Generative Design
Rethinking linear workflows
by Matej Dubiš

Doctoral research: The Potential of Generative Design in Automotive Design
Realization: 2014 — 2018
Researcher: Mgr. art. Matej Dubiš, ArtD.
Research supervisor: Prof. Peter Paliatka
Text: Michala Lipková

Generative design enables us to design increasingly complex, optimized, or mass-personalized products. Matej Dubiš's research pursues generative design methods and their potential for a specific discipline: automotive design.

The research mainly focuses on the methodology of generative design, specifically, the designer's role and the generative design process divided into four blocks: concept, algorithm, parameters, and results. Based on them, the thesis described in detail the possibilities of applying generative methods in the automotive design process, focusing on their impact on how designers work, think, and use tools.

The tangible outcome of the doctoral research is three physical demonstrations of different generative methods in designing a steering wheel, hypothetically mass-produced by 3D printing technology.

The dissertation project of Matej Dubiš, successfully defended in 2018, extensively explores a fast-accelerating field of methodologies and applications of generative design. In the preface of the thesis, Dubiš suggests that there is nothing less we can expect from the field of generative design in the future than "a complete transformation of the design profession as such" (Dubiš, 2018, 9). Additionally, the author stresses that designers "need to understand and utilize the emerging opportunities to keep creating relevant designs" (Shapes of Logic, 2018, 55).

Dubiš restricts his research interest to the intersection of design (as a professional field), automobile (as a subject of design), and generative creation methods. The research questions were defined as follows:

- Is it possible to meaningfully connect automotive design and generative design methods?
- Which uses of generative design methods in automotive design are the most promising?
- What are the benefits and pitfalls of such a connection?

The research compares the 'classical car design process' and the incorporation of generative systems into design development. Dubiš illustrates the difference by describing the car exterior design process as one aiming to achieve a perfect shape ('car sculpture') following technology and industry-specific design requirements, using traditional techniques such as sketching and clay modeling. On the other hand, while using generative design methods, instead of shaping the final form directly, an algorithm is created to generate it:

"Incorporating generative systems into a design process instantly increases the effectiveness of modeling complex or variable structures. Together with digital fabrication, they also allow for previously impossible design approaches. Various kinds of data can be used for creating thoroughly personalized products. Optimization algorithms can be directly integrated into a design process. Designers can truly mimic nature by applying its principles in form finding. Possible convergence points between the two design approaches arise mainly from the specifics of car design and the cars themselves. The data-rich nature of modern cars provides innumerable options for data-driven design development, optimization, or customizability. Properly implementing generative methods will open new ways of connecting design and engineering" (Shapes of Logic, 2018).

In the literature review part of the thesis, the author introduces several different examples of good practice to illustrate the implementation of generative methods into automotive design workflows at multiple different stages (Mercedes-Benz Bionic Car study 2005, Renault Twin'Z concept 2013, sound-absorbing structures in Peugeot Fractal 2015, BMW VISION NEXT 100: Alive Geometry 2016 or EDAG Genesis 2014). The theoretical part of the thesis further describes different fields of application of generative design. Dubiš identifies and analyses six areas of applications, related mainly by positive relationship to computing technologies as a tool for creation: generative art, computer-aided design, digital architecture, digital manufacturing, data-driven design, and artificial intelligence (Dubiš, 2018, 23 - 30).

While admitting that none of the definitions of the term 'generative design' can currently be considered as established and generally accepted, in chapter 2.1, Dubiš sums up that different existing definitions and explanations intersect on the fundamental role of the algorithm, rules, or code in the design process. In his research, Dubiš refers to this entity as the 'generative system'. Based on documented analysis of scholarly sources, the research suggests working definitions of 'generative method' and 'generative system' (Dubiš, 2018, 20):

"Generative methods in design are those design methods that involve working with a generative system."

"A generative system in design is a functionally autonomous system, generating decisions, elements or properties of elements at the level of design creation."

Along with the summary of generative methods' understanding and following up on the theoretical work of Philip Galanter (Galanter, 2016, 2008), who suggests that the key element of generative art is the use of an external system to which the artist cedes partial or total control, Dubiš suggests the following definition of generative design, suitable for the scope of his research:

"Generative design is any design practice in which the designer hands over control to a functionally autonomous system that contributes to or is on the verge of providing the finished design work" (Dubiš, 2018, 22).

