Computational Methods for Industrial Design

Management Summary

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Initial Situation

Two years ago, I heard the term computational design (CD) for the first time. Being interested in digital design tools, I started to educate myself about the field. The further I learned about the topic, the more fascinating but at the same time confusing CD got to me. With terms like parametric, generative, and evolutionary design, I quickly lost an overview of what CD was.

In architecture and engineering, computational design finds more and more applications and acceptance as a tool. In industrial design, the use of computational design is still relatively rare. If used, it often does not go much further than making surface patterns for products.

For my thesis, I want to explore what applications of CD could be interesting for industrial design and prove that CD is more than a tool for pattern creation.

Questions and Theses

During my thesis, I oriented myself on the main question:

What tools can computational design offer to the field of industrial design?

And on the secondary questions:

1. What are the current applications of CD in architecture and engineering, and can they be applied to industrial design?
2. What are the current weaknesses of CD?

And formulated the theses:

1. Even though widespread usage of CD in industrial design is still rare, the possible applications of CD for industrial design can be versatile and go further than the creation of aesthetic surface patterns.
2. There are CD tools for industrial design from the early design stage until the production stage.

Introduction to Computational Design and Related Terms

To be able to follow the results and conclusion of this thesis, it's important to have a rough understanding of the CD field.

Computational Design (CD): Computational design is an umbrella term that includes computational power and data to produce designs.

Parametric Design (PD): "PD is a design approach based on the use of parameters to describe sets of designs".[1] For the thesis, I reduced the term of parameters to number slides with a minimum and a maximum limit.

Generative Design (GD): Generative Design, like CD is an umbrella term that includes different methods to generate designs. GD in this thesis is limited to a parametric bound method for exploring a designs

Performance-based generative design: Generative design processes that use at least one objective to optimise a design.[2]

Non-performance-based generative design: Generative design processes that are not bound to optimise designs. These methods are purely for exploring the design space.

Topology Optimisation (TO): Topology Optimisation is a method "which aims to optimise the distribution of material."[3] by removing material from the design without weakening the product's structural strength. Objectives can be: "minimising the weight, maximising stiffness, reducing stress, reducing displacement". [4]

Procedure

In the first step, I analysed several papers and conducted an interview with Aman Agrawal, a computational designer with a background in industrial design. The goal was to have a better understanding of what the field of CD was. In the next step, I made further research on different projects and applications of CD. From there, I analysed two parametric projects, and one performance-based-, non-performance-based GD and TO project. For each of the GD and TO projects, I conducted an experiment to test and translate these tools to the field of industrial design. Therefore, I used the visual programming language Grasshopper, which comes with the CAD software Rhinoceros 3D.

[1] (Caetano, Santos and Leitão, 2019, p. 297)

[2] (As cited in Vlah, Žavbi and Vukašinović, 2020, p. 452)

[3] (Vlah, Žavbi and Vukašinović, 2020, p. 452)

[4] (Ibid, p. 452)

Results

In each of the analysed projects/papers, I found exciting approaches for industrial design. The analysed approaches demonstrated the variety of CD. From design exploration in a more conceptual way that leaves room for the designer's subjectivity to producing highly optimised designs.

I could reinsure my thesis by testing and analysing several CD tools. With non-performance-based GD, I found a tool for conceptual design exploration, with performance-based GD and TO I found a tool to optimise a design. Furthermore, PD which supports early stage till production-ready CD tools.

Table 1 shows a summary of my findings to the analysed and tested computational design tools.

Table 1: Summary of the explored CD tools

CD Tools	Strengths / Use	Weaknesses
Parametric Design	• Pattern creation • Adaptable designs • The base for further CD applications • Applicable in every design stage	• It needs more time to define an initial design than with CAD • Simple designs can be already very complex to define
Non-Performance Based GD	• Design exploration • Making subjective design decisions • It does not need design objectives • The designer can interfere in the GD process • It can be used at the beginning of the design stage	• Very time consuming for an initial design exploration
Performance-Based GD	• Optimising designs based on objectives • Evaluating designs • Design exploration • It can be used in the beginning or middle of the design stage	• Needs quantifiable measures to work • The designer cannot interfere in the GD process
Topology Optimisation	• Optimising design structures • Inputs for new design ideas • Creation of organic geometry • It can be used in the beginning or middle of the design stage	• Knowledge of statics to properly apply • Very power-intensive to calculate • Difficult to steer designs into the desired direction • Often bound to additive manufacturing

Outlook

Remaining Problems with CD

1. High level of complexity to solve relatively simple design problems
2. Lack of quantifiable metrics to evaluate designs

Even though Grasshopper does not require writing code, the process to learn the program and get some usable outcome takes significantly more time than with traditional CAD software

Since CD is based on numerical inputs, the outputs of such systems are also bound to that. With measures, which are hard to quantify, such as subjectivity, industrial designers would need to come up with other measures to solve CD problems.

Outlook Practical Thesis

Considering the CD applications analysed in this thesis, I see the most potential for my practical thesis in making a product that can adapt to individuals rather than being fitted for the average human. Therefore, I intent to use PD for its hight flexibility and adaptive nature. Furthermore, I aim to test and apply further CD tools during my practical thesis.

Bibliography

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