Reflection

Initially my interest in graduation studio was to combine application of structural mechanics and climate design within a computational framework. As I had realised within a year of building Technology studio that computational design is getting more necessary and common practice within every field of architecture. Shell structures had fascinated me since I became familiar with them. Their design, analysis and optimisation can highly be favoured from computation design. In my effort to combine all my interest, I proposed to optimise a shell structure with considerations of daylight and ventilation. It was soon advised by that I had to limit my scope due to time constraints. I focussed on the structural aspect of grid shells and found some research done on discretization of shells based on statics. Some recent studies have shown promising results in improving performance of grid shells by focusing on statics. But some methods have limitations in alignment of beams with direction of stresses, some are not able to achieve homogenised grid for feasibility of construction, some do not produce planar cladding, and some do not take preferences of the designer into account. My focus shifted to computation design method for layout of static-responsive grid shells which overcame these limitations.

A research by design method was adopted to create a workflow for discretization of free form geometry into quadrangular grid, based on statics and apply the workflow on a case study. The main goal of research was to create an algorithm which was capable of generating various solution for given problem, using data analytics and visualisation methods for making informed design decisions. I also wanted to create a visualisation method to help user choose a solution from a set of solution based on hard criteria such as structural performance and constructability and soft criteria such as personal preferences.

The first part of the research focused on generating a quadrangular grid which is aligned to the conjugate vector field representing principal stress vector stress generated by Finite Method Analysis. Existing stress lines generators are used to visualize flow of forces and their results cannot be used for generating constructible grid shells. A custom stress streamline generator was created using coding language python. As new to coding I had a sharp learning curve in order to create this algorithm. A highly customized tool was designed after two months of iterative process. Results from this tool were not directly usable as predicted and another homogenisation step was developed. The homogenisation step was successful but disturbed the alignment of some beams with principal stress directions as the beams moved on the shell tangentially to be more or less equally spaced. Another step in the process was added which aligns the beams back at their new positions. Also, an algorithm was developed to make faces of the shell planar. Homogenization and planarity were given importance because, I wanted to make a method which produced shells feasible for construction. After all the required steps, a novel method to generate quadrangular grid shells was developed.

The first part of the research was successful, but it was realised that, to achieve the main objective, a new method for visualisation was not required. Already existing methods were analysed and one of them were used for data management and visualisation. With the remaining time, it was decided to make the algorithm more robust so as it could be applied to different free form surfaces with varying boundary conditions and add further features to improve the constructability and performance of the grid shell.

Dynamic relaxation was used for homogenisation, alignment and planarity steps. The code for dynamic relaxation was not written by me considering time constraints. Instead a commercially available tool was used. This tool had its own limitations and I had to work with them. Though the results were satisfactory, it was not the best way to do it. The processes could be improved with own algorithms using the logic provided in the thesis in future research.

This kind of research is usually done by civil engineers and mathematicians. As an architect, sometimes I found it very difficult to understand the algorithms developed by precedent work because they were co-written by mathematicians. Also, these algorithms are not available publicly. I worked my way around these hurdles and by understanding the logic used in the best way I can and making my own algorithms. Learning a coding language was very essential for achieving the goal of this thesis.

The resulting grid shell have been analysed structurally and shows improved performance compared to quadrangular grid shells generator by standard method. The results are promising for real life application. Meaning that the workflow can be used to find a homogenised quadrangular grid shell which are stiffer than their predecessors. Grid shells are used for approximating free form geometry for various projects around the globe. Using this method can save time, money and material which was required to make a grid shells stiff by thicker beams or extra stiffening members.