As the author aptly states, digital and computations techniques are not the only example of a "functionally autonomous system" — a generative approach to creation can use biological generative systems (Neri Oxman, Tomáš Libertiny) or material-driven systems (Antoni Gaudí) to name a few, the research, however, focuses solely on the context of digital design tools. As the definition mentioned above suggests, the generated output does not have to be the final design and usually comes to its further processing in the design process:

Three 3D printed results of steering wheel design process case study, named after the generative system used: Heterogenous HoneyComb (page 29), Delaunay Construction (page 30) and Custom Stress Lines (page 33).

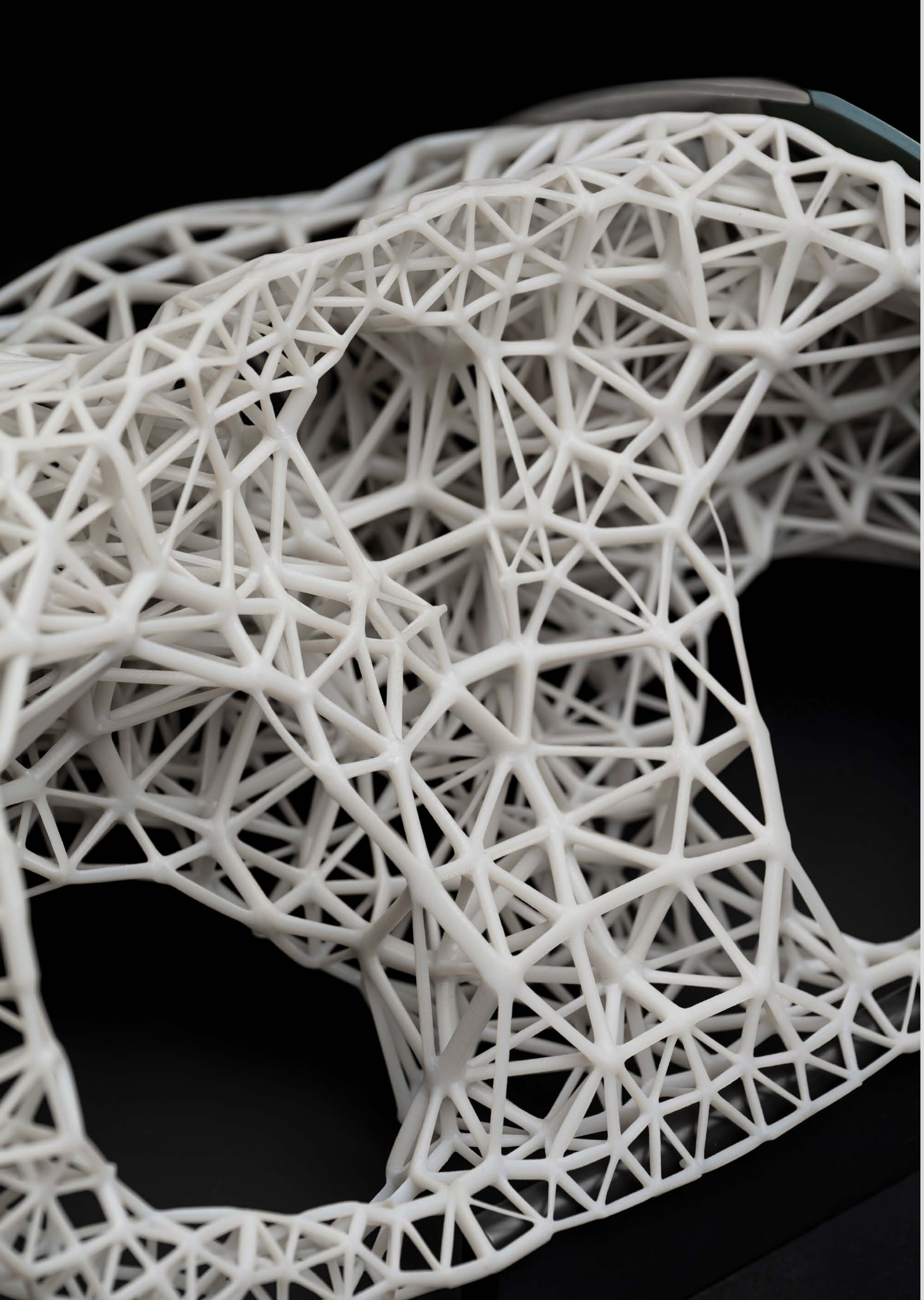
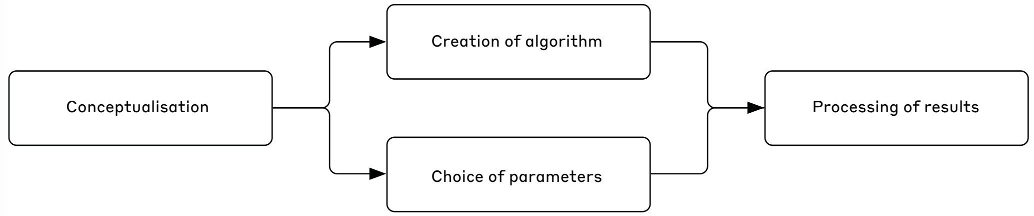


