

Universidad Internacional de La Rioja

Substantial Changes in Graphic Design with the Emergence of Generative Design Processes

Cambios profundos en Diseño Gráfico con la Aparición de los Procesos de Diseño Generativo

Master's thesis/ Trabajo fin de Máster (Trabajo Tipo 1)

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Donostia, 04.02.2019

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Keywords: Generative design, Graphic design, Communication design, Computational Creativity Generative design methods are gaining importance in all the design industries. Responding to a detected lack of research on generative design (GD), especially in graphic design, this thesis provides an overview of key concepts, history, areas of application and state of the research on the topic. Based on insights from this overview, four essential unanswered questions are addressed, leading to some main conclusions about the present and future of generative design. Generative design is found to be a revolutionary method of creation that initiates a new era in design and possibly humankind, making it very probable for it to last in time. As a main reason for graphic design lagging behind in the application of generative processes, the concept of the "linguistic gap" is introduced. There is a great linguistic difference between the psychological and aesthetical concepts on which graphic design problems are based and the algorithmic language of computer code. This makes it difficult to define and evaluate generative processes in graphic design. Concerning the changing role of human designers in the generative design process, algorithmic thinking and programming are identified as essential skills for designers in the near future. Addressing a further away future, it is stated that a complete substitution of human designers by generative Artificial Intelligence (AI) systems is probable. In a critical debate, the implied economic, social, cultural and ethical problems in this kind of future are discussed. As the main approach to prevent possible problematic consequences of generative design in the future, a change in design education and general education is recommended. Lastly, a practical application of generative processes in graphic design is proposed in the layout of the thesis document and conclusions are drawn from the corresponding learning and creation process.

0_ Resumen

Palabras clave: Diseño generativo, Diseño gráfico, Diseño de comunicación, Creatividad Computacional Los métodos de diseño generativo están ganando importancia en todas las áreas del diseño. Respondiendo a la escasez de investigación sobre diseño generativo, especialmente aplicado al área de diseño gráfico, este trabajo proporciona una síntesis de los principales aspectos clave de este tema, incluyendo sus conceptos esenciales, su historia, aplicaciones y el estado de la cuestión. Basado en la información recopilada, se detectan y tratan cuatro preguntas esenciales acerca del presente y futuro del diseño generativo que no han sido respondidas adecuadamente hasta la fecha. El diseño generativo se identifica como método revolucionario de creación que inicia una nueva era en Diseño y probablemente en la historia de la humanidad. Por ello, se considera un fenómeno cuya perduración en el tiempo es muy probable. Como una de las principales razones por las que el diseño gráfico lleva cierto retraso en la aplicación de métodos generativos, se introduce el concepto del "abismo lingüístico". La gran diferencia entre los conceptos psicológicos y estéticos que definen problemas de diseño gráfico y el lenguaje algorítmico del código computacional hace que la definición y evaluación de procesos generativos sean una tarea muy difícil en diseño gráfico. Respecto al profundo cambio en el papel del/la diseñador/a humano/a en el proceso de diseño generativo, el pensamiento algorítmico y la programación se detectan como habilidades clave para los/as diseñadores/as en un futuro cercano. En cuanto a un futuro más lejano, se expone que una sustitución completa del/la diseñador/a humano/a por sistemas generativos de inteligencia artificial es probable. A través de un debate crítico, se exponen las problemáticas económicas, sociales, culturales y éticas que traería consigo un futuro de este tipo. Como posible manera de prevenir estas consecuencias problemáticas del diseño generativo a largo plazo, se recomienda un cambio en la educación de diseño tanto como en la educación general. Finalmente, con la maquetación del documento de trabajo fin de máster se propone una aplicación original y práctica de métodos generativos en diseño gráfico y se exponen conclusiones obtenidas a través del proceso correspondiente de aprendizaje y creación.

When I started working on this project, I wasn't aware of the fact that being a designer these days meant living a moment that will probably be classified as historical in a few years. I think many of my colleagues are not aware either. By launching this work, I hope to bring some light into the dark.

1.1 Introduction

Currently, we find ourselves in times of great change.
Conti (2016) talks about the beginning of a new era in human history. After having passed the ages of Hunter-Gatherer, Agriculture, Industrial and Information age, we are now standing on the doorway to "augmented age", where thanks to new technologies and artificial intelligence (AI), humans will start to work together with robots that will "augment them cognitively, physically

"This is the next stage in the evolution of Design.
And it's happening now"

(Autodesk, 2016, 1:38)

and perceptually" (Conti, 2016, 14:04). The emergence of these new forms of AI, that are getting more sophisticated every day, opens up new possibilities in all kinds of disciplines and implicates substantial changes in our way to work, produce, problem-solve and live the world but also brings up questions

that we should critically look at. One of the big innovations of this augmented era is the appearance of **generative design** (GD). In (computational) generative design processes, the designer cedes part of their control to a programmed system which autonomously creates ideas or solutions to the creative problem based on a certain code or algorithm. Incorporating generative processes into design stands for a paradigmatic change in our use of tools. These can now, for the first time in history, be used in an active rather than a passive way (Guida, 2014a). Knowing the problem to solve and our specific restrictions and criteria, generative tools can autonomously create problem-solving solutions that could not have been imagined by a human being. Generative algorithms work as autonomously and effectively as evolution but much quicker and as a human-controlled tool (Conti, 2016).

These developments are clearly provoking a radical change in the role of the human designer during the design process. Being the

"With generative design, ordinary people can achieve extraordinary results."

(Avital & Te'eni, 2008, p. 364)

new tools the ones who generate solutions, designers find themselves in a position where responsibilities and functions have to be rediscovered as AI takes over part of the process. This moment is an important turning point for the whole design industry, its outcomes, processes and humans working in it.

Among the industries that have implemented generative tools in their workflow, there are some fields adapting and incorporating the new technologies much quicker than others. Generative approaches are already well-known and are being developed and used in areas like architecture, product design, and engineering. Communication design, formerly known as graphic design, is a slower developing area in which we are still not taking much advantage of our possibilities. In this thesis, I intend to discover some of the reasons why graphic design is lagging behind.

Although design methods have been evolving in this way during the last two decades, we can clearly observe that literature and investigation on the topic are still sparse and the changing role of designers is not often discussed in papers. I have detected a strong need for a resuming work on the topic in order to promote a better understanding of the generative phenomenon and to discuss the importance and profoundness of changes in this historical moment. To do so, I provide a critical overview of the topic and address some essential questions that have not been treated sufficiently in the existing research, and that might define core problematics and potentialities. This thesis concentrates on generative design processes used especially in graphic/communication design. I enrich these theoretical efforts by proposing a practical application of GD in the layout of the thesis. The graphic material on the background of every page of this document is created by a generative tool specifically designed for this purpose. It creates illustrations based on real-life data related to my daily work on this project. The work-day every illustration refers to is indicated in the lower left corner of every page.

1.2 Justification

Generative Design (GD) is a recently emerging topic and very young phenomenon. This new way of designing is still in its fledgling stages and there is very little research dealing with the generative phenomenon. Technology is developing as quickly as never before and it seems like research is not able to keep pace with these rapid innovations and advances. However, this lack of documentation and examination does not reflect the importance the generative approach has for our society in general and for the design industry in particular. Most of the specialists in this field agree that GD is likely to be the most profound novelty in the design industry in the last century and will affect future design processes and outcomes in a significant and lasting manner. The rise of AI as a co-worker for contemporary designers means a paradigm shift for the whole field. Design processes and the designer's role inside these processes are changing profoundly. This implies that this revolution is not only a technological one but has a philosophical and socio-cultural impact as well.

As always with the upcoming of great technological, philosophical, and sociological changes, there is great potential for positive development, but also a certain threat of inadequate handling or misuse of the new possibilities. Possible risks and problems can be initially disguised by the "enchantment of technology" (Gell, 1992).

These problems might occur if technological aspects develop much quicker than theoretical, philosophical or sociological research regarding them. This can lead to an industry being overrun by a technological phenomenon without having the tools and the preparation to adapt to it and exploit it correctly. It is the responsibility of the research community to contribute to an adequate, responsible and full exploitation of the phenomenon's potential. This can be done through a high-quality research basis providing theories, methods, and insights related to the new phenomenon so that future professionals and researchers can rely on and be guided by the gathered knowledge and understandings. Therefore, especially with young phenomena like GD, every contribution to that basis is an important grain of sand.

sparse. This thesis is therefore focussed on said area, contributing to the research panorama by providing a complete overview of the topic, by answering some specific unanswered questions and by presenting a practical application of generative graphic design in the layout of this document. Thereby it fills a small part of the detected gap in research. The decision to incorporate a practical contribution is based on the assumption that proper research on this topic is impossible without also understanding the practical aspects of GD. To do so, I had to undertake a learning process of a generative programming language first. Besides the final, tangible, graphic outcomes of this process, the experience itself

I found GD research specialized on the area of graphic design to be especially

provides valuable insights into the practical aspects of working with generative software. If it is assumed that the main advantage of generative tools is that the designer is not limited anymore by tools externally created by programmers, then we can only fully exploit these techniques if the designers themselves are capable of creating the tool or if they work in close collaboration with a programmer. By introducing myself into programming, I wanted to explore the results a designer can achieve in about 3 months of low-dedication auto-didactic training.

I consider that this thesis is relevant and interesting for designers and design researchers as well as for other people involved in design processes such as programmers, engineers, technicians, and producers. Apart from the design industry, it affects and is relevant to society in general: as a group of consumers of designed products on the one hand and as part of a responsibly evolving and progressing world on the other hand.

1.3 Approach

1.3.1 Approach of solution

The approach to providing a solution for the detected lack of research on generative communication design has two dimensions:

The thesis is mainly a qualitative, literature-based investigation with the objective of giving an overview of the state of the field in generative graphic design and answering some specific, unanswered questions. The detected lack of research and documentation will be approached by a review and summary of existing literature and a critical examination of the topic regarding some concrete questions to be answered.

Apart from this mainly theoretical approach, the provided solution will be enriched by a practical part. Generative technologies will be used to design the layout of the proper thesis document. This can be seen as an original and creative contribution to the research topic which provides a direct practical application of the concepts developed in the theoretical part. As I had no former experience with generative design, I approached the practical part in a somewhat experimental way. Part of the process and prior to the actual creation of graphic material was a personal learning process of programming generative tools with the *Processing* software. The process was auto-didactic and its duration was equivalent to the development of the theoretical part but with a much lower dedication. In congruence with this experiment and the topic of my research, the proper layout of this thesis is a manifestation

of a generative design process. All the tools used to produce the graphic material have been programmed by myself from scratch.

In the context of UNIR's categorization, this approach corresponds to a master's thesis of type 1: manifestations, tendencies and emerging experiences in visual culture and digital graphic design.

The exact methodological procedure regarding the presented two dimensions of the approach can be consulted in the methods section [chapter 3].

1.3.2 Scope and boundaries

The thesis will explicitly concentrate on GD in the area of graphic design. However, articles about related fields such as architecture or product design are included if they provide significant general ideas that help understand the generative phenomenon or answer the research questions.

Due to the novelty of the topic and relatively little existing literature, I aspire a more or less complete overview of relevant literature and authors. Nevertheless, I cannot guarantee completeness.

Regarding the practical part of the project, I certainly could have achieved more sophisticated results by working together with a programmer. However, this personal experience of learning a generative programming language gave me the opportunity to evaluate the viability of incorporating generative tools in the repertoire of a communication designer with little prior education or experience in algorithmic design. This constitutes an important part of my contribution which is why I gladly accept the boundaries this implies for the quality of the graphic material.

1.3.3 Goals and focus

The goal of this thesis is to enrich the research panorama on generative design. This enrichment is based on three main goals:

- (1) To give a well-structured overview of the phenomenon of generative design and former related research
- (2) To answer a few concrete questions that go further than the current literature and
- (3) To provide a practical application of generative tools in graphic design.

The specific research questions corresponding to goal 2 are:

- » Generative Design: Will it last in time?
- » Why is graphic design lagging behind (in the application of generative processes in comparison with architecture or engineering)?
- » Will generative processes extinguish the profession of the designer?
- » How to prepare for the future? (What consequences can generative tools have and how can we prepare for a future with GD?)

Goals are described in more detail in chapter 3.

1.4 Structure

After this first introductory chapter and a very basic definition of key concepts [chapter 2], the thesis is structured in five main sections:

The first section [chapter 3] builds the framework for this thesis. Herein, I will define the general and specific goals of research and explain the methodological approach I have followed to reach these goals.

The second section [chapter 4] will provide an overview of the topic. Herein, I will clarify the most relevant concepts and point out some areas of application of the generative approach. I will outline an overview of the history of GD and GD research. I will dig into the relatively recent application of generative methods in the specific area of graphic design, illustrating the explanation with a few example cases. In order to guarantee a correct visualization of the images provided in this section in their full detail-richness without interrupting the reading flow, all the images are presented at a larger scale in the Appendix III. Readers can easily get there by clicking on the image.

In the background chapter [4.3.8], I will present authors of reference and their points of view and contributions. This provides a general and neutrally displayed overview of the state of the field and responds to my first research goal. Highlighting the detected gaps in research, I will make the transition to the third section in which I intend to partially fill these gaps.

This third section [chapter 5] is dedicated to satisfying the second research goal. Herein, I intend to answer four unanswered questions concerning the present and future of generative processes in graphic design, the changing role of the designer in these processes and the effects generative methods may have on society in general. I will dedicate one subchapter to each stated research

question. The organization of every subchapter will be individually adapted to the specific question and will critically merge insights gained from former research with my own conclusions and ideas.

The fourth section [chapter 6] responds to the third research goal and treats the proper design and layout of this thesis. It will provide an explanation of how the graphic material of this document is connected to the topic and comment on the contribution it makes. As a practical application, I want this to be an example of possible novel utilities for generative tools in graphic design. I will also draw conclusions from the creative process and my personal experience with acquiring GD skills.

In the last section [chapter 7], I will come to some main conclusions and propose a few questions for further research.

This thesis deals with the incorporation of generative processes in the context of graphic or communication design. To provide a general framework for the next chapters, I will very briefly define these basic terms generative, design and graphic design.

However, as pointed out in the structure chapter above, the exhaustive definition and presentation of the generative phenomenon as well as its history, the state of the field and authors of reference will be presented all together in chapter 4. This structure adapts much better to the proposed research goals and is more logical than incorporating an exhaustive background chapter in this part of the document.

Generative

"What kind of forms could we design if we wouldn't work with references anymore? If we had no bias? If we could free ourselves from our preconceptions and education?"

Michael Hansmeyer (2012, 0:18), the architect and programmer who asked this question, suggests looking to nature, the greatest architect of forms that ever existed. However, instead of copying or mimicking nature, his idea is a form of design "based on the natural principles leading to its growth and form" (Nordin, Hopf & Motte, 2013, p. 2931). Generativity is nature's essential model (Jaschko, 2005). Using this model for design means using nature's processes (like splitting cells or evolution) and code these as algorithms. Hereby, not the form itself is designed, but the process that makes the form (Hansmeyer, 2012). This is the essence of *generative design*; shifting our attention from creating the final product to "meta-designing" a process that creates the product. This process has the form of a computational algorithm or source code written by the designer that takes over part of the design process. The GD process works through a cooperative, synergetic relationship between human designer and generative system.

Design

GD can be applied to any kind of design process. But what is *design*? One of the basic word definitions provided by English Oxford Living Dictionaries (2018) is the following:

"Do or plan (something) with a specific purpose in mind."

While this might define the verb "design" in general, by using the word in conjunction with "graphic" we actually refer to it as a discipline rather than a single activity.

Todd Olson (2017) makes what I consider a rather successful attempt to define design as a discipline:

"Design (verb), as a discipline: plan the creation of a product or service with the intention of improving human experience with respect to a specified problem" (Olson, 2017, para. 4).

This definition resumes several main aspects of design as a discipline: "design is a deliberate act with pre-set intentions", there is the intention that the design will actually be implemented, "the objects of design are products and services, which [...] interface with people [...]"; "improving human experience is the general objective of design"; "each instance of design effort is focused on a specified problem in human experience" (Olson, 2017, para. 4). Eckert, Kelly & Stacey (1999a) point out that "the term design covers a wide range of tasks, activities, and products, but in all cases, it entails solving what psychologists call an ill-structured problem" (p. 6). It is, therefore, "characterized by a distinct thinking style" (p. 6).

Graphic/Communication design

In this thesis, I concentrate on GD in the context of one specific field of design: communication design or graphic design, which can be used synonymously. To avoid confusion, I will generally refer to the field as *graphic design*.

There have been uncountable intents to define graphic design in the past. However, finding a complete and correct definition is still a very difficult task. Most of the definitions agree on the basic assumption that graphic design is a form of communication through mainly visual artifacts. This is why lately the field is being called communication design rather than graphic design. It has also been suggested to see graphic design as a form of visual culture (Jobling & Crowley, 1996). Three factors have been identified to distinguish graphic design: it has to be mass-reproduced, accessible to a wide audience and convey ideas through a combination of words and image (Jobling & Crowley, 1996). Barnard (2013) resumes the different functions graphic design has in a social, cultural and economic context: information, persuasion, decoration, magic and a metalinguistic and phatic function.

3_ Goals & Method

3.1 Initial hypothesis and general research goal

As a preliminary hypothesis, it is assumed that the phenomenon of generative design constitutes a profound paradigmatic change for the design industry that will have strong and lasting effects on the industry and on the entire society.

Based on this initial assumption, the general goal of this thesis is to enrich the research panorama on GD in 3 ways:

(1) By providing an overview of the generative phenomenon. This is done by explaining and defining key concepts and by resuming the state of the field in GD research, presenting authors of reference and their positions. The goal of this overview is to facilitate the general understanding of what generative design is and to discuss the importance of the phenomenon for the design industry and its future. I want to contribute to strengthening the investigative basis on the topic in order to facilitate continuing research as these generative processes gain importance in the future and new aspects come into play.

- (2) By answering very specific unanswered questions regarding the present and future of generative design (see specific research questions [chapter 3.2]), pointing out its potentialities as well as critically highlighting possible problematic consequences.
- (3) By offering a practical application of generative design in the layout of the proper thesis document. I propose a layout based on the output of an auto-programmed generative tool fed by data connected to my work on this project. Firstly, this graphic output constitutes an original application of generative processes in editorial design and layouting. Secondly, the process of acquiring the skills to program a generative tool and the process of creation itself provide valuable insights. By undertaking this personal experiment I want to evaluate advantages, disadvantages and the viability of the usage of generative tools for a graphic designer. These insights and conclusions can help to identify possible problems to be solved regarding generative design in practice.

By enriching the research panorama on the field, the overall goal is to give designers and researchers tools that will allow the industry to prepare for what is still ahead. I consider an early, good understanding of the phenomenon to be the only way to foster a wise, meaningful and responsible use of these new design tools.

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3.2 Specific research questions

The specific goal is to answer four main questions regarding generative methods in graphic design:

Question 1: Generative Design: Will it last in time?

This question deals with making a prediction of how timeless the generative phenomenon will be in design practice.

Question 2: Why is graphic design lagging behind?

In the answer to this question, I identify reasons for a more advanced application of generative methods in architecture and engineering if compared to graphic design.

Question 3: Will generative processes extinguish the profession of the designer?

This question deals with the concern of designers getting completely substituted by AI systems in the near and further future.

Question 4: How to prepare for the future?

In order to answer this question, I set out possible negative consequences of generative tools for society and make suggestions on how to prepare for a future with GD.

3.3 Method

"An important pathway to knowledge is via a framework called methodology" (Onwuegbuzy & Frels, 2016, p.51).

In this section, I will set out the methods pursued on my pathway to reach each of the objectives and goals outlined above.

In general terms, this thesis can be classified in the category of qualitative research. Data taken into account to answer the research questions are mainly written documents as well as some graphic material and videos. As the defined goals of this project include two essentially different aspects, the methodological approach is also divided into two sections.

3.3.1 A comprehensive literature review for goals 1 and 2

To satisfy the first two general goals (providing an overview of the field of GD and answering the specific research questions), I followed a methodology inspired in the *Seven Step Model for a Comprehensive Literature Review* by Onwuegbuzy & Frels (2016). This methodology consists of seven general steps which I took as a framework and adapted to the needs of this project as detailed below:

Step 1: Exploring beliefs and topics:

As a first step of my process, I did some general and non-exhaustive search for literature, websites, blog articles, and videos concerning generative design. In the first place, this gave me a general overview of the state of the art, topics, possible questions to ask and answer, keywords, and areas of application for generative approaches. During this first phase, I basically relied on a general Internet search via Google and Google Scholar.

Based on this general overview, I formulated my general goal and my specific research questions which I had found unanswered in the first approach to the topic.

Step 2: Initiating the search:

To initiate a structured literature search, I identified the 3 main keywords concerning my research topic and their corresponding synonyms:

generative	graphic	design
parametric	communication	(art)
computational		
procedural		
algorithmic		

I searched for these keyword combinations on the following platforms and journals:

- » Google Scholar
- » Academia.edu
- » ResearchGate
- » ScienceDirect
- » UNIR Library
- » Sage Journals
- » Web of Science

Google Scholar as a general search tool containing articles published on all the other platforms provided by far the most and best results.

To broaden the results a little more, I also carried out the same keyword search in German and Spanish. However, this did not contribute many documents.

Step 3: Storing and organizing information:

This step was basically done parallel to step 2 and any literature search during the entire project. To organize the literature and information I was obtaining, I used an excel spreadsheet. This spreadsheet contained information about every single book, article, blog, website or video I had found during my research. The information was categorized by columns containing: the type of document, author, year or date, title, a one-sentence summary of what it contained and how it was interesting for my project, the source I got it from and the complete citation in APA format for my references section. I also color-coded: if I had been able to download the document (bright green), if I had only online access (dark green), only partial access (yellow), or no access at all (red). This spreadsheet accompanied me during the whole research process and was very helpful as I could search by keywords, authors, years etc.

Step 4: Expanding the Search:

As already mentioned, generative design is a relatively new field and research is still sparse. I quickly noticed that I wouldn't come very far by only searching for the initially defined keywords. I had to broaden my search parameters to get a better overview of the topic and to satisfy my research goals. I also decided that although this thesis concentrates on generative approaches in graphic design, general assumptions and findings were applicable from neighbor fields like visual arts and architecture. I also found

out that research of more specific subtopics belonging to graphic design wouldn't necessarily contain the keyword graphic or communication.

To expand my results I followed different methods:

I searched again for my keywords but eliminating graphic/communication.

I spread my results from inside outwards by searching for authors and papers cited in the literature I already had.

I spread my results by identifying more relevant keywords in the literature I already had and searching for them in the same way as in step 2. These keywords included:

- » Generative dynamic/fluid visual/brand identity
- » Post-logo
- » Computational creativity
- » Generative information visualization
- » Generative Typography
- » Generative Architecture
- » Generative + Engineering/product design
- » Relational Design
- » Emergence + Design
- » Evolutionary systems + Design

As very novel topics are often discussed verbally before being published in a scientific context, I wanted to include information and ideas spread in conferences and talks. Therefore, I included the video platforms *Youtube*, *Alexander Street*, and the *TED conferences* platform to search for my keywords.

Step 5: Selecting and deselecting information:

After the 4th step, I had recollected a total of 181 books, articles, thesis, online articles, and videos. In the 5th step, I had to identify which of these sources of information were really relevant to my topic and were to be included in the background section of my thesis [chapter 4.3.8]. To do so, I established some criteria to help me assess the relevance of each document:

- » **Crit. 1**: The document contains information relevant for a general understanding of the characteristics of generative processes for design;
- » **Crit. 2**: The document is accessible to me: I can, by any means, access its full-text and it is written in English, Spanish, German, Italian or Portuguese;
- » Crit. 3: The document is directly related to the area of graphic design;
- » Crit. 4: The document's author is widely cited in other topic-related articles;
- » **Crit. 5**: The document was published after 1999 or, if older, provides valuable insights into the history of generative design.

