Freeform follows functions
Graduation plan

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§ 1 Argumentation of choice of studio

I aim to learn and use a computational design approach that permits to ensure architectural and structural design quality. This is done by addressing soft aspects of architectural design using methodologies from the exact sciences for describing the design process mathematically. These methods are computational intelligent methods, since they are uniquely able to address the complexity of design.

§ 2 Problem statement

The problems to be studied are identification and application of computational methods to effectively handle; in the first place the complexity issue of systematically finding better design solutions during the architectural design process, and secondly structural issues concerning non-standard tessellation of freeform roofs and their rigidity. In particular focusing on identifying optimal design solutions, satisfying several, sometimes conflicting, objectives concerning an architectural concept, functionality and structural performance.

§ 3 Research

Main research question

“How to create a performance driven freeform non-standard tessellated roof structure using parametric modelling and evolutionary optimization for the architectural and structural design?”

Sub questions

- “Is evolutionary computation suitable to identify integral designs involving structural assessment in the fitness assessment loop?”
- “Can numerical analysis be used to identify rigid structural tessellations for freeform structures?”
- “Is evolutionary computation suitable to identify a complex roof geometry, which satisfies functional and architectural requirements of a redevelopment program?”

Goal

The goal of study is to verify the validity of the proposed computational intelligence-based design methodology and develop additional computational means for non-standard rigidity analysis by means of a design assignment.

§ 4 Design assignment

As a case study the design of a market hall in The Netherlands will be proposed in a redevelopment setting. The focus will be the design of a performance-based complex geometry and non-standard tessellated roof. Performance of a number of objectives will be taken into account. Multi-objective optimization will be used to reach highest performing designs. The objectives deal with structural performance and functionality in relation to the architectural concept of a freeform roof in a redevelopment setting.
§ 5 Method description

First a technical scientific literature study will be conducted, followed by precedents research and analysis. Furthermore, proposed software will be studied. For the design case a parametric approach for the generation of shape, structure and tessellation patterns will be used. A structural rigidity assessment method using matrix operations and the singular value decomposition developed by S. Pellegrino and C.R. Callendine in the late 80’s and 90’s will be used as a basis to develop a design tool, which can identify rigid non-standard structural tessellations.

Followed by the implementation of the IDO computational formalism as proposed by Bittermann (2009). This includes performance evaluation with a fuzzy neural tree and evolutionary search using a Pareto based genetic algorithm for multi-objective optimization. IDO allows dealing with the complexity of the architectural design, which encompasses a multitude of possible design solutions and non-linear relationships between problem entities (i.e. conflicting objectives).

§ 6 Relevance

The scientific relevance is profound understanding of the architectural design process with a focus on building technology as an intelligent activity. The roles of form, structure, feasibility, redevelopment, abstraction and objective-based search in this process will be further clarified through the study.

The relevance for society is the guaranteed quality of a proposed design, which is very desirable due to the present economic fallback, resource scarcity and other environmental concerns. This will be uniquely achieved by means of computational performance measurement and ensuring systematic design synthesis.

The design case in particular is relevant to the European food industry, since due to new European legislation the preparation and sale of food on open-air markets becomes impossible. The internationally proven typology of the market hall is relatively new for The Netherlands and offers a solution that meets the modern requirements. Society will benefit from the qualitative local urban improvements associated with the redevelopment of the original market location.

The newly proposed rigidity tool for pin-jointed frameworks allows architects and structural engineers to search for, and identify useful structures with a new architectural expression. It allows for complex envelopes built with different tessellations than basic triangulated doubly curved surfaces.

§ 7 Literature


General practical reference
First Dutch Market Hall, Rotterdam, MVRDV