Diagram of human activities in
the process of generative design



“Algorithmization of part of the creative process does not necessarily mean weakening the author-creator position. Although the author often retreats from classical design positions using generative methods, his or her skills and experience find other applications. A different type of author-product relationship emerges, determined by working with the source data and logic that generates the form. Figuratively: The designer puts down the sculpting spatula and takes the DNA of his creation directly into his hands” (Dubiš, 2018, 34).

Dubiš further suggests a diagram of human activities in the process of generative design:
Conceptualization — Creation of algorithm / Choice of parameters — Processing of results

As the author further explains, conceptualization is understood as a crucial phase of planning the overall design process, which precedes the ideation phase:

“Conceptualization is an intellectual activity, present at the beginning of each step in the design process — thinking about the design in the process of its creation. (...) ... [During conceptualization], we form the absolute foundations of the design to be created: the problem to be solved, the general approach, the design intention, the desired results, and the procedure by which we plan to reach them. Following steps of the creative process, gradually realize and materialize this concept” (Dubiš, 2018, 39).

The research brings a unique take on the methodology of the generative design process from the perspective of industrial design: The author analyses algorithm types (top-down and bottom-up), reflects the ‘algorithmizability’ of the task in the design process; he compares the concept of linear/sequential development with iterative prototyping from the perspective of design. Parameters are categorized by their origin, according to the method of entry, and according to the function of the parameter in the generative system. Finally, the author describes different types of outputs of the generative systems, along with the possibilities of their post-production.

The second part is devoted to the practical application of acquired knowledge, aiming to demonstrate and evaluate the possibilities of using generative methods in car design. After a series of smaller experiments, the three explorative case studies of the steering wheel design became the tangible output of the practice-based phase of the doctoral research. The use of generative methods was explored at various phases of steering design. The result of the practical part consists of several generative systems and design parts combining the use of generative and conventional design methods. In all presented case studies, Dubiš uses the scheme ‘concept - an algorithm - parameters - result’ to describe the design process; each subprocess is described in detail and analyzed.

The diagram Continuity of Demonstrated Design Methods visualizes the design process that preceded the three presented objects. The design process started with initial topological optimization, the goal of which, in this case, was not to verifiably optimize the design of the steering wheel but to adopt the method itself and explore the possibilities of its use in the design process. Dubiš has used a Millipede add-on for Grasshopper by Kaijima Sawako and Michalatos Panagiotis as the main software tool for topological optimization.

The results of the initial topological optimization (TO) were used in three further experiments with three different goals: Custom Stress Lines (to better render stress flow in the TO model), Heterogenous HoneyComb (to create well-controllable, regular structure, modified by TO data), Delaunay Construction (to create flexible, compact spatial structure). The three experiments bring results generated by the algorithmic system, iteratively created by the designer. Since the generated outputs were far from the functional steering wheel, further steps focused on bringing data closer to the designer's function of the object by digital sketching, NURBS modeling, and even with further use of the generative system in the design of the steering wheel details: design of the intermediate structure and surface support, variable grid of reinforcement and attachment of outer shell or the parametric haptics (chapter 4.3.10.1) and thumb tracing (chapter 4.3.10.2) experiments:

"During the creation of a generative system, the designer responds to the given problem not with a specific shape but with an idea encoded in the algorithm. Do I want to show the flow of forces in the model? I will program a drawing system that will track these forces. (...) In the next step, it was necessary to focus on the 'humanization' of the results so far, both artistically and functionally. I tried to achieve artistic humanization through a human author's interpretation of the generated form. I focused on the aesthetic specifics of the individual structures and their creative potential for inspiration in the styling of the steering wheel. By functional humanization, I mean getting closer to an ergonomically suitable and otherwise practically usable steering wheel. Again, the goal was not the complete design of the steering wheel, but rather a methodological grasp of some important milestones on the way towards it" (Dubiš, 2018, 146).

