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DESIGN STRATEGIES FOR DIRECT PRECIOUS METAL 3D PRINTING

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KEYWORDS

3D printing, computational design, generative design, natural systems, digital fabrication.

ABSTRACT

The technology of direct precious metal 3D printing allows for realization of design typologies and products at a groundbreaking level of complexity and customization. The developed intricate computational model inherits design, detailing, and fabrication information. These are combined within one single process, allowing for eager interaction through testing, evaluating and optimizing. Starting from a strictly system-based and mathematical design approach, the potentials of randomness and mistakes in the system are investigated, looking into natural artifacts. Natural artifacts are intriguingly beautiful and fascinating, yet never perfectly shaped in a mathematical sense. They are based on very strict mathematical rules that define their base geometry; the final outcome though is endlessly variable and differentiated. The designed process is independent of scale, materiality and function - these are considered when defining constraints and parameters. The aim is to explore how variability changes the design and thinking process, merging formerly separated disciplines. How can technology be exploited to optimize designs in order to fit in our consumer-good based society while giving back desired individuality and uniqueness?

INTRODUCTION

Metal 3d printing

Within the fields of Architecture and Design, the use of additive manufacturing has for a long time been limited to building prototypes or models in materials that are not suitable for construction or finished long-lasting products. The technology of direct metal 3d printing allows for producing highly specialized and unique products and has over the past few years developed on a high pace, mainly applied in an engineering environment for machine parts such as aerospace or medical engineering. In the process fine metal powder is melted together with a laser; a 3D printed piece therefore has the same quality as a casted metal piece but offers a range of opportunities in design. The design process is therefore influenced by the request of generating shapes that are not producible by any other technique. Three advantages are of special interest within the project:

- The technology allows for producing series of unique pieces at no higher cost than series of standard pieces.
- Parts can be printed interlocking which means that a unique experience of the interaction between digital and physical model can be created.
- Within a piece these interlocking parts can be varied from one to each other.

The interaction of a piece with the human body combined with constraints and opportunities of the fabrication method set the frame for the project. In the current status this process is tested in the realization of precious metal products such as luxury jewelry but is embedded in a larger research of creating series of unique and varying construction parts within the field of Architecture. Two specific examples are discussed in the paper to describe the developed process. The intricate computational model inherits design, detailing and fabrication information - These steps are combined within one single process, allowing for eager interaction through testing, evaluating and optimizing. For each design problem, a new tool is scripted, aiming at most effectively emphasizing and optimizing characteristics of the design. The architect is no longer ‘only’ the designer for a single physical design problem, but moreover the designer of a specific computational tool that communicates between the digital and the physical world.

DESIGN PROCESS

Scale - Geometry first

Designing a scale-less process means to integrates design, detailing and fabrication in one single computational model. Always starting from a geometrical logic, the process allows for thinking in a scale-less environment in the developmental phase. Yet the scale of course plays a major role in very project - it comes into account when precisely defining constraints and variables for the developed design-process. (Figure 1)

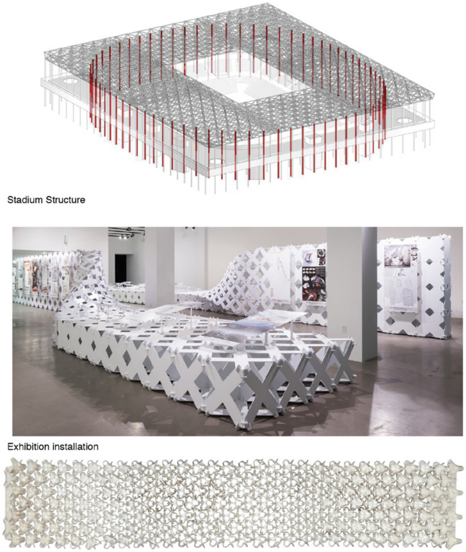


Figure 1: Thinking process: Stadium Structure - Exhibition Installation - Bracelet.