All the included documents had to satisfy Crit. 1 and Crit. 2. In case a document satisfied only the first two but none of the others, I undertook a deeper investigation to decide whether it was sufficiently relevant to be included. Especially Crit. 4 provided valuable information about the relevance of the publication in the research panorama. As GD is an only recently arising topic, Crit. 5 did not result in many exclusions as almost all of the articles concerning the topic had been published after 1999 anyway. Through this step, I selected a total of 57 papers, written by 64 authors to be included in the background section.

Although they might not have reached sufficient relevance to be included into the literature review, many of the documents I did not include in my background chapter are cited in other parts of this thesis to provide further secondary information or underline stated arguments.

Step 6: Analyze and synthesize information:

Completing this sixth step resulted in the background section of this thesis [chapter 4.3.8.], which satisfies research goal number one. I decided to structure the provided overview of the research panorama and state of the art by authors and topics. To do so, I first synthesized the work of every author from whom I had included a publication in my stock of relevant documents. Authors had between one and six corresponding publications. Then, I organized authors by topic, approach or research fields. In the first section, I put together all the researchers that have contributed to GD research by coming up with important or novel theories or models about the topic. Beginning with the two most relevant names in the field, the order of the other researchers was organized by clustering those with common or contrasting aspects in their theories. In a second block, I included all the authors explicitly related to generative processes in graphic design with a subsection of all the authors treating the topic of dynamic brand identities. After these two most relevant blocks, I included a paragraph about especially important authors in the field of generative architecture. Highlighting the upcoming interest of younger researchers and the beginning incorporation of GD in design education I then listed some authors who have published a bachelor's, master's or doctoral thesis on the topic. In order not to neglect practical aspects of GD, I finally introduced some practice-focused publications.

Step 7: Critical analysis of the information regarding the specific research questions:

This seventh step led to chapter 5, answering the specific research questions. To complete the second research goal, I revisited all the documents included in step 6, but with a different focus. Question by question, I identified statements made by any of the authors found in step 4 that were relevant to research the answers to these questions. If these statements were insufficient, I also included documents that had been excluded from the background chapter. Based on the retrieved information and on own conclusions drawn from my research process, I provided answers to the stated questions.

3.3.2 <u>A practical approach</u> for goal 3

The third general goal of this thesis is to provide a practical contribution to the research topic. To satisfy this goal, I propose a layout based on generatively created graphic material taking in real-life data related to my work on this project. In this paragraph, I will lay out the methodology followed to create this graphic material.

Learning to code

When I started to work on this project, I didn't have any practical knowledge about generative design, the necessary tools or methods. GD indispensably includes a co-working process between a human designer and a generative software. As software nowadays does not understand natural language, my first step was to learn a programming language through which I could create a custom generative tool. I chose this software to be Processing, a language based on Java and designed for creating visual arts via code. I started this learning process approximately five months before finishing the layout of this thesis, which means that I had an about three months long, low-dedication learning process. This process was guided by the book Learning Processing: a beginner's guide to programming images, animation, and interaction by Daniel Shiffman (2009) as well as the corresponding video classes available at learningprocessing.com. Shiffman's methodology is based on a gradual acquirement of the basic functions of Processing by providing theoretic information and applying it to practical exercises. Personal practice and experimentation is an essential part of the process.

Collecting data

As I wanted the generated graphic material to have a connection with my work on a meta-level, I began to collect data from the first day I started working on this project. My goal was to create a time-based data-set of work-related activities. Therefore, I started registering the following variables every day for the whole duration of the project (140 days):

- » Number of hours dedicated to searching literature (in code: search)
- » Number of hours dedicated to reading literature or watching video material (in code: readwatch)
- » Number of hours dedicated to writing (in code: write)
- » Number of hours dedicated to coding and layouting (in code: code)

I also included two variables from my private life:

- » Number of hours of sleep
- » Having done sport (yes/no) (in code: sport)

I later excluded the sleep variable because of lacking variance.

From the four work-related variables I also calculated the total hours of dedication per day (in code: *total*).

To fit 140 days onto 105 pages, I excluded the days between October 15th and November 17th, 2018 as well as the days after the 3rd of February, 2019. The complete spreadsheet of data is available in the Appendix II and can be consulted for a deeper understanding of the connections between days, data and generated images.

Creating the generative tool

Once I had acquired a medium level of control over Processing, I started experimenting with possible programs that could adjust to the constraints of my project. I wanted to create data visualizations in which every variable would influence a certain graphic aspect of the created material. This way, the graphic material would also provide information to the reader, besides having an aesthetic dimension.

The final generative of random points

based on a network of random points moving across the screen. Depending on the values of the six variables it is fed, the points lead to different graphic manifestations on the canvas:

» total: The total hours of dedication determine the number of moving dots there are (minimum 3 (for 0 hours) and maximum 30 points (for 12 hours))

The total hours also determine the color of the background. The more hours dedicated, the stronger the background color. If 0 hours were dedicated, the background is white.

- » search: The moving points create filled circles, whose diameter reflects the hours spent on searching literature. This means that the more hours spent searching, the bigger the circles. As the circles are in motion, they manifest on the screen as lines. A higher number of searching hours results in bolder lines, whereas 0 hours of searching, result in no lines at all.
- » readwatch: The moving points create unfilled circles, whose diameter is 5 times the hours spent reading or watching. Therefore, a higher number of hours spent reading and watching results in bigger outlined circles. If 0 hours were spent reading or watching, no outlined circles appear.

- write: When the distance between different moving points goes below a certain maximum distance (in code: maxdistance), a line is drawn between these points. The maximum distances is determined by the hours of writing or coding, whichever is bigger. This means that the more hours dedicated to writing/coding, the more and longer the lines.
- » code: The hours spent coding or layouting determine the curvature of the lines drawn between moving points. So, the curvature is directly proportional to the number of hours dedicated to coding or layouting: the higher the number of hours, the more curved the lines. The maximum distance for points to create a line between them depends on coding or writing, whichever is bigger. Therefore, spending a great deal of hours on coding results in the creation of many long and very curved lines. Whereas with 0 hours dedicated to coding or layouting but at least one hour dedicated to writing, the lines are completely

- straight. With 0 hours dedicated to writing nor coding, there are no lines created between points.
- » sport: This variable can be either true or false (sport was done or was not done). Whenever sport is true, the lines created by writing and coding as well as the circles created by searching are colored purple, otherwise they are white.

The final image used for the background of the pages of this document is created by capturing and exporting the created forms after a certain time. To slightly balance out the little graphic manifestations in case of few dedicated hours, the timeout for the capture is inversely dependent on the total hours of dedication. For maximum hours, the timeout for saving the graph is 1 second, for minimum hours it is 4 seconds. Thanks to this correction there is at least some visible graphic outcome for days with lower dedication.

For a better understanding of the tool, the following images show typical outcomes for different combinations of hours dedicated to the different activities.

The program is fed by a spreadsheet containing all the variables [Appendix II] and automatically runs through all the days, creating an illustration for every day and exporting it to a pdf named with the correspondent date. This way, all the images can be created automatically in little time. After creating one drawing for every day/ page, the position on the page is decided individually and adapted to the textual content. In some cases, the contrast of the image had to be modified to guarantee legibility. This was done by lowering the opacity of circle and line elements.

The original and complete code of the created generative tool is accessible in the Appendix [Appendix I].

Figures 1-9: Example images of how the



total: 3, search: 0, write: 0,

readwatch: 3, code: 0, sport: no

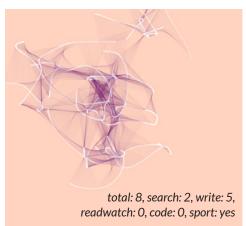


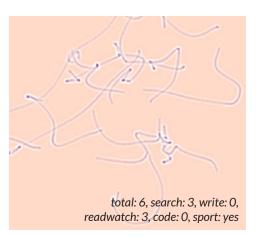
total: 10, search: 1, write: 0,

readwatch: 3, code: 6, sport: no









Understanding the Generative Design phenomenon

"For the first time computers became involved in an activity that had been the exclusive domain of humans; the act of creation".

(Frank Dietrich, 1986)

This chapter responds to the first research goal. Its purpose is to explain the generative phenomenon and to give a detailed overview of the research panorama regarding generative design.

4.1 Introduction to Generative Design

Although we entered post-digital age a while ago, the majority of graphic design products are still not using digital tools in a purely digital way but rather an analogical one.

Traditionally, designer's works have always been determined by the tools used to create them. Creatives had to adapt their solutions to the available systems and software built by programmers. As a consequence, designers found themselves in a prisoner-like situation which does not reflect the concept of creativity, supposedly inherent to this profession.

However, whereas until the 90s – the "age of transition" as called by Baule (2007, cited in Guida, 2014a, p. 128) – there was no noticeable intention to make the change from the analog to the digital world, we can now observe how this imprisonment is being dissolved little by little. At first, it was only an insider practice on media art fairs and conferences; artists would start to use computational programming to include data and chance into their artworks, creating completely new and unexpected, fascinating visual worlds. Now, these generative processes have also been discovered by graphic design (Schmidt-Friderichs in Bohnacker, Groß & Laub, 2009).

We are living a paradigm shift in design that formally creates new visual worlds. However, the essence of this shift remains hidden for many people: the possibilities of programming languages like *Processing* will change the designer's role. With GD, the design-educated user of prefabricated digital tools is converted into a programmer of an individually customized digital toolbox (Schmidt-Friderichs, in Bohnacker et al., 2009). Guida (2014a), one of the leading investigators on GD, states that "the evolution is in the way of using digital tools, not anymore in a passive but in an active way. [...] Graphic designers can build their digital tools basing them on design and aesthetics needs. Innovation is in the creative process, not in the final result [...]" (p. 128).

This shift implicates a complete change of the design process, converting the designer from a mere artisan into a manipulator of the design's meta-layer based on abstraction and information (Schmidt-Friderichs in Bohnacker et al., 2009). This step up to the meta-layer "empowers the designer, freeing him from the constraints of predefined computational

tools, and promoting creative freedom [...]" (Duro, 2012, cited in Guida, 2014a, p. 122).

The implementation of programming into the creative process refers to the delegation of part of the creative process to a computerized system defined by a set of rules. Based on defined parameters, this system will take over the labor of creating solutions to the design problem. Depending on the type of system, it will even select and develop these solutions. This means that the designer does not have to physically produce the solutions anymore but rather defines the solution space; less time is invested in artisanal production and more time can be invested in research and experimentation, which can make the final results more satisfying (Guida, 2014a).

4.2 Key concepts and definitions

"Generative" comes from Latin *generare/generativus* and can be defined as capable of producing a result as a consequence of an autonomous process (Tomatis, 2014, p. 19). A "generative process" is one that independently creates outcomes that can't be exactly anticipated or predicted.

Generative art

As defined by Philip Galanter, one of the most widely cited authors on generative art,

"generative art refers to any art practice where the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, which is set into motion with some degree of autonomy contributing to or resulting in a completed work of art" (Galanter, 2003, p. 228).

Galanter always underlines the key idea that in generative art the artist gives away part of their control to an external system. As a consequence, the result is different to what they would have created based on spontaneous decisions or inspirations.

His definition implies that generative art processes are not necessarily linked to computational or digital systems. The "external system" Galanter refers to can equally be a mechanical system or even another human being. However, in this thesis I will generally refer to *computational* generative systems when mentioning generative systems.

Generative systems

Generative systems are systems that allow "rule-based decision making" (Epler, 2017, 0:09). This means that, based on a number of rules or abilities that form an algorithm, the system creates some type of output (sound, data, graphics etc.). The designer's role is to define these rules.

According to McCormack, Dorin & Innocent (2004), the key properties of generative systems are: "the ability to generate complexity", "the complex and interconnected relationship between organisms and environment", "the ability to self-maintain and self-repair" and "the ability to generate novel structures, behaviors, outcomes or relationships" (pp. 158-159).

There are different types of generative systems that work in different ways: self-assembly systems inspired by biology and chemistry, evolutionary systems that simulate the process of natural selection and reproduction, and grammar-based systems as well as shape grammars. I will not go into detail here, for further information about the different generative systems McCormack et al. 's (2004) paper on generative design is a recommended lecture.

Emergence

As regards computer-based aesthetics creation, a concept that has always been linked to the generative idea is that of *emergence* (Bardebes, 2015). *Emergence* is a phenomenon similar to Gestalt in psychology. It is present when the whole is greater than the sum of its parts. Applied to computer-aided generative creation, that means for Monro (2009) that the generative process and its outcome is somehow surprising even if we have complete knowledge of its construction. Also, even after the initial moment of surprise has passed, its behavior should still create a sense of wonder or mystery (Bardebes, 2015).

Randomness and chance

Concepts of randomness and chance refer to a lack of pattern or predictability, with every event inside a range of possible events having equal probability to happen. The existence of randomness and chance in the creation process allows the generation of emergence in computer-based art and design. Although these concepts are not at all unusual in traditional art and creation, they are indeed the essential elements in computational GD. With randomness and chance in the GD process, it is possible to create almost infinite variations of a design and therewith explore the whole solution space. The idea of randomness as a motor to create variability depicts the similarity between computerized GD and evolution: Variations are created by chance (mutation), some of them are selected according to a certain criterion (fitness) and then developed further (reproduction).

4.3 Generative Design

"Metadesign represents [...] an enhancement of the creative process at the convergence of 'art' and 'science'."

(Giaccardi, 2005, p. 348)

Bohnacker et al. (2009) define generative design as a cyclical process. A simple idea is transformed into an algorithm which manifests itself in a source code. This code produces output via a computer and returns it to the designer. Through this feedback loop, the designer reinforms the algorithm and source code. "It is an iterative operation, relying on the feedback exchange between the designer and the design system" (Agkathidis, 2015, p. 16).

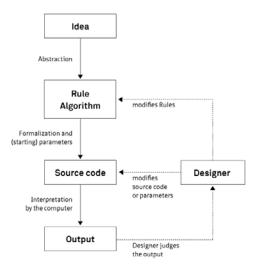


Figure 10: Generative Design process (Bohnacker et al., 2009, appendix A.0)

4.3.1 <u>How generative design is different from traditional</u> <u>design</u>

GD is fundamentally different from traditional design in a few key aspects, which are essential to define and understand generative processes. They also build the argumentation basis to defend the assumption that GD means a paradigm shift for the design industry.

Active tool-using

"Whenever one uses software to create an image, the finished product speaks partly of the user's input, but more than most would care to admit, of the constraints imposed by the software and the output it is capable of producing" (Dorin, 2001a, p. 661). This restriction of liberty during the design process is finally overcome with the emergence of generative systems. In a GD process, "the designer does not interact with materials and products in a direct ("hand-on") way but via a generative system" (Fischer & Herr, 2001, p. 3). As mentioned above, the main difference between traditional design processes and generative processes is that the design tools are used in an active rather than passive way. This means that the designer does not create the final design itself but a tool that creates the design.

"Computers that creatively come up with ideas on their own are the heart of generative design" (Kowalski, 2016, para. 7). This shift is the essence of a very profound change in our way of working. Up to now, even the most sophisticated digital design processes and tools have been nothing more than imitations and automatizations of the traditional resources of the industry, digital metaphors of the analog drawing table (Cardoso & Capdevila, 2009), "tools for execution, waiting for people to tell them what to do" (Kowalski, 2016, para. 5). The new generative, algorithmic design tools represent the real leap from the analog to the digital world. Generative tools create the

opportunity to overcome our condition as passive users and reach out to opportunities that really exploit the characteristics of the digital world (Cardoso & Capdevila, 2009).

Growing vs. making

Seen in a different way, we can also mention a fundamental difference in the manner products are created with traditional processes vs. generative ones: With classic design processes, products are *made*. "Things which are made, [...] are an assemblage of parts put together, or shaped, like sculpture from the outside inwards" (Watts, 1991, p. 39). Products created generatively are *grown* rather than made. "Things that are grown, shape themselves from within outwards – they are not assemblages of originally distinct parts; they partition themselves, elaborating their own structure from the whole to the parts, from the simple to the complex" (Watts, 1991, p. 39). The design process with generative tools is much more similar to the idea of seeding, breeding and growing and therewith much closer to production as it happens in nature. Actually, we can observe how evolutionary generative systems create results that look very similar to products of millions of years of evolution in nature. Agkathidis (2015) states that "form is no longer being made, but found" (p. 17).

Efficiency

Another very obvious aspect that differentiates traditional design from generative design is the number of possible solutions that can be elaborated in a certain time. As mentioned above, a GD system is able to simulate millions of years of evolution in just a few minutes. A generative algorithm does not only produce one or two solutions to the design problem. Making

use of randomness, it produces possibly infinite different solutions to the same problem that all match the defined constraints and goals. All of them inside the same "grammar". A human designer could never create a comparable amount of sketches in an appropriate time during a design project and would therefore always only be exploring a small part of the whole solution space.

But the quantity of produced solutions is not the only advantage. Also the quality, referred to as the accuracy and detail richness of the sketches, can be very high without any extra effort. For instance, for the design of a building, thousands of variations can be generated and all of them could be viewed and tested as a high-quality 3D-model like the one the architect would normally produce only in the final phase of the project.

The aspect of a greater efficiency brings along another very important advantage of generative methods: The possibility of automatically creating accurate and detailed digital models has a strong positive influence on the communication process between designers and technicians. Failures in this "communication bottleneck" can result in great inefficiency, errors, and losses in time and resources. If designers can create consistent, complete and technically correct designs by using generative systems, the communication difficulties with technicians can be overcome (Eckert et al., 1999a).

Design process

Another aspect that is different between classical and generative design is the design process itself. As this aspect is especially relevant for the thesis' focus, I will treat it separately in chapter 4.3.7.

4.3.2 Main applications of generative design in the present

Art

One of the main fields of application of generative processes, and also its origin, is art. Artists started to experiment with non-digital generative processes long before computers became a tool of general access. Generative processes are used in all the different art disciplines such as music, visual arts or even literature. Without going into detail here, the outcoming pieces of generative art can range from electronic music and algorithmic composition over paintings, installations, performance and sculpture to generative poems and books. *Software Art* and *Live Coding* are new forms of art, specifically linked to the generative phenomenon. The *Demo Scene* and *VJ Culture*, as a completely established part of youth culture, have converted generative methods into an "everyday method of creation" (Galanter, 2003, p. 226). Areas, examples, and authors are infinite and I don't pretend to even scratch the surface here. Two examples of generative art are presented in figures 11 and 12.

Underlining the aforementioned statements on the importance and novelty of the generative art and design phenomenon, there is the case of the "Portrait of Edmond de Belamy". On October 26, 2018, while working on this project, I was witness of a historical moment in generative art: The mentioned artwork, created entirely by AI, sold for nearly half a million dollars at the "first-ever auction of its kind" ("This AI-generated portrait", 2018, para. 1).



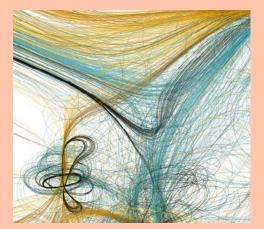


Figure 11: Reas, Casey (2001). *Path.* (Reas. com, n.d.) (cropped)

Casey Reas creates generative prints and installations and is one of the creators of the *Processing* software as well as art professor and author of several books on the topic.



Figure 12: Barrat, Robbie (n.d.) *plant-art*. (Barrat, R., n.d.) (cropped) Robbie Barrat creates drawings based on data retrieved from houseplants.



Figure 13: Nervous system (2014). *Kinematics Dress.* (Photography by Steve Marsel Studio) ("Kinematics Dress", 2014) (cropped)



Figure 14: LMB architects (2016).

Generatively designed Ceiling of the Voxman School of Music. (Photography by Tim Giffith). (Fixsen, 2017) (cropped)

Fashion design

In the field of fashion design, the Kinematics dress by Nervous System should be mentioned [Fig. 13]. This generatively designed and 4D-printed piece of clothing clearly demonstrates Manovich, Malina & Cubitt´s (2005) principle of *variability* as a characteristic inherent to purely digital creations; The Kinematics dress is not a single dress but rather infinite versions of itself, adapting to every possible body on the planet and being different every time without any extra effort.

Although they will be mostly cited in the category of graphic design, the efforts of applying generative approaches to knitwear design by Eckert, Kelly & Stacey (1999a, 1999b, 2000, 2006) technically belong to fashion design too.

Computer graphics and animation

Generative approaches in animation films or video games permit an incredibly realistic synthesis of hair imagery, smoke, fire or plant population and even complete and autonomous animations with real-world behavior (Galanter, 2003).

Architecture

Design problems in architecture are usually very complex and unique for each project. Also, mistakes in their solution can have very severe consequences and high costs. Generative processes help to explore a wide design space to determine the best solution to fit high-level defined goals and constraints instead of relying on single architects' experience and intuition. Generative tools in architecture can help to design entire buildings or spaces, such as the VU Exhibit Hall 2017 (Villaggi & Nagy, 2017) or to adapt single pieces of a building to a specific purpose, like the acoustically optimized ceiling of the concert hall at the Voxman School of Music by LMN architects (Bernstein, 2018) [Fig. 14].

Product design and engineering

Product design and engineering might be the fields that are currently exploiting generative processes the most, with amazing, highly novel and effective outcomes. Specific problems in product design and engineering have usually been resolved in a certain way for decades, always improving the specific solution but without exploring entirely different ones. The introduction of generative tools is helping to entirely change the approach of resolving design problems in a way that would be impossible without Al. As the outcome of product design or engineering processes is normally a physical object, especially evolutionary techniques are being of great benefit here. Without taking into account former solutions to a problem, a generative system can design pieces out of a block in an evolutionary way (based on mutation and fitness testing). "Basically, they find solution(s) to a problem by maintaining a population of possible solutions according to the 'survival of the fittest' principle" (Renner & Ekárt, 2003, p. 709). Even reallife performance data can be recollected and automatically looped back into the design process which then improves itself according to such data. The outcome of this process is the best possible solution for the problem and generally radically different to the former solutions created by humans. These generative approaches are intimately linked to the existence of novel and very recent production possibilities. New materials and additive manufacturing techniques like 3D-printing make these solutions possible to implement practically. "The things that have limited us in the past (software, materials, manufacturing...) no longer do so" (Autodesk, 2018, 1:28). To name just one example, Airbus recently designed a new bionic partition (wall to separate crew from passengers) [Fig. 15] for their airplanes and managed to lower its weight by 45% thanks to generative design (Micallef, 2016). Currently, they are working on generating a design for the whole airplane body [Fig. 16].



Figure 15: Airbus. (2016). Generatively designed bionic partition for Airbus. (Micallef, 2016)



Figure 16: Airbus. (2016). Bionic Design for airplanes of the future. (Keller, 2017)

Graphic or Communication design

Although in general terms it still does not seem very common to utilize generative processes in graphic design, they have been used for different types of designs in the past decade. Maybe the most obvious field of application is information graphics, where real data is taken as an input to create visual output. This was done for example by the studio Onformative, which created a generative illustration for a wallpaper for Telekom, based on data retrieved from their Facebook user interaction ("4010 Facebook Tree", 2013) [Fig. 17]. Another quite developed field is the creation of generative fluid brand identities. There are plenty of examples, like for instance the famous generative visual identity for Nordkyn whose logo depends on real-time weather data[https://vimeo.com/108765350; Fig. 18]. However, generative processes can be used to create any kind of graphic, image, illustration or audiovisual piece. As this is the main

focus of this thesis, in order to avoid redundancies, this will be discussed in detail in chapter 4.3.5.



