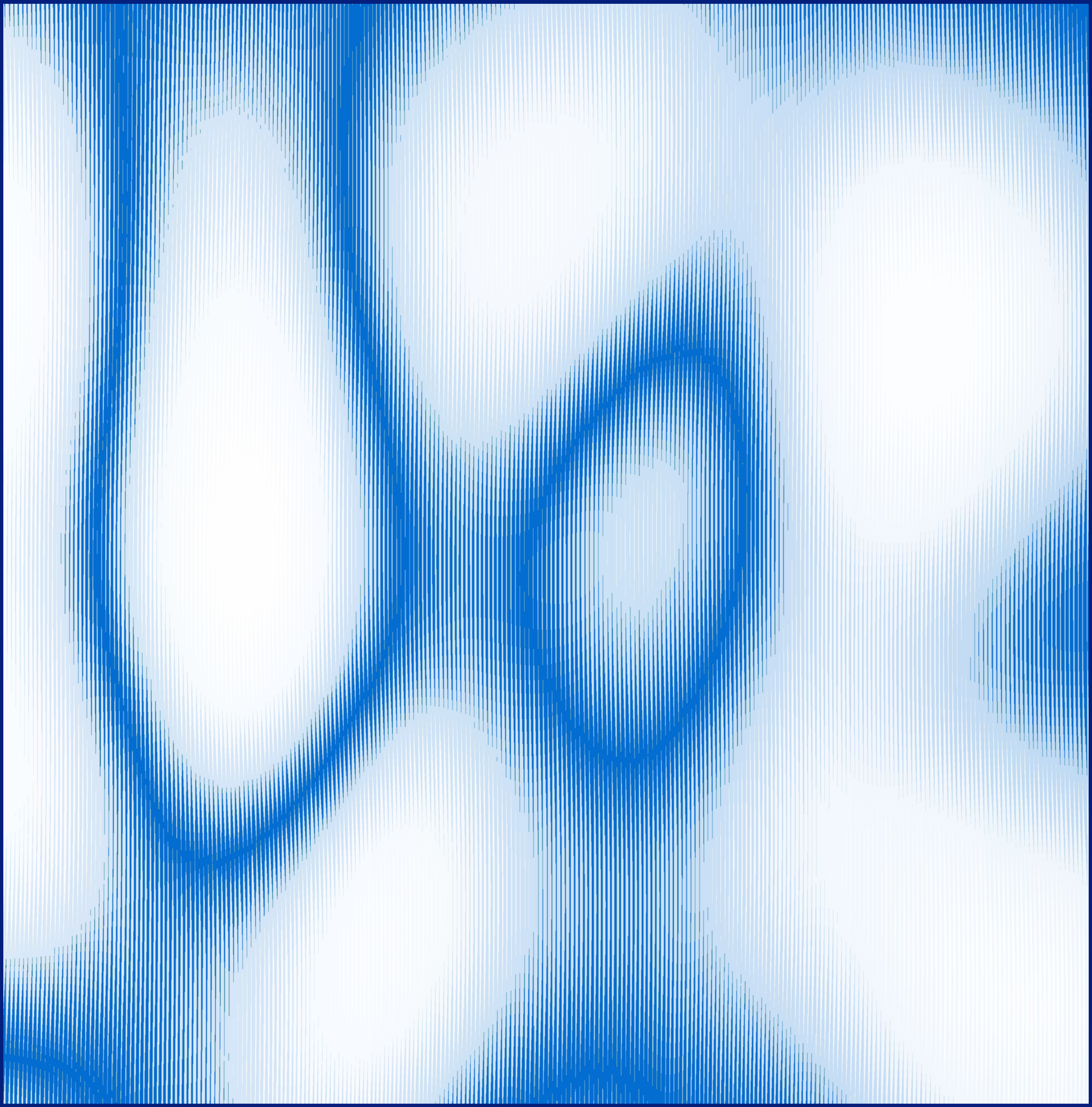

Codes for Creativity

A creative-processes-oriented inquiry into designing interactive products powered by generative systems

Caio Barrocal

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Barrocal, Caio
Codes for creativity: a creative-processes-oriented inquiry into designing interactive products powered by generative systems / Caio Barrocal; orientadora Clice de Toledo Sanjar Mazzilli. - São Paulo, 2021.
187p.

Dissertação (Mestrado) - Faculdade de Arquitetura e Urbanismo da Universidade de São Paulo. Área de concentração: Design.

1. Design. 2. Interface Multimídia. 3. Sistemas Autônomos. 4. Interação Homem-máquina. I. Mazzilli, Clice de Toledo Sanjar, orient. II. Título.

Elaborada eletronicamente através do formulário disponível em: <http://www.fau.usp.br/fichacatalografica/>

Codes for creativity

A creative-processes-oriented inquiry into designing interactive products powered by generative systems

códigos para criatividade
uma investigação orientada a processos criativos sobre o design de produtos interativos suportados por sistemas generativos

Caio Barrocal,
BSc Computer Science (University of São Paulo, 2018)

Master's thesis submitted to the Design Program of the School of Architecture and Urbanism (FAU) in partial fulfillment of the requirements for the degree of Master of Science in Design at the University of São Paulo.

Thesis Supervisor: Clice de Toledo Sanjar Mazzilli (Associate Professor at FAU-USP)

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FAUUSP

São Paulo, Brazil
Dez, 2021

Candidate: Caio Barrocal

Title: **Codes for creativity: A creative-processes-oriented inquiry into designing interactive products powered by generative systems**

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This thesis has been reviewed and approved by the following committee members:

Prof(a). Dr(a).: ______________________

Institution: ______________________

Evaluation: ______________________

Prof(a). Dr(a).: ______________________

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Date: ___ / ___ / _____

Abstract

Barrocal, C. (2021) **Codes for creativity: A creative-processes-oriented inquiry into designing interactive products powered by generative systems** (Master's Thesis). School of Architecture and Urbanism (FAU), University of São Paulo, São Paulo.

Relying on a multidisciplinary theoretical foundation with contributions from the disciplines of design and computing, this research seeks to understand the creative processes employed by contemporary professionals for designing interactive products powered by generative systems. Such motivation comes from the idea that generative systems pose significant changes for the design process when they are employed to synthesize intended products entirely or partially, thus suggesting that producing scientific literature on the subject provides design maturity for practitioners and academics interested in their application. Therefore, to grasp the aforementioned creative process and enable a qualitative multiple case strategy, we began by building a comprehensive theoretical foundation on the themes of creative processes in design; interaction design; and generative creation and computational thinking in design. These foundations provided us with relevant theoretical patterns, which were synthesized into a first model to be confronted with the case studies for verification. To carry out this process and achieve this research's goal, we relied on in-depth interviews with professionals and on the analysis of final and partial deliverables provided by them to picture the processes undertaken and propose an accurate model comprising the relevant aspects of the creative process studied.

Keywords: generative design, interaction design, generative creation in design, computational thinking in design.

Resumo

Barrocal, C. (2021) **Códigos para criatividade: Uma investigação orientada a processos criativos sobre o design de produtos interativos suportados por sistemas generativos** (Dissertação de Mestrado). Faculdade de Arquitetura e Urbanismo, Universidade de São Paulo, São Paulo.

Apoiando-se em uma fundamentação teórica multidisciplinar com contribuições das disciplinas do design e computação, esta pesquisa busca compreender os processos criativos empregados por profissionais contemporâneos no design de produtos interativos suportados por sistemas generativos. Tal motivação vem da ideia de que os sistemas generativos instigam mudanças significativas no processo de design quando são empregados para sintetizar total ou parcialmente os produtos pretendidos, sugerindo que a produção de literatura científica sobre o assunto possa enriquecer as referências para profissionais e acadêmicos interessados em sua aplicação. Portanto, para apreender o referido processo criativo e possibilitar uma estratégia qualitativa de estudos de casos múltiplos, começamos por construir uma base teórica abrangente sobre os temas de processos criativos em design; design de interação; e criação generativa e pensamento computacional em design. Tal fundamentação nos forneceu padrões teóricos relevantes, os quais foram sintetizados em um primeiro modelo a ser confrontado com os estudos de caso para verificação. Para realizar esse processo e atingir o objetivo desta pesquisa, contamos com entrevistas em profundidade com profissionais e com a análise dos materiais finais e parciais fornecidos por eles para retratar os processos empreendidos e propor um modelo preciso abrangendo os aspectos relevantes do processo criativo estudado.

Palavras-chave: design generativo, design de interação, criação generativa em design, pensamento computacional no design.

Acknowledgments

This work represents so many things to me. After graduating in computer science, I was hoping to continue studying and practicing the two themes I am deeply passionate about: design and computing. Fortunately, I encountered such places both professionally — working as a digital product designer — and academically. During this journey, I was lucky to be surrounded by amazing people who supported me and made this work possible through many contributions. I would like to thank them with all my heart:

To my parents, Alvaro and Tania, for raising me as a curious man, always believing in me and pushing me forward. I learned a lot with you, and I hope you could learn a lot with me as well.

To Beatriz, my sister, for always caring for me and for making time to contribute with amazing insights about this work.

To Clice Mazzilli, my supervisor, and Leandro Velloso for the valuable contributions.

To Daniela Hanns, my first academic supervisor, for introducing me to a field I realized is the one I wish to dedicate my career to.

To Alexandre Rangel, Bruno Aricó, Caio Velenosi, Camila Gonçalves, Dimitre Lima, and Gabriela Castro, for accepting to participate in this research and to share their works with me.

To Thássya Macedo, Duda Rodrigues and my former colleagues at FJORD São Paulo, for guiding and inspiring me during my first steps as an interaction designer.

To Adauto, Alice, Bel, Camilla, Cocito, Fernanda, Guilherme, Inaiá, Jean, Jorge, Luisa, Murilo, Nina, and Tati, my friends, for being so kind to me and making this journey definitely more manageable.

And to Danilo, for all the love, companionship, and for taking me as I am.

5

Final Considerations

References

List of Figures

Introduction

Relying on a multidisciplinary foundation with contributions from the disciplines of design and computing, this study seeks to answer the following question: **What are the main aspects of the creative processes employed by contemporary professionals for designing interactive products powered by generative systems?**

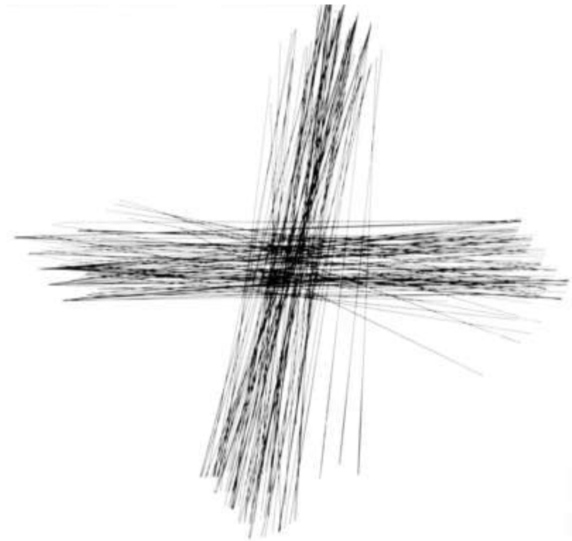
When facing this question, the reader might notice that our starting point is that there are differences to be understood between design processes in which generative creation is employed and conventional ones — those in which such approaches are not used. Therefore, we rely on a multiple case study strategy focused on contemporary practices to induce hypotheses and insights that might allow us to understand them. In addition, this work is also motivated by expanding the resources of academic production concerning generative creation as a participant and a characterizing aspect of creative processes in design, especially in interaction design.