In an initial state, a geometrical system is chosen accordingly to its potential of fulfilling the functionality and material integrity of the given design problem. In a first step it can be observed on a purely mathematical level. Looking precisely into how the system's geometry influences its performance allows for constituting similarities to the actual design requirements. Characteristics that could be relevant for the final design are filtered; these can include structural aspects, porosity, agility or simply aesthetics. The system finally is chosen accordingly to its potential of fulfilling the functionality and material integrity of the given design problem.

The principles of the chosen geometrical structure are then abstracted and translated into a three-dimensional model. Taking the example of nature, there is no distinction between material, structure or shape - one single system solves several problems at various levels of hierarchy through geometrical formation. Variables of the generated system are defined - which factors should be stable and which factors can change in order to generate the variations of the system? Further, the range in which the variables can occur and how their value is influenced have to be explored. Parallel to this variability, an explicit design intention has to be developed. At what point are the generated outcomes evaluated and how can I measure the effectiveness of a design outcome? And how do the evaluation results inform the optimization of the design?

For each new design task the same questions are posed: Is it possible to scale natural strategies? To which extent is it possible? How can performative aspects, such as structural ability be implemented rather than purely abstracting the visual appearance? How can these complex systems be actually fabricated? The principles of the chosen geometrical structure are then abstracted and translated into a three-dimensional model. Taking the example of nature, there is no distinction between material, structure or shape - one single system solves several problems at various levels of hierarchy through geometrical formation. The aim is to explore further how variability changes the design and thinking process, merging formerly separated disciplines. How can technology be exploited to optimize designs in order to fit in our consumer-good based society while giving back desired individuality and uniqueness

TECHNOLOGY - PRINTER SPECIFICATIONS

The printer specifications have great influence on the designed pieces. The desire within the pieces always lies in making them as light as possible while offering unique and comfortable design for the wearer. Therefore we are working with minimum possible thicknesses of 0.35mm per part. Generating large overall volume while minimizing the piece's weight, optimizing the amount of handcrafted finish needed while offering a new user experience. The technology's economical scalability, as well as its long-term potential has to be explored.

DIGITAL TO PHYSICAL

In each of the designs the step from the digital to the physical environment is extremely valuable - since the artifact is 100 percent calculated and exactly predictable, the factor of materiality and finishing plays a major role; it is the

Figure 2: Digital Model - Physical Model.

only not entirely from the digital environment predictable part of the pieces. Although reflection and material appearance can be simulated the actual impact of the piece on a wearer's cognition is not comparable with a physical experience.

APPLICATION

Genesis Collection - Series of unique pieces

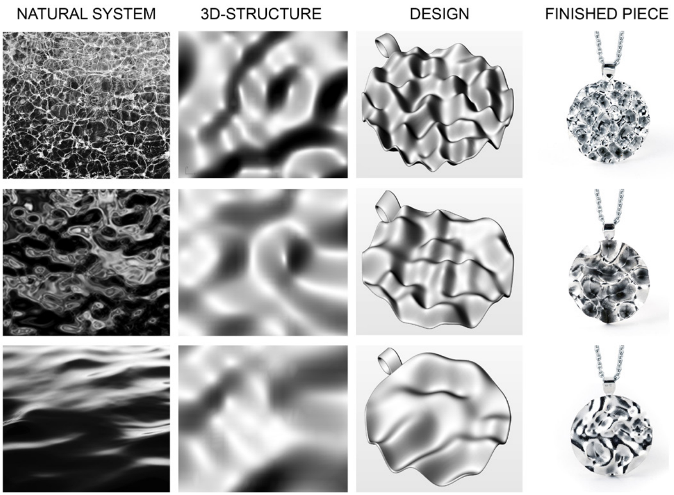


Figure 3: Genesis Collection: Natural System - 3D Translation - finished piece.

In the genesis collection, the surface of water and how it changes in different environments was analyzed and translated into unique pieces of pendants. The range of states of the surface was observed: The geometry of the wave can be described through rotating circles, depending on external influence such as wind conditions and the depth of the water in a specific location. The underlying principles of the moving surface are captured in static moments in the developed script. For generating the shape of the pendant the principles are abstracted, translating them with coordinates as simple as possible into a 3-dimensional shape. In the design, the wave height and intensity can be varied. The thickness of the piece is then added in a way that the piece is as thin as possible.