Figure 17: Onformative. (2013). *Facebook tree*. ("4010 Facebook Tree", 2013)
This illustration generated from Facebook data was created for a Telekom Store.



Figure 18: Neue Design. (2010). Generative Logo for Nordkyn. (Neue Design, n.d.). (cropped)

This logo for the Norwegian peninsula Nordkyn changes depending on real-time weather data. Video available at https:// vimeo.com/108765350 (Neue Design Studio, 2014).

4.3.3 <u>How generative processes work in practice: a quick</u> introduction

Working generatively means working together with software that, based on certain constraints and parameters, helps to generate solutions to a problem. For current engineering and product design, there are three main approaches through which this assistance can be provided by computational systems (Tamburini, 2017): Topology optimization (used by software such as Altair's solidThinking Inspire or Frustrum's Generate) and Lattice and surface optimization (used by nTopology's Element) are mere form optimization algorithms. To date, they mainly improve given objects in means of weight, strength and material usage by removing unnecessary material from a given form. Form synthesis, the third approach, really generates design solutions from scratch, satisfying specific objectives introduced by the designer (such as functional requirements, material type, manufacturing method, performance criteria, or cost restrictions). The most famous software using this approach is Autodesk's Project DreamCatcher.

For graphic designers and artists, objectives of using generative systems are different to those for engineers. Generally, there are no clear performance parameters or restrictions. The creation of visual grammars and aesthetics, sometimes based on data visualization, are the important aspect here. Generative processes to design visual output can be implemented in different programming languages, compiled by different environments. Tools that can be used by generative artists and designers are for example *Processing*, *NodeBox*, *StructureSynth* for 3D-structures, *VVVV* for motion graphics, audio, and video, or *Adobe Flash*.

Processing

The language and environment that has been used to create the visuals for this thesis is *Processing*. *Processing* is an Open Source programming language that constitutes an alternative to proprietary software tools. The Processing project was started in 2001 by Ben Fry and Casey Reas as a promotion of programming literacy in the context of visual arts ("Processing", n.d.). Currently, Processing is used in art schools, universities, artists' labs and design and architecture studios all over the world. It has a large community, good documentation, and a well developed learning environment.

Although there do exist frameworks to lower the amount of actual code to be written by the designer, like for example HYPE, the way of communicating with the generative system is still via pure code. This can be a serious barrier for designers as informational thinking and coding basics are currently not included in a designer's education. NodeBox is an alternative that has implemented a more graphical user interface but the way of communicating with the system is still very abstract and has a relatively slow learning curve for people not used to algorithmic thinking.

4.3.4 History and origins of generative design

Despite what many might think at first sight, generative art and design do not have their origins in the invention of computers. The famous generative art theorist, Phillip Galanter repeatedly points out that generative art is actually "as old as art itself" (e.g. 2003, p. 236). He identifies the use of a system as an indirect production method with some degree of autonomy as an essential part of generative artistic creation (Galanter, 2003). Personal control has to be diminished, making the artwork somehow rule-based. But this external systems or impersonal processes do not have to be computational, or even digital. "They may be physical, psychological, sociocultural, biological, or abstract (formal). And if abstract, they may or may not be implemented in a computer" (Boden & Edmonds, 2009, p.10).

Galanter investigates about generative art in the context of Complexity Theory. It is impossible for me to go into detail here but, basically, generative art systems are viewed inside a two-dimensional space where the x-axis represents the degree of order or disorder and the y-axis represents the complexity. Complexity is highest where order and disorder are in balance. At the very end of the "order" side of the diagram, we can find

"Design is dead.
Design should be alive. Everything in this world changes. So should design"

(Paul Hughes in Pearson, 2012, p.5)

systems such as symmetry and tiling, at the "disorder" end there is randomization (Galanter, 2003) [Fig. 30]. This theory helps to identify generative art in history. If symmetry and tiling can be seen as a system (even if it is a highly ordered and low complex one), then the oldest known art artifact can be seen as generative art. The 70,000-year-old etching is clearly a grid design of triangular tiles and would therewith prove Galanter's assumption that generative art is as old as art itself. As later examples of art utilizing simple highly ordered symmetry or geometry systems or number sequences, we can name M.C Escher's tile artworks as well as those of different minimal artists such as Carl Andre or Paul Mogenson (Galanter, 2003). While accepting the application of highly ordered systems such as symmetry as an antecedent of GD might seem a little difficult, the case becomes much clearer when we take a look at the other side of the diagram: randomness. Probably some of the first conscious usages of randomness were the musical dice games in the 18th century by Kirnberger, Mozart and Haydn. Single musical

fragments could be recombined randomly, being dice throwing the system which determined the order (Zweig, 1997).

However, many researchers see the origins of an active use of randomness and chance in art in the appearance of contemporary art in the 1920s. Surrealists prioritized the "unconscious mind" over personal decisions and used techniques like psychic automatism to minimize the influence of personal control over the creation (Boden & Edmonds, 2009). Dadaists like Tzara or Duchamp equally tried to remove artists' intention and intervention by building artworks entirely on chance. Contemporary dance and performance artists like Cunningham started early to defend the ceding of control from the artist or choreographer to random influences and to the proper audience. Similar ideas would be promoted and explored intensely during the 1950s and 60s by artists like Lygia Clark in Neo-Concretism, Trisha Brown in contemporary dance or Jackson Pollock in painting. By the same time, some artists belonging to the kinetic art movement experimented with movement being triggered by uncontrollable influences. Hans Haacke in the 1960s introduced art systems based on biological and physical processes. Maybe one of the most famous contemporary artists when talking about chance as part of the creation is the composer John Cage. By inviting randomness into his compositions, he tried to eliminate the authority of the author (Pritchett, 1996).

Inspired by the mentioned movements, conceptual artist Sol LeWitt, proposed his "Wall Drawings" around 1969, which I personally see as one of the most obvious non-digital antecedent of generative art. The physical materialization of these artworks was mainly done by people other than himself, who simply executed the exact rules and instructions given by LeWitt. His famous phrase "The idea becomes the machine that makes the art" (LeWitt, 1967, p. 79) represents the essence of the generative idea.

After this quick overview of pre-computer generative art, we can formally date the beginning of computational generative art to February 1965. This is when computer art was exhibited for the first time in history in the exposition "Generative Computergraphik" by Georg Nees in Stuttgart (Boden & Edmonds, 2009). Together with Nees, Frieder Nake, Michael Noll, and Manfred Mohr can be named as pioneers in generative computer arts. Nees was also the first to make a Ph.D. on computer art and to publish a book on the topic (Franke, 1971). Since the terms "generative art" and "computer art" were coined these years, they have been used almost synonymously although I have pointed out earlier that generative art is not necessarily computer art and vice versa. Since then, numerous generative artists have sprouted all over the world. In 1970 the Department of Generative systems was founded at the School of the Art Institute of Chicago by S. L. Sheridan (Kirkpatrick, 1980). Of course, the appearance of the Personal Computer would have a great impact on generative art and design methods. Muriel Cooper, co-founder of the Visual Language Workshop at MIT in 1974 was a pioneer in using interactive media in design. She would, later on, inspire famous generative artists like John Maeda, who initiated the platform "Design by numbers" at the MIT Media Lab in the 1990s (Maeda, 2001). This project, eventually incorporating Ben Fry and Casey Reas, would be the origin of generative processes entering classrooms and of the Processing platform (Reas & Fry, 2007). Processing made generative art widely available to basically anybody with a computer and is therefore referred to as the "turning point in the production and proliferation of generative art" by art analyst Jason Bailey (2018). Numerous artists have made themselves a name in the creation of generative art since then. Jared Tarbell, Joshua Davis or Robbie Barrat are just a few of them.

In architecture and engineering, there had always been a certain interest in mimicking nature for the construction of man-made devices and buildings. This interest arose especially with the emergence of "bionics" in the 1960s (Steadman, 2008). In the 60s and 70s, the first evolutionary strategies and shape grammars were used in architecture (Steadman, 2008), like for instance in the work of Stiny and Mitchell, 1978. Computational Evolutionary Methods could be applied in engineering solutions since the 1970s. In 1989, Soddu, who is still a reference in generative art and architecture, described his generative approach to architecture and town design in his book Citta' Aleatorie, Generative solutions have become especially useful and applicable since the development of additive manufacturing and 3D-printing since the 1980s (Goldberg, 2018).

4.3.5 How and where are generative processes being applied in graphic design?

After having given a general overview of generative art and design, I want to concentrate on generative *graphic* design in the following parragraphs. There are two different views on the question of generative processes in graphic design: First I want to talk about the "how" (for what can we use generative systems), later I will make a resumed list of the "where" (areas inside graphic design that use generative processes).

How: Inspiration vs. creation

In almost all fields and cases of design, one of the very first steps of the design process includes active inspiration (during the research phase). Designers search for a broad spectrum of relevant visual inspiration to actively stimulate creativity and trigger new design ideas. One possibility to reach inspiration is by exposing themselves to previous solutions that have something in common with the current design situation. This is an especially relevant step for any design that is created by adapting and combining preexisting design elements (Eckert et al., 1999a) but it has also been proven that inspiration is essential for coming up with original and novel design proposals. According to cognitive scientists, human beings inevitably construct novel ideas from their prior knowledge and experiences (Marsh, Ward & Landau, 1999; Ward 1994). However, relying on existing solutions can make it really tricky to come up with original ideas and break a common solution practice in its essence. "Prior knowledge can make it difficult to think of alternative approaches" (German and Barrett 2005; Wiley 1998, cited in Chan, Dow & Schunn, 2018, p. 111). Also, former mistakes in problem-solving can easily be repeated over and over again.

In this context of inspiration, generative systems can help to break the cycle of ever repeated inspiration in the same material. Visual, inspirational material can be created by a generative system and then used by a designer to stimulate their creativity. Eckert et al. (1999a) write: "[...] we regard providing starting points for humans to design by modification as an important role for generative systems" (p.7). Avital & Te'Eni (2008) in their theory of *generative fit* and *generative capacity* (more in chapter 4.3.8.) point out that "a system with high generative fit inspires people to create something unique" (p. 357).

Jones, Brown, McCormack, Pachet, Young, Berry, Asaf & Porter (2009) propose an Input-Processing-Output system to enhance human creativity. This kind of system tries to stimulate creative flow through computational feedback. It takes in a human idea and responds to it with a transformation of that idea, to which the human designer responds again and so on. The approach is similar to creation processes in a human team.

In summary, generative approaches can be applied not only as a process to produce the final design solution but also as a source of inspiration for the human designer. This can provoke more original and novel solutions than the classic inspiration in analog designs and previous experience.

Where: Applications of generative design in graphic design

An area of graphic design that has always had a certain "generative" aspect, is Information Visualization. Expressing quantitative information visually is "generative" in the sense that there is external data influencing the visual outcome. In order to turn abstract raw data into something meaningful and understandable, some kind of algorithm is needed and the visual parameters cannot be freely manipulated by the designer. Although most graphs are still designed from scratch by the hand of a designer, generative approaches have become more common in the last years. The use of algorithmic language in information design allows visualizing much larger amounts of data and, more importantly, it allows generating animated and interactive visualization (Curralo, 2015). Making data visual is necessary to enable the human brain to understand abstract information and hidden patterns in large amounts of data, "enhancing and amplifying human cognition" (Curralo, 2015, p. 100). To reach this ultimate communication goal, information design needs to create communication efficiency. Following Grice's (1975) maxim of manner, the information has to be as brief and relevant as possible. "However, while visualization is the main focus, perceptualization is the underlying goal, and aesthetic considerations are supposed to drive the desired effectiveness of communication" (Curralo, 2015, p.101). With generative approaches and the appearing of new possibilities of interactivity, this effectiveness can be reached better than ever.

An example for generative information design is *Ultravioletto* 's "Decode" data visualization installation for the *Digital Design Days* 2017, which turned social

media interaction around the event into "an evolving visual flow [...] [which] combines the analogue and the digital worlds" ("Digital Design Days", 2017) [Fig. 19]. Cruz & Machado (2011), in their paper *Generative Storytelling for Information Visualization*, develop a conceptual framework called "Generative Storytelling" and narrate the story of declining empires in the 19th and 20th century in a visual and interactive way [Fig. 20].



Figure 19: Ultravioletto. (2017). *Decode*. ("Digital Design Days", 2017) (cropped) This generative design turns social media interaction into visual graphs.



Figure 20: Cruz & Machado. (2011).

Generative Storytelling. (Cruz & Machado, 2011, p. 80)

This data visualization tells the story of declining empires.

After information design, which is more obviously linked to the generative idea because of its innate connection with data, the most widespread and experimented application of GD in graphic design are probably **Generative Visual Brand Identities**. Going under different names like fluid brand identities, dynamic identity systems, logo systems, algorithmic logos, postlogo, and many more, this phenomenon refers to visual brand identity systems that are non-static and created in a generative way. This means that the brand's mark can have multiple variants and that their forms somehow depend on parameters given from an outside system. There are marks whose variations depend entirely on random parameters, on manually customizable variables or on external real-life data.

This kind of identities "aim to improve a traditionally static visual experience with a multi-dimensional angle" (Hsu, 2013, p. 41).

There are already numerous examples of fluid identities in the brand world, mostly created after 2009 (Adrzeiczak & Glinka, 2015). The most famous examples might be the before mentioned fluid identity for Nordkyn [Fig. 18]. Another well-known example is the endlessly variable identity for Casa da Música in Oporto, designed by Sagmeister & Walsh with a logo generator that transforms the mark "like a chameleon" ("Casa Da Musica", n.d.) from application to application [Fig. 21]. A more exhaustive list of famous fluid identities would include MIT Media Lab [Fig. 22], Bordeaux Metropole, City of Melbourne [Fig. 23], NAi, Brooklyn Museum, idtv, architects, OCAD University, imagine8, AOL, Mobile Media Lab, Award, Management for design, Lovebytes Festival [Fig. 24] and many more. Not only are the practical examples numerous and varied but also the scientific literature on the topic is much broader than on any other topic related to generative approaches in graphic design. For a broad selection and detailed description of generative identity projects there have been several articles, thesis and books published in the last years, including Dynamic Identities (van Nes, 2012), Identità Dinamiche (Secolo, 2011), Dynamic Branding Thesis (Jochum, 2013), Computación e identidad visual corporativa (Bohórquez, 2011), The evolution of visual identities from static identities to dynamic identities (Delahunty, 2013) and Generative Visual Identities. New Scenarios in Corporate Identity (Guida, 2014a).

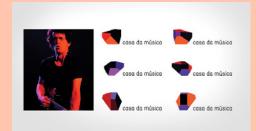


Figure 21: Sagmeister & Walsh. (2007). Generative logo for Casa da Música. ("Casa da Musica", n.d.)

This generative visual identity takes in color information from pictures.

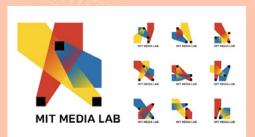


Figure 22: E Roon Kang & TheGreenEyl. (2011). Generative visual identity of MIT Media Lab. ("MIT media lab identity", 2011)



Universal Everything. (2007). Generative monsters created for the Lovebytes Festival of Digital Art 2007. ("Lovebytes Faces", n.d.)



Figure 23: Landor. (2010). Generative Branding for the City of Melbourne. (Landor, 2010)

Even if examples are much sparser and research is almost inexistent, the generative approach has, of course, been applied to other branches of graphic design.

There have been, for example, **audiovisual advertising** pieces like the ones for Porsche or Nike, proposed by *Onformative* which take in performance data to create 3D-animations [Fig. 25].

Ten years ago, in 2008, one of the first generative applications in **editorial design** was created. The publisher *Faber and Faber* launched "Faber Finds", a generative book cover creator which designs unique book covers based on different decorative elements and taking into account the genre of the book (Lucas, 2008) [Fig. 26]. Another generative piece of work dealing with book covers has been developed by Duro, Machado & Rebelo (2012). In their paper, they present generative approaches for the design of a series of book covers based on the analysis of the texts' shape rather than its content. The graphical outcomes visualize data drawn from punctuation marks, paragraph frequency, average length of sentences, chapter structure and length etc. (Duro, Machado & Rebelo, 2013) [Fig. 27].

The history of generative typography design dates back to the 1980s when Donald E. Knuth developed the Metafont System and created the mathematical typography "AMS Euler". In 1990, Blokland and van Rossum created "Beowolf", programmed with a randomizing algorithm (Butler, 2016). Recently, in 2016, Butler created a new form of generative typeface that is "legible, progressive [and] utilizes the power of the computer to create something that would not be conceivable using traditional digital techniques [...]" (p. 40) [Fig. 28].



Figure 25: onformative. (2016). 3D-videos based on athletes' training-data for Nike. ("Nike Strike Series FA 16", 2016)

Figure 27: Duro, L., Machado, P. & Rebelo, A. (2012). Generative book covers based on text shape and chapter characteristics. (Duro et al., 2012, p.1)

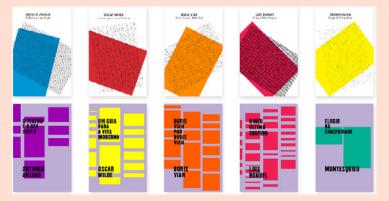




Figure 26: Schmidt, K., postspectacular. (2008). "Faber Finds" book cover generator. (Lucas, 2008)
This tool creates unique book covers based on the genre of the book.

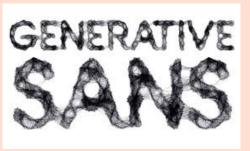


Figure 28: Butler, L. (2015). *Generative Sans: A generative Typography.* (Butler, 2015)

Being part of the few researchers dealing with generative graphic design nowadays, Eckert, Kelly & Stacey specialize in the area of **knitwear design**. Since 1999, they have been creating several automated systems to assist knitwear designers in their creative process. For example in the creation of garment shape designs (Eckert, Kelly & Stacey, 1999b), patterns and the generation of color schemes with an evolutionary system (Kelly, 1999).

Of course, GD systems have also been used in **poster design**. To name just one example, there is the poster series for the yearly "Poetry on the road" literature festival designed by Boris Müller from 2002 until 2013. The images for the poster series vary greatly from year to year but are always based on the idea of "a computer program that turns texts into images" (Müller, 2002) and the outcomes are always appealing and surprising [Fig. 29-31].

While in areas like engineering the benefits and usages of GD are very clear and obvious, in graphic design it has to be discussed, in which cases generative approaches make sense and in which they do not. This would be most certainly a very interesting topic to investigate more exhaustively, but it is outside of the scope of this thesis. However, I will try to approach this question very briefly and in general terms.

The aforementioned function of generative systems as an inspiration source is no doubt a valuable usage of generative processes in graphic design. Nonetheless, when it comes to generating the actual outcome or product, this question is much more difficult to answer. In very short terms, and based on the research done for this thesis, I think that generative approaches make sense when the required design solution has a certain complexity. In the field of visual identities, for example, the creation of a fluid identity makes sense if the entity it represents has a dynamic, liquid, organic and somehow inconsistent aspect, a very varied target or if it deals with non-tangible values like emotion, experience or knowledge. Guida (2014b) has investigated the use of fluid identities for cultural heritage places. He found that "this idea about the post-logo does not belong exclusively to the cultural heritage sphere but is rather undoubtedly congenial" (p. 1115). It is no coincidence that we find post-logo identities especially in the cultural and public sector, for instance in city branding, art galleries, and museums. It is exactly this kind of

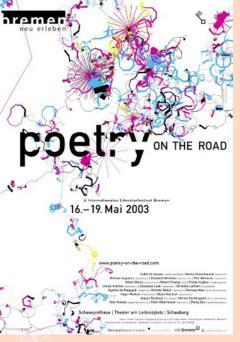


Figure 29: Müller, Boris. (2003). Generative poster for Poetry on the Road Festival 2003. (Müller, 2003)



Figure 30: Müller, Boris. (2006). Generative poster for Poetry on the Road Festival 2006. (Müller, 2006)



Figure 31: Müller, Boris. (2013). Generative poster for Poetry on the Road Festival 2013. (Müller, 2013)

institution that has outgrown the static logo and needs an identity that can represent its variability, reference to context, non-linearity and variety (Felsing, 2010) (i.e. *City of Melbourne*, *Bordeaux Metropole*, *Casa da música*, *Bologna*, *Historiska Museet*...etc.). The use of a generative identity can also be justified within sectors that are explicitly linked to new media, technology or design. In this case, a generative approach can be justified because it refers to the entity's activity on a meta-level (i.e. *MIT Media Lab*, *MML*, *architects*...). The same happens with any kind of future-oriented or experimental enterprise. Whenever we are talking about non-branding applications, it seems like generative approaches are especially useful when we are dealing with a *series* of applications such as a series of posters or book covers.

Another factor that facilitates the use of a generative approach is the existence of *data* around the design problem. We can really embrace algorithmic design if we can make it depend on more than just randomization, for example by making it graphically represent some aspect of the project we are working on. This is clearly visible in the design of the *Lovebytes Festival* poster by *Universal Everything* or in Duro et al. 's (2012) book covers. In the end, GD is a powerful tool to visualize information and is suitable whenever visualizing information for a project is suitable.

Also, for any graphic design project, the use of generative approaches can introduce a modern, futuristic or technological aspect.

4.3.6 Why this need for generative design? Sociocultural aspects

New possibilities in technology or art are manifestations of a society in continuous development and improvement. Humankind evolves, which creates new necessities and new solutions to these necessities (not always in this order). Leading sociologists have found that technological change and development are growing exponentially (i.e. Kurzweil, 1999) and the current society is already in an advanced moment of this exponential curve. This also brings social and cultural changes with it. However, this growth is to date limited to the most developed societies in the world, leaving less technologized ones excluded from its benefits or even making them suffer from problems produced by it. It is therefore clear that with exponential growth and evolution, also the gap between more and less developed societies grows exponentially. It has to be clearly pointed out and critically taken into account that research concerning GD, including this thesis, is entirely concentrated on the most developed and technologized societies. The necessities and sociocultural aspects creating the need for GD do not apply to great parts of the human society and what might solve problems in the developed world, might create others in different areas. The sociocultural aspects laid out in this paragraph mainly apply to the developed world as well and should be understood inside this limitation of scope. Sociologist Zygmunt Baumann talks about our current life in "liquid

Sociologist Zygmunt Baumann talks about our current life in "liquid times", where information is no longer static and material but mobile and ephemeral (Peeters, 2016). We can observe a decrease in personal real-life social interaction and find ourselves at the same time in an era of extreme dependence on virtual social interaction embraced by social networks. There is a clear shift of interests in the millennial generation, attributing less importance to material goods and valuing emotions and experiences. Organizations are transformed from mere distributors of material goods into

platforms that "offer an experience that creates an emotional attachment" (Delahunty, 2013, p. V). Experiential advertising is ruling marketing, consumers increasingly seek engaging, and brand-consumer connections are built around emotions and experiences. Practices like User-centered Design and Co-creation underline this new relationship between organizations and consumers. As organizations are defined by their customers, and personality is constructed in virtual social networks, people increasingly lose their sense of identity and find themselves struggling between the need of belonging and individuality. This phenomenon is reflected by the extreme ramification of any kind of cultural or artistic movement. There are no clear categories anymore, thousands of different movements and styles coexist and the borders between fields and professions are getting more and more blurry. Graphic design, being exactly the medium that represents communication between organizations and their target population, of course, has to adapt to this modern "liquid" life. The emergence of generative design approaches represents this adaption. The aforementioned post-logo identities are the most obvious graphic manifestation of the new liquid society as they represent the continuous search for new forms of identity. "People no longer expect only visual identity in itself but also uniqueness, freshness and above all effectiveness. Flexibility and dynamism of the identification are increasingly often required [...]" (Andrzejczak & Glinka, p. 1). If the identity of an organization is like the personality of a person, generative visual identities represent much more exactly the aspects that characterize personality. Personality is inconsistent, context-responsive, dynamic and flexible. Behavior is not fixed itself, it rather depends on a "base code or method of managing a process" (Guida, 2014b, p. 1113). GD represents exactly this idea of a base code or algorithm that determines the outcoming behavior. Generative identities, as a richer visual language, are therefore much more likely to express the diversity of contents and values that corporations need

to transmit nowadays (Guida, 2014b). Besides, GD as a method focused on the process rather than the result represents the focus of people on experience, rather than products.