Before delving deeper into the investigation, though, relevant concepts must be introduced along with a historical panorama of the context in which generative creation was enabled.

The use of the computer as means of creative production is a relatively recent phenomenon. The first relevant experiments were executed in the 1960s, mainly in Europe and the USA, when programmers and artists began exploring algorithms and machines to generate shapes and sounds. At this time, and in a pioneering spirit, people like Vera Molnar, Manfred Mohr, and Lillian Schwartz saw the computer as a promising creative medium, learned to program, and played a leading role in the computational art scene by designing visual pieces and innovative interactive experiences.

One of the first formal opportunities for establishing the computer as a creative setting amongst artists and designers happened when Max Bense (1910-1990) — an influential German philosopher and academic of the fields of aesthetics and semiotics — invited the mathematician Georg Nees (1926-2016) to expose his computer-generated graphics in an experimental concretist exhibition in 1964 (Figures 1 and 2). In the following year, Nees and Bense published the booklet "rot 19. Computer-Grafik", one of the primary

1. The Ulm School of Design was founded in 1953 by Inge Aicher-Scholl, Otl Aicher and Max Bill. The school gained international relevance by emphasizing the holistic, multidisciplinary context of design, beyond the Bauhaus approach.



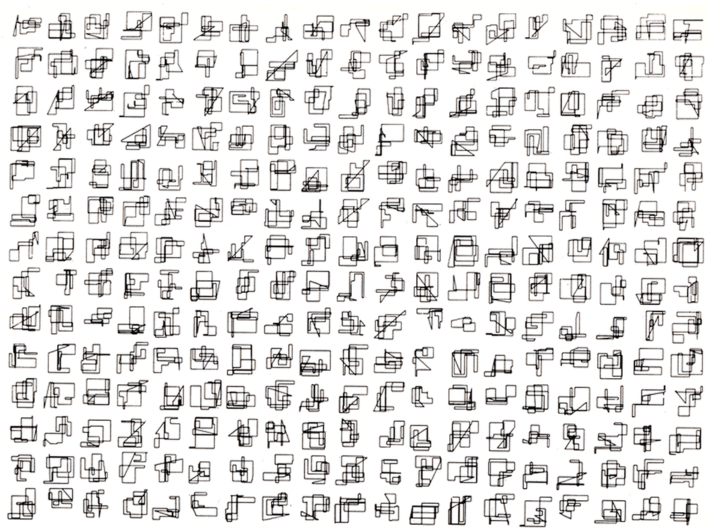


Figure 1 (top): Georg Nees. Andreaskreuz. 1968.
Figure 2 (middle): Georg Nees. 23-corner graphic. 1965.

— if not the first — publications that presented the computer as a means of creative production. A few computer-generated works have been exposed in the booklet, along with the algorithms behind their creation (Nake, 2018).

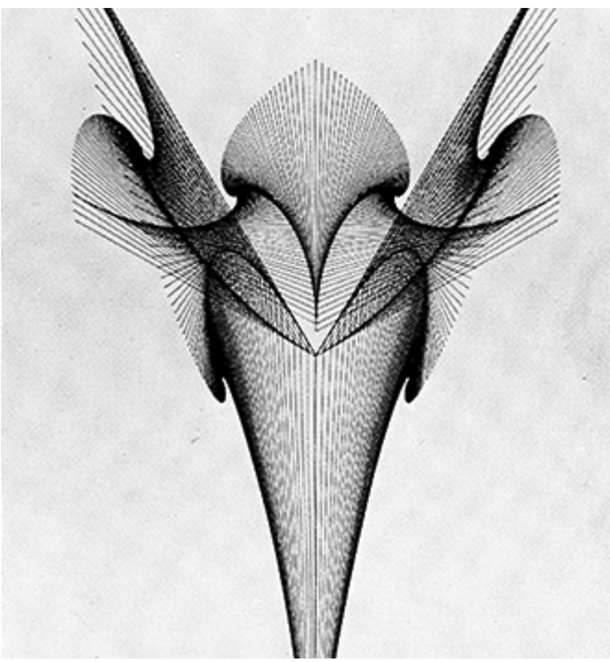
Both initiatives stem from Bense's enthusiasm for using computational thinking in design to formalize aesthetic processes and propose a new design methodology strongly influenced by scientific methods, something that marked his trajectory at the HfG-Ulm[1]. The appeal of seeing design as the creation of systems and patterns capable of generating products, rather than the direct creation of unique artifacts, was continued by Horst Rittel (1930 - 1990) when he replaced Bense at the HfG-Ulm in 1958 (Neves, 2015).

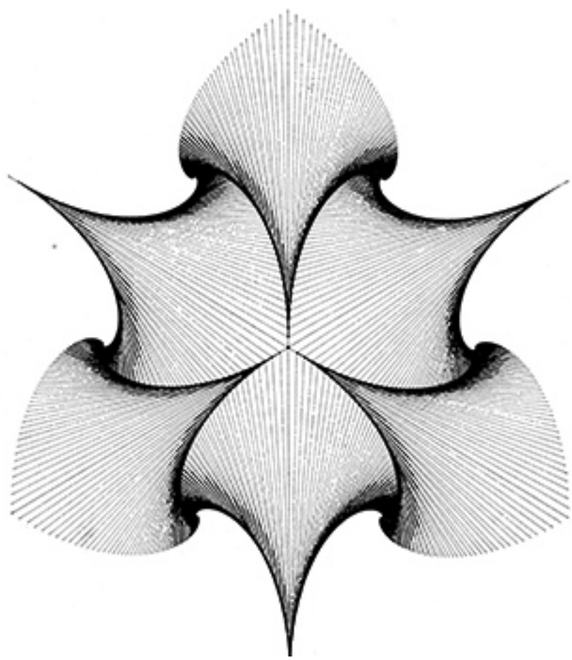
Another symbolic moment for the establishment of computing as a creative medium and for disseminating its aesthetic qualities amongst a wider audience was the Cybernetic Serendipity exhibition. The event was curated by Jasia Reichardt and took place at the London Institute of Contemporary Art in 1968. On occasion, computer-generated images were exhibited along with music, poetry, dance, and animation produced totally or partially in the "new medium". In addition, the initiative resulted in proposals for new interfaces and visual pieces, such as the algorithmically-created pair made by Kerry Strand on a Calcomp 770 computer connected to a plotter from the same manufacturer (Figures 3 and 4) (Reichardt, 1968).

Simultaneously, in Brazil, intellectuals like artist and designer Waldemar Cordeiro (1925-1973) and physicist Giorgio Moscati experimented with generative algorithms and programming languages as they partnered in using the computers of the University of São Paulo to produce visual art. In 1969, this collaboration resulted in a series of pictures, "Derivatives of an image" (Figures 5, 6 and 7), in which different results were obtained by the same algorithm, only by varying the degree of a differential equation created by them.

Alongside the efforts made by scientists, engineers, and companies in pushing computer graphics technologies and designing aesthetically instigating interfaces, the use of computers as creative material has evolved.

2. Reas and Fry were graduate students at the MIT Media Lab and members of the Aesthetics and Computing research group created and coordinated by John Maeda.
3. Java is an object-oriented programming language. It was created in the early 1990s by James Gosling and his colleagues at Sun Microsystems.





This outgrowth allowed them to occupy a symbolic space in popular culture, everyday life, and the working processes of several professionals.

However, accompanied by successive simplifications of use and the creation of proprietary software tools, this adhesion also contributed to the positioning of the computer as a "black box" — a concept proposed by Flusser (2002) to illustrate the power relations and limitations inherent to using pre-programmed tools. Omine (2014, 38) contributed to this discussion by suggesting that if software allows regular people to use computers, on the other hand, it limits the computer to a pre-programmed device. Essentially, when using any type of software, users work within the limitations imposed by it. Professional designers' work processes, for example, have been commonly mediated by proprietary tools such as Adobe Photoshop and Adobe Illustrator for over three decades now.

Nevertheless, creative experimentation with the computer beyond the "black box" has not stopped. The algorithmic works endorsed by Max Bense and produced by the pioneers of computational art motivated several other professionals to continue studying and developing computing as a fruitful creative medium, extrapolating the uses delimited by available proprietary software. The emergence of Processing — a programming language created in 2001 by Casey Reas and Ben Fry[2] —, for example, was a milestone for these intentions.

As an extension of the programming language Java[3], to which native functions were added in order to facilitate the creation of aesthetic elements, Processing emerged with the goal of becoming a sketching-software, an educational tool focused on programming for a visual context. However, as time went by and the number of users increased, the language received improvements and evolved to become one of the main references of generative

Figure 3 (previous page / bottom left): Kerry Strand. Hummingbird.1968.
Figure 4 (previous page / bottom right): Kerry Strand. Crest. 1968.
Figures 5, 6 and 7 (top): Cordeiro and Moscati. Derivadas de uma Imagem (Derivatives of an Image). 1969.

tools, even serving as a professional alternative to the aforementioned proprietary software.

Formally, generative creation consists of the design of systems or processes, such as a set of natural language instructions, a computer program, or a machine, which are put into execution with a certain degree of autonomy contributing to or resulting in a complete work (Groß et al., 2018; Grünberger, 2019; Galanter, 2003). Such autonomy can be guaranteed in several ways: through the writing of instructions that respond to randomness; by designing an interface that has an expected general behavior but delivers a different experience depending on unpredictable inputs captured by the computer; or even through complex mathematical models such as the capital market and the weather.

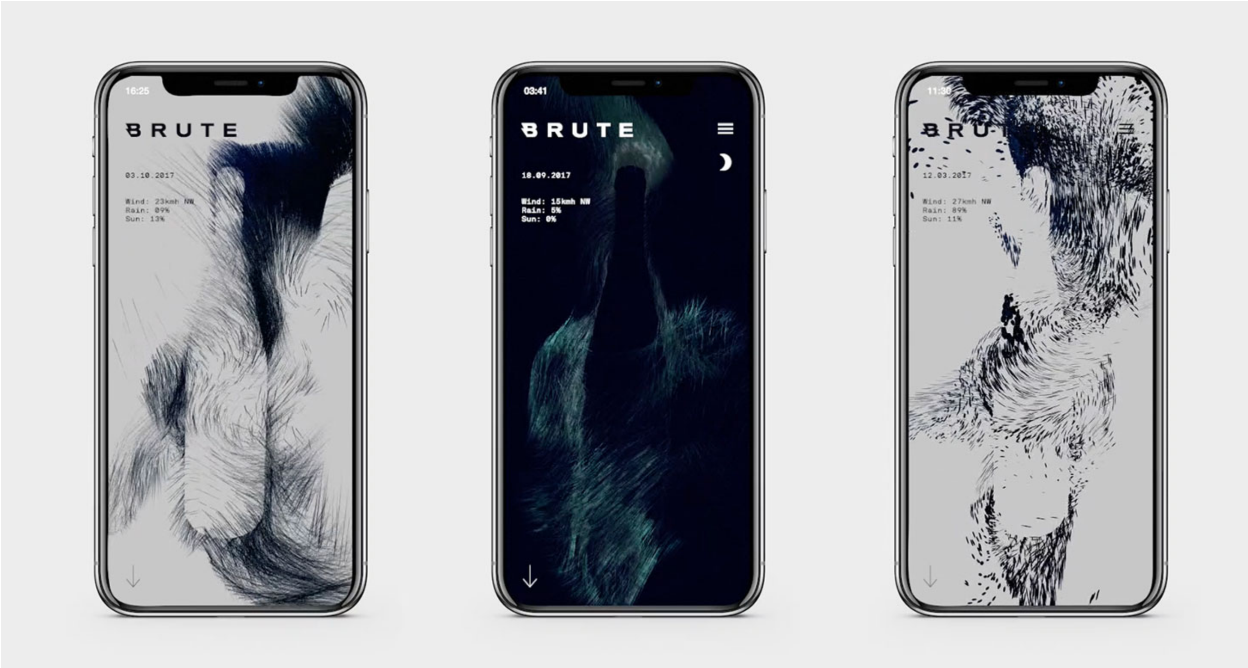
The critical point is that computational intelligence will be used as an active participant in the creative process and not only to support the decisions made (Mountstephens & Teo, 2020) In design, the now added computational complexity promotes a fundamental change in the creative process as designers are no longer executors of tasks, but conductors. Role that Groß et al. (2018, p.5) consider to be that of an “orchestrator of decision-making processes”. Essentially, this type of creation gives up total control, which is partially conducted by the computational intelligence of the chosen system.