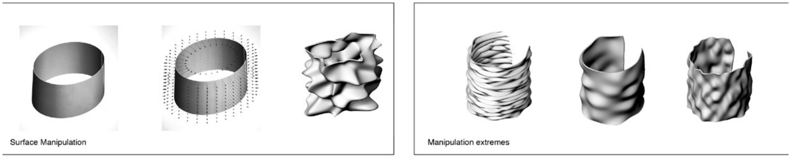


Figure 4: Genesis Collection - Pseudo-Randomness.

Embrace Collection - Hierarchy and Variation

In the embrace collection the focus lies in how the piece adapts to the human body and interacts with it. It is based on the principle of a fine scale structure on the one hand protective, at the same time smooth and adaptive. It creates a new sensual appearance for the user, rigid but smooth, like a woven fabric. The basis here is a three-dimensional, component that in assembly interlocks with the neighboring components. In this case, merely the performative part of the scale structure is translated rather than the literal natural geometry itself. Since the component interlocks in a two-dimensional way, the components' base-geometry is at first developed in two dimensions. At first, different options were tested of interlocking parts based on 3-sided to 8-sided geometry. As a first step the polygons were layout in a two-dimensional pattern, looking into options of how to build various pieces from them. In a second step the polygons were three-dimensionalised in different ways - for each polygon there are various options for three-dimensionalization. Main criteria here is the ability to vary the shape from one component to another as well as the weight of the pieces.

After executing a few formal tests and printing prototypes to test physical behavior, the decision was made to go further with the hexagonal shape, splitting it into two triangular guidelines defining the geometry. This geometry was chosen because it allowed for a very differentiated way of combining components and creating variation of pieces. On the one hand it generates a high degree of flexibility and on the other hand the geometry is not obviously readable like in the four-sided polygon. Since there are three points in which components can be connected together, it is possible to generate a linear as well as a diagonal appearance. It allows for generating a great variety of pieces starting from one single geometry. In further steps, the factor of irregularity will be added which allows for an even higher degree of variation. One further important factor is to develop a geometry that is smooth from all sides, therefore easy to wear and comfortable for the customer.

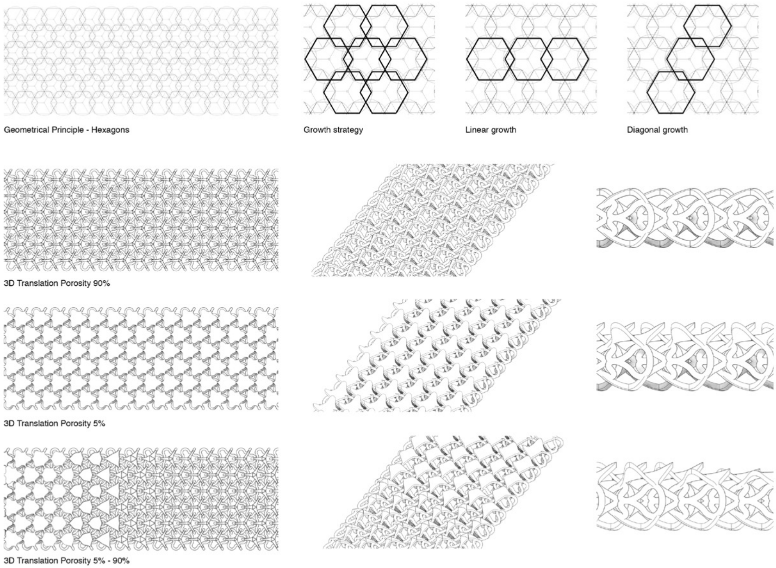
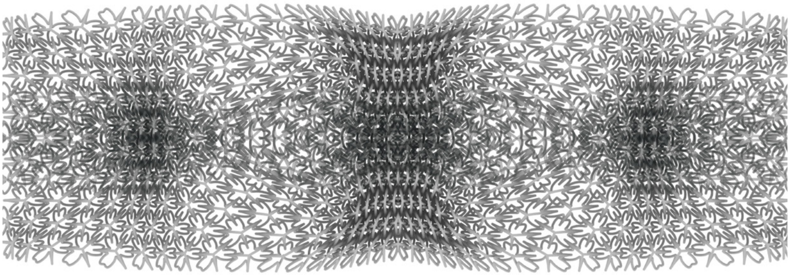


Figure 5: Embrace Collection interlocking system geometry variations.