Galanter (2009) proposes a very good summary of cultural aspects that determine the upcoming of generative art movements. He talks about the growing gap between scientists' and humanists' worldviews, about the characteristics of modernity vs. post-modernity and the increasing complexity of the relationship between authors and readers in post-modern ages.

Another aspect that made GD possible in the first place is, of course, the recent technological development itself: GD means designing in cooperation with artificial intelligence and artificial intelligence is a relatively new and still emerging field. Also, data visualization is an important factor and information has never been more accessible than now. In times of Big Data, where information storage is cheap and massified, data collection is more and more normal. GD constitutes a possible usage of these great amounts of data and at the same time a method to handle and understand it.

We also must not forget that graphic design has always been influenced by other disciplines such as product design, engineering or architecture. The emergence of GD in these neighboring fields had an important influence on its emergence in communication. And in architecture or engineering, generative processes could only emerge how they did thanks to the breakthroughs in additive manufacturing and 3D-printing.

In summary, we can assume that generative processes in graphic design are a consequence of several technological and sociocultural developments in the last decades.

4.3.7 <u>How the design process changes with generative tools implied</u>

As mentioned before, including a generative system in the design process implies substantial changes in its organization and in the place the human designer takes in it. To analyze these changes, I will first present a quick summary of how the classical design process can work and then dig into the GD process. As this is a very young field, there is no single model or theory on how this process should work, but the existing explanations and theorizations do not differ much from each other.

How do we classically design?

Designing means solving an *ill-structured* problem (Simon & Gilmartin, 1973). The solution for this kind of problem cannot be derived from the original problem formulation. This means that the problem-solving process is non-linear and that there might be more than one good solution or answer (Eckert et al., 1999a).

Of course, there is not one single approach to design. We can find many different models of the design process and every designer has their own way to approach problems. However, there are a few very common ways to confront design problems. Probably the most popular approach is using the *Design Thinking* methodology, which can be applied to all kinds of problemsolving processes, not only in design.

Design Thinking is an iterative, non-linear, solution-oriented process consisting of different phases between which designers are free to jump back and forth. These phases generally include the concepts empathize, define, ideate, prototype, and test. Design thinking can be seen as a system of three overlapping spaces: inspiration, ideation, and implementation (Brown & Wyatt, 2010). The essential idea is to alternate between convergence (creating material/ideas) and divergence (breaking down, selecting) [Fig. 32].

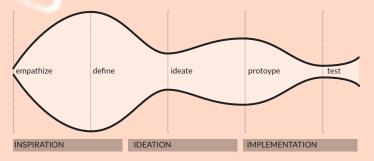


Figure 32: Design Thinking Process. Adaption from Redesigning Theater (n.d.)

Since a few years now, design processes have been moving closer and closer to the future user of the solution to be designed. First design became user-centered and then, more recently, another shift can be observed, from user-centered to participatory design (Sanders, 2003). In these new landscapes of co-designing, the classical roles of users, researchers and designers are merged. (Sanders & Steppers, 2008). However, the basic idea of inspiration, ideation, and implementation as global phases seem to persist through most of the models of design processes.

Also, it has been found that human natural design behavior follows a cycle of reformulating the problem, creating a solution (sketching) and evaluating this solution (Eckert, et al., 1999a) [Fig. 33]. This cycle fits into the *Design Thinking* methodology which has simply enriched it with more specific steps, rules, and tools.

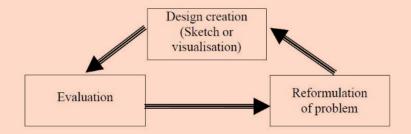


Figure 33: The human design cycle. (Eckert et al.,1999a, p.4).

Fischer & Herr (2001), who deal with the question of how to teach generative design, have come up with an extremely simple explanatory model to depict the essential difference between traditional and generative design. Their "model" for traditional design looks like this [Fig. 34]:

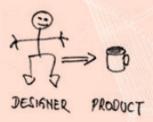


Figure 34: Model of the traditional Design approach. (Fischer, 2001, figure 1)

Of course, this is extremely simplistic but it can help to define the GD process on a very general level.

How does the generative design process work?

This very basic model proposed by Fischer & Herr (2001) looks as follows when a generative system is incorporated into the process [Fig. 35]:

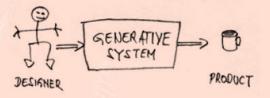


Figure 35: Model of design approach when a generative system is included. (Fischer, 2001, figure 2)

Although this might seem too obvious, this model gives us one important insight: The designer does not interact with the final product in a direct way anymore but via a generative system which is interposed (Fischer & Herr, 2001).

For a more exact understanding of the process, this simplistic model can be enriched by additional ideas. Eckert et al. (1999a) argue that the GD process is analogous to the human design process and depict it with the following scheme [Fig. 36]:

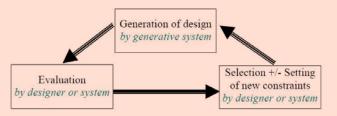


Figure 36: Generative design cycle. (Eckert et al., 1999a, p.4).

The generative process on a global level is equally based on phases of generation, evaluation and selection/reformulation. It is argued that "the generative design cycle of a generative system closely matches human thought processes in design and the organization of work in some design industries" (Ecker, et al., 1999a, p. 6). It, therefore, fits naturally in already existing human design methodologies.

A very similar model, which focuses a little more on the practical aspects of the process, is the one proposed by Villaggi & Nagy (2017). This model completes the process "inside" the generative system with a pre-generative and a post-generative phase, which brings us closer to a global model for the whole design process [fig. 37]:

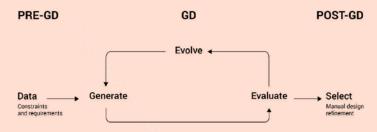


Figure 37: The generative workflow (for architecture). (Villaggi & Nagy, 2017, para. 9).

A similar model can be found in *Autodesk*'s presentation of the software *DreamCatcher*. What is called "Data" in Villaggi & Nagy's model is renamed into "Define", which I think is more adequate [Fig. 38]. At the end of the process, fabrication is included as the final phase.

Define	Generate	Explore	Fabricate
AUT TEN			

Figure 38: Autodesk. (n.d.). The DreamCatcher workflow. ("Project Dreamcatcher", n.d.)

This model clearly shows how the generative system works together with the human designer. The phases "Define" and "Explore" are usually the ones connected to the human designer. Morgan Fabian (Autodesk University, 2018) points out that, in this "collaborative partnership" between human and computer, the human is the "boss" who has to define the rules, evaluate the outcomes and make decisions. But, at the same time, it's a student-coach relationship with the system working as a coach for the human.

A complete model of the design process should probably include parts of all the former mentioned models and relate them in a reasonable way.

Creating such a model could be valuable for the design industry, research and education but this is out of the scope of this thesis.

However this final model might look like in the end, a few conclusions can be drawn even without having seen it. We can see that the incorporation of the generative system as a player in the creative process does not change the process in its roots. It rather substitutes the human designer with a system in certain phases of the same process. In which exact phases this may happen is highly dependent on the nature of the design problem to solve.

Starting with the inspiration phase, computers can help designers in several different ways. They can provide inspirational material and therewith stimulate the human creativity for the following phases. This can be done by collecting and classifying previous solutions or by creating entirely new imagery related to the project. They can also analyze great amounts of data and represent it visually to make the problem understandable and definable in the first place. This initial contribution of the computer represents the "empathize" phase in design thinking and has a divergent nature: Material is recollected or created (divergence) and given back to the human designer, who then has to define the problem on this basis (convergence).

Moving on in the design phases, the most obvious and common use of a generative system takes place in the proper creation phase (including "Ideate", "prototype" and sometimes "test" in design thinking). Fed by the problem definition, the system explores the solution space by creating a great number of possible solutions (divergence). This process can be iterative and have an evaluation and adaption phase inside the system (like in evolutionary systems) or it can return the "raw" solutions directly to the designer, who takes over the evaluation part. This phase, again, has a divergent nature and results in different possible solutions, based on which the designer has to make decisions or redefine the problem (convergence). As we can see, especially the divergent phases are taken over by the system and the convergent phases remain in the control of the human designer. This makes sense as human designers have very highly developed abilities to quickly perceive and evaluate a design visually and computers' strength lays in quickly producing different solutions. Like in a classical allhuman team-work situation, every team member takes over the part they are best at.

Whenever a generative system is implied, the essential and initial task of the designer is to define the problem and its constraints, as well as to explain them to the system. Herein lays the great difference between classical design thinking and design thinking for generative creation. By asking the designer to first translate the problem into an algorithmic source code, they are obligated to start with the design parameters instead of preconceived ideas or previous experience (Karle & Kelly, 2011). "In designing through algorithms, the design effort is clearly focused on specifying designed classes of artifacts, rather than on the subsequent process of creating individual members of those classes" (Eckert, Stacey & Clarkson, 2000, p. 7). This means that the role of the designer concentrates on the creation and manipulation of the genotype that can then unfold into many different phenotypes (McCormack & D'Inverno, 2012).

In conclusion, I want to point out that the generative approach is more a redistribution of responsibilities than a substantial change in the design process itself. However, this has a great influence on how designers have to think and what kind of activities they have to perform. A "good" designer in the classical design thinking methodology is not necessarily a good designer when working with a generative system. Research question three [chapter 5.3] will concentrate on the question concerning what characteristics a good designer needs to have in the context of these new processes and if the designer will be entirely substituted by the system someday.

4.3.8 <u>Scientific background: authors of reference in generative design research</u>

In the following paragraphs, I want to give an overview of the most important researchers and their findings in the field of generative design, especially applied to graphic design. The presentation will be ordered by researchers but only some will be examined in depth providing details on their theories, whereas others will only be mentioned. I will list a total of 64 authors (in bold) I consider of interest in this context, without claiming completeness. I think this can provide a sufficiently profound overview of the research panorama and the state of the field.

Maybe the most cited researcher on generative art and one of the most important generative art theorists is **Philip Galanter**, who published several papers and important theories regarding the topic. His definition of generative art, published in *What is Generative Art*? from 2003, is cited in almost all the related works. In the above mentioned paper, he provides "two views on the term generative art" (Galanter, 2003, chap.2). One bottom-up, where he resumes current fields of generative art activity and one top-down, defining the term in a more literal way.

A very important part of his research applies Complexity Theory – the study of systems – (Galanter, 2008) to generative art. Explaining generative systems in the context of Complexity Theory, he provides an extremely logical and well-structured basis for research on generative art and design. Based on notions of effective complexity by Gell-Mann, Galanter classifies generative art systems in a two-dimensional space, with disorder as one of its axes and complexity as the other. As shown in figure 39 (Galanter, 2009), complexity is highest when order and disorder are in balance. At this point of maximum complexity, we can find Genetic Systems and A-Life (Artificial Life).

On the end with maximum order and low complexity, we can find systems like symmetry and tiling, which he also includes as generative systems. On the highly disordered side, there are simple randomization systems. This scheme can be used to classify the different existing generative systems and to decide whether an existing artwork, for example from the past, is generative or not. He proposes various exemplified analyses of that kind, also answering questions about whether generative art is a subset of abstract art or computer art, and whether handmade art can be generative too. Furthermore, he analyzes the generative aspects of some famous artists and their work.

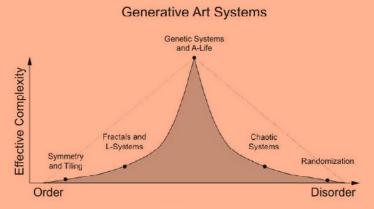


Figure 39: Generative Art Systems in the context of Complexity Theory. (Galanter, 2009, figure 8.1, p.236).

Galanter also deals with generative art in the context of current sociological, cultural and philosophical theories. In his paper *Thoughts on Computational Creativity* (2009) he proposes a summary of his work: a synthesis to reconcile the fundamental split in the worldview of humanities and sciences inspired by Complexity Theory. In this synthesis, he investigates creativity in the context of the contrary positions of science and humanities culture, modernism and post-modernism and their notions of authorship

and progress. On this basis, he asks some essential questions about computational creativity and the usage of evolutionary systems to create art and answers some of them. A key problem that Galanter (2016) identifies in generative art are the still very limited possibilities of computational aesthetics evaluation. His notions about the state of the art in complex aesthetics measurement will be essential to research several of the questions proposed in this thesis [chapter 5].

The researcher I want to mention in second place in this review is **Jon** McCormack. McCormack's artistic and scientific work is concerned with computational creativity, generative computing and related concepts like emergence. His artistic work "explore[s] biology and our understanding of living systems through algorithmic instantiation of natural processes [and] synthesis of behavior [...]" (Dorin, 2001b). He bases his work on the assumption that creativity is still one of the very few capabilities in which humans haven't been exceeded by computers (McCormack, Boden & D'Inverno, 2009). Therefore, it is a "grand challenge" for computer science, to whose solution his efforts contribute. McCormack sees the solution to this grand challenge in an interdisciplinary approach. Therefore, he has united researchers from very diverse disciplines to investigate the topic. This has created a group to which some authors refer to as "McCormack's precious bubble" (Boden & Edmonds, 2009, p. 24) and that includes for example Alan Dorin, Margaret Boden, Mark D'Inverno, Troy Innocent, Gordon Monro, Oliver Brown, Jonathan McCabe, and Mitchel Whitelaw. According to McCormack, generative systems – and the new design methodology they imply - offer a "paradigm shift for the process of design" and the expression of that process" (McCormack et. al., 2004, p. 156). He finds that generative processes are having significant effects on design culture and methodologies in general. Inspiring alternative approaches to

design problem-solving, they introduce "ideas of evolution, breeding, cross-fertilization and adaption" (p. 157) into the design process.

McCormack proposes a clear categorization of methodologies for GD that include Self-organization and Self-assembly, Evolutionary Systems and Generative grammars. Furthermore, he identifies four key properties of generative systems: "The ability to generate complexity", a "complex and interconnected relationship between organism and environment", "the ability to self-maintain and self-repair" and "the ability to generate novel structures, behavior, outcomes or relationships" (2004, pp. 158-159). McCormack is also one of the very few researchers that dedicate at least a few paragraphs to the role of the designer in GD. He points out that the relationship between designer and created artifact has shifted from direct to indirect. "The design process becomes one of meta-design where a finished design is the result of the emergent properties of the interacting system" (McCormack et. al., 2004, p. 162). He also leaves no doubt to the fact that "the human designer remains [...] central to the design process", as there is no computational method to overtake his or her task of guiding the relationship between "process specifications, environment and generated artifact" (2004, p. 162). "In this sense, generative design still requires the skill and artistry that encompasses any mode of design" (2004, p. 164).

At the end of their book *Computers and Creativity*, McCormack & D'Inverno (2012) propose some very interesting questions about the future of computational creativity. It is discussed how computers can enhance human creativity, if computer created art can be properly valued, what computing can tell us about creativity and how creativity and computing matter to education. They conclude affirming that "many of the next major innovations in the design of hardware and software will come from attempts to extend our individual and collective creativity" (McCormack & D'Inverno, 2012, p. 435).

McCormack & D'Inverno (2012) also deal with the question of why the generative approach is so interesting for a variety of practices and how it might progress in the future as long as it remains relevant to creative practices. Concerning these doubts, they postulate *Ten questions concerning generative computer art* (2012). Interesting philosophical and sociocultural considerations, which I will not try to resume here, emerge in this paper. Having come up in Galanter's research as well, the problem of how to judge generative art and whether human aesthetics can be formalized seem to be central to the discussion on the future of generative art and the role of the human designer.

In their 2001 paper on the factor of *emergence* in generative art, McCormack & Dorin come up with the concept of "Computational Sublime". Based on the traditional idea of sublime with an extensive history in art and philosophy, computational sublime represents "simultaneous feelings of pleasure and fear in the viewer of a process realized in a computing machine" (p. 12).

Inside "McCormack's bubble" we can find several other researchers that have greatly contributed to the general research panorama on generative art and design. **David Brown** (2009), for instance, addresses an essential question that comes up repeatedly in almost all the papers concerning generative systems: whether computational artistic creativity can be evaluated and how. Although a lecture of his paper would give much more interesting insights, his findings can be superficially resumed like follows: After taking into account several theories and models of creativity evaluation, Brown concludes that a Computational Artistic Creativity system would have to be able to "evaluate its own output for creativity" (p. 7). While he believes that this might be possible for systems that create *products*, he has "grave doubts" (p. 7) that it can ever be possible for those creating *art*.

In his paper Seven catchy phrases about generative creativity, Simon Colton (2009) provides a great statement towards various theories about generative art developed by other researchers. In a well-expressed and entertaining way, he disassembles common assumptions and arguments about computer creativity. Working as a kind of advocate of the "true beauty of the artifacts our software produces" (p. 2), he criticizes Turing-test style experiments proposed for generative art and points out that the real purpose of computer created art should be to "produce something which no-one has produced before", instead of resembling human-created artifacts. Such a Turing-test for generative art is discussed for example by **Kevin McGuire** (2011). Colton also makes some propositions about how to reach the creation of an autonomous creative system with no human involvement.

Jones et. al. (2009) deal with a – to this date – under-theorized aspect of the relationship between creativity and computation: "using computational systems to provoke, augment and reshape the human creative experience" (p. 1). They propose an Input-Processing-Output system that stimulates creative flow through computational feedback.

Saunders (2009) proposes a novel computational model of creative processes based on "curious agents".

Also to mention here is **Alan Dorin.** He co-authored many of McCormack's papers and is also co-founder of the *Centre for Electronic Media Art (CEMA)*, as well as the *Iteration conference*, both created by Dorin and McCormack in 1999 in Melbourne.

Related to the previously mentioned concept of emergence and treating the question of creativity in a generative computer-assisted process, **Iris Asaf** (2009) provides an extremely interesting theory on computational creativity. She explains the mysterious aspect of uncertainty and unpredictability – "often said to be the essence of creativity" (Boden, 1995, p.1) – with a

reflection made by Duchamp in 1959. Duchamp brings up the concept of the "gap" in a creative process which is similar to the idea of emergence. This "gap between the designer's mental image of what an expected outcome could be and what is actually produced" (Asaf, 2009, p.3) seems to be something indispensable for any process that can be considered "creative". In GD processes, the gap between the "unexpressed but intended" and the "unintentionally expressed" (Duchamp, 1959, p. 77) is moderated by a dialogue between the human designer and the computational system. As a conclusion, she argues that, as long as this gap exists and the results are non-obvious to the artist or designer, the established mechanisms "enable the generative design or artistic process to become creative" (Asaf, 2009, p. 4).

Margaret Boden, who had also treated the issue of *Creativity and unpredictability* before (1995), has worked with McCormack and others mentioned above in several occasions. She published a general paper about generative art in 2009 co-authored by **Ernest Edmonds.** This work gives an excellent overview of the history of generative art and provides a "taxonomy of generative art" (p. 8) which distinguishes and defines eleven different types of art. I won't describe the proposed categories (Ele-art, C-art, CA-art, D-art, G-art, Evo-art, R-art, I-art, CI-art, and CR-art) in this thesis but they present a very useful help in drawing the line between computer, generative, interactive, evolutionary art etc. Also, some problems regarding aesthetics are addressed. Apart from this paper, Boden has published several articles and book chapters on computational creativity in the context of artificial intelligence, proposing *Computer models of mind* (1988) and *Computer models of creativity* (2009).

Andrew Blauvelt sees generative design as a manifestation of a new phase of modern design, which we currently find ourselves in. In his theory about

relational design (2008), modern design can be divided into three major phases: The first one, concerned with formal design languages, brought up several "isms" and was preoccupied with form. The second one (since the 1960s) focused on the symbolic value of design and its content. The third and current wave (since the mid-90s) "explores design's performative dimension" (p.3). This latest phase has moved on from form (1st phase) and content (2nd phase) to context and is related to relational, contextual, programmatic and process-oriented design. Blauvelt describes this as a dramatic paradigm shift for the nature of design and the roles of designers and consumers. "Relational design is obsessed with processes and systems to generate designs, which do not follow the same linear, cybernetic logic of yesteryear" (p. 5). This movement has its eclipse in GD, which deals with the creation of "designs for making designs" (p. 5).

Whereas Blauvelt's theory is a more historical-sociological one, there are several other theories that introduce conceptions of GD in different contexts. Michel Avital & Dov Te'eni (2009), for instance, detect a void in research of performance and fitness evaluation for information systems that are supposed to enhance human creativity. They bring up the two considerations *generative capacity* and *generative fit* for generativity in computational systems. While generative capacity is an attribute of a person, very similar to creativity, generative fit is an attribute of a system and refers to its ability to enhance generative capacity in a human. "Systems with high generative fit help people to realize their generative capacity" (Avital & Te'eni, 2009, p. 346). This theory is especially valuable to reflect on generative systems in their function to stimulate human creativity [see chapter 4.3.5.].

Rivka Oxman & Ning Gu confirm the general notion that "design theories

and processes are undergoing re-formulation and an epistemological shift" (2015, p. 1). They defend the theory that the development of new parametric tools is contributing to a new "distinctive design methodology" they call Parametric Design Thinking (PDT) (p. 1). The major difference to traditional design thinking is that the designer has to begin with design parameters instead of preconceived design solutions (Karle & Kelly, 2011). Paul Sohi (2017) talks about Al aiding or taking over especially the first phases of the classical design thinking process which deals with precedence study.

Marlies Peeters in her article Designing in liquid times (2016) illuminates GD in its sociocultural context and focuses especially on the changes in the relationship between designer, design, and audience. She draws special attention to questions of authorship and reproducibility of generative designs and points out that "contrary to more traditional or conventional types of design, a generative design cannot be easily reproduced or appropriated" (p. 22). She also distinguishes between generative design and design that has been generated. "In generative design the process itself [and not the end product] is the goal of the designer" (p. 24). According to her, the essential phenomenon adding value and appeal to a generative design, in comparison to a classical author-controlled design, is emergence. Her assumption about the lower possibilities of appropriation of generative works is based on the fact that emergent designs can be specific to a particular time, location or use. Concerning the relationship between design and audience, she reminds us of Roland Barthes' (2002) and Nicolas Bourriaud's (Bourriaud, Pleasance, Woods & Copeland, 2002) manifestations about the role of the reader as an active meaning-maker in an open and fluid interaction, and Blauvelt's theories about relational design (2008). In this sense, GD finally empowers the audience to "customize their own process of understanding" (Peeters, 2016, p. 28).

Underlining the relevance of context in GD, **Elisa Giaccardi** (2005) provides a theoretical perspective on "metadesign". She formulates that metadesign creates environments to "cultivate creative conversations" (p. 343). In this sense, graphic design is shifting from a printed image to a "reactive computer program" (p. 345). Like others, she sees the phenomenon of GD in the context of an emergent cultural development with methods and theories, discussing "the problems of anticipation, participation, and emergence" (p. 346). As users' needs and behaviors cannot be anticipated because of their ill-structured and changing nature, the audience has to be "engaged in the problem-framing and -solving process, both when the system is designed and [...] used" (p. 346). "Metadesign represents a cultural shift from design as 'planning' to design as 'seeding'" (p. 348).