Whether due to the unpredictability of results, possibilities for parameterization and optimization, or the ability to support artifacts that respond in real time, several designers, programmers and artists such as Dimitre Lima, Patrik Hübner, Casey Reas, Memo Akten, Ben Fry, Tim Rodenbröker, Alexandre Rangel, Jarbas Jácome, Guto Requena, Stuart Batchelor, Manfred Mohr, and Vera Molnar have been relying on generative creation to deliver artifacts with instigating aesthetic and functional appealing. In design, more specifically, generative systems can enable the production of flexible visual identities, objects and packaging, fonts and infographics, and interactive artifacts — the outline of this research — as illustrated by the following examples.

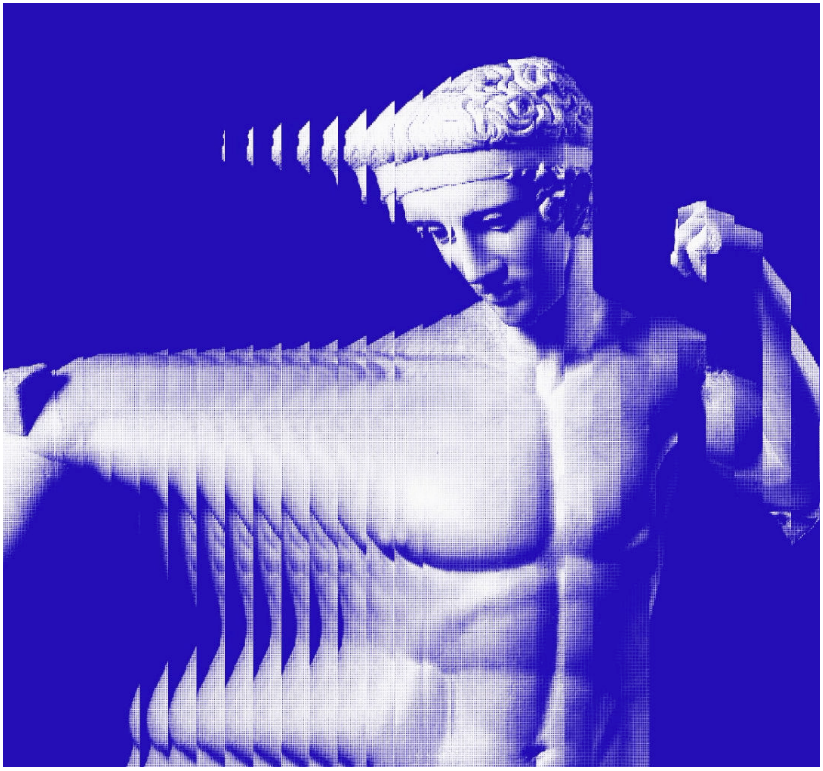
German designer Patrik Hübner created in 2018 an example of how generative systems can be employed in the design of interactive products. Hübner was challenged to design a website that could emphasize the forces of nature involved in the production of Brute’s wines and explore the harsh climate of the German city of Hamburg, where grapes are grown, as a symbolic and aesthetic differential. The designer then developed a website powered by a generative system fed with data related to wind speed, temperature, sunlight, and rain, responding in real-time to weather stimuli (Figure 8). With this input, the system manifests unpredictable behaviors and visuals that are still consistent with the values proposed for the brand. In addition, the user can interact with the page through movements of the mouse. Visual objects

Figure 8 (**next page/ top**): Screenshots of the interface designed by Patrik Hübner for Brute. 2018.

Figure 9 (**next page/ bottom**): Materializations of the brand’s visual identity designed by Patrik Hübner for Brute. 2018.


16:25
BRUTE
03.10.2017
Wind: 23kmh NW
Rain: 09%
Sun: 13%
03:41
BRUTE
18.09.2017
Wind: 15kmh NW
Rain: 5%
Sun: 0%
Wind: 27kmh NW
Rain: 89%
Sun: 11%


2017
BRUTE
Crafted by the elements
Wind 13.5 km/h
Rain 1713 mm
Sun 2190 hrs
2017
BRUTE
Crafted by the elements
BRUTE
BRUTE
Wine crafted by the elements
Some grapes
are nurtured.
Ours are tortured.



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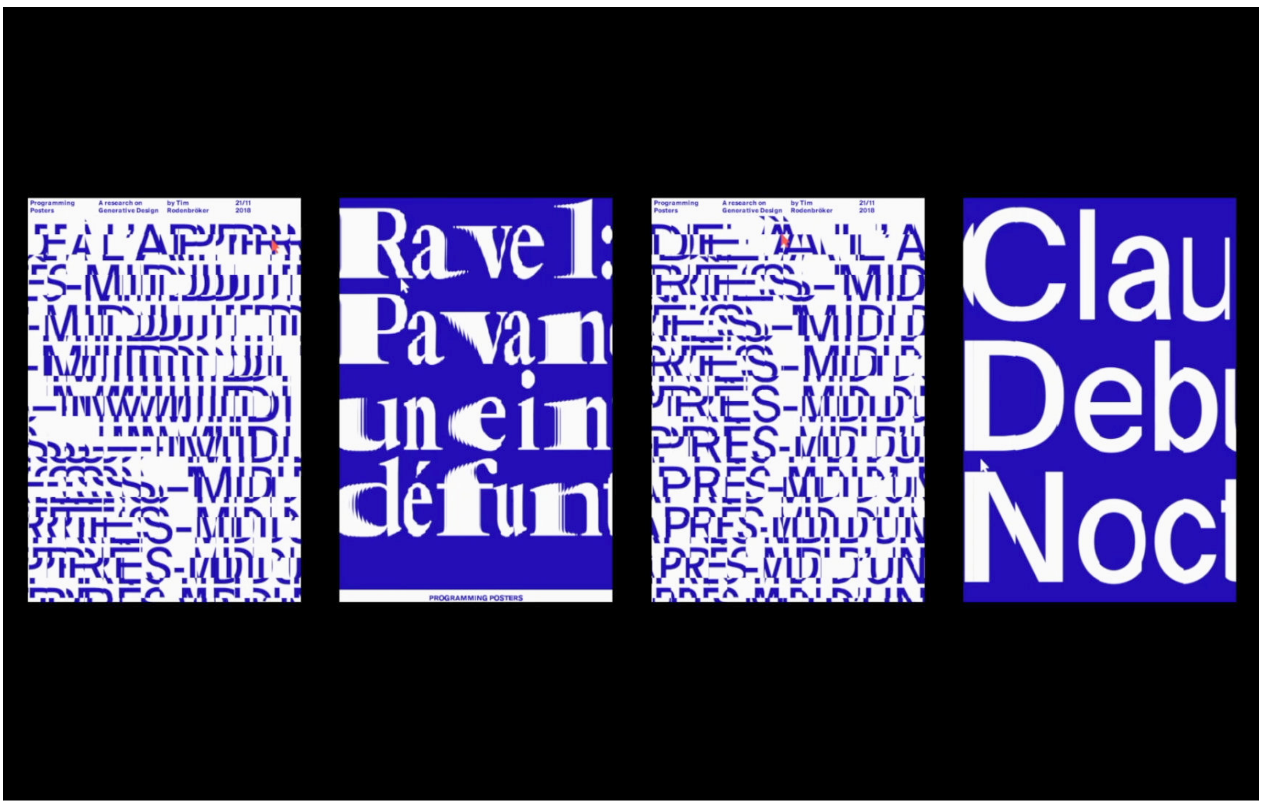
Programming Posters
by Tim Rodenbröker

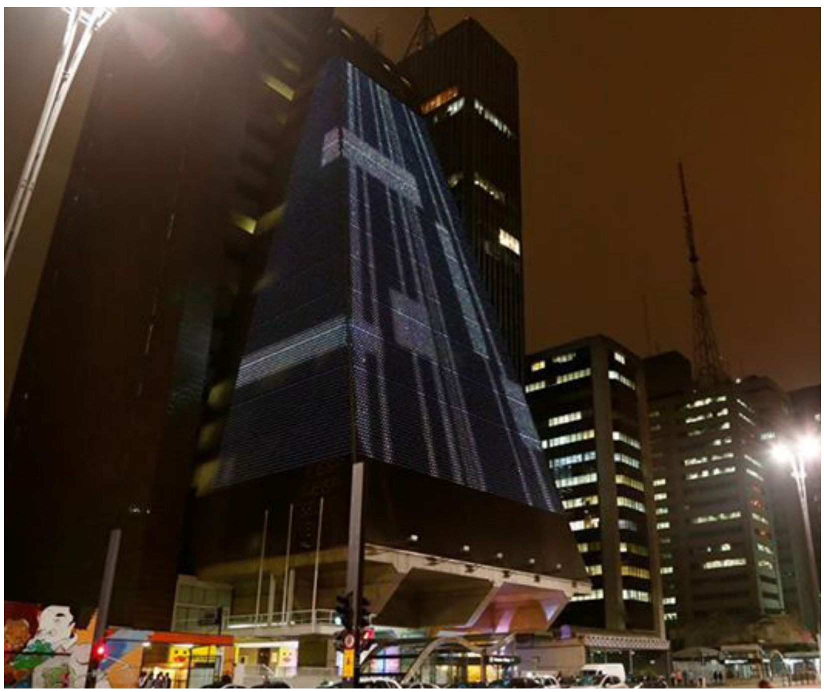


Programming Posters
A research on Generative Design
by Tim Rodenbröker
21/11 2018
PROGRAMMING POSTERS

