**: Sustainable Design Graduation Studio
- **Teachers / tutors**: Andrew Borgart, Michela Turin
- **Argumentation of choice of the studio**: N/A, the sustainable design graduation studio is the only option for Building Technology Masters Students

**Graduation project**
- **Title of the graduation project**: Gridshell Optimization through Principal Stress Lines

**Goal**
- **Location**: N/A, TU Delft Entrance
- **The posed problem, research questions and sub questions**:
  - Currently grid-shell design is either based on two main ideas, patterning / tessellation, or grid division. Is it possible to generate a viable method of grid-shell design using principal stress lines to optimize elastic stiffness with minimal volume of the structure.
  - How can grid-shell roof patterns and design be effectively optimized?
    - **Sub Questions**: How can optimization be defined? Can optimization be defined by weight and strength alone? How can gridshell patterns be optimized along principal stress lines?
The design assignment after generating proper integral analysis will be to design and compare the grid-shell surface for the front of the TU Delft Bouwkunde entrance in with standard parameterizations of gridshell forms.

This should be formulated in such a way that the graduation project can answer these questions. The definition of the problem has to be significant to a clearly defined area of research and design.

**Process**

**Method description**

The thesis and research will be approached in the following way:

First, the script both grasshopper and Python code will be developed testing for errors and inconsistencies. The code will be based off of the previous works of D Smidt (2014) and S Pellegrino (1986). These include development of the multi-criteria optimization and rigidity analysis. The multi-criteria optimization will be conducted through the use of Bollinger and Grohmann Engineer’s Octopus plug-in for Grasshopper as it uses Pareto based algorithms for its evolutionary optimization. However, the incorporation of these various forms of code created by a different subset of languages will also have to be spliced together.

As most topology optimization is done using continuum analysis rather than discrete analysis rendering most optimization systems relatively useless.

Second, the script will be tested on a subset of base shell examples that are standard models. This would first be a test of the method on a 10 bar truss problem followed by a single curved surface. If the system works on a single curved surface, the following test will be to examine the code on a double curved surface.

Thirdly, the script will be applied to the case study grid-shell structure of the new Macallan visitor’s center. By doing this test case we can examine how efficiently the system provides structural performance when compared to standard timber grid-shell structures that have been recently designed.

Lastly, with time permitting, the final design for the structure to be used on would be to develop a small model using my defined design methodology to create a thin grid-shell structure.

**Rough Proposed Outline:**
Literature and general practical preference

The major theories presented within the paper are shell theory, form-finding using particle spring method, principle stress line optimization, and stiffness optimization. Using these methods form-finding of grid-shells can be analyzed through dynamic spring form finding systems to optimize form with the grid being developed using streamlines in 2D systems.

Sources not limited to but including:


Reflection

Relevance

The research undergone in this process will allow architects and engineers the ability to design lighter shell structures. This methodology can easily be transferred to shell structures using smaller mesh sizing, allowing to find optimum shapes of shells with holes and significantly reduced weight. This reduction in weight of both grid-shell and shell structures is significant as since optimization occurs along the structures, it significantly reduces the amount of steel or concrete needed to create these architectural forms.

As steel and Portland cement produce roughly 2 kg CO2 and 0.85 kg CO2 eq / kg respectively [1] [2]. By reducing the amount needed in each structure, large steps can be made to reduce the CO2 output of the construction industry.

This reduction in weight also leads to several other advantages. The demand for materials required to make concrete for example, especially quartz sand, is currently decimating local ecosystems as riverbeds and beaches are being stripped bare [3]. Steel faces similar issues, with iron ore shortages already affecting many smaller steel plants in 2017.

While grid-shells are already efficient at spanning large distances and create large open spaces, the popularity of this method is growing significantly with recent large scale projects including Google Mountainview Campus, Kings Cross Station, Macallan Visitors Center, and Yas Hotel all finishing up within the last 10 years. This means that while they are indeed efficient, there must be constant examination for improvement, and with new network analysis and topology optimization algorithms coming into their own in the last several years, examination of these analyses on the structures must also be developed.

## Initial Planning:

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**Time Planning**

- Activity 1: Starting Date and Duration
- Activity 2: Starting Date and Duration
- Activity 3: Starting Date and Duration