This idea of "seeding" leads us directly to one specific way of creating generatively: using evolutionary systems. Since the early 1990s when Sims (1991), and Todd & Latham (1994) combined evolutionary techniques with computer graphics, several researchers and artists have focused their attention on evolutionary generative systems. Based on genetic algorithms, these systems create a solution space that manifests itself in a population of phenotypes based on a genotype. One of these researchers is **Mathew Lewis**, who provides a great overview of the concepts of evolutionary design and the many remaining problems regarding solution spaces and fitness evaluation (Lewis, 2008). **Ross, Ralph & Zong** (2006) investigate the automatic evolutionary synthesis of aesthetically pleasant images using a mathematical model of aesthetics, focused on composition and color.

Some of the very first publications on GD specifically referring to graphic design are the papers of **Claudia Eckert**, generally working with **Ian Kelly**

and/or Martin Stacey. Their work is mainly focused on knitwear design but always taking into account and drawing lines to graphic, communication and conceptual design. Already in 1994, Eckert & Stacey published a paper on the empowerment of designers over technology in knitwear design. In their publications of the following years, concepts of intelligent support of the design process begin to appear. In 1999, the word "generative systems" first appears in a paper title. In Interactive Generative Systems for conceptual Design: An Empirical Perspective (Eckert, et al., 1999a), all the key assumptions and ideas that others would later repeat and cite are already present. Eckert et al. defend the idea that human designers and generative systems have complementary abilities. This is why in human-computer-synergy "greater creativity and effectiveness than either humans or AI systems can manage on their own" (p. 1) can be achieved. Perceptual evaluation of designs (fitness evaluation) is seen as the ability where humans have great advantages. The paper also proposes a very simple model of the design process with a generative system included, which consists of a cycle of generation, evaluation and selection/reformulation [Fig. 36]. It is foreseen that implementing the evaluation part of the process into a computer system will be very hard or impossible, an assumption that until today, almost 20 years later, still reflects the opinion of most researchers. The researchers argue that generative systems can be a powerful method to stimulate creativity and actively enrich the designer's context for inspiration. In addition, they can help to overcome communication problems between designers and technician during the process. In the same paper, they discuss two practical applications of generative approaches: Kelly's evolutionary system for color scheme design and Eckert's garment shape design system. This 1999(a) publication, which I consider a brilliant and pioneering work on the field, is followed by many others until actual dates which I won't go into detail on.

In a different area of graphic design, **Pedro Cruz** and **Penousal Machado** have developed a conceptual framework for information visualization with a generative approach: *Generative storytelling* (2011) describes an approach to visually narrate "data fabulas". The researchers apply the framework to visually tell the story of the decline of western empires in the 19th and 20th century [Fig.20]. Machado, in collaboration with **Lígia Duro** and **Artur Rebelo**, presents an approach of "Generative Narratives" for the design of book cover series based on data visualization (2012) [Fig.27].

Greg Judelman (2004) suggests relating the technically oriented information visualization community with arts and design disciplines, creating the opportunity for greater interdisciplinary collaboration. This would open the doors for addressing shared research problems in a "multi-perspectival space and a broader cultural context" (p. 6).

Leon Butler provides valuable insights into generative typography design in his paper on *Generative Sans*, a generative typography he developed in 2016 [Fig.28]. In addition to its generative nature itself, this typography creates dynamic ligatures between letters, depending on the concrete composition of letters in a word. The new form and aesthetic reached by this design is "legible, progressive [and] utilizes the power of the computer to create something that would not be conceivable using traditional digital techniques while still remaining in the control of the designer"(p 40). Also concerned with generative typography is **Yeohyun Ahn**, who has published several versions of his book "Type + Code" (2008, first version in 2007) showing collections of his typographic research using computer codes.

After this overview of the research background on generative design and art in general and touching some of the more specific approaches to generative graphic design, I now want to dedicate a few paragraphs to the by far most

common field of application inside graphic design. This is, as mentioned before, the one dealing with *generative visual identity systems* (or fluid brand identities).

Francesco E. Guida, for instance, has published several papers about the evolution of visual identities towards post-logo systems in the last 20 years. In his 2014(a) paper for the Generative Art Conference, he gives a well-structured overview of the phenomenon of the new post-logo in form of toolboxes, called "Logo-Generators", including some practical examples. As the responsible professor for the Bachelor's Graphic Design Studio at Politecnico di Milano, he implements GD into the official education of future designers. In a different paper from 2014(b), Guida investigates Dynamic Identities in Cultural Heritage. Cultural Heritage places, museums, city branding and art galleries are identified as sectors for which generative identities generally make sense. They better represent their dynamic, multiple and changing aspect as well as their focus on the transmission of emotion and knowledge. In this paper, he identifies, classifies and analyzes several examples of generative identities in this sector. In 2016, he (Guida & Voltaggio) describes a spiral model as a methodology for the creation of fluid visual brand identities he applies in his classes.

In all his papers, he repeatedly underlines that the real evolution with GD is the use of digital tools in an active way. This frees the designer, who can now create their own toolboxes instead of being limited by the possibilities of existing software. He encourages the implementation of programming into designers' educational curricula (Guida & Voltaggio, 2016).

Similar to what Guida states in his paper about cultural heritage, **Lapetino** (2011) points out reasonably that a fluid visual identity is not always the right way to go and its usefulness depends on the organization it longs to represent.

Irene van Nes published a book in 2012 that recollects a whole lot of dynamic identities that arose in the previous years. She puts the phenomenon of dynamic identities in a sociocultural context, where brands are no longer just a single recognizable mark, but rather a platform where like-minded people come together, creating an experience and emotion (p. 6). She identifies six components of an identity system: logo, type, color, language, graphic elements, and imagery. To claim itself dynamic, an identity system has to "un-fix" one or more of these components to freely play with them. One approach to do so is the generative one, which still has a pretty low percentage of usage in the examples she can present in 2012. She classifies her collection of dynamic brands by different categories, of which "generative" is one. Apart from being an excellent recollection and providing interesting assumptions and theories in the introduction part, this work reminds us that not all dynamic identities are generative and helps to draw a clear line. I think it also illuminates the fact that brands felt the need to adapt to the new fluid, context-related and dynamic society before computerized generative processes became famous. This can help to understand that the upcoming of generative identities is not entirely because of new technological possibilities but is responding to a real sociocultural need.

Taiwanese researcher Ming-Chieh Hsu (2013) goes more into detail in his study about dynamic identities in interactive aesthetics. He states that dynamic identities have a multi-dimensional angle that influences both users' cognition and mentality. In his paper, he introduces three key factors of interaction aesthetics: the cognitive level of recognition, the physical level of functionality and the psychological level of emotion. He analyses 44 dynamic identities in a case-study and interview method and is able to classify them in three types of dynamic identities: "functionality", "entertainment", and "identification". The different types enhance different design principles. He

finds out that "functionality" dynamic brand identities, which enhance the principles of "customization" and "modularity", have gained importance in recent years but that "entertainment" identities, which enhance the principle of "aesthetically pleasing", still have the largest percentage. He also suggests that "design thinking should gradually integrate technology in the identity system, using both the concept of automatic data placement, mathematical operations, program algorithm, and system module, to create data visualization and also to maintain design aesthetics from traditional brand identity, which is very important" (Hsu, 2013, p. 48).

The work of Andrzejczak & Glinga (2015) tells the practical process of the creation of a generative dynamic identity system for the Lodz University of Technology. The resulting identity system can generate over 1.5 million unique logos for the employees of the university, depending on data on their sex, degrees, faculty and function on it, institute and function at it, team and function on it, and position at the university. The interesting and novel aspect of their work is that they subject the logo to a usability test with real users. This test surveys the learnability, memorability, errors, and satisfaction of the users regarding the logo system. This brings up a characteristic of generative identities that is greatly ignored by most other researchers: the possibility to communicate actual information through the different phenotypes. In such information-rich generative logos, not only the general notion of multitude and dynamism is communicated but users can actually "read" the logos and retrieve the information it is generated with. Despite some detected problems, their overall results show that even with such a great number of features, users were able to read 75% of the information provided. Another paper about computation and generativity in brand identity design with a practical aspect is proposed by Andrés Téllez Bohórquez (2011). In a practical case, he constructs the algorithmic logotype upon the

Christiane Herr (2002) investigates the utility of introducing complexity theory into architecture and draws some conclusions about the future challenges in the field.

Maybe it is thanks to Guida's, Soddu's and so many others' efforts to introduce the generative approach into design education that we can definitely see rising interest in university students in investigating the topic. During my research, I have stumbled upon several brilliant bachelor's, master's and doctoral thesis treating the topic and, in the end, I myself am part of this movement. I would like to highlight several works: Bardebes (2015) provides an excellent overview of concepts like chance and emergence, relevant to generative art and design. This master's thesis is a practical project exploring the intersection of interaction and the poetic by creating randomly generated, interactive, electronic devices. Tomatis (2014), in his bachelor's thesis Generative Generation, provides a very wellorganized overview of how generative processes add value to graphic design and where their main applications lay. Jochum (2013) presents a wide-reaching collection of generative dynamic branding projects, analyzing each of them by the mentioned components of a brand identity (see above: Irene van Nes). Through a broad and profound case study methodology, he identifies 15 keywords as the essence of dynamic identities. Also treating dynamic identities, Secolo (2011), through numerous case examples, tells the story of how brand identity has evolved historically, becoming dynamic, relational and generative in current dates. Delahaunty (2013) published his dissertation on the evolution of visual identities from static to dynamic and how this new way of constructing identity can "either impede or help the

five composition principles proposed by Casey Reas: Repeat, Transform, Parametrize, Visualize and Simulate.

Lisa Pearson (2013) concentrates on a different aspect coming up in the context of generative dynamic brand identity: the question of authorship and trade protection of a fluid mark. She also proposes a taxonomy of seven different species of fluid marks. She identifies a lack of legal possibilities to protect fluid marks, which is why there are only partial and unsatisfactory solutions to this problem until today.

Although his efforts concentrate mainly on the field of architecture, it feels impossible not to name Celestino Soddu in this recompilation of important researchers on GD. Already in 1989, he presented a generative approach to architecture in his paper Città aleatorie. Since then, he is an important referent in generative art, design and architecture research, and leads the Generative Design Lab at Milan Polytechnic University. He points out that during the Industrial era, products were mass-produced as "undistinguishable multiples" (Soddu, 2002b, p. 292). The new generative forms of design enable to "rediscover the naturality of the artificial object" (Soddu, 2002b, p. 292) which can now be produced as a unique and unrepeatable product, like handmade objects, but yet realized in fabrics. He brings up the concept of the "new artificial naturality" (Soddu, 2002b, p. 294); Generative designs produce uniqueness and complexity through unpredictable events. Beauty and harmony can be directly designed without realizing each single possible artificial event. Complexity and recognizability are other essential aspects of GD identified by Soddu (2002a).

Also focused on architecture, **Asterios Agkathidis** is another name I want to include here. His book *Generative Design* (2015) gives a good overview of the generative phenomenon in architecture and its different methodologies

identity of a company or organization" (p. V). He identifies successful and less successful cases of dynamic identities and underlines that not every identity has to be dynamic. Paraggio, in the bachelor's thesis *Data design* (2011), writes about generative visual identities and dynamic data visualization methods. Jiang (2018) explores how data-driven storytelling visualization can be used for brand communication. Serra (2013) in her master's thesis argues that "integrating generative design as a new stage in the design process dramatically simplifies the handling of changes" (p. IIII). Based on Simon's (1973) manifestation about design problems being ill-structured, she argues that "design tools, in order to truly support and accomplish the needs of the design process, must embrace change" (p. 2). She proposes an algorithmic design approach for architecture and evaluates it.

In the context of GD related to education mention should me made of **Thomas Fischer** and Christiane Herr, who present a research paper on *Teaching Generative Design*. Generative design is identified as a recently emerging educational field that still lacks methodologies, experience, and material. They come up with several terminological clarifications and simple explanatory models and a list of techniques and contents to be included into a curriculum on GD. This kind of work – and what will follow its footsteps – can be extremely valuable for the development of the generative phenomenon, as it is novel designers on whom said future depends.

Besides the theoretical research background, there are a few *practice oriented* publications I wish to mention here.

Maybe one of the most important practical books is *Generative Design*: visualize, program, and create with processing by **Bohnacker**, **Gross**, **Laub** & **Lazzeroni** (2012). Fundamental principles of coding are explained and readers are taught little by little how to create generative designs with

Processing. The lessons focus on formal aspects like color, form, type and image and teach progressively with loads of example material. All the material and the corresponding code can be viewed on the related website. A similar approach is the one followed in Learning Processing: A beginner's guide to programming images, animation, and interaction by Daniel Shiffman (2009). This method includes free accessible classes in video format and a great variety of practical online exercises and solutions corresponding to the lessons of the book and classes. This is also the method I chose to learn Processing for the practical part of this thesis. Another book on the Processing language was published in 2009 by Kostas Terzidis. Famous generative artist **John Maeda** has also published a book on learning to *Design by numbers* (2001), as well as another one teaching his Laws of simplicity (2006). And, of course, the very inventors of the processing language Casey Reas and Ben Fry, also propose more than one book on learning *Processing*, such as Processing: a programming handbook for visual designers and artists (2007), or Form + code: in design, art, and architecture (Reas & McWilliams, 2011), as well as several others.

As we can see, the great majority of teaching material on practical generative programming for visual art and design focusses on the *Processing* language.

Nodebox provides a first-step-guide and several tutorials on their website but I could not find a systematic teaching method similar to those available for *Processing*.

4.3.9 Conclusions

Although GD is a relatively new phenomenon and still in its fledgling stages, we can see that there is already a promising research basis. Different theories try to explain the generative approach in a mathematical, philosophical or sociological context. Also, we have seen intents to classify different types of GD and to identify characteristics in comparison to traditional design approaches. Some of them propose methodological schemes of how the GD process works.

The upcoming of generative systems is generally seen as a paradigm shift in design culture. There are several concepts that are identified as essential by almost the whole research community: the idea of emergence and the related concept of unpredictability seem to be crucial to generative art and design. Also, the classification of GD as a process-oriented and context-related approach that constitutes a kind of conversation with its audience. From the view of the designer, the possibility to use digital tools in an active way is identified as the great revolutionary aspect of this phenomenon. In general, two main functions of generative design processes are mentioned: the creation of designs itself, and the stimulation of human creativity. In both, computer-human-synergy is essential.

The difficulty of computational aesthetic evaluation is discussed as the main problem of generative systems in visual art and design and some of the researchers express serious doubts that this problem can ever be solved properly. This also seems to be the underlying reason why basically all the researchers defend the importance of the human designer in GD processes. Designers being completely substituted by computers does not seem to be a major concern these days. However, none of the cited papers specifies for which time frame in the future they are making this assumption. Designers being extinguished by computers is not a major topic in any of the cited papers and at most mentioned briefly.

General concerns that have come up in various previous works are the questions of how to judge or evaluate generated art and designs and if they can be considered "creative". One possible way of judging computational art is proposed with McGuire's Turing-test (2011). However, this test has been criticized for missing the point of the generative approach. Related to these questions, the problem of authorship arises in several papers.

In summary, I have identified a general lack of research that specifically concerns graphic design and is not related to dynamic brand identities. I have also noticed that basically none of the existing works deals with the question of why there is such a considerable gap between the development of generative processes in graphic design as compared to other disciplines like engineering.

Also, research on how to implement GD into design education is very sparse and very few assumptions are made about the future of GD. The question whether GD is a timeless phenomenon is not clearly answered. None of the researches deals with possibly problematic consequences of generative approaches and how to avoid them.

I think it is obvious and normal that there is still room for further research and there are many unanswered questions. In the following chapter, I will address some of these identified questions.

<u>5_</u>

Present and future of Generative Design: some essential questions

"The best way to predict the future, is to invent it."

(Alan Key)

In this section, the investigation process is focused on satisfying the second research goal. I identified four essential questions that have not been addressed in a sufficient manner by previous research. I will approach these questions by systematically revisiting and analyzing the information obtained through the comprehensive literature review in chapter 3 and by adding my own conclusions and contributions.

5.1 Question 1: Generative Design: Will it last in time?

Different human-made phenomena, findings and inventions in disciplines such as science, industry, art or design have shaped the succession of the world's history. Some of these phenomena changed the world, some others died out after a few years and never came back. The interaction and the development of these phenomena have shaped the world as it is today and tell the story of human evolution (in a non-biological way). Single events or groups of these phenomena can be called trends, fashions, styles, movements, ideas, inventions or revolutions, with the most important ones dividing history in different eras. In the following paragraphs I want to discuss GD in a global context and analyze whether it can be considered a timeless phenomenon.

Timelessness

To do so, I must first explain what I mean by "lasting in time".

There are two different interpretations of this phrase. The first corresponds to the definition of *timeless* in Oxford Living Dictionaries (2018):

"Not affected by the passage of time or changes in fashion."

This can refer to a certain created item, artwork or even style that in a certain culture is considered by a significant part of the society to conserve its importance and popularity despite the passage of time and the end of the fashion¹ it originally belonged to. Examples for this can be famous paintings like the Mona Lisa or some of the items that were created during the Bauhaus movement. In this interpretation, the item itself remains exactly the same.

Another way of seeing timelessness is not that much for single items but for certain ways of doing something. This kind of "timeless method²" is a specific manner of achieving a certain goal that does not change in a long period of time. These timeless methods can mark the beginning of an era³ when they are invented or the end of it when they are substituted by a different method. This applies when they constitute a revolutionary⁴ change in comparison to former methods. An example of this kind of phenomenon is, for

instance, photography. When it was invented it substituted the traditional method of creating images representing the real world, which until then had been painting. This marked the start of a new era. Since then, it has evolved in many ways but still exists and preserves the same methodological essence. A modern camera records light on a digital sensor instead of a chemically manipulated surface, but the idea of registering light to produce an image remains exactly the same almost 2000 years later. The steam engine, for example, also marked the beginning of an era but was substituted by the modern internal combustion engine at some point, both of these moments marking eras. But even here, although the modern engine does not work with steam anymore, the essential idea of functioning has been further developed and still remains.

In this type of timelessness, the method does not stay exactly the same; it is constantly evolving while maintaining its essential idea.

In history we can find many movements that developed a certain style⁵ as well as a certain method of doing something. In these cases we can often see that the method goes on in time while the specific style disappears. Take for instance the method of creating art by reassembling existing material, called *collage*. It was (re)discovered and became widely known during the Cubist movement in the 1920s. The aesthetic features of the Cubist style were substituted by different styles later, but the method of creating by *collage* remains until today and has been further developed.

To underpin the understanding of *timelessness*, I will provide definitions of some of the essential concepts that have come up (according to Oxford Dictionaries, 2018):

- ¹ Fashion: "A popular or the latest style of clothing, hair, decoration, or behavior."
- ² Method: "A particular procedure for accomplishing or approaching something, especially a systematic or established one."
- ³ Revolutionary: "Involving or causing a complete or dramatic change."
- ⁴Era: "A long and distinct period of history"
- ⁵ Style: "A distinctive appearance, typically determined by the principles according to which something is designed"

Timelessness of the generative phenomenon

Regarding generative design, many authors and researchers have made it very clear, that it "refers to a way to create art rather than an art style" (Galanter, 2003, p. 239). This means, as in collage for instance, that the *method* of creating is not linked to a specific aesthetic style or fashion. A collage can be cubist but it can equally be expressionist, minimalist or a post-modern photomontage. GD is not a style and not a specific movement either. According to Galanter (2003, p. 240) "Generative art as a system oriented art practice is much too large to be claimed by any single art movement". The generative approach is a method of creation, a tool, a "way of understanding, exploring, and reexamining the role of design and designers [...]" (Blauvelt, 2008, p.14). "It carries with it no particular motivation or ideology. In fact the use of generative methods may have nothing to do with the content of the work at all" (Galanter, 2003, p. 240). Therefore it cannot be assigned to any particular art style or movement like computer art or abstract art. "In contrast to the critical, conceptual and social analysis that has traditionally

surrounded art movements, definitions of generative art are primarily methodological classifications which have little, if anything, to say about the art itself or the motivations of those who make it" (McCormack et al., 2012, p. 2). It can be seen as "a reflexive method of thinking about design and beyond design, rather than as a new praxis of design" (Giaccardi, 2005, p. 347). "Generative design should not be seen as a formal revolution, but as a revolution in the way of thinking a design. As a result, they can be applied to any style [...]" (Serra, 2013, p.13). Although I consider that GD, as well as almost any other method of creation, especially those connected to technological progress or conceptual ideas, cannot be seen as completely disengaged with a certain ideology, one can affirm that generative design has a "discipline- and medium-independent methodological focus" (McCormack et al., 2012, p. 15).

In summary, there is a general consensus in the research community about generative art and design *not belonging to any art style or movement* nor being one itself. It is rather defined as a *method or tool* for creation.

There is an equal consensus regarding the *importance* and novelty of this method in the evolution of art and design. Terms like "paradigm shift" and "revolutionary" are widely spread in literature. For McCormack, GD offers "a paradigm shift for the process of design and the expression of that process. [...] Conceptualization shifts from the primacy of objects to envisaging interacting components, systems and processes, which in turn generate new artefacts, with special properties" (2004, p. 1).

One way of explaining the revolutionary aspect of generative creation is by analyzing its relationship to nature. Art, design, architecture, and engineering have in many occasions mimicked nature, copying its style. For example by applying the Golden ratio, Fibonacci sequence or organic forms to create more harmonious artworks and designs (like in the apple logo). Or by copying

the structure of natural materials to obtain the same characteristics in an artificial object in engineering (like Velcro). The revolution in GD is that it no longer copies the *style* of nature's products but rather its *procedures* and principles of creation. Instead of copying the phenotype of a bird to construct something that can fly, GD would copy the idea of a genotype that changes through an evolutionary process until it has the perfect form for flying. This corresponds to the idea of growing and breeding instead of making products. Other revolutionary aspects of GD are the usage of tools in an active way and the way humans and computers relate to each other. These aspects have been explained in detail in chapter 4.3.1. They all constitute profound and radical changes in the method of creating.

Blauvelt (2011) talks about the generative phenomenon as the essential part of the third major era in modern design history: the era of "relationally-based, contextually-specific design" (p. 2). His three phases of design represent a shift from *form* to *content* and finally to *context* (Blauvelt, 2011). "The nature of design [...] has broadened from giving form to discrete objects to the creation of systems and more open-ended frameworks for engagement: designs for making designs" (p. 5).

Resuming the last two paragraphs, we can see that generative design:

- » is not a style but a method or approach, and
- » represents a radical change in design practice.

Remembering the definition of timelessness given above, we can conclude that GD is very probable to be timeless in the methodological sense. It has been clearly identified as a *method* and as *revolutionary*. Therewith, it is very likely that the generative methodology marks the beginning of a new era in design, if not in humankind. Conti (2016) talks about "augmented age", giving this new era a name. This novel way of thinking in design might

change the field in an extremely profound way and seriously shake up roles, responsibilities and outcomes in the design industry. Especially in graphic design, we are still at the threshold of this new era and many of the changes are yet to come.