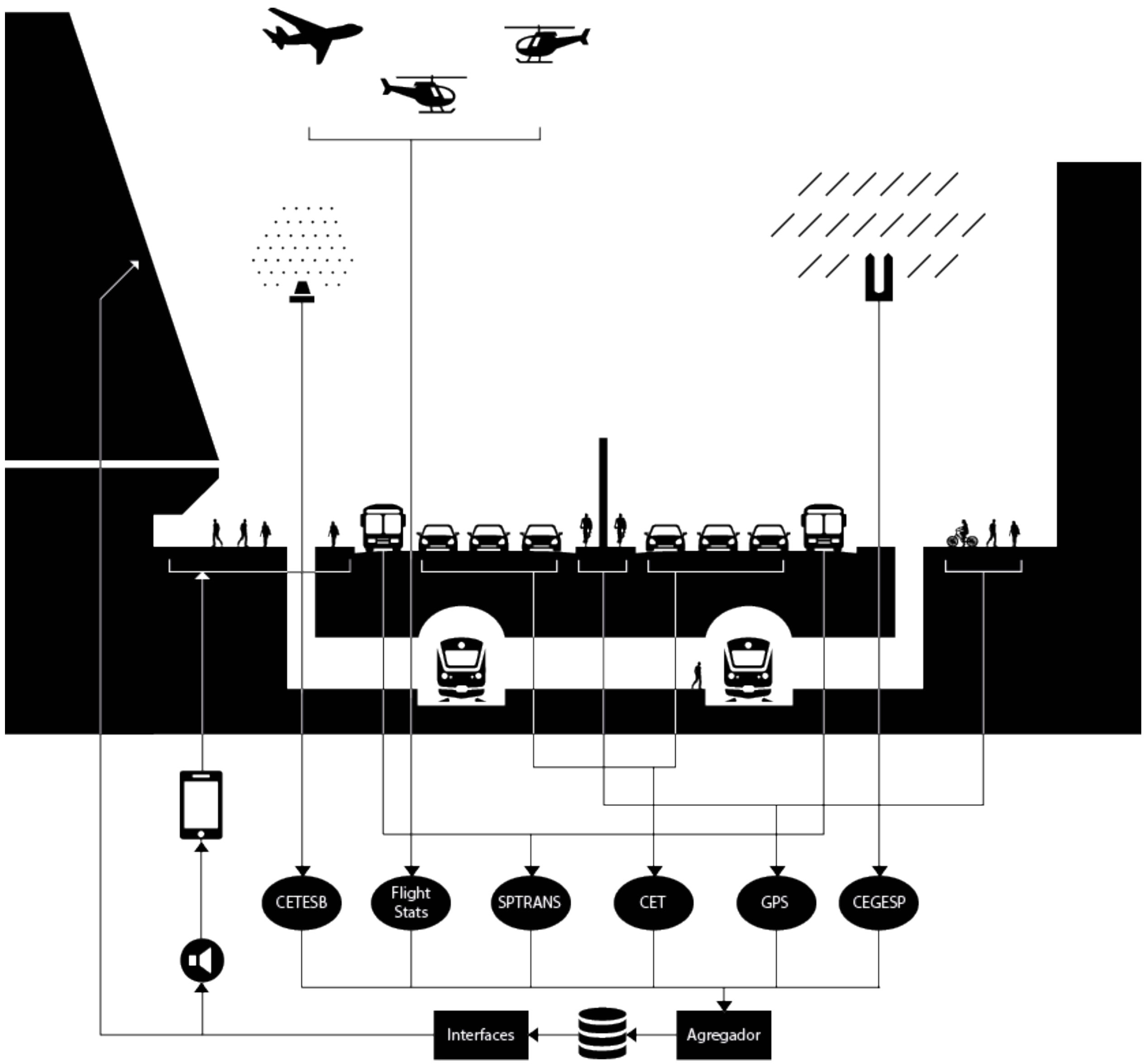
produced by the system developed by Patrik Hübner were also applied in other materializations of the brand's visual identity, such as packaging and advertising posters (Figure 9). Notably, the Initiative was nominated for the 2018 Cannes design awards — in the brand identity category — and for the 2019 German design award (Hübner, 2018).

The Programming Posters series created by German designer Tim Rodenbröker in 2018, is another example of generative creation in interaction design. In this project, Rodenbröker sought to explore generative design to experiment with visual languages and reimagine the poster for a digital context (Figures 10 and 11). Therefore, the work reckoned on a system that computationally generated graphical objects that composed the posters. To do so, the system was connected to sensors and powered by real-time data from the users' interactions. At the same time, this data was used to modulate the behavior of the compositions to synthesize interactive experiences (Figure 12).

Our last example is the project created by Daniela Hanns, Leandro Velloso, and Mauricio Galdieri for the exhibition Arquinterface, held between November 13th and December 13th, 2015, at the Avenida Paulista in São Paulo, Brazil (Figure 13). For the so-called Fixos_fluxos project, a generative system was developed, powered by environmental and traffic data from the avenue — supplied by local governmental companies — (Figure 14), and employed to synthesize interfaces capable of expressing the perception and experience of the street. Furthermore, the project relied on the lights on the facade of the



Figures 10 and 11(previous page / top): Tim Rodenbröker. Programming Posters. 2018.
Figure 12 (previous page / bottom): Tim Rodenbröker. Programming Posters. 2018.
Figure 13 (current page / bottom): Photography of the facade of the FIESP building, in São Paulo, during the presentation of the project. 2015.


CETESB
Flight Stats
SPTRANS
CET
GPS
CEGESP
Interfaces
Agregador

FIESP building and on an Android app to transform the collected data into visual and sound elements.

Motivated by a vibrant production we exemplified through the cases above, this research intends to propose a model for the creative processes in question to holistically understand how generative systems integrate and influence them. As discussed at the beginning of this work, our starting point is that there are differences to be understood between processes in which generative creation is employed and conventional ones — in which such approaches are not used. As an attempt to delimit and illustrate the scope of this research, the following goal has been pursued: **To propose a model containing relevant aspects of the creative processes undertaken by contemporary professionals when designing interactive products powered by generative systems.**

Concerning its relevance, generative systems can be used in the design of interactive products because they can provide aesthetic and functional differentiation, something potentialized by the greater availability and ease of access to sensors and digital data — which can feed this type of system. In addition, the emergence of technologies and programming languages focused on non-specialists fostered experimentation with computing as a creative material, which placed generative creation as an accessible and productive field even for designers who are unfamiliar with computer science. Through the current research, we also intend to contribute to the field by making such systems more approachable regarding how and when they are employed, thus increasing the understanding of generative creation as a participant in the creative processes involved in designing the artifacts in question.

Lastly, as a critical counterpoint, authors such as Couldry and Mejias (2019), Zuboff (2018), and O'Neil (2016) discuss the harmful impacts of pervasive technologies and business models based on autonomous systems and data capture in our lives and social organizations. Recent documentaries such as The Social Dilemma (2020), directed by Jeff Orlowski, and The Great Hack (2019), directed by Amer and Noujaim, also address the subject and bring it into a more popular language. Despite not being the focus of this research, discussing these issues in the scope of design and delving deeper into the functioning and logic of this type of artifact might promote a critical perspective for future designers of digital products.

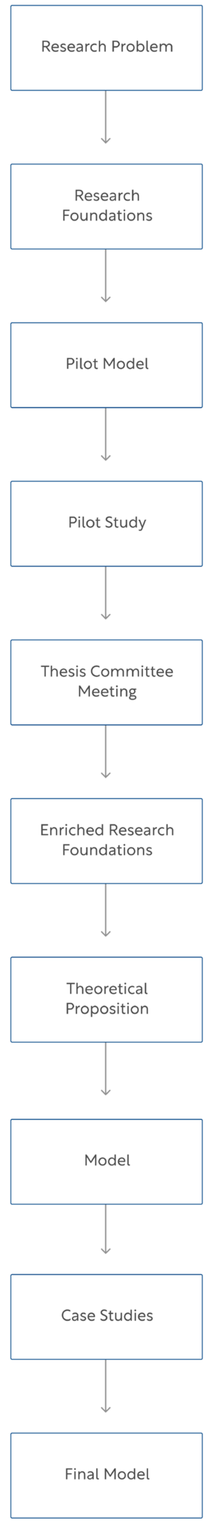
Introduction to method

The nature of this research is qualitative and based on a multiple case study strategy. Such an approach was selected because of the exploratory nature of our question, its contemporaneous scope, and the impossibility of controlling the phenomenon being investigated. Stake (2000) refers to case study approaches as a good choice for generating understanding, experience,

Figure 14 (previous page): Representation of the Avenida Paulista and the data sources used in the project. 2015 and conviction regarding a specific subject. Yin (2014), in turn, highlights the practical nature of the strategy as he acknowledges its potential to investigate contemporary phenomena in their context. Another critical motivator for this choice was the complex relationships involved in understanding creative processes — it might raise a myriad of aspects related to the process and designers' backgrounds and beliefs. An assortment of variables should be taken into account at the same time that delimiting them might be complicated and undesirably reductive. That said, a holistic approach was favored (Yin, 2014). Similarly, Gray (2012) states that case studies are precious and valuable when the purpose is to explore questions in which relationships might be ambiguous and uncertain. However, despite highlighting the exploratory potential of case studies, the author acknowledges that the method relies on a deductive approach which reflects on the need of previously elaborating a theoretical foundation to guide the collection and analysis of data.

Therefore, our research began with the construction of a theoretical foundation capable of sustaining our case studies. As Yin (2014) referred to, the intention was to select and organize the "study propositions" to guide them. Such a foundation is addressed in chapter 1. Nonetheless, the studies mentioned above have been executed with projects of interactive products created by professionals or studios, and in which generative creation has been employed as a central element. Still, because we understood that information concerning the creator and the creative process was necessary to answer our research question, the pair professional-process, or team-process, was considered our unity of analysis. Additional criteria for selecting cases are documented in chapter 2 along with a complete discussion of the methodology we followed.

Finally, to ensure reliability and make a more accessible contribution to the field, an online database[4] was set up with the cases studied — professionals, their creative processes, and the interactive products they developed using generative systems.



Structure

This thesis is composed of four chapters: ***Research Foundations, Method, Case Studies***, and ***Results***. The first of them is divided into three subchapters representing this work's conceptual layers: **creative processes in design**, interaction design, and **generative creation and computational thinking in design.**

In subchapter 1.1 — **creative processes in design**, we build the repertoire to describe and understand the creative processes investigated adequately. Relying on authors such as Sawyer, Cross, Lawson, and Dorst, the research is appropriately framed as an investigation of creative processes in design. In addition, definitions and models regarding the creative activity and

4. https://caiobarrocal.format.com/codes-for-creativity

its specificities when in a design process are discussed.

In the second subchapter — **interaction design**, we make our research corpus more approachable. In other words, to enable interaction design processes to be interpreted, we rely on the field's literature to answer central questions, such as: "What is interaction design?", "What are the main approaches ?", "What is a conventional interaction design project like?" and "Which models have been guiding the creation of interaction designers, especially in the professional practice?

Finally, the subchapter on **generative creation and computational thinking in design** draws a historical and conceptual parallel between design, algorithmic creation, and generative creation. Therefore, authors, references, and definitions are presented to allow the delimitation of this study's object along with important theoretical propositions about the participation of generative creation in design processes. In this subchapter, generative creation is defined, the motivations for its use are raised, and its differences are introduced compared to other design approaches. We also discuss the possible idiosyncrasies of creativity within an intersection between computational thinking and design thinking.

In the second chapter — **method**, this research's methodology is fully presented along with partial results and improvements suggested by the pilot study and the thesis committee. Then, after being improved, the foundations were transformed into a model to be successively evaluated and verified through the **case studies** discussed in chapter three.

Finally, in the fourth chapter, **results** are discussed, and our research question is answered. To this end, this chapter summarizes the evolution through which the model has gone throughout the research and presents its final version, accompanied by the last discussions and inferences.

Figure 15 (previous page) : Illustration of the method followed.

Chapter 1

Research Foundations

Research foundations

1.1 Creative processes in design

> *Design is an activity associated with creativity and creative fantasy, the spirits of invention and technical innovation. The design process is often seen as a sort of act of creation. It is certainly a creative process. However, design does not take place in a vacuum, with a completely free choice of colors, shapes, and materials. Each design object is the result of a development process influenced by various — not only artistic — conditions and decisions* (*Burdek, 2005, p. 225*).