The publicly available thesis describes the technical details of all case studies, methodology, and design process steps. In conclusion, the author claims that the great support for the relevance of the thesis was the nine-month internship spent in the environment of VW Group Future Center Europe (July - September 2016 and July - December 2017) in Potsdam, Germany. The design studio supported the physical realization of the final tangible outputs of the dissertation project — 3D printed demonstrations in the steering wheel design process.

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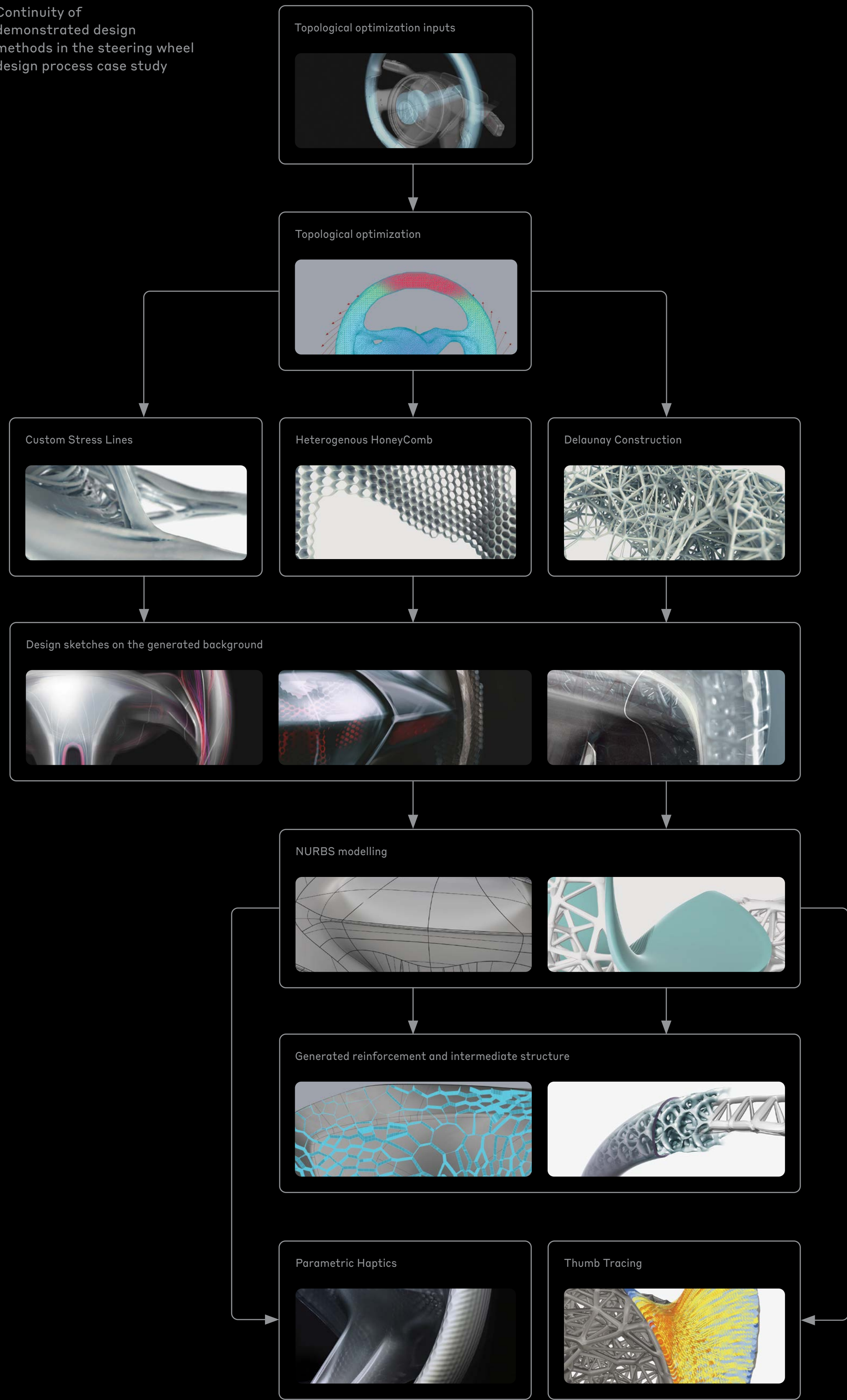
During his doctoral studies, Matej Dubiš helped implement Grasshopper modeling and parametric design at VW Group Future Center Europe in Potsdam, Germany. He currently works as a human-machine interface designer in ŠKODA AUTO a.s.

Continuity of demonstrated design methods in the steering wheel design process case study



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