Right now, in the infancy of GD, we can recognize that many generatively created products present certain aesthetic and stylistic characteristics. Typical lattice structures resulting from topology optimization in engineering or somehow "computerized" and very "digital" looking pictures, resulting from randomized codes in graphic design, seem to appear throughout different generated artifacts. These stylistic aspects are not inherent to the methodological approach but rather a style as well as a side product of the still existing technological limitations. Therefore, as style and technology evolve, these aesthetic characteristics are very probable to disappear and be substituted by other aesthetics, adapting to new fashions and styles in the future. However, the idea of designing systems that design the actual artifact is likely to remain until it is substituted by a new method, marking the beginning of a new era and ending the current, recently starting one.

Regarding these considerations on a meta-level, it is high time to critically highlight that not the whole world develops at the same pace, which generally leaves entire parts of society or geographical areas excluded from certain phenomena for several centuries. Therefore, it must be taken into account which societies or groups have access to GD at this specific moment in history. To date, GD, its opportunities and its possible advantages mainly affect the most developed and powerful countries and societies, while less technologized and globalized societies remain marginalized. One must bear in mind that this thesis, as well as most western scientific publications, refers to the cultural context in which it was created and that

the presented findings might not correspond to a wide range of people living on this planet at the current moment. More critical and global examinations of the topic with a certain focus on how to expand the benefits of GD to the technologically marginalized parts of the world could be a valuable path for future research.

5.2 Question 2: Why is graphic design lagging behind?

After reviewing the research panorama on the generative phenomenon and the cases of generative approaches used in the real world, it seems that the graphic design industry is lagging behind in this matter. Typical examples of generatively created designs can be found in art, engineering or architecture. In architecture, generative approaches have been used to adapt buildings to their environment or to provide a perfect ratio between material use and stability. In engineering, generative approaches have found utility in the creation of many different products, from soles of running shoes with perfect spring characteristics (New Balance, 2016) to skeletons for drones (Matsunaka, 2017) or 3D-printed self-designing cars (Jackson, 2018). Even in fashion design, generative approaches seem to have found their place, for example in the design of the famous 4D-printed Kinematics Dress by Nervous System (Garcia, 2014) [Fig. 13].

In graphic design, however, it is more difficult to find examples, especially if you are looking for anything other than dynamic visual identities. Most of today's graphic designers would not even know about the existence of generative tools and there is no software for graphic designers that facilitates designing generatively without writing pure code (like Autodesk

for engineers). Therefore, in a common design studio, it is very unlikely to find someone with the skills to design generatively. But why is that so?

During my research, I have found three main reasons for this backlog of the generative method in graphic design:

The "linguistic gap"

The first reason refers to what I call the "linguistic gap". I have pointed out previously that designing generatively is a process of communication between a human designer and a computational system. In any communication process, there is some kind of message which is encoded by the sender and decoded by the receiver. It is understood if both share the same code to encode and decode the message (i.e. Berlo, 1960). If the two do not speak the same language, a process of translation has to be interposed. Humans and computer do not naturally speak the same language and do not think in the same way. Computer thinking is algorithmic, logic, mathematical and digital (based on only two contrasting states: 0 and 1). Humans' natural language and thinking is plastic, relative and extremely complex. It depends on experience and knowledge and the ability to recall it, habits, instincts, perceptions, and even as "weird" phenomena as emotions. Even the most advanced artificial intelligence systems nowadays are not capable of translating the subtleties of human natural language into a language they can understand. Therefore, until today, in most of the communication between humans and computers, the translation is provided by humans. This happens generally by traducing ideas into code which can be understood by the computer.

The closer the message to translate is to the language of the computer, the easier the translation process. This means for example that a mathematical formula or a physics law is relatively easy to translate into code because the proper language of physics or mathematics is very close to the algorithmic way of thinking of a computer system. By contrast, translating, for instance, an emotion or humor into code is basically impossible because the nature of the two languages is fundamentally different.

Coming back to the initial question and comparing the "languages" of engineering and graphic design, it is obvious that they differ radically. Graphic (or communication) design helps to communicate messages between human beings (for example between a company and their target). This means that the messages graphic design classically encodes are encoded in a very "human" language. They are highly dependent on peoples experience, humor, emotions, symbolisms and common knowledge.

Engineering problems, on the other hand, are generally formulated in the language of physics and mathematics. Their constraints can be put into mathematic formula, dealing with physical variables like strength, weight, pressure, size, hardness, position etc.

This means, that engineering's innate language is much closer to computer language than graphic design's language. This implies that the translation process, which is necessary to incorporate a computer system as a co-worker into the creation process, is much more difficult in graphic design than in engineering.

This huge "linguistic gap" – graphic designers have to deal with when wanting to work generatively – is one of the reasons why graphic design is lagging behind in the application of generative systems in their design process.

A cultural problem

Many researchers make statements similar to the following: "Research in generative design production is relatively recent, and therefore a serious challenge for designers, generally with slight notions of programming languages, and much less expertise in computing sciences" (Curralo, 2015, p. 103). It is a general assumption that graphic designers have less experience and expertise in mathematics and information technology. They are not used to algorithmic thinking and do not know any programming languages. "Parametric design [...] initially requires the designer to take one step back from the direct activity of design and focus on the logic that binds the design together. [This] introduces additional concepts that have not previously been considered as part of 'design thinking'" (Woodbury, 2010, "Parametric Modeling", para. 4). Lack of knowledge and skills on a certain field generally stem from the underlying education someone received. To date, graphic designers' education is based on concepts mainly stemming from psychology and aesthetics while engineers' education is based on mathematics and physics. Education in informatics and algorithmic thinking is generally not included in a designer's curriculum because it is not seen as a necessary skill for their future job. "In design schools today, students are taught how to use CAD tools and how to experiment within the limits of the applications, but they are never taught how to channel their creativity through the language, structure, and philosophy of programming" (Terzidis, 2009, p. XX). Of course, this circumstance has its roots partly in the "linguistic" condition explained in the previous paragraph. The language of engineering problems is much closer to mathematics and physics and the language of graphic design problems much more connected to psychology and aesthetics. However, both disciplines basically deal with problem-solving and the skills they require are not as different as many might think. In a very simplified way, we can say that to come up with a novel solution to a problem you need

creativity and a problem-solving method (a style of thinking). One method that humans use to solve problems and that has found to be extremely successful, is computational thinking (Wing, 2006). Therefore, it is an extremely valuable method to learn for any person in any discipline, but especially for designers. Even in design as it was until this current paradigm shift, incorporating computational thinking into designers' curricula would have made a lot of sense. But in the current scenario, it seems absolutely indispensable.

Thus, alongside the shift in design methods and process, there has to happen a cultural shift in the way design is generally perceived as a discipline. In this new era of generative design, algorithmic and computational thinking is undoubtedly a necessary skill for graphic designers and has to be incorporated in their education. This is a change in how design is understood by society and the education system. And changes are slow. For engineering disciplines, the same shift in design processes does not imply such an enormous cultural shift because computational thinking was already recognized as a necessary skill for this discipline.

This means that whatever time the cultural shift in graphic design takes, is time getting "lost" for actual work with generative systems in the industry. Therefore, it is lagging behind. If computational skills and programming are not part of design education, designers do not have those skills and therefore have strong limitations in using them in their work; and if GD is not best used by prepared designers, it is not getting developed (or at least much slower). This way, we enter a kind of vicious circle where the backlog gets larger and larger.

This cycle is underpinned by another cultural phenomenon: Graphic design as a research field receives much less investment than engineering. This stems from the fact that Return of Investment (ROI) produced by design is much less measurable and tangible than ROI produced by engineering. Less

investment implies less research and less research implies less evolution of the field.

In summary, as a second reason for graphic design lagging behind in the generative method, I have identified the cultural problem of design being seen as a field more related to psychology and aesthetics than to technology and computational thinking. Due to this perception, education of designers is not sufficiently focused on teaching computational and algorithmic thinking skills and therefore, graphic design could not implement the generative method as easy as engineering disciplines.

The big problem of aesthetics evaluation

The last reason I want to point out here is undoubtedly the most investigated and important one. The "linguistic gap" from the first paragraph is not only an obstacle to explaining a problem to the computer, but also to evaluating if the solutions proposed by the computer are good or not.

In engineering, as in the formulation of the problem, the evaluation of the solution is generally very simple. The features that determine the quality of the solution are usually based on physical variables and can, therefore, be easily tested. Sometimes this "fitness test" can even take place virtually, without physically fabricating the proposed item. Does it fit into the space it has to fit in? Does it sustain the weight it has to sustain? How much material do we need to produce it? And so on.

In graphic design, the situation looks very different. As the produced items are means of communication between humans, their quality depends on how good they transmit the message they have to transmit and how this influences the receiver's behavior. The message can be knowledge, understanding, insight, emotion etc. The desired behavior can be to have them buy a certain product, spend more time in family, donate money, go to a certain event, or simply feel more conscious about a certain topic

or experience a subtle change of opinion towards it. Even a laugh or the experience of pleasure, beauty or fear can be desired behaviors. This means that to evaluate the quality of a graphic design product, we need to rely on psychological and aesthetic judgments. This happens to be something computers are extremely bad at and humans are extremely good at (Eckert et al., 1999a, p. 5).

According to Galanter (2009), generative systems have four essential components. The fourth of these components is "the ability to assess fitness in a population to enforce 'survival of the fittest'" (p. 14). This fitness function in graphic design would have to be a mixture of psychological evaluation and aesthetic evaluation. He states that this component is unsolved in generative art and design to date. "Aesthetic measures, if possible at all, will be very complicated [...]" (Galanter, 2009, p. 15). Eckert et al. already stated in 1999 that implementing aesthetic evaluation into a computer system would be almost impossible and since then science hasn't made the significant step forward to solve this problem. Brown (2009) doubts that real aesthetic evaluation will ever be possible for a computer. And even if it was possible, the computer would still have to learn how to understand all the nonaesthetical, subtle, psychological meanings of graphic design products. And not only understand the meaning, but also predict if it influences a certain group of persons in a certain way. Just by thinking of how many "human" and extremely unstable, unpredictable, and complex variables this includes, it is perfectly clear that, if ever, this will take many years to be implemented in an intelligent computer system.

As long as these judgments cannot be done by a computer, the fourth component of a generative system necessarily has to be undertaken by a human being. This impedes that significant advantages of generative systems, like the ability to simulate evolution, can be exploited by graphic design.

In summary, the third reason for graphic design lagging behind in GD is that technology is not sufficiently advanced to allow fitness evaluation inside the generative system for communication design problems.

In conclusion

To answer the question of why graphic design is lagging behind in the application of generative methods, I have detected three main reasons:

- 1. There is a large "linguistic gap" between the language in which graphic design problems are expressed and the language computers can understand. This makes the translation process much more difficult than for engineering problems.
- 2. In current culture, graphic design is still seen as a discipline mainly related to psychology and aesthetics. Therefore, computational thinking skills are not implemented in design education, which slows down the process of using them in practice.
- 3. Evaluating solutions for graphic design problems is impossible for computer systems to this day. These evaluations would include aesthetics and psychological judgment and it is to doubt if this will ever be possible for artificial intelligence.

Most certainly the most difficult problem to overcome is the third one. However, even assuming that it cannot be solved in the near future, graphic design can use generative systems for purposes that do not include the necessity to evaluate the outcome inside the system. The evaluation part will continue in the hands of the human designer and will lower the efficiency of generative systems. Nevertheless, generative methods can bring great benefits to graphic design processes and outcomes.

The identified cultural problem can be resolved by changing the society's conception of the design discipline and by incorporating computational thinking into designers' curricula. This would lead to more research and more practical application of generative processes in graphic design and speed up its evolution.

5.3 Question 3: Will generative methods extinguish designers?

In the previous chapters, I have repeatedly cited authors talking about a paradigm shift and a big revolution in the design industry and in society, with generative methods being implemented in the design process. Talking about this topic, we cannot help but experiencing a certain subliminal concern about our future as designers. If these generative systems take over large parts of the design process, will we even be necessary in the

"Our intelligence is what makes us human, and AI is an extension of that quality."

Yann LeCun

future? Or will we be substituted by computers? Will our job be a victim of technological advance like so many others have been?

It is rather surprising that this question, or even the concern about it, is mostly mentioned only in passing, adding a few casual sentences somewhere in the conclusions part of research papers. Should it not worry us a little more? Or are we really that safe?

To address this kind of question about the future, we need to define a time range we intend to make a prediction for. Therefore, my answer will be divided into two parts: One concerning the nearer future and one the further future.

From a short and mid-term perspective

"Computer programs have taken over many traditionally human intellectual tasks, leaving less and less tasks for traditional designers to do" (Terzidis, 2009, p. xxi). Nevertheless, right now, there seems to prevail a positive view on designers' future in the research panorama. There is general consensus that designers will remain essential to the design process, even with generative systems being incorporated. It is frequently pointed out that the designer's role will change dramatically, but their existence does not seem to be in direct danger.

"While there are often worries about technology making the role of designers and engineers obsolete, this is simply not the case. Design thinking isn't going away, it's evolving to take advantage of modern tools. In the same way a carpenter uses a power drill instead of a hand drill, the product designers and engineers of tomorrow will slowly abandon manual processes" (Paul Sohi, product designer at Autodesk, 2017, para. 4)

Eckert et al. (1999a) point out that humans and computers have "complementary" abilities, which is why the human cannot be easily substituted by a computer. "The role of the human designer remains, as with conventional design, central to the design process. [...] Generative design still requires the skill and artistry that encompasses any mode of design" (McCormack et al., 2004, p. 162-163).

The calmness with which designers face their future nowadays is basically

due to the fact stated in the last paragraph of question two; graphic designers could only be completely substituted by computer systems if the problem of aesthetics and psychological judgment can be solved. And this seems improbable at the current moment. Actually, if this is the condition, engineers are much more likely to be fully substituted by computers than graphic designers, because the fitness function for engineering problems is already successfully implemented in computer systems.

However, design researchers and working designers are very aware of a

drastic change in the designer's role in the design process. The phenomenon of roles and responsibilities changing over time is very natural and we have seen it plenty of times in the past. When mechanical printing was invented, the ability to be a good calligrapher lost importance, with CAD systems like Photoshop, manual and redundant tasks have been taken over by computers, which enabled designers to focus increasingly on the concept (Terzidis, 2009). This implies that abilities, typically taken into account to identify design "geniuses" can suddenly become completely unnecessary while other abilities and characteristics gain in importance. "In the near future, computers will take over parts of our design process that we thought were sacred" (Wang in TNW, 2018). In the panorama of the recent shift we are facing, designers "will construct the tool that will enable one to design in an indirect meta-design way" (Terzidis, 2009, p. xxi). This means that "we humans will be less in the business of forming or 3D modelling and more in the business of really understanding what are our requirements of the design" (Tamburini cited in Howarth, 2017). "[Generative design] initially requires the designer to take one step back from the direct activity of design and focus on the logic that binds the design together" (Woodbury, 2010). This initial "step back" or "step up" to the meta-level of design is the big difference between design as it was and design as it will be. To successfully

use generative methods, "the willingness (and ability) of the designer to consider the relationship-definition phase as an integral part of the broader design process" (Woodbury, 2010) is crucial.

Remembering the GD process in graphic design, there are two essential parts where the designer is still needed: At the beginning of the design cycle, the design problem has to be understood, defined and translated to computer code. At the end of the cycle, the solutions proposed by the computer have to be evaluated and selected in order to reinform the generative system about their fitness.

The definition phase in the first part of the design cycle requires designers to "start with the design parameters and not preconceived or predetermined design solutions" (Karle & Kelly, 2011). This definition of parameters and relationships "is a complex act of thinking. It involves strategies and skills, some new to designers and some familiar" (Woodbury, 2010). This new required complex act of thinking implies an approximation of designers' thinking to the way computers think (reducing the "linguistic gap"). New necessary skills for designers willing to work with generative systems are therefore algorithmic thinking, mathematical thinking, and abstract thinking. "Yesterday's designer was closely linked with the command-control vision of the engineer, but today's designer is closer to the if-then approach of the programmer" (Blauvelt, 2008, p. 5). Of course, it is not only the way of thinking that determines how capable the designer is to explain the design problem to the generative system. It is also their ability to translate this problem into computer language: namely their ability to write code and program. Apart from algorithmic thinking, programming skills are indispensable for designers who want to embrace generative methods in their design processes (Serra, 2013). As always, the development of certain skills does not only depend on education or implication, there are also

inherent characteristics of human beings that facilitate the acquisition of these skills. "It has been found that critical thinking and logico-mathematical intelligence have a positive impact on algorithmic design skills" (Korkmaz, 2012). Thus, these might be additional characteristics that predict a person's success as a designer in the future.

On the other end of the design cycle, Eckert et al. (1999a&b) have identified visual perception and perceptual evaluation as powerful skills to help with aesthetic evaluation. Already during the Bauhaus movement in the 1950s, Gropius and Moholy-Nagy talked about the importance of "visual intelligence" in good designers (Findeli, 2001). It seems obvious that it is of utmost importance for a designer to "have a well developed aesthetic appreciation" (Lawson, 2005, p. 12). As long as computer systems cannot make aesthetics value judgments, this will remain an essential skill or even gain in importance. Another skill that is related to the problem definition, as well as the psychological part of evaluation, is a certain amount of empathy. Designers must understand their target, often even better than the target understands itself. This ability remains untouched in GD as long as computers are not able to deeply understand human behavior and desires. Between the problem definition phase and the evaluation phase, there is the actual creation phase. The skills this phase used to require from human designers included creativity (the ability to come up with a novel solution to a problem), drawing and sketching (Lawson, 2005) and visualization skills (Eckert et al., 1999b). If this phase is now taken over by the generative system, this might indicate that these skills will be less important for future designers.

Taking into account these changes in necessary skills for future designers, it can be noticed that the "Archetype of Design Curriculum", proposed by the Bauhaus school is getting rebalanced. This model sees design as a perfect mixture of art, science, and technology (Findeli, 2001). With the recent shift,

the art part seems to shrink while the science and technology parts grow.

In conclusion, in the short and medium term, designers are unlikely to be completely substituted by Al due to its missing capability of providing aesthetics and psychological evaluation. However, the role of the designer in the design process, and therewith the required skills for being a good designer, are changing considerably. Algorithmic thinking, programming skills and aesthetic value judgment gain in importance, while skills related to actual physical creation of products become less important.

From a long-term perspective

"Despite the apparent difficulty in solving the problem [of aesthetic value judgment in computer systems], the attempt to move digital art beyond the raw generativity of the computer to something more like an aesthetically critical artificial intelligence is too compelling a goal to ignore. While success cannot be guaranteed, work is sure to continue" (Galanter, 2016, p.174).

Even if a computer system with better abilities to judge aesthetics and psychological variables seems an utopia today, research will keep developing such a system and might succeed over the long term. Colton (2009), for example, describes a possible way this could be achieved:

"[...] A criticism that people often level at so-called creative software is that it has no purpose. That is, if the human didn't run the software, analyze its output and publish the results, then nothing would happen - which is not a good sign that the software is creative. This is a very valid criticism. However, it is one that we can manage by repeatedly asking ourselves: what am I using the software for now? Once we identify why we are using the software, we can take a step up

the meta-mountain and write code that allows the software to use itself for the same purpose. If we can repeatedly ask, answer and code for these questions, the software will eventually climb its meta-mountain, and will create autonomously for a purpose, with no human involvement." (n.p.)

On the TNW conference 2018, Che-Wei Wang presented the formula of how a computer system would have to look like to completely substitute a human designer. This kind of system combines three ingredients: Generative Design, Neural Networks, and Natural Language Processing. Neural networks are the solution to the aesthetic value judgment problem. A neural network can be trained on "fuzzy values" like personal aesthetic value judgment and taste by being fed with a big amount of data/images and the corresponding judgment. It learns what kind of items you like or dislike and, based on this knowledge, it can then make an aesthetic value judgment of a new item. According to Wang (TNW, 2018), this kind of neural network is coming in a very near future and could predict, for example, if a newly designed item will be successful on the market, based on information about the success of previously designed items. Natural language processing would solve the "linguistic gap", as it allows to describe the design problem and its constraints in plain, human words. This technology is developing very fast, although I think it is still far away from understanding subtle human expressions or emotions on a level necessary for creation in graphic design. As soon as those three ingredients get sufficiently developed, there will be no need for any type of special skill anymore to design any type of product. "This will change the design industry in ways that we can't see yet" (Wang in TNW, 2018, 12:00). Wang predicts, that "design is going to get creepy": robots will be able to generate new products based on our likes, habits, inspirations, experiences or behaviors. A similar statement was made by McCormack (2012):

"If an aesthetic measure of algorithm can be devised, then it could be used to

automate the generation of aesthetic artefacts. [...] If the formalization included knowledge of individual tastes and preferences, the artefact could be tailored differently to every individual, uniting modern mass-production with aesthetic haute culture on an unprecedented scale" (p.6).

Although there surely is still some way ahead, the development of a complete, independent generative system seems much closer than expected. Even nowadays, we can already observe developments like Logojoy in graphic design. This free online software designs complete visual corporate identities in minutes, based on just some simple choices the user makes. Of course, the outcomes are still disappointing and not comparable with a human-designed logo, but the mere existence of this solution gives us an idea of how far we actually are from being completely substituted. The three ingredients identified by Wang (TNW, 2018) are all separately developing very quickly on a pretty high level. Joining them into one system will be only a very small last step. Therefore, Wang makes it very clear that computers will indeed take away designers' jobs. "Design Neural Networks", the artificial substitutes for human designers will be trained to work like your favorite designer, won't have an ego, will not ever complain and will ask for no payment nor vacation (Wang in TNW, 2018). If these systems exist, the choice between a human designer and an artificial designer from a boss perspective will not be too difficult.

In summary, I come to the conclusion that, even if it seems improbable that designers get substituted on a short or mid-term basis, I consider it very probable they will be extinguished in a further future. This can happen as soon as computer systems get powerful enough to perform all the tasks belonging to a proper design process better than humans do. Taking into account that graphic design deals with human-focused communication, this could still take a while. However, I am not prepared to make a prediction in years. Also, these assumptions are based on predictions related to the evolution of technology, disregarding other variables such as legacy restrictions or ethical and cultural limitations that could be imposed and that would slow down the process.

A total takeover of computer systems in the design and production of any type of product can have severe consequences for human life. Some of the consequences and possibilities to prevent - or prepare for - will be discussed in question 4.

5.4 Question 4: How to prepare for the future?

"As a result of the use, misuse, and, often, abuse of computational design tools, many have started to worry about the direction that design may take in the next few years" (Terzidis, 2009, p. xxi).

Generative design is, without doubt, an amazing development which can help the human society to take a big leap towards its next step of evolution and a new kind of society. However, like every powerful change in human history, it also has its dark sides and potentially problematic effects. Current research on GD is extremely concentrated on the present and on technological development. The influences such developments have on society might be more in the hands of sociologists and philosophers. To answer this last question, I will not undertake a sociologist literature review but rather concentrate on the predictions of a few persons who were able to provide a

holistic worldview between technology, design and sociology.

The goal here is to clearly and sincerely point out some negative effects the development of GD might have on the industry and on society and to make suggestions about how to prevent or prepare for these upcoming challenges.

Possible problems created by generative design

Generative design has many positive effects that have been explained in detail on the last 60 pages of this work. It will make design more efficient, it will help to come up with entirely new solutions, it will free designers to concentrate on what is really important, it will give meaning to the huge amounts of recollected data we store, it will make people's lives easier, etc.. Linked to these advantages, three main threats have been identified, which GD will challenge our society with:

Design getting weaponized

This first threat can already be observed today, but it might be severely intensified in the future. Design could get weaponized. Wang (TNW, 2018) illustrates this threat by a concrete example scenario in which GD is abused to manipulate people's political behavior: Large companies (like Amazon) could generate a very large amount of random products and sell them to users. They could then track how each of these products changes their buyer's political stands and behavior. People would therewith, without knowing it, become part of a machine learning loop, training an AI system on how to manipulate political orientation. The outcome of this kind of learning loop could easily influence an election in the future. However, Wang (TNW, 2018) also points out that, although taken to the next level, this is just the nature of tools. "Good guys will use tools to do good things, and bad guy will use them to do bad things" (14:55). Nevertheless, there are problems with GD that can make it dangerous, even in the hands of "good guys".