Studying creativity and the phenomena that support it gained popularity and relevant funding during the XX century, as leaders began recognizing it as an essential element for economic success and the solution of complex social problems. More specifically, the first modern studies about creativity were executed during the 1950s and 1960s. In the beginning, the focus was on understanding creativity by researching so-called exceptional creative personalities. Influenced by a predominant behaviorist[1] tradition, many researchers studied the lives and practices of artists, scientists, and designers socially recognized as exceptional creators, in order to identify general aspects and traits that could somehow explain the conditions and paths through which a person should go in order to be creative (Sawyer, 2012, p. 63).

Many traits were indeed identified as related to a creative personality but none that could determine it. It is true that certain types of personalities are more inclined towards creativity, however this inclination seems to be the result of a very complex mixture of different traits. The rise of the importance of cognitive psychology changed the focus of creativity research from studying personality traits to understanding mental processes shared by all individuals in their act of creation. These "representational structures of the mind, their interconnections, and the mental processes that transform them", as referred to by Sawyer (2012, p. 87), became the center of research in the field and also the foundations of a definition for the creative process.

As stated by Lubart (2018, p. 3), "the creative process can be defined as a sequence of thoughts and actions that comprise the production of work that is original and valuable". However, he also acknowledges that this

1. "Behaviourism is a highly influential academic school of psychology that dominated psychological theory between the two world wars. Classical behaviourism was concerned exclusively with measurable and observable data and excluded ideas, emotions, and the consideration of inner mental experience and activity in general." (Britannica, 2019).

definition needs to be accompanied by further explanation. Despite using the word 'sequence', Lubart explains that it refers to the existence of a chain of events, "which unrolls over time, with a beginning and, potentially, an end". Such sequences may be non-linear, and characterized by diverse steps, phases and activities. 'Thoughts and actions', according to the author, refer to "both internal and external operations that contribute to the emerging production", which is essentially an outcome that can be either tangible or intangible, expressed in some permanent or more ephemeral form (visually, verbally, mathematically and so on).

The chain of thoughts and actions would only be considered a creative process if its outcome was something original and valuable though. Such a novelty not only "must be present, at least, for the person, or people, involved in the process" (Lubart, 2018, p. 4), but also correspond to goals and needs within the context. The author also uses these last acknowledgments to distinguish the terms 'creative process' — defined above — from 'process of creation' — that can bring something into being but through a repetitive act that creates more of an existing item.

One of the first models for the creative process was proposed by psychologist Graham Wallas in 1926, as he aimed to explain creativity through four sequential steps: preparation, incubation, insight, and verification (Figure 16). In preparation, the creator looks for the necessary knowledge so that the problem can be tackled. Incubation represents when the idea recedes to the subconscious mind, where it continues to be elaborated and influenced by other experiences that might happen. The moment of insight is when creators "have" their ideas, and lastly, in the moment of verification, these ideas are judged and refined (Sawyer, 2012, p. 89).

As attention to intelligence and problem solving in the mid twentieth century grew, researchers of the field seeked to go beyond the "popular four-stage description of the creative process" (Lubart, 2018, p. 7). These initiatives resulted in valuable contributions about the cognitive operations and problem-solving abilities behind creative activity, divergent and convergent thinking, and the role of evaluation during them.

Moreover, Graham's model illustrates an individualist approach to creativity — a tradition in creativity research that looks for answers by studying a single person while this person is engaged in creative processes. Sawyer (2012, p. 7) explains that this approach is associated with "first-wave personality psychology — which studies the traits of creative people — and

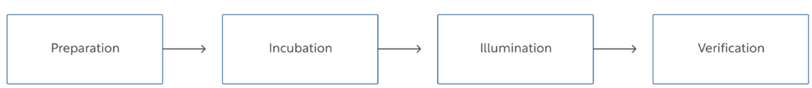


Figure 16 : Visual representation of the Wallas model.

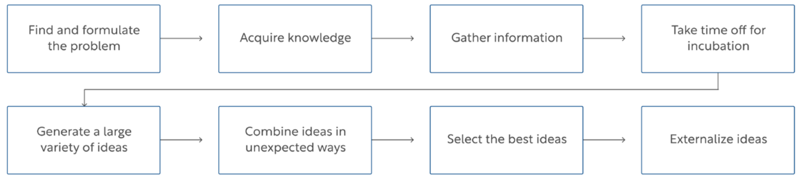
second-wave experimental cognitive-psychology — the branch of psychology that studies how people think, perceive, learn and remember". When it comes to defining creativity, the author still explains that researchers of the field can be grouped into two major categories: the already discussed individualist approach, and a sociocultural one — which studies creative people working together in social and cultural systems.

Despite being complementary, Sawyer (2012, p. 8) points out that these two approaches define creativity differently due to the also different analytic focus. The individualist definition would be that "creativity is a new mental combination that is expressed in the world", while the sociocultural one would be that "creativity is the generation of a product that is judged to be novel and also to be appropriate, useful, or valuable by a suitably knowledgeable social group".

By examining many past contributions of theories and models to creativity, Sawyer (2012, p. 88-89) created the following "integrated framework" that describes the eight stages of the creative process. Like Lubart (2018, p. 9) — that suggests that "the creative process is an orchestrated symphony of more specific processes that play together, or in sequence as part of the whole" —, Sawyer (2012, p. 88-89) agrees that despite being represented as a linear process with specific steps, there is a consensus in the field that creativity is not resulted by a single, unitary mental process, but from many different ones that could be associated with the stages below.

1. **Find and formulate the problem**. The first step is to identify a good problem and formulate the problem so that it will be more likely to lead to a creative solution.
2. **Acquire knowledge relevant to the problem.** Creativity is always based on mastery, practice, and expertise.
3. **Gather a broad range of potentially related information.** Creativity often results from mindful awareness of unexpected and apparently unrelated information in the environment.
4. **Take time off for incubation.** Once relevant knowledge and apparently unrelated information have been acquired, the unconscious mind will process and associate that information in unpredictable and surprising ways.
5. **Generate a large variety of ideas.** Unconscious incubation supports the generation of potential solutions to the problem, but conscious attention can also result in possible solutions.
6. **Combine ideas in unexpected ways.** Many creative ideas result from a combination of existing mental concepts or ideas.
7. **Select the best ideas, applying relevant criteria.** The creative process typically results in a large number of potential solutions. Most of them will turn out not to be effective solutions; successful creators must be good at

2. IDEO is a design company known for its human-centered, interdisciplinary approach. It was founded in 1991, in Palo Alto, Californi



selecting which ideas to pursue further.

8. Externalize ideas using materials and representations. Creativity is not only about having an idea; creative ideas emerge, develop, and transform while being expressed in the world.

Once it improves the understanding of the results and the nature of the creative activity, Sawyer's framework (2012, p. 88) is undoubtedly beneficial. The author, however, recognizes that it focuses exclusively on "what's going on in the creator's mind" — an individualist approach —, which is not always sufficient to explain real-world creativity and its evident collaborative and socio-cultural nature. For example, when working in groups, individuals naturally have their creative processes influenced by additional aspects inherent to collaboration. Elements that may empower or diminish creativity, depending on how these groups are created and managed. Nevertheless, groups outperform individuals in a series of relevant tasks, such as spatial problems (problems that involve three-dimensional spatial information and manipulation) and problem finding (when the nature of the problem is not well understood and needs to be formulated).

Since there are different approaches, settings, and goals to creativity, many models have been proposed throughout the past decades. Some of them also intended to capture the more collaborative elements of it. A good example is a model created by IDEO[2], with five different stages: understand the market, observe real people, visualize new concepts, evaluate and refine prototypes, and implement the new concept. Besides being naturally collaborative, the model also incentives practical experiments, and rapid decision making due to the nature of the consulting services provided by the firm.

Since creativity is "at the heart of design, at all stages throughout the design process" (Baxter, 1995, p.61), studies and models about it might contribute to a much greater understanding of the processes undertaken by those tackling design problems. Something that might promote a more mature overall design practice and contribute to the discipline as a whole. As suggested by Lubart (2018, p. 13), for example, "it may be possible to enhance creativity by training people to engage in certain process steps",

Figure 17 (top): Visual representation of Sawyer's model.

which suggests that consciously reflecting and exercising creative activity might indeed empower designers and other professionals approaching design problems. But is problem-solving in design different from any other problem-solving at all?

Designers are individuals, thus they will still be executing mental processes described by Sawyer's model. However, we can understand design challenges as problems that "are both goal-oriented and constrained and which depend upon a designer's perception of the context of the problem" (Kelly & Gero, 2021, p. 3). A statement that allows us to distinguish these specific problems from other ones, say, those that may not be goal-oriented and constrained — such as some artistic activities involving self-expression, and those in which all variables are known beforehand, such as some math puzzles "in which the designer's perception of the context is irrelevant to the solution". Lawson and Dorst (2009, p.28), for example, refer to design as "a mixture of creativity and analysis" because despite having to creatively develop propositions, a designer's creativity "is not unrestricted". The project must achieve a certain set of goals, create value for both prospective users and the client, and so on.

Cross (2006, p.99) argues that design is also different from conventional problem-solving approaches due to the specific ways in which problems are framed and solutions are generated throughout a project. Such idiosyncratic "knowledge that has been developed relating to how people reason when engaging with design problems" as referred to by Kelly and Gero (2021, p. 2) can be considered design thinking.

Being the core of design thinking, when framing a problem, a designer cognitively, yet unconsciously, builds a complex aggregation of interrelated knowledge (the frame) that becomes the lens through which the design problem is understood and within which design actions are envisioned (Kelly & Gero, 2021, p. 3). In other words, when faced with a design problem, designers appear to constantly build and rebuild the frame as they are looking for the best ways to organize relevant aspects of both the problem space and the solution space. According to Cross (2006, p. 102), when framing, "designers select features of the problem space to which they choose to attend and identify areas of the solution space in which they chose to explore". Because this frame is constantly changing, and since "the problem cannot be fully understood in isolation from consideration of the solution", designers tend to coevolve these two spaces by using solution conjectures as the means to increase their understanding of the problem until a satisfactory result is produced.

Framing as a characterizer of design thinking explains:

- Why wicked problems are good candidates for this type of thinking (variables are unknown and the knowledge needed to address the problem is incomplete);

- Why designers benefit from appropriately researching users, the context, and similar design solutions — strategies that will contribute to the elaboration of the frame towards a proper design solution;
- And why design solutions tend to be very specific to the design problem tackled (Kelly & Gero, 2021, p. 3).

To capture the idiosyncrasies mentioned above and other core aspects of design, Lawson and Dorst (2009, p.50) proposed that a successful design initiative is composed of the following five categories of abilities: **formulate, represent, move, evaluate** and **manage**. Along with them, they suggested the following visual representation to picture the components of a generalist design process:

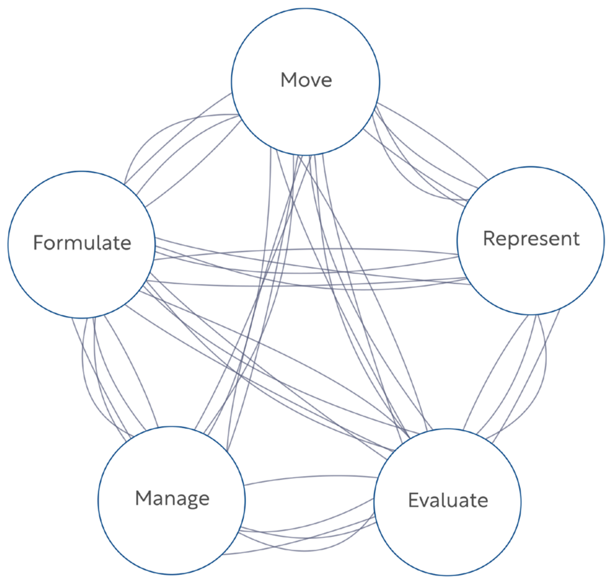


Figure 18 (above): Reproduction of the visual model proposed by Lawson and Dorst (2009).