The attraction of irregularity

Starting from a strictly system-based and mathematical design approach, the potentials of randomness and mistakes in the system are investigated, looking into natural artifacts as a basis. Natural artifacts are intriguingly beautiful and fascinating, yet never perfectly shaped in a mathematical sense. They are based on very strict mathematical rules that define their base geometry; the final outcome though is endlessly variable and differentiated. Variation may be expressed in size, geometry, porosity or color within a certain range. The designed process is independent of scale, materiality and function - these are considered when defining constraints and parameters. They are essential in setting up the project's constraints. Experience shows that the clearer the limits are set, the more freedom is created to develop a strong design outcome.



Introducing Irregularity

Figure 6: Introducing irregularity.

Principles learned from nature are extracted and implemented in the metal 3D prints. Another dimension is therefore added to the strictly system-based design approach. In the past, the developed geometries show variation in a very regular and readable way. Within a piece each segment changes gradually in shape to be slightly different from its neighboring segments. Variation has been expressed mainly through gradients. Four strategies have been investigated to create an organic and at first sight mathematically incomprehensible overall shape. Each of them usually provides very different outcomes, and for some designs they can be combined to generate a meaningful result.

1. Pseudo-Randomness: In the system-based design approach, geometries are defined and programmed by vectors and values. Instead of defining one final value for a certain geometrical dimension, in this option a range of possible values is fed into the system. Important here is to define a range of numbers within which a meaningful shape is created. Often it is a process of trial and error to find out about the minimum and maximum value.

2. Created diversion through manual surface-modeling: Many of the generated geometries are based on the division of a surface. The code can be programmed to divide the surface into segments and the final geometry is developed by directly manipulating or generating another shape on the surface. Before running a code, the surface can be manually manipulated by changing its isocurves at their controlpoints. The shape of the isocurves influences the shape of the surface and therefore the script that is running on the surface. As soon as the surface is not rectangular and flat any more it will have an effect on the regularity of the generated geometry.

3. Intended destruction: Removing or manipulating parts manually after a shape has been created. This is the option in which manual decisions are taken in a second step.

4. Errors: Frequently when scripts are run, unexpected errors occur and sometimes these errors create beautiful and unplanned shapes. This is definitely the most uncontrolled and non-predictable way of varying a shape.

For all four methods it is clear that the more profoundly a generated geometry is developed and understood, the more freedom can be set up to create variation. The reflection in this stage of developing directly 3D printed metal pieces introduces the following questions: How much does irregularity effectively add on to the overall design? Is it too ‘forced’? Is it just implemented to justify the technology or does it actually make the pieces more attractive, comfortable and as a result more valuable?

CONCLUSION AND FURTHER DEVELOPMENT

In the current state the developed strategies are successfully tested in different designs. These designs may vary in size, shape and function, still the thinking process is the same for each new task. Embedding this research in a larger, ongoing process of projects, the same is true for very different scales. The focus in each of the projects - no matter which scale - lies in creating differentiated shapes, consisting of complex and unique parts and realizing shapes with new technology that haven’t been possible to being produced without the tools.

Within the body of work, the question of scale of course still does matter in the final results. In larger projects the thinking process may be applied to parts of a construction, such as customized joints that are 3d printed. The exciting part of working in such a small scale is the quick realization and extremely fast feedback on design. The next step will be to print prototypes of various irregular pieces and compare their behavior in the real world. The aim is to explore further how variability changes the design and thinking process, merging formerly separated disciplines. How can technology be exploited to optimize designs in order to fit in our consumer-good based society while giving back desired individuality and uniqueness?

The applied methods leave no space for mistakes or unpredictability, each irregularity is based on a system as well or on rules of how to interrupt the system. Except for very few unwanted mistakes that create some unexpected working outcome, everything is thought through within the system. At some part this almost forced need to control every step and every little detail on a macroscale can lead to controlling values that do not even matter or appear in the real world. Sometimes focusing on every detail in a mathematical sense generates a loss of the big picture.

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