One of these problems is that GD is a "Black Box" (Wang in TNW, 2018). Codes are already so complex that even programmers generally only understand a small part of them. When machines start to write their own code based on machine learning loops, these codes will get so complicated that almost no one will be able to understand or correct them anymore. This implies that the power over these tools will be in the hands of very few people. And very few people having a load of power is always a threat to the rest of society and leads to even greater inequality and exploitation.

Generative systems are only as good as the data they feed off

A second main problem that is identified is the extreme interwovenness of neural networks with data. Neural networks learn to make judgments based on high amounts of data. If this data is somehow incorrect or does not fit the design problem, the outcome of the generative design process is equally incorrect. Data is not always right, valid or reliable and can be easily misused, which makes it highly irresponsible to rely solely on data as input (Wang in TNW, 2018). With this second problem, ethical issues come into play. "Machines don't have common sense" (18:27) and we have to be extremely critical with the data we use.

"Machines will only see what you train them to see, they will only learn things that you tell them to learn but they will do things that you never told them to do and they will make things that you never told them to make" (Wang in TNW, 2018, 21:20)

Artificial intelligence will take away our jobs

As pointed out in question three, there is little doubt that, in a not too far away future, intelligent systems might take over humans' jobs. They have already taken over a large proportion of repetitive and monotonous jobs during the era of the industrial revolution and, as technology is getting

intelligent now, it will now also affect creative and more complex jobs. Masuda predicted in 1981:

"The prime innovative technology at the core of development in industrial society was the steam engine, and its major function was to substitute for and amplify the *physical* labor of man. In the information society, 'computer technology' will be the innovational technology that will constitute the developmental core, and its fundamental function will be to substitute for and amplify the *mental* labor of man" (p.31).

These predictions might have not come true during the Information Age which they were made for, but it seems more than probable that they will become true in this new "augmented" or "machine" age.

McAfee (2013) identifies two main problems arising in a society where

the majority of human labor has been substituted by machines. The first problem is an economic one and based on the fact that unemployed humans will not have the economic means to buy the products that are made by the machines. This would lead to an economic breakdown. The second problem is a social one and we have already been observing it during the last 20 years. The part of the population most affected by machines taking over jobs is the lower and middle class. Jobs of less educated and intelligent people will be taken over first and this will lead to an even extremer gap between lower and upper class. But employment is not only a source of economic power but also a "provider of social relationships, identity in society and individual self-esteem" (Winkelmann, 1997, p. 1). It has been found in numerous sociological studies that unemployment leads to decreased psychological well-being, increased crime rates, lower marital stability and higher mortality (Winkelmann, 1997). This would mean that the benefits of the new machine age are basically reserved for a highly educated, intelligent and creative upper class and in my opinion this cannot be our goal.

How the new society might look like

Although the predicted problems above might seem frightening and remind of a dystopic Science Fiction movie, all the mentioned authors actually have a very positive attitude towards this future. It is predicted that work will be more interesting, design will be more adaptable to different individuals, and we will be able to focus our lives on things that really fulfill us. McAfee (2013) predicts a flourishment of idea interchange, creativity, art, and science. Masuda's (1981) predictions, which were originally made for the information age, were actually ahead of times and seem to fit now better than ever. He thinks that while in industrial age the main goal in society was economic, the focus of these new societies will be society itself. According to him, society will change from a capitalist private enterprise organization to a voluntary civil society with social activity and voluntary community as its fundamental pillars. This society will be characterized by public capital and knowledge-oriented human capital responding to the principle of synergy and social benefit. This view fits McAfee's prediction of a society of "total abundance". If there is no need to compete for material goods anymore, the focus of attention will move to "softer" aspects of life, like spare time, social interaction or experiences. This shift can already be observed in the millennial generation which values experience much more than material goods (Morgan, 2017).

"The most advanced stage of the information society will be the high mass knowledge creation society, in which computerization will make it possible for each person to create knowledge and to go on to self-fulfillment" (Masuda, 1981, p. 33).

Colton (2009) focuses on generative systems in artistic disciplines and disassembles the common fear of Al taking over the world:

"Good art makes you think. [...] Hence, our software should produce artefacts with the explicit purpose of making the human audience think more. [...] More than any other aspect of computational creativity research, this sets us apart from researchers in other areas of Al. In these other areas, the point of the exercise is to write software to think for us. In our area, however, the point of the exercise is to write software to make people think more. This might help us argue against people who are worried about automation encroaching on intellectual life: in fact, in our version of an Al-enhanced future, our software forces us to think more rather than less" (Colton, 2009, n.p.).

How to prepare for this future?

To make the horrifying predictions from the first paragraph match with the marvelous view of the future from the second paragraph, we need to offer some solutions. GD has the potential to make our society collapse and to make it flourish. To turn us into poor, powerless dots in the manipulation loop of machines or to make us happier, self-fulfilled and living in abundance. But what are the steps to take to ensure the latter to happen?

In my opinion and based on my research, there is only one logical answer to this question, and it can be resumed in one word: *education*. If one of the major problems that make generative systems so powerful and dangerous is its condition of a "black box", we need to "un-black-box" it (Wang in TNW, 2018). Anyone should be able to understand what happens in the box, which is why anyone, no matter what their profession or life purpose might be, should learn basic concepts of machine learning and artificial intelligence

(Wang in TNW, 2018). If everyone has a clear idea of how machines learn and work, what they are able to do and on what data they rely, this creates a society with a critical attitude. This makes manipulation more difficult and puts power in the hands of everyone instead of only a few. A specific step to get there could be implementing machine learning, programming and Al into children's curricula and offering public courses of adult education on the topic.

Wang also proposes for every single one of us to think about which parts of our job will be taken over by Al and which will remain under human control. His specific advice for designers is, instead of just waiting for the takeover, to "become a robot tamer" (20:24), to learn how to use generative software. The essential idea of these pieces of advice is to actually take advantage of the knowledge we have about our jobs and about what machines are able to take over. And, based on this consciousness, prepare for the takeover. This preparation generally consists of acquiring new skills and knowledge that can help us take a step up onto the "meta-mountain", how Colton (2009) called it. "Designers will become conductors rather than composers, directors rather than actors and air traffic control rather than pilots" (Wang in TNW, 2018, 22:41).

As a solution for the economic and social problems in a society where most jobs have already been substituted by machines, McAfee (2013) proposes a guaranteed minimum income as a basic solution. This would avoid the economic breakdown and the social problems caused by unemployment. However, the psychological consequences of unemployment (even with a minimum income) would still be grave for whole generations of people who did not have the chance to build up a life purpose apart from their job. For younger generations, on the other hand, the right education could form intrinsically curious and motivated human beings who would not be affected negatively by not having a permanent job. Free, democratic education

systems could be the key to shape this kind of persons. Similar to Wang's statements, McAfee underlines that the best preparation for the future is to be aware of the challenges that are going to come. Communicating openly, clearly and sincerely about the future society and its problems, humankind will be able to overcome the challenges this new, super-abundant context will create for us.

In summary, I come to the conclusion that education is the key to prepare for a future with generative design. There still seems to be very little research about what and how to teach GD in an efficient way. A first approximation is the research proposed by Fischer & Herr (2001). However, if we want to assure a good, wise and meaningful use of generative tools in the future, we should urgently think about how to implement algorithmic thinking and basic concepts of machine learning and AI into our education system. This is not only proposed for specific design education, but for education in all the disciplines, as well as in basic education for children. Looking ahead to a future where most of the jobs will be replaced by machines, we should also change the basic principles of our education systems towards methods that foster intrinsic curiosity, self-organized learning, and creativity.

Graphic creation for the layout of this document

In concordance with the research topic, the graphic material used in the layout of this thesis document was created by a generative tool. This tool, created specially for this purpose, takes in data concerning the different activities I carried out while working on this project. Every page of the document represents one specific day of my working process whose date is printed out in the bottom left corner. The different work activities (searching, writing, reading and watching, coding and layouting), as well as one private activity (sport), are reflected in different visual aspects of the created images (line thickness, connection lines, outlined circles, curvature of connection lines, color). The methodological details can be consulted in chapter 3.3.2. and the original source code is available in the Appendix I. The cover of the document is designed

using the generative tool but with no connection to real data, simply searching a pleasant composition through various repetitions and intents. The rest of the layout (text styles, typography, text composition etc.) is designed following the traditional process without any generative method involved. The text composition is based on a 8x6 grid system to which I freely adapted the written content of every page. I will not go into detail on this non-generative part of the layout. However, the coexistence of generated graphic content and customly designed layout demonstrates how traditional and generative graphic design can live together in harmony, complement and reinforce each other.

The decision of basing the layout of the thesis on generatively created images, had serval reasons. On the one hand, this consitutes an original application of GD for a graphic design purpose. On the other hand, the learning process I had to undertake to acquire the necessary programming skills provides valuable insights into the usage of GD for graphic designers. These can help to evaluate the viability of acquiring GD skills and the difficulties related to that acquisition.

Conclusions from the generatively created outcomes

As pointed out in the previous chapters, generative approaches are still not usually applicated in the context of graphic design. This document can be seen as a possible example of how to use generative methods in editorial design and layouting. The specific method is not meant to be reproduced in other works or contexts, it rather shows that there are plenty of possibilities to incorporate generative tools in communication design problem-solving.

In this case, data was used to justify and direct the generative tool. By introducing generatively created drawings into this work, not only does the aesthetic value increase, but a whole new dimension of meaning is added. The new layer of information provides the reader with insights into the creation and investigation process without reading any additional text. Where normally no information would be available (in the page backgrounds), now a story is told in a non-verbal way. This adds value and meaning to the overall proposal.

The illustrations have been chosen not to be totally "readable". One cannot retrieve the exact amount of hours spent on every activity by contemplating the graphics. Therefore, they are not a reliable information visualization but rather an aesthetic – but meaningful – design content. They give a general and relative idea of the work process. It can be concluded which kinds of activities overweighed in certain parts of the process, which were absent, and when dedication was especially high or low. If the document was printed out, the lateral of the paper stack would represent a color-graded graph of the work process.

Contemplating the final graphic outcomes and its cohabitation with the

written contents, the issue of legibility and composition must be critically examined. Ceding control over the background of the pages to the generative system and real-life data led to different rather incongruous artifacts. For example, some pages with high text and image density have backgrounds with high graphic content while other pages with more blank space stayed entirely white. Having full control over the design, this could have been balanced out. In my opinion, however, the charm of every page representing a specific day with real data overweights the created imperfections in the composition. To guarantee legibility at all times, I manually corrected the contrast and position of the background images on critical pages. Apart from the additional information provided about the creation process, the incorporation of a generative tool was especially meaningful in this specific project as it is closely linked to the research topic. The data chosen to be used by the generative tool are justified in the university context of the project, which is not only defined by the scientific contribution itself, but also by the learning process related to it. In a different context, different data (such as text density, chapter length, historical data, publication numbers,

Although not many graphic design projects are inherently related to GD, a similar approach can be imagined for a very wide range of different projects and design challenges. As already pointed out earlier, the existence of data related to a project can justify the incorporation of generatively created material. The provided example application within this document underlines the fact that generative designs are highly context-dependent and customizable. In order to add real value to a product, the used tool should be specifically created for every single case and a conceptual connection between the product and the generated images should be established. Data is not indispensable for generative graphic design, but can help to add meaning to the proposal. Assuming that every single visual element in a communication design product should help with the communication process, aesthetic artifacts based on project-related data can enrich this process in a very meaningful way. Living in times of Big Data, the data that can be used does not need to be collected for the purpose of the project itself, that is, we can also rely on existing external data connected to the project. For instance, if the design challenge was layouting the annual report for Greenpeace, data about temperature changes, ice melting or rubbish accumulation could be used. This data could be represented, like in this thesis, in a temporal way but also spatially, interactively or concept-dependently. The graphic manifestations of the input variables can be adapted to the corporate identity of the stakeholder or reflect a different variable relevant to the specific project. Ideas and possibilities of this kind are almost infinite and the visual outcomes of any project of this kind would be highly individual, diverse and context-specific. Therefore, as stated by Peeters (2016), copying or appropriating generatively produced material is not as easy as it might seem.

In conclusion, this example application shows that there are plenty of possibilities of using generative design to solve communication design

etc.) could have been used.

Nevertheless, this does not mean that the generative approach is correct for any graphic design problem. It is to be decided for every specific project if a generative tool provides additional value and meaning to the design. In the same way as not every type of visual material (photography, manual illustration, type etc.) is suitable for every project, using a generative tool is not genuinely adequate either. Yet, it is a very powerful approach to come up with new creative solutions that we should take into account whenever briefing a new project.

Conclusions from the learning process

As a second purpose of this practical application, I want to provide a firsthand report of the practical implications of working with generative tools for a graphic designer. As for most other graphic designers, my education concentrated on aesthetic-psychological concepts and prefabricated design software, being basic notions of HTML and CSS the only programming skills included. Having exposed myself to a learning process of a generative programming language enables me to draw some basic conclusions on several practical aspects of introducing generative methods into graphic design practice. This process was limited in time, focused on creating a specific outcome for a specific date and my dedication to it was much less than full-time. This made it very similar to the real-life context of a graphic designer who, for the first time, needs to apply a generative approach to a design project.

On a general level, it has to be pointed out that designing generatively for graphic design purposes is still a relatively arduous endeavor. The available

tools are difficult to learn and abstract to work with. Hard code has to be written from scratch and a complete understanding of a programming language is required. This represents a considerable difference to the visual way of creation that graphic designers usually follow. For designers with no prior experience or a certain talent in algorithmic thinking or information science, this can be a serious obstacle.

However, accepting this lack of auxiliary software that could help overcome the need of learning a programming language in the future, I also come to the conclusion that designing generatively with what exists to date is not at all impossible. The *Processing* language and the corresponding learning method are very accessible and start from a total beginner level. Acceptable results can be achieved in a very short time, depending on interest, effort and logical thinking abilities of the designer accepting the challenge to learn GD. Therefore, the current unawareness of generative approaches in the communication design community cannot simply be justified by the difficulty to acquire basic programming skills. The current ignorance towards the topic might be more due to the aforementioned gap in design education and the lethargy of the educational system, as well as design agencies, to adapt to the new possibilities.

My conclusions from this learning process overlap with my conclusions from research question four (4). I strongly recommend incorporating teaching of algorithmic thinking skills and programming into designers' education. However, even not having learned any of those skills before, I consider it relatively easy to acquire basic GD skills in an auto-didactic way without investing an inappropriate amount of dedication. To initiate this acquisition, the *Processing* software and learning methodology can be thoroughly recommended.

Conclusions and future research

7.1 Conclusions

Recapitulating starting point, goals and methods

This thesis is the product of five months of scientific labor dedicated to the topic of generative design. It is the reaction to a problem detected in the current design research panorama, which I considered necessary to address: For a few years now, generative processes have made their way into the work processes of all the design disciplines. This new phenomenon implicates a paradigm shift in the way we relate to design and there are strong indicators that it is also the key to a new era in human evolution. However, research on this topic, especially in graphic design, is still very sparse. I found that several topics and questions had not been addressed in research nor had there been provided a structured and complete overview of the topic.

To fill in part of this detected gap in research, I framed three main research goals, which I addressed through a defined methodological approach [chapter 3].

Within the proposed scope and boundaries, the three goals could be satisfactorily fulfilled. Logically, the general problem of lacking research on any topic cannot be solved by one single research project. However, I consider the summarizing effort, the proposed questions and answers, as well as the practical application provided by this thesis to be a valuable contribution to the state of the field.

Findings Research goal 1

The overview provided in order to respond to my first research goal showed that generative design differs substantially from traditional ways of designing. I detected four main topics that shape this difference and indicate how profoundly design is changing with the emergence of generative methods: the usage of tools in an active rather than passive way, products being grown rather than made, a considerable leap in the efficiency of design processes, and a substantial change in the design process itself. Further investigation regarding the design process showed that this change is not so much characterized by substantial new phases or modification of order, but rather by an adjustment of responsibilities. Generally speaking, a generative system is interposed between the human designer and the created product. This means that the labor of the human designer is substituted by the system in certain phases of the process. I found that especially affected are the divergent phases, which concentrates the designer's responsibility on problem definition and evaluation of solutions. The resulting GD process has a meta-design character.

Generative design is commonly considered a paradigm shift for design processes and products, initializing a new era of design that is relational, contextual and process-oriented. This assumption builds the basis for my initial hypothesis about the importance and world-changing aspect of the generative design phenomenon. I see this hypothesis to be supported by the findings I gathered through my research. However, it must also be underlined that in the context of a world as the sum of different human societies in different stages of development and technologization, the importance of the phenomenon does not affect all humans in the same

way. Although this could not be highlighted sufficiently inside the scope of this thesis, it has to be taken into account that the new possibilities created by GD are only available to a small part of the entire human society to date. I found that these sociological, philosophical and ethical aspects are widely ignored in the current research panorama, leaving considerable potential for a more relativizing and critical examination of the topic in future research. Considering GD research in a similar way Umberto Eco (1965) examined positions regarding the mass media, we can observe that almost all the positions to date are "integrated", and "apocalyptics" are almost inexistent. In my opinion, however, a more "apocalyptic" view on the topic, pointing out not only beneficial outcomes but also possible problems and examining the phenomenon in a critical way, could inspire important thoughts and push the field in a positive direction. This is why I included some critical aspects in my research questions.

Regarding the topics GD research is currently concentrating on, I could identify several common questions of interest in the research community. The problem of computerized aesthetic value judgment is one of them. This problem is the basis for a widely spread and extremely calm attitude towards the possibility of human designers being substituted by AI. In my third research question I point out that I do not entirely agree with the assumption that human designers will remain essential to design processes on the long term. In the current research panorama, more inclusive, realistic, and long-term considerations about the consequences of AI for the design industry are missing.

Just like there have been attempts to explain the emergence of generative methods in the present sociocultural context of a liquid society, future-oriented social, ethical, and legal considerations about design with AI and consequences for the entire human society should get included into research.

A connected but more specific topic of interest I identified through my research is the discussion about computer created artifacts being valued and considered as creative and how this evaluation can be performed. As GD methods have been identified to be human-created, actively used tools, I consider that their outcomes can be valued as creative, in the same way this can be done with artifacts created by passively used tools. However, I do not regard Turing-test methods to be of much value to judge the creativeness of AI-created artifacts, as their purpose is to create novel designs that could not have been created by humans.

The topic of generative processes in graphic design was found to be underrepresented in the research panorama, with a strong predominance of works regarding generative dynamic brand identities. This thesis intends to contribute to research concentrated on graphic design, but there is still infinite potential to explore possible applications of GD for communication design purposes.

Findings research goal 2

In order to satisfy my second research goal, I addressed four specific questions regarding the present and future of generative design, which I found to be insufficiently answered in the existing literature.

After a thorough analysis of underlying concepts and statements in current research, I come to the conclusion that GD will last in time and get further developed in the next years and decades. This assumption is based on the finding that GD is not a style nor a movement, but rather a novel method or tool and that this method implicates a radical shift in the way we design and think about design. The combination of these two characteristics can be seen as a strong indicator for timelessness, based on other revolutionary phenomena in the past.

I detected three main reasons to explain why, in the application of generative processes, graphic design is lagging behind other disciplines like engineering: There is a "linguistic gap" between the psychological and aesthetical concepts usually transmitted by graphic design products and the algorithmic codelanguage computers understand. This gap complicates the process of translating the design problems into system code. For other disciplines, like engineering, the languages of design problem and computer system are much more similar and therefore easier to translate.

While disciplines like engineering have always been linked to mathematics and IT, graphic design is considered to be closer to psychology and aesthetics, which influences the concepts included in design education. This consideration is not entirely true anymore but, as it has a cultural nature, the process of changing is slow and difficult. In engineering, however, the cultural assumption remains correct and only minor changes in education are required.

Because of the "linguistic gap", it is not possible for currently existing computer systems to judge aesthetical and psychological aspects of designs. While graphic design products need to be judged exactly on the basis of these aspects, engineering products have much clearer and easier code constraints and testing variables. Therefore, a "fitness test" cannot be implemented in generative systems for graphic design to date.

Due to the current problem of computerized aesthetic value judgment, designers are unlikely to be completely substituted by AI in a near future. However, characteristics and skills that make a good designer are changing drastically. Algorithmic thinking, programming skills and aesthetic value judgment gain in importance.

Regarding a further away future, however, I disagree with the general assumption that designers cannot be substituted by computers. This entire substitution can take place as soon as neural networks and natural language

processing are sufficiently developed to understand and evaluate subtle human expressions and aesthetics.

The evolution of generative systems presents certain problems for designers and society. According to the statements of Wang (TNW, 2018), these problems are: design getting weaponized, generative systems relying on data which can be incorrect, and AI taking away our jobs. Nevertheless, there is reason to believe that a future with GD and AI can be a positive evolution leading to a flourishment of idea interchange, creativity, art, and science (McAfee, 2013). To achieve such a positive future, I identified correct education as a key factor. In order to "un-black-box" generative systems and guarantee their use for good and meaningful purposes, every member of society needs to be educated in machine learning concepts. Design education should include programming and algorithmic thinking and general education should focus on creating curious, self-organized and creative individuals.

Findings Research goal 3

Satisfying my third research goal, I created a generative tool which produced the visual design elements used for the layout of this thesis based on data related to my work on the project. The visual outcomes lead me to the conclusion that there are plenty of possibilities to incorporate GD in graphic design problem-solving, that have not been explored to date. It also underlines the context-dependent and relative condition of GD, that is generally included in its definition, and depicts that generatively designed artefacts cannot be easily appropriated or copied. The application I propose is based on data and constitutes an example of what kind of data can be used for graphic design purposes. It is also made clear that existing data is one reason to use the generative approach for graphic design purposes, although I also point out that it is not indispensable. With or without data, I consider it essential to bear in mind that, with today's possibilities, GD is not suitable

for every design project but it has to be decided individually whether the generative approach adjusts to the specific project.

Considering the learning process I undertook to acquire the necessary skills to program a generative tool, I found that the situation for current graphic designers is still somewhat uncomfortable. To work with GD as a graphic designer nowadays, a comprehensive understanding and learning of a programming language is necessary and actual source code has to be written from scratch. A more designer-friendly way of creation, resembling the traditional way of visual composing to which graphic designers are used, would help to overcome this huge obstacle. It remains to be seen if upcoming software like Adobe Sensei will provide these possibilities. Until such software is accessible, however, I come to the conclusion that it is possible for every designer to acquire the necessary programming skills with the tools currently available to create simple, satisfactory generative tools in an adequate time and with reasonable effort. If programming skills and algorithmic thinking are implemented in education, newer generations of designers will undoubtedly be able to create generative designs on a whole new level. However, current designers who don't have such basis can anyway initiate themselves into it through, for example, the Processing methodology and language. I found this to be a very satisfying and empowering experience, which I recommend to every graphic designer.

Overall Evaluation

The theoretical and practical research process I undertook while working on this project has opened up a whole new field of design and of research to me. I am now even more convinced of my initial hypothesis: I consider generative design to be the start of a new era that will not only affect design but also society as a whole.

I think that, by providing this work, I was able to contribute significantly to a better understanding of the generative phenomenon and its importance. However, there is still considerable room for critical analysis and the inclusion of social, ethical, legal and cultural aspects.