Formulating

In a design project, the problem is rarely well defined. Either because it has not been sufficiently specified yet or because certain aspects need to be more explored. Still, even when a project's scope is extensively defined, it is a quality of design thinking to experiment with other ways to frame it (Cross, 2006, p.100). Moreover, the execution of a design project is also strongly solution-oriented instead of problem-oriented. Designers tend to spend more time developing solutions and assessing their adequacy than scrutinizing the given problem until every detail is apparent. There is a common belief that the complete definition of a problem must precede execution, but such conjectures of solutions are the means to the necessary understanding of the problem and the refinement of what is being proposed (Cross, 2006, p.100).

Despite suggesting that formulating needs to happen at the beginning of a project might be simplistic, designers certainly need to have a keen eye for understanding and exploring the challenge that motivates their creation. According to Lawson and Dorst (2006, p.52), "the quality of design work produced depends as much on the ability of the designer to frame the problem relevantly and productively, as on the ability to arrive at an interesting solution from this standpoint".

The authors still highlight two main steps within formulating: identifying and framing the problem. When identifying, designers find and organize the many relevant components of the problem. In other words, they "name" the entities that characterize the problem and analyze their aspects and impact on the overall strategy. Framing (which has already been discussed), on the other hand, represents designers' ability to build the lens through which the problem will be understood and tackled (Lawson & Dorst, 2006, p. 51).

Representing

Designers tend to constantly represent and externalize ideas, thoughts, and concepts related to the challenge they are supposed to solve. Besides illustrating the direction towards the solution, tools and methods such as sketches, models, low and hi-fi prototypes, mockups, and computational representations also allow designers to evaluate and communicate what is being proposed (Lawson & Dorst, 2006, p. 108).

Besides helping designers to envision solutions and to anticipate challenges and mistakes, representation-related abilities enable developments that could be either vertical — when improvements and refinements of an idea that is currently being elaborated are proposed — or horizontal — when alternatives to the current idea are generated (Cross, 2006, p. 108).

This dialog between designers and relevant representations throughout the project is essential for mastering the context and the tackled problem. Thus, more than some documentation, these activities are considered at the core of design work to enhance communication, alignment between parts, and overall understanding (Lawson & Dorst, 2006, p. 54).

Moving

As previously discussed, design work is notably solution-oriented. In other words, once design problems may never be successfully converted to well-defined ones — to which there are answers for every variable involved — designers seek satisfactory solutions instead of the optimal ones. This propositional nature of design work also leads designers to think in terms of a considerable, yet balanced, amount of conceptual alternatives (Cross, 2006, p. 103-107).

The generation of solutions is so central to design projects that sometimes it is mistakenly believed to be the only one. However, whether due to the insertion of a novelty to the design process, a refinement, or a new feature for the product being created, it is through these constant moves — design propositions — that a project is navigated from beginning to end (Lawson & Dorst, 2006, p. 54).

Still, because moving is an essential and complex part of the design process, Lawson and Dorst (2006, p. 54) also relied partially on the distinction of forms of creativity (p and h) made by Margaret Boden (1990) to classify the ideas generated during a process and infer its originality:

1 - An idea may be novel in all of history, which is considered rare in our contemporary hyperconnected society (h);
2 - An idea might be novel for the designer or the team that is undertaking a creative process (p);
3 - An idea might be utterly novel within a specific creative process, even if it had already been explored for the proposal of other creations; and
4 - An idea might derive from another one that has already been proposed in the process.

Evaluation

Designers must know which solutions to pursue and when they are ready to stop, which requires analytic and evaluation abilities. On some occasions, necessary criteria might be defined beforehand (e.g., a product that needs to consume a specific amount of electric energy). These criteria might even be numerical so that machines and algorithms can evaluate the project. However, most common design projects will require designers to judge multidisciplinary objective and subjective dimensions of the ideas and solutions being discussed and know when to stop this judgment (Lawson & Dorst, 2006, p. 56).

Notwithstanding, Lawson and Dorst (2006, p. 56) also add that evaluation in design is much more than choosing one among a few project alternatives according to objective or subjective criteria. The authors see this process as a process of deliberation, once it is essentially susceptible to differences in point of view regarding what should be considered a good or bad design. Some designers and critics, for example, choose to follow a more practical point of view — in which an artifact is considered good if there are people interested in buying and using it — while others argue that quality is inherent to everything we do, apart from how the audience receives it. Lastly, others consider projects aligned with their core values (e.g., simplicity, honesty, and originality) the good ones. In the end, evaluating designs often involves measuring the importance of each one of these systems of values and criteria so that they become the structure for decisions that need to be made (Lawson & Dorst, 2006, p. 56).

Managing

Finally, when managing the process, designers are also reflecting on how it is being executed. These are moments when they take a step back and ask themselves if the undertaken creative process is good or bad. Through management-related activities, designers can also analyze and identify the many conceptual paths followed and decide which ones they should abandon or keep pursuing. During these management moments, designers also judge the overall adequacy of the creative process with the project brief, which allows them to make necessary adjustments or plan partial deliverables (Lawson & Dorst, 2006, p. 58-59).

After discussing the creative process and studying these thoughts applied to a generalist design context, further knowledge regarding the manifestations of the above-discussed concepts within an interaction design practice is necessary. Such discussion is made in the following subchapter.

Before proceeding, though, we summarize the main contributions of this subchapter through the sentence and the board below.

The creative process can be understood as a chain of thoughts and actions that comprise the production of original and valuable work (***Lubart, 2018; Sawyer, 2012***)**.** ***Within a design context, due to the specific ways in which designers frame problems and tend to coevolve problems and solutions*** (*Cross, 2006; Kelly & Gero, 2021; Lawson & Dorst, 2009*), ***the mental processes encompassed by generalist models of the creative process*** (*Sawyer, 2012*) **can be reorganized and reclassified into the set of activities formulate, represent, move, evaluate and manage** (*Lawson & Dorst, 2009*). **Emerging ideas in the process can also be classified in four different ways regarding their originality** (*Lawson & Dorst, 2009*).

Board 1: Main Contributions of Subchapter 1.1

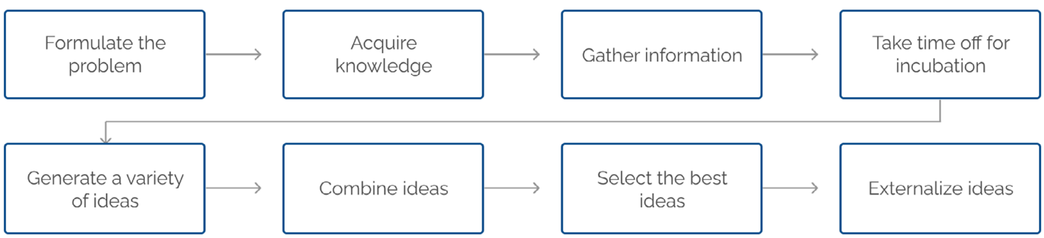
Created by the author

Theoretical Contribution (TC.1)

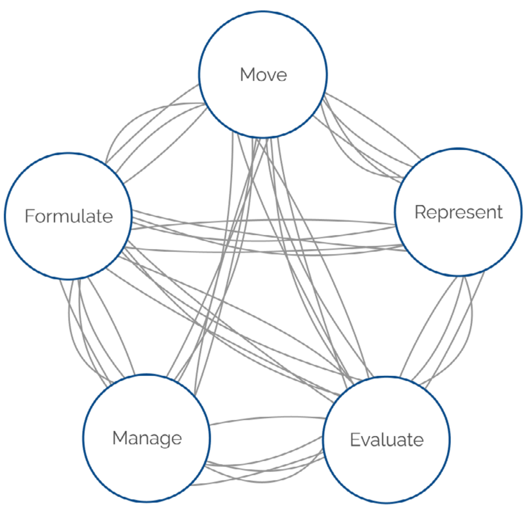
The creative process can be understood as a chain of thoughts and actions that comprise the production of work that is both original and valuable (Lubart, 2018; Sawyer, 2012)**. Within a design context, due to the specific ways in which designers frame problems and tend to coevolve problem and solution** (Cross, 2006; Kelly & Gero, 2021; Lawson & Dorst, 2009)**, the mental processes encompassed by generalist models of the creative process** (Sawyer, 2012) **can be reorganized and reclassified into the set of activities formulate, represent, move, evaluate and manage** (Lawson & Dorst, 2009)**. Emerging ideas in the process can also be classified in four different ways regarding their originality** (Lawson & Dorst, 2009)**.**

Models

Sawyer's model of the creative process (2012) .



Lawson and Dorst's model of the creative process in a generalist design context (2009) .



1.2 Interaction design

Even if it is possible to build generative systems in the physical world, it is through computers that their contemporary applications are mainly conceived — especially after programming languages focused on aesthetic creation such as Processing and openFrameworks became popular. Moreover, since generative systems are not a specific technology or device but a computational logic, their possibilities may evolve along with the overall technological scenario. For example, if such systems were mainly used in the creation of visual art, animated films, and interfaces with limited interactivity during the XX century, today, they can be incorporated into websites and support mobile apps, displays, and VR devices.

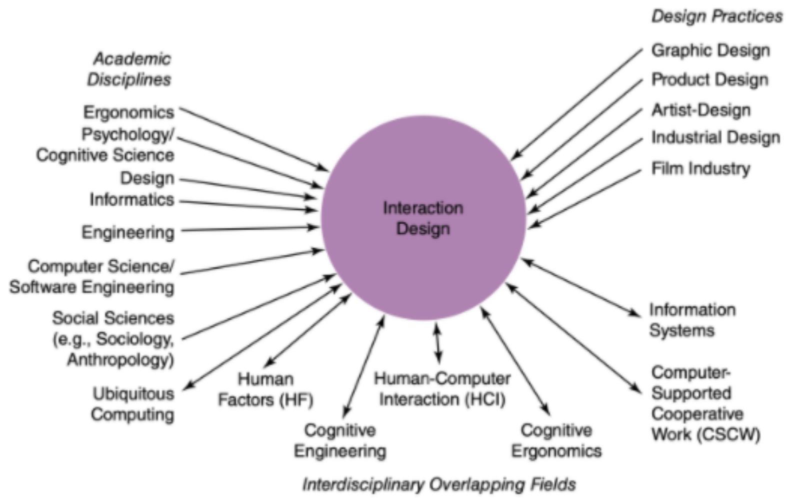
We start from the idea that a foray into interaction design can point out essential theoretical contributions so that our research objects (processes employed by professionals when designing interactive products powered by generative systems) can be appropriately analyzed, described, and understood. Apart from being focused on essential products of the digital era, interaction design is technologically agnostic — the focus is on defining how interactive products, systems, and services behave independently of the platforms and devices that are supporting them (Saffer, 2009, p. 14). This is also why we chose to study the discipline.

Interaction design can be understood as the discipline that seeks to define the shape and behavior of interactive products, services and systems (Goodwin, 2009, p. 5). Regardless of welcoming different purposes, during interaction design projects, designers constantly answer questions such as:

1. What activities will the product or service support, and how?
2. What information do users need at each point in that process?
3. What information does the system need from users and the context?
4. How is functionality segmented and manifested?

According to Goodwin (2009, p. 4-5), those questions help interaction designers shape products and services that are useful to human needs and goals.

Another aspect highlighted by authors of the discipline is that interaction design takes advantage of learnings from other "sister" fields, such as human-computer interaction, visual design, product design, computing, information architecture, and psychology. Saffer (2009, p.21) and Goodwin (2009, p.5) attribute part of this multidisciplinarity to the fact that interaction design has been treated as a formal discipline, or specific profession, for a short time. "It is a young field, still defining itself and figuring out its place among sister disciplines" (Saffer, 2009, p. 20). Furthermore, according to Sharp, Rogers, and Preece (2019, p. 38), interaction design naturally draws from approaches of longer-established design disciplines, such as graphic design, industrial design, and architecture. They illustrate what they call the "components" of interaction design through the diagram below:



Essentially, interaction designers define what will be and what will cause the interactions involved in a given product or service. However, the many above-discussed intersections and the "generalist" aspect of the discipline foment divergent points of view concerning the general objective of an interaction design project. Saffer (2009, p. 4) categorizes them into the following three statements:

1. A technology-centered view, through which the ultimate goal of designers would be to turn "raw" inventions of engineers and scientists into artifacts that people enjoy using;
2. A behaviorist view, according to which interaction design should aim to define the behavior of artifacts, environments, and systems (e.g., products);
3. And a social interaction design view, according to which interaction design would be inherently social, aimed at facilitating communication between people through products and artifacts.

These different ways of perceiving the discipline become more explicit, for example, when some authors define interaction design as the design of "interactive products to support the way people communicate and interact in their everyday and working lives" (Sharp et al., 2019, p. 9), while others pose it as a discipline "focused on defining the form and behavior of interactive products, services, and systems" (Goodwin, 2009, p. 5).

In addition to the three different ways of looking at the discipline,

Figure 19 (top): Sharp, Rogers, and Preece. Components of Interaction Design. (2019, p. 38).

Saffer (2009, p. 33) states that there are four distinct approaches to conducting an interaction design project: a **user-centered design** approach; one centered on the **activity** to be performed; a **systems design** approach; and a last approach he named g**enius design**, which is guided by the designer's expertise and intuition.

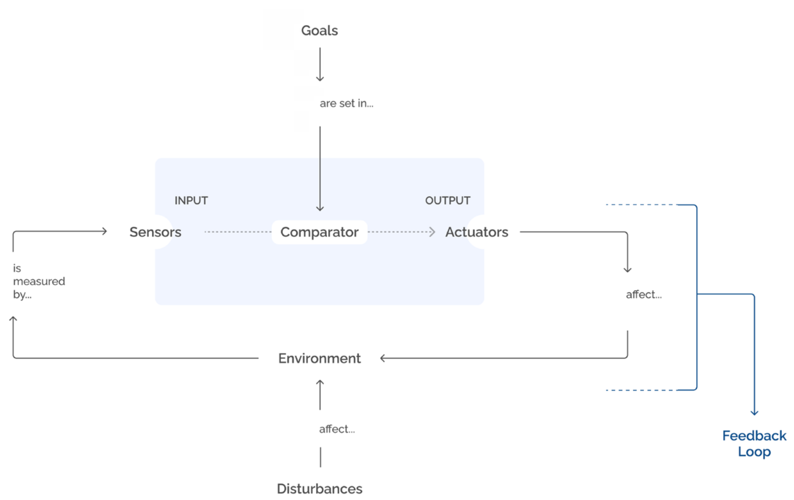
First, user-centered design is based on the simple assumption that only users of the solution are capable of "knowing" how it should be. Because of this, the primary and most important source of information throughout the project is evidence obtained about or through potential users. In this approach, a considerable time is spent understanding the worlds of the people that might use the product: their preferences, background, emotions, and expectations. Designers see themselves as the ones who will mediate and facilitate this information towards the final artifact (Saffer, 2009, p. 33).

Sharp et al. (2019, p.39), for example, place interaction design as a form of "making design" in which "the artifact's use and target domain are investigated by taking a user-centered approach to development. Users' opinions and reactions to early designs are sought, and users are involved appropriately in the development process itself. This means that users' concerns direct the development rather than just technical concerns".

A possible opposite to user-centered design is the genius design approach, which is guided by the experience and intuition of designers (or team), and in which design decisions are made according to their judgment (Saffer, 2009, p. 43).

The activity-centered design approach, in turn, relies on the understanding of the set of actions that compose the activity to be performed, be it the preparation of a sandwich or the search for a job. This approach is based on the "activity theory", a model in vogue in the first half of the 20th century, which considers tools an externalization of the mental processes involved in acting or communication. In other words, the goal is to unravel and understand the various actions, decisions, requirements, and limitations that make up a given activity, as a means to propose tools that can, in a better or more innovative way, get it done (Saffer, 2009, p. 37).

Finally, in systems design, professionals arrange specific components and interrelated entities — systems — to develop final solutions. This design approach is opportune when dealing with complex problems as it offers a holistic perspective to the design process. Users and activities no longer occupy the center of the design process. Instead, as illustrated by Figure 20, they are seen as part of a context of use that can be described as a system, along with its environment and main components. Designers' job is to define these relationships and components. Lastly, in spite of being commonly referred to in the realm of digital systems, it is worth saying that systems can also be composed of people, devices, machines, and objects, ranging from a simple central heating system to entire governments or the stock market



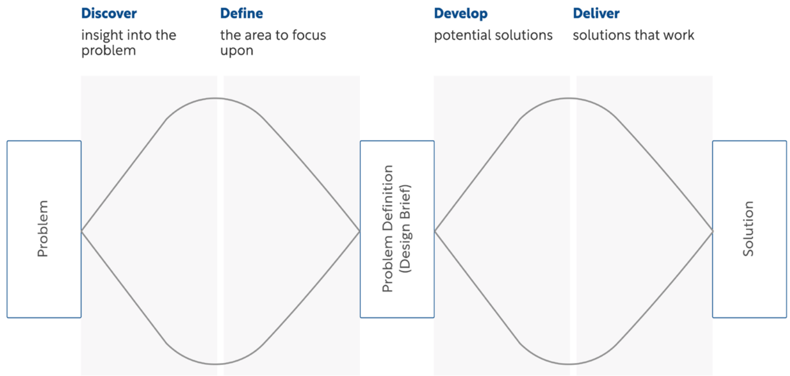
(Saffer, 2009, p. 38).

To illustrate systems design, Saffer (2009, p. 38) drew on the discussion by Pangaro and Hubberly (2007) in defense of a rescue of cybernetics as a valuable analogy for today's designers. They relied on the model of a generic system below as an auxiliary to professionals who must address the design of artifacts for complex interaction contexts between humans and the most varied types of machines.

Naturally, the approach also characterizes the process that practitioners and academics believe an interaction design project must go through. For instance, Sharp et al. (2019, p. 38) emphasize the similarities between interaction design and other fields of design by choosing to explain its specific activities and processes through the generalist double-diamond model (Figure 21). They believe that interaction design follows the four phases (discover, define, develop, and deliver) of the model but with a solid user-centered foundation that determines the decisions and methods to be considered during the process.

First, in the **discovery** stage, designers essentially seek to gain insights to understand the problem space deeply. According to Sharp et al. (2019, p. 41), "deciding what to design is key, and exploring the problem space is one way in which to decide". In the creation of a new version of an existing interactive product, for example, investigating and analyzing the problem space implies understanding what the current user experience is like; understand why a change is necessary; what requirements must be considered in the design of this new version; and understand in what terms

Figure 20 (top): Reproduction of the model of a generic system: its goals, environment and main components (Saffer, 2009).



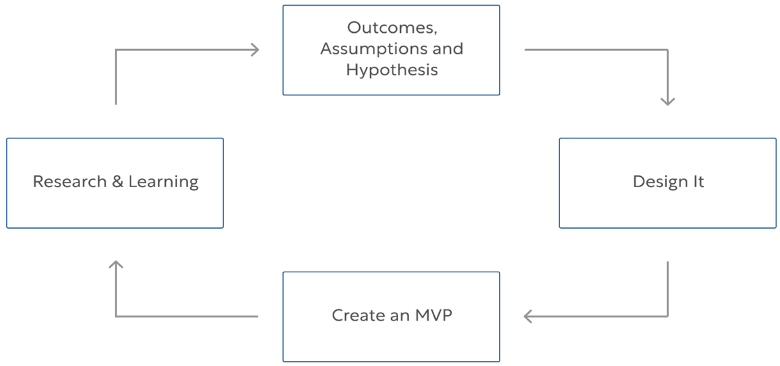
it is expected to improve the user experience. Since they advocate a user-centered design approach, the authors naturally believe in an investigation of problem space that primarily considers users' realities, expectations, and needs.

Furthermore, discovery activities end up collecting data that enables the project **definition**. At this posterior stage, requirements, constraints, and relevant aspects of the problem are transformed into a clear brief to orient the execution of the project.

Sharp et al. (2019) also argue that the discovery and definition steps of the double-diamond model can be grouped into a first (among four) basic interaction design activities called **requirements discovery**. In such an activity, the focus is on understanding target users and the value that a given interactive product should deliver to them. Furthermore, this understanding obtained through data collection and analysis becomes the basis of the product requirements that will guide the project.

The remaining three basic activities of interaction design, according to the authors, belong to the **development** stage of the double-diamond. The first one — **design of alternatives** — comprises the production of simple sketches, models, and also the detailed production that contemplates the careful articulation of colors, sounds, images, and icons. In other words, it encompasses both the proposition of nascent ideas and high-fidelity design deliveries. **Prototyping** — the second basic activity within the development stage — seeks to enable the test of solutions according to relevant criteria and user evaluation. Prototyping is also critical if we consider that interaction

Figure 21 (top): Reproduction of the interaction design model proposed by Sharp et al. (2019, p. 38).
Figure 22 (next page / top): Reproduction of the lifecycle model proposed by Sharp et al. (2019, p. 51).



design involves the definition of not only visual aspects, but also product behaviors, navigations, and responses. To this end, various prototyping methods can be employed: from staging or creating wireframes on paper to making sophisticated digital prototypes with very high fidelity (Sharp et al., 2019).

Still in the development stage, the last basic activity of interaction design is **evaluation**, which represents the processes employed by the professionals to measure propositions in terms of a variety of criteria. In this process, data about the experiences users have when interacting with a specific product or prototype is used to judge the usability and acceptability of the project (Sharp et al., 2019).

Finally, returning to double-diamond, the product is polished, produced, and released at the **delivery** stage, possibly accompanied by valuable specifications to guarantee its quality.

In addition to understanding the basic activities of interaction design, it is also important to know how they relate to one another. An organization that Sharp et al. (2019, p. 51) call the **lifecycle model** (Figure 22). Although many projects follow a conventional process of discovering requirements, generating alternatives, prototyping, and evaluating, these activities are expected to feedback and instigate changes in each other. Also, as will be discussed further on, factors such as design style, teamwork dynamics, deadline, and budget can dictate the emphasis given to each of the activities in the model and thus how they are organized.

Saffer (2009, p. 48) also relies on the double-diamond model to propose an interaction design process composed of the six following stages: ***design strategy; design research; structured findings; ideation and design principles; refinement; and prototyping, testing, and developing.*** According to the author, such a process is necessary once "designing a product for everyone, everywhere, for all time is not realistic".