Bearing in mind the conclusions drawn from my fourth research question, the practical part of my project and the associated learning process can be seen as a demonstration that educating oneself in GD is possible and worth the effort. If, with this work, I may inspire other designers to do the same, we are already a little step closer to a society prepared for the next era.

7.2 Future research

Expressed in a very simplifying way, the achieved progress in a field is inversely proportional to the scope there still is for further research.

Generative design and corresponding research are young and ideas for further research are manifold. There is not enough room here to list all the ideas I have on how the field could be completed and enriched. Therefore, I will reduce my proposal to a few suggestions that have come up in this thesis.

When and where do generative approaches make sense in graphic design?

In chapter 4.3.5, I investigated current applications of generative approaches in graphic design. One of the insights I got from this investigation is that generative approaches do not make sense for each and every single project. Some more specific research has already addressed the question where and when generative dynamic brand identities are more or less reasonable but I still see a strong need for further investigation on this topic. Future research, ideally in form of a interdisciplinary project, could be dedicated to establishing more exact criteria to be taken into account when deciding whether to use a generative approach for a communication design project or not. Considering the rapid progress of this research field, a periodical revision of possible areas of application could have direct advantages for graphic designers working in practice and could prevent the phenomenon from being exploited without reasoning and discrimination, producing inadequate solutions for design clients.

Where else to use generative design in graphic design?

As pointed out in chapter 5.2, graphic design is still lagging behind in the application of generative methods and these methods have been used for

only very few types of graphic design problems in the past. While there are already many generative dynamic brand identities, there are very few applications in other fields like editorial, poster or commercial design. There are entire branches of communication design where generative approaches seemingly have never been tested. Could we use generative systems in wayfinding design, packaging, web design etc.? Further research could be dedicated to detecting new possibilities in branches that have neglected GD to date. Generative processes open up entirely new possibilities which we have not thought of until now. What about personalized, unique posters, gift cards or packaging based on people's personal data? What about educational e-books adapting interactively to the learning process of every student? What about websites that change with the interaction of its users?

Generative design for inspiration

In chapter 4.3.5, I pointed out that generative processes cannot be utilized only to create the final design product, but also for inspiration purposes. Using GD as inspiration could be a good way to introduce generative systems into the classical design process. This would have the side effect of designers becoming more acquainted with generative methods in practice and incorporating them in their intellectual collection of possible problemsolving methods. Further research could focus on creating a framework for generative inspiration. I imagine a first approach to such a framework looking like current online inspiration platforms like *Pinterest*, but with completely novel imagery being created in real-time based on parameters modified by the designer without needing any programming skills or software.

Making generative design more accessible for graphic designers

One of the reasons why graphic design is lagging behind in the application of generative methods is a lack of easy to handle generative software specialized in communication design problems. Of course, this lack is partly due to the "linguistic gap" mentioned in chapter 5.2. However, research could be dedicated to exploring possibilities of creating generative graphic design software similar to what exists with *Autodesk Within* for engineers. If graphic designers could start to use generative methods even if they do not have programming skills, this could help to proliferate GD in the graphic design community. A first version of such a software is seemed to be currently developed with *Adobe Sensei*.

Generative design education

It has been mentioned several times in this thesis – and is one of the main conclusions from the whole researching process – that introducing algorithmic thinking and programming skills, as well as basic machine learning concepts, in general and design education is essential. Only with these skills becoming widely spread, the possible negative consequences of GD on a long-term basis can be prevented [see chapter 5.4]. In a nearer future, generative tools will make up a large part of designers' work practice. Therefore, initiating further research on how to teach these kinds of skills is maybe the most relevant and urgent recommendation to be mentioned here.

Generative design in a general and global context

As repeatedly pointed out in this work, current research is entirely focused on the social and cultural context of the most developed countries in the world and on the present moment. I detected the necessity to investigate GD in a global context of differently technologized societies with the problems and injustices this implies. I also consider that an examination of cultural, social, economic, legal and ethical consequences of GD in the future could be of great benefit. Future research could be dedicated to these considerations and possible ways to react to them, building up a philosophical standpoint towards a future with AI, with the benefit of the whole human race being the overall goal.

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Appendix I: Original code of the generative tool

This code has been created in *Processing*.

```
class Dotweb {
  //VARIABLES OF DOTS
  int number;
 float[] x= new float[number];
 float[] y= new float[number];
 float[] timex=new float[number];
 float[] timey=new float[number];
 float increment;
 float maxdistance;
  float curvefactor;
  //CONSTRUCTOR
  Dotweb (int Tempnumber)
    number=Tempnumber;
    x= new float[number];
    v= new float[number];
    timex=new float[number];
    timey=new float[number];
    //maxdistance for lines --> hours writing
    maxdistance=map(write[current], 0, 9, 10, 200);
    curvefactor=0:
    for (int i=0; i<number; i++) {
     x[i]=-1;
     v[i] = -1;
      timex[i]=random(0, number);
```

```
timey[i]=random(0, number);
    increment=0.004;
 void movedots() { //moves the dots around
    for (int i=0; i<number; i++) {
      x[i] = map(noise(timex[i]), 0, 1, -200, width+200) + random(-
map(readwatch[current], 0, 5, 0,0), map(readwatch[current], 0, 4, 0, 0));
      y[i]=map(noise(timey[i]), 0, 1, -200, height+200)+random(-
map(readwatch[current], 0, 5, 0, 0), map(readwatch[current], 0, 4, 0, 0));
      timex[i]+=increment;
      timev[i]+=increment;
  void showcircles() { //draws circles where the dots are
    for (int i=0; i<number; i++) {
      noStroke();
      //dark fill when sport is done and there are no lines(writing)
      curves (coding)
      if ((write[current]==0) && (code[current]==0) && (sport[current]==1)) {
        fill(80, 0, 100, 20);
      else {
        //more transparent white fill when background is darker
        fill(255, map(total[current],0,12,255,90));
        //more SEARCHING HOURS --> bigger circles
      ellipse(x[i], y[i], search[current]*2, search[current]*2);
      stroke(255, 80);
      noFill();
      //READING HOURS --> non-filled bigger circles around dots
      ellipse(x[i], y[i], readwatch[current]*5, readwatch[current]*5);
 void drawcurves() {
    //CODING HOURS --> curvature of the lines
    curvefactor=map(code[current], 0, 9, 0, 2000);
    //if sport done --> purple lines
    if (sport[current] ==1) {
      stroke(80, 0, 100, 8);
```

```
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```

```
if (sport[current] ==0) {
                //lines more transparent when total hours more
                stroke(255, map(total[current], 0, 12, 110, 10));
           //maxdistance determined by code or write, whatever is bigger
           if (code[current]>write[current]) {
                maxdistance=map(code[current], 0, 11, 10, 250);
           if (write[current]>code[current]) {
                maxdistance=map(write[current], 0, 11, 10, 250);
           //Draws lines between spots when they are closer to each other
                  than maxidstance
          noFill();
          for (int i=0; i<number; i++) {
                for (int j=0; j<number; j++) {
                    //&& eliminates misterious curve of first point with itself
                     if ((dist(x[j], y[j], x[i], y[i]) < maxdistance) &&(dist(x[j], y[i]) < maxdistance) &&(dist(x[j], y[i]) < maxdistance) &&(dist(x[j], y[i]) < maxdistance) &&(dist(x[i], y[i]) < maxdistance) 
                                   y[j], x[i], y[i])>0)) {
                           curve(x[i]+map(noise(timex[i]), 0, 1, -curvefactor,
curvefactor), y[i]+map(noise(timey[i]), 0, 1, -curvefactor,
curvefactor), x[i], y[i], x[j], y[j], x[j]+map(noise(timex[i]),
0, 1, -curvefactor, curvefactor), y[j]+map(noise(timey[i]), 0, 1,
-curvefactor, curvefactor));
import processing.pdf.*;
Table tfmdata:
String[] date;
Float[] search;
Float[] write;
Float[] code;
Float[] readwatch;
int[] sport;
Float[] total;
float cutofftime;
int current;
int numofrows;
```

```
int lastTime = 0;
Dotweb dotweb1;
color backgroundcolor;
boolean runonce =true;
void setup() {
  size(1240, 1240);
  background (255);
//import data from table
  Table tfmdata = loadTable ("2019 01 17 TFMdata-copia.csv",
"header");
  date= new String[tfmdata.getRowCount()];
  search= new Float[tfmdata.getRowCount()];
  write= new Float[tfmdata.getRowCount()];
  code= new Float[tfmdata.getRowCount()];
  readwatch= new Float[tfmdata.getRowCount()];
  sport= new int[tfmdata.getRowCount()];
  total= new Float[tfmdata.getRowCount()];
  current = 0;
  numofrows=tfmdata.getRowCount();
  for (int i=0; i<tfmdata.getRowCount(); i++) {</pre>
    TableRow day =tfmdata.getRow(i);
    date[i] =day.getString("date");
    search[i] =day.getFloat("search");
    write[i] =day.getFloat("write");
    code[i]=day.getFloat("code");
    readwatch[i]=day.getFloat("readwatch");
    sport[i]=day.getInt("sport");
    total[i]=write[i]+code[i]+readwatch[i]+search[i];
void draw() {
 //runs this part only once (defines number of dots, starts
recording PDF, determines background color)
  if (runonce ==true) {
    background(255);
    dotweb1 = new Dotweb(int(map(total[current], 0, 12, 3, 30)));
    backgroundcolor= color(255, 179, 145, map(total[current], 0,
12, 0, 255));
 beginRecord(PDF, "TFM "+date[current]+".pdf");
    fill (backgroundcolor);
```

```
noStroke();
    rect(0, 0, width, height);
    runonce = false;
//MAIN PART: executes parts of the class dotweb
  dotweb1.showcircles();
  dotweb1.movedots();
  dotweb1.drawcurves();
//saves screenshot after 1-4 secs depending on the total hours
  cutofftime=map(total[current], 0, 12, 4000, 1000);
  println(cutofftime);
 if ( (millis() - lastTime >= cutofftime)) {
 //saveFrame("ATFM_"+date[current]+".png");
 endRecord();
   lastTime = millis();
 if (current>= numofrows) {exit();}
 else {
 current=current+1;
 runonce=true;}
```

01/2019

Appendix II: Spreadsheet of workrelated data used by the generative tool

By clicking on the date, you can directly jump to the correspondent page.

date	search	write	code	sport	readwatch	total
2018_09_19	0,5	0	0	1	3	0,5
2018_09_20	1	2	0	1	2,5	3
2018_09_21	3	0	0	0	1	4
2018_09_22	0	2	5	1	0	7
2018_09_23	0	3	5	0	0	8
2018_09_24	0,5	0	0	1	4	0,5
2018_09_25	1	0	0	1	4	1
2018_09_26	1	1	0	1	1	2
2018_09_27	2	1	0	0	2	3
2018_09_28	1	1	0	1	2	2
2018_09_29	0	1	5	1	0	6
2018_09_30	0,5	2	5	1	0,5	7,5
2018_10_01	3	2	0	1	1	5
2018_10_02	2	0	2	1	3	4
2018_10_03	2	0	0	0	4	2
2018_10_04	2	0	0	0	0	2
2018_10_05	0	0	0	1	0	0
2018_10_06	0	0	0	0	0	0
2018_10_07	0	1	0	0	1	2
2018_10_08	0	1	0	0	0	1
2018_10_09	1	0	0	0	1	1
2018_10_10	0	0	0	0	0	1
2018_10_11	3	3	0	1	3	6
2018_10_12	1	3	0	1	3	4
2018_10_13	0	0	0	0	0	0
2018_10_14	0	0	4	0	0	4
EXCLUDED: 2018	_10_15 until	2018_11_17			4	

	date	search	write	code	sport	readwatch	total
Œ	2018_11_18	0	0	0	0	1	0
	2018_11_19	2	4	0	0	3	6
	2018_11_20	1	3	0	0	2	4
	2018_11_21	2	5	0	1	4	7
	2018_11_22	1	6	0	1	3	7
	2018_11_23	1	8	0	0	3	9
	2018_11_24	0	1	0	0	2	1
	2018_11_25	1	9	0	0	2	10
	2018_11_26	0,5	6	0	1	2,5	6,5
	2018_11_27	0	4	0	0	1	4
	2018_11_28	0	4	0	1	2	4
	2018_11_29	0	2	0	0	1	2
	2018_11_30	1	3	0	0	1	4
	2018_12_01	1	4	0	0	1	5
	2018_12_02	0	4	0	0	1	4
	2018_12_03	0	6	0	1	1	6
	2018_12_04	1	7	0	1	2	8
	2018_12_05	1	8	0	0	3	9
	2018_12_06	0	8	0	0	2	8
	2018_12_07	0	7	0	1	2,5	7
(1	2018_12_08	0	3	0	0	0,2	3
	2018_12_09	0	9	0	0	0	9
	2018_12_10	2	5	0	1	0	7
	2018_12_11	3	4	0	0	0	7
	2018_12_12	3	2	0	1	0	5
	2018_12_13	5	3	0	0	0	8
2	2018_12_14	0	0	7	0	0	7
	2018_12_15	0	0	11	0	0	11
Ń	2018_12_16	0	0	2	0	0	2
	2018_12_17	0	0	6	1	0	6
	2018_12_18	0	0	0	0	0	0
	2018_12_19	0	5	2	1	0	7
	2018_12_20	0	0	0	0	0	0

code

sport

readwatch total

2018_12_21	0	0	0	0	0	0
2018_12_22	0	4	0	0	0	4
2018_12_23	0	0	0	0	0	0
2018_12_24	0	3	0	0	0	3
2018_12_25	0	0	0	0	0	0
2018_12_26	0	4	0	0	0	4
2018_12_27	0	2	0	0	0	2
2018_12_28	0	2	0	0	0	2
2018_12_29	0	0	0	0	0	0
2018_12_30	0	0	0	0	0	0
2018_12_31	0	2	0	0	0	2
2019_01_01	0	0	0	0	0	0
2019_01_02	0	1	0	0	2	1
2019_01_03	0	0	0	0	0	0
2019_01_04	0	0	0	0	4	0
2019_01_05	0	0	0	0	0	0
2019_01_06	0	0	0	0	0	0
2019_01_07	0	0	0	0	0	0
2019_01_08	0	0	0	0	0	0
2019_01_09	0	0	0	0	0	0
2019_01_10	0	0	0	0	0	0
2019_01_11	0	0	0	0	0	0
2019_01_12	0	0	0	0	0	0
2019_01_13	0	0	0	0	0	0
2019_01_14	0	0,5	0	0	4	0,5
2019_01_15	0	0	5	0	0	5
2019_01_16	0	0	9	0	0,5	9
2019_01_17	0	0	10	0	0	10
2019_01_18	0	0	9	0	0	0
2019_01_19	0	0	0	0	0	0
2019_01_20	0	0	0	0	0	0
2019_01_21	0	0	0	0	0	0
2019_01_22	0	3	2	0	8	0

date	search	write	code	sport	readwatch	total
2019_01_23	0	0	4	0	2	0
2019_01_24	0	0	4	0	3	0
2019_01_25	0	0	1	0	1	0
2019_01_26	0	0	0	0	0	0
2019_01_27	0	0	0	1	0	0
2019_01_28	0	0	0	0	0	0
2019_01_29	0	0	0	1	0	0
2019_01_30	0	0	0	0	0	0
2019_01_31	2	2	1	0	0	5
2019_02_01	0	0	4	0	0	4
2019_02_02	0	2	0	0	0	0
2019_02_03	0	1	1	0	3	5
· · · · · · · · · · · · · · · · · · ·						

date

search

write

Appendix III: Images

To get back to the original page of the image and continue reading, click on the image again.

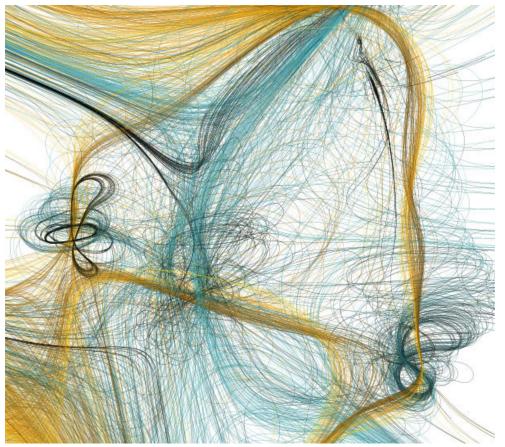


Figure 11: Reas, Casey (2001). *Path.* (Reas.com, n.d.)
Casey Reas creates generative prints and installations and is one of the creators of the *Processing* software as well as art professor and author of several books on the topic.

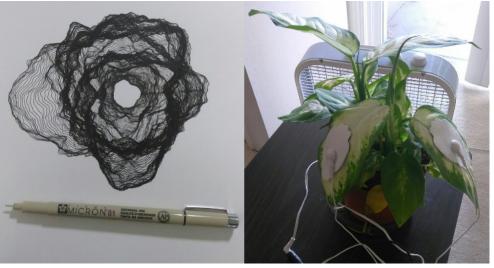


Figure 12: Barrat, Robbie (n.d.) *plant-art*. (Barrat, R., n.d.) Robbie Barrat creates drawings based on data retrieved from houseplants.



Figure 13: Nervous system (2014). *Kinematics Dress.* (Photography by Steve Marsel Studio) ("Kinematics Dress", 2014)



Figure 14: LMB architects (2016). *Generatively designed Ceiling of the Voxman School of Music.* (Photography by Tim Giffith). (Fixsen, 2017)



Figure 17: Onformative. (2013). *Facebook tree*. ("4010 Facebook Tree", 2013) This illustration generated from Facebook data was created for a Telekom Store.



Figure 18: Neue Design. (2010). *Generative Logo for Nordkyn*. (Neue Design, n.d.). This logo for the Norwegian peninsula Nordkyn changes depending on real-time weather data. Video available at https://vimeo.com/108765350 (Neue Design Studio, 2014).

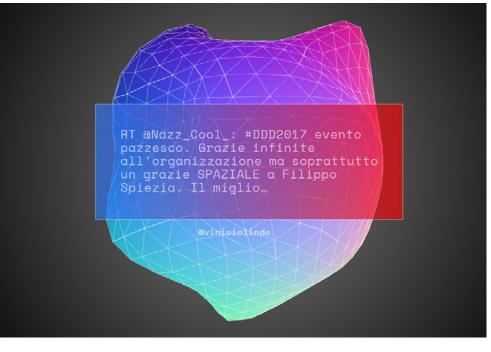


Figure 19: Ultravioletto. (2017). *Decode*. ("Digital Design Days", 2017)
This generative design turns social media interaction into visual graphs.

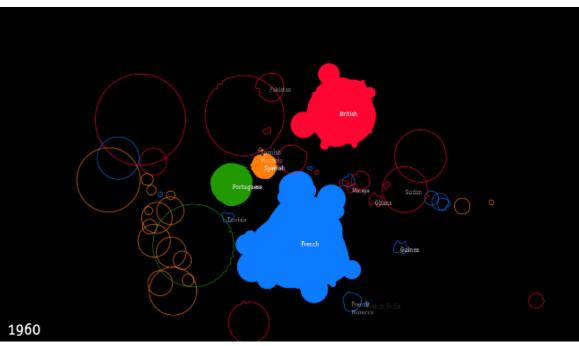


Figure 20: Cruz & Machado. (2011). Generative Storytelling. (Cruz & Machado, 2011, p. 80) This data visualization tells the story of declining empires.



Figure 21: Sagmeister & Walsh. (2007). Generative logo for Casa da Música. ("Casa da Musica", n.d.)

This generative visual identity takes in color information from pictures.

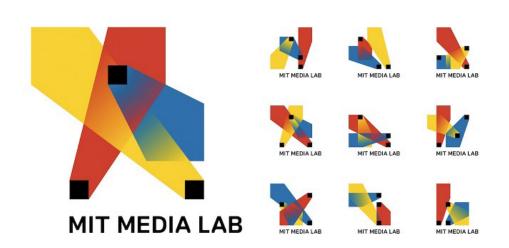


Figure 22: E Roon Kang & TheGreenEyl. (2011). Generative visual identity of MIT Media Lab. ("MIT media lab identity", 2011)

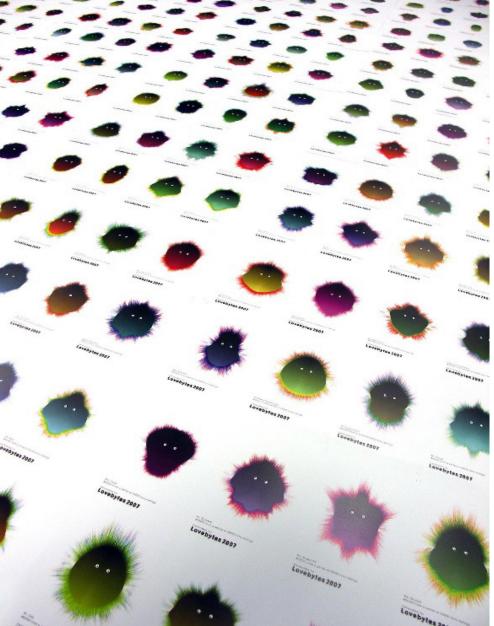


Figure 24: Universal Everything. (2007). Generative monsters created for the Lovebytes Festival of Digital Art 2007. ("Lovebytes Faces", n.d.)



Figure 23: Landor. (2010). Generative Branding for the City of Melbourne. (Landor, 2010)

WILDE



Figure 25: onformative. (2016). 3D-videos based on athletes' training-data for Nike. ("Nike Strike Series FA 16", 2016)

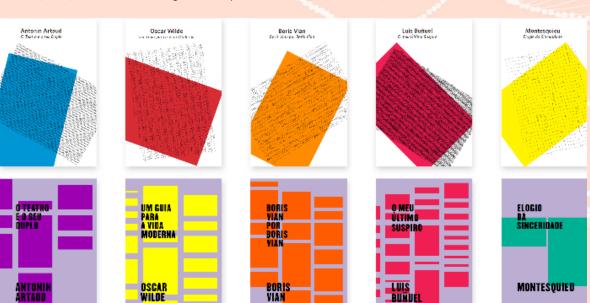
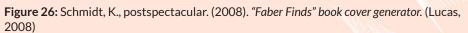


Figure 27: Duro, L., Machado, P. & Rebelo, A. (2012). Generative book covers based on text shape and chapter characteristics. (Duro et al., 2012, p.1)



This tool creates unique book covers based on the genre of the book.



Figure 29: Müller, Boris. (2003). *Generative poster for Poetry on the Road Festival 2003.* (Müller, 2003)



Figure 30: Müller, Boris. (2006). *Generative poster for Poetry on the Road Festival 2006.* (Müller, 2006)

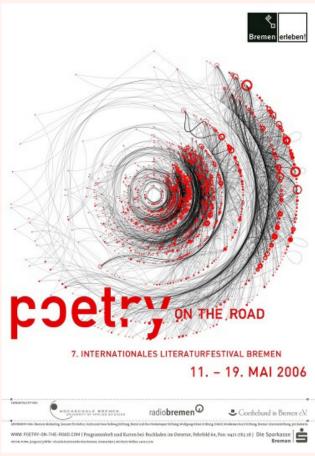


Figure 31: Müller, Boris. (2013). *Generative poster for Poetry on the Road Festival 2013.* (Müller, 2013)

<u>Thanks, Gracias,</u> <u>Eskerrik asko, Danke</u>

Especial agradecimiento a Esther Moñivas Mayor, cuyas aportaciones me han motivado en este trabajo y han orientado mi expectativa profesional.

Gracias a Itziar por mantener vivo al Okapi.

Thanks to Serena for her proofreading efforts.