At the beginning, the product and project planning activities shape the **design strategy**, which captures both the final vision and the tactics of the project. Some of the main activities involved in the design strategy are: framing the problem or opportunity to be addressed; determining the differentiating aspects to be articulated by the product; envisioning and communicating the design vision to other stakeholders; and creating roadmaps to make project goals more tangible (Saffer, 2009, p. 49).

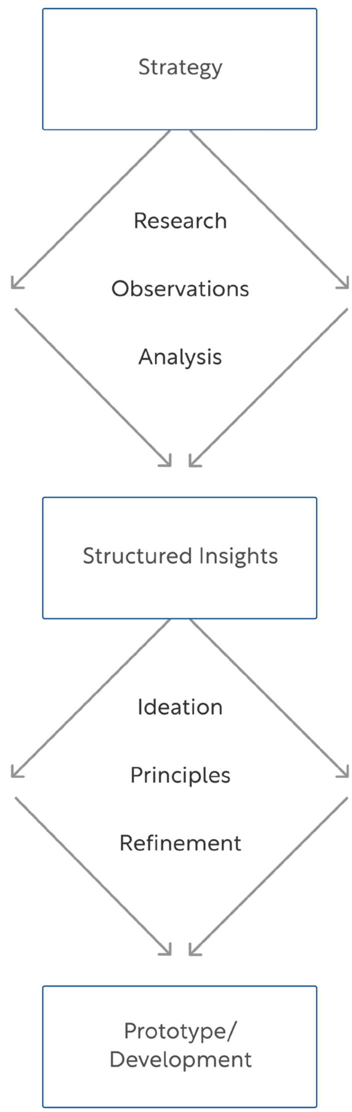
In the **research** stage, designers seek to investigate potential or existing users of the artifact and the relevant contexts of use. To this end, in addition to research planning activities, a myriad of methods can be selected and executed, depending on the approach and on how the problem was framed. Whether through interviews and observations or workshops and group activities, the research stage also provides insights for better conduction of the process to be followed (Saffer, 2009, p. 74).

Structuring findings comprises the organization, interpretation, and synthesis of the data collected through research. In this stage, raw data is transformed into visualizations that make sense for the team and relevant stakeholders, such as models, charts, personas, or user stories (Saffer, 2009, p. 94). Then, after gaining insights about the context and users, a stage of **ideation** and definition of **design principles** begins. At this point, ideas and concepts are proposed, judged, and selected to go forward. However, according to Saffer, it is important to evaluate and select these ideas according to solid design principles. Not only to objectively evaluate the available options but also guide how they will be refined and developed in the rest of the process.

In the **refinement** step, these concepts are duly specified and elaborated according to the project's limitations, requirements, and intentions as ideas move from initial propositions to more detailed artifacts such as sketches, sitemaps, wireframes, task flows, and service journeys.

Lastly, in the **prototyping, testing, and development** stage, professionals deliver a greater level of detail through the design of final interfaces and prototyping of interactions and behaviors. At this moment, aspects that might be difficult to express by other means, such as movements, animations, interactions, and timing are clarified. In addition, prototypes can be tested with users to detect errors and incorrect assumptions (Saffer, 2009, p.170-184).

In addition to a deep understanding of users and potential users, an essential part of the restrictions and requirements emerge with a holistic investigation of "the full context of the design problem" (Moggridge, 2007, p.



725). Based on these thoughts, Moggridge (2007, p. 730) proposed that the interaction design process comprises the following ten essential elements: **constraints, synthesis, framing, ideation, envisioning, uncertainty, selection, visualization, prototyping**, and evaluation. The author also advocates for a possibly disordered execution, in which steps can be (and probably will be) repeated and alternated.

In this model, design starts with understanding the relevant **constraints**, that is, user needs and expectations, mental models, functional requirements, technical and budget regulations, timeframe, and competitor

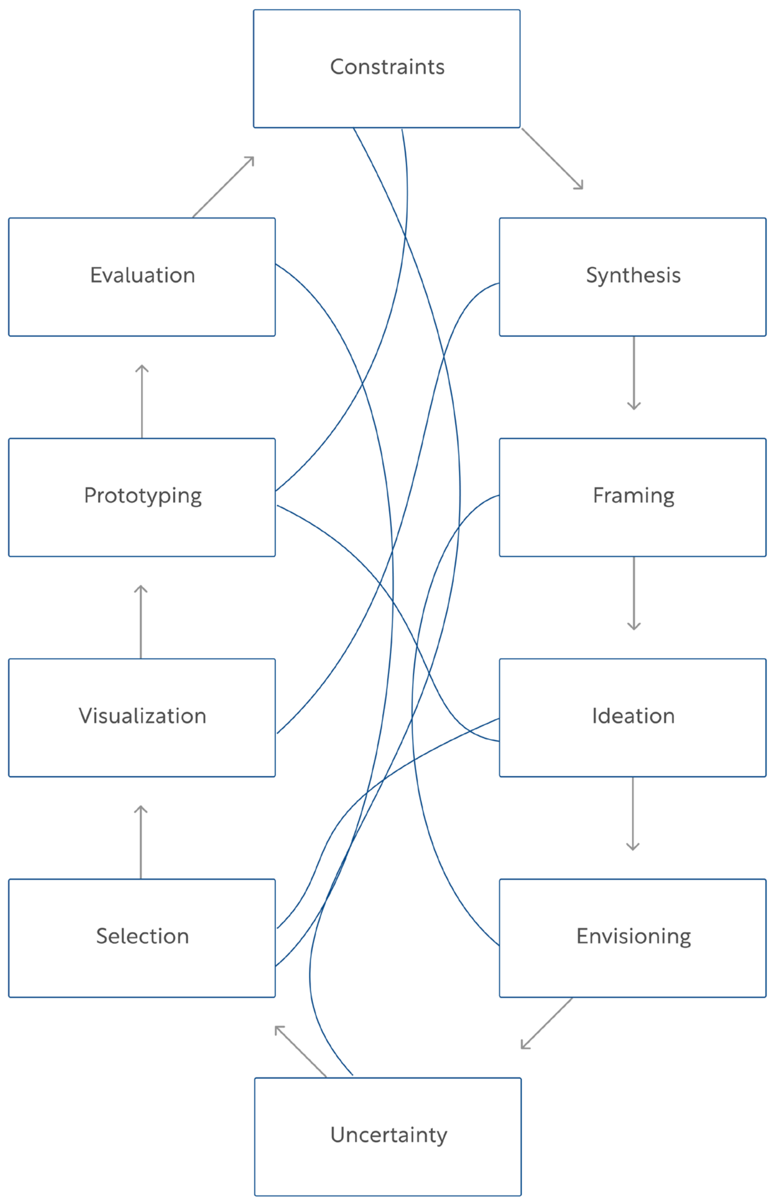


Figure 23 (previous page / right): Reproduction of Saffer's model (2009, p. 48). **Figure 24 (current page / right):** Reproduction of Moggridge's model (2007, p. 726).

analysis. Moggridge argues that a robust mapping of these constraints must be done and absorbed by designers before further work. Moreover, the author also argues that more complex projects benefit from numerous and diverse teams precisely because of the ease with which a “shared mind” can deal with the many inherent constraints.

The author also postulates a **synthesis** process that constantly takes place in the subconscious “shared mind” of the design team. According to him, it is during these moments that all relevant issues are processed and used to propose ideas and other elements for the development. **Framing** represents analyzing the problem and organizing its components to make it more approachable. As stated by Moggridge (2007, p. 731): “One project may be best framed by a journey through the experience, another by a four-quadrant analysis of people’s attitudes, and another by a nested hierarchy of attributes”. Furthermore, like Saffer, Moggridge acknowledges the importance of a moment of **ideation** in the interaction design process. More than that, he understands that a suitable framing of the problem can organize the generation of ideas and that it does not happen as a temporally delimited phenomenon, but rather spread all over the project.

When **envisioning** a particular solution for the problem, designers begin considering concrete representations and how the specific solution will take shape and relate to the elements of the context. In other words, the solution is seen as the product, which consequently shifts thinking to a convergent perspective. Accordingly, **uncertainty** is placed as a fuel that urges designers to pursue better solutions. These are the considerations and questions put on the propositions so that they continue to be elaborated. For instance: “Is this simple enough? Is it consistent with what already exists? Can we make it work faster?”. Moggridge also includes in his model the **selection** of design ideas, in which most promising propositions are chosen according to relevant criteria established by the designer (or team). As a complement, the author argues that it is common for disagreements among team members to happen at this moment of decision.

Visualization activities allow the solution to take shape as communication artifacts, bridging the gap between envisioning and prototyping. It represents and illustrates what is being proposed so that the message is clearer. For example, in a digital product context, designers can elaborate sketches of the interfaces that will be implemented to illustrate technical requirements to a development team. Moreover, designers rely on **prototyping** strategies to test the solution’s adaptability to specific criteria by incorporating more complex aspects and behaviors into the aforementioned representations and models. In an iterative design process, prototypes facilitate the project’s path while evolving from basic hunches to getting closer and closer to the envisioned design.

Lastly, Moggridge’s model comprises **evaluation** activities that take place throughout the design process. The author establishes a design approach with constant and anticipated moments of questioning, capable of guiding designers from the beginning — when deciding the most promising concepts and ideas to pursue —, until the examination of which adjustments should be made before release.

By also reckoning on an observation towards practice, Kim Goodwin (2009, p.7) proposed an interaction design process based on the method of Goal-directed design, developed by the design consultancy Cooper (now part of Wipro Digital). Following the activity-centered approach discussed by Saffer, Goal-directed Design assumes that the best way to design a successful product is by focusing on understanding the goals relevant to it. Such investigation involves uncovering the many requirements and opportunities behind users' goals, business goals, and indirect objectives, say of those who might want to buy the product but not necessarily interact with it. According to Goodwin (2009, p. 7), the method was entirely developed by analyzing the real world and consists of four main components: the **principles, patterns, process, and practices**. Kim also states that a successful application of the method depends on a team with qualified people and necessary skills.

As discussed in the previous models, the **principles** represent general directions that will guide the elaboration. They are sentences or concepts specifically developed for the project in question, which will help propose and judge solutions. **Patterns**, in turn, represent an orientation towards taking advantage of consolidated patterns of interaction and use. These "building blocks" of the interaction designer's vocabulary, according to Goodwin, might be standardized layout choices for a given website that seeks to be intuitive, the use of interactions that already exist in other applications made for the same device, or even public component libraries, such as Google Material Design, or the Apple Human-Interface Guidelines.

Despite introducing the elements, though, Goodwin's discussion about Goal-directed Design concentrates mainly on its design process described through seven steps: **project planning, research, modeling, requirements definition, framework definition, detailed design, and implementation support.**

The model starts with a **project planning** step. The focus is on identifying the project's stakeholders, determining the main goals, and outlining a plan for the activities to be carried out. Although the still-undefined state of the problem makes it difficult to predict deadlines and durations accurately, the author argues that an experienced designer should be able to propose an initial schedule to measure time and costs.

Goodwin also emphasizes the importance of a **research** step. Her premise is that a problem needs to be first comprehended to be solved. In addition to understanding the design problem research also contributes to building consensus between the team and the people involved. Furthermore, by raising objective data, research activities also contribute to a faster and more accurate design process development. In the **modeling** stage, raw research data is analyzed and synthesized into models that are useful for the project. A widespread modelling method, for example, is creating a set of relevant personas. However, these models can also represent other important aspects of the problem, such as work processes and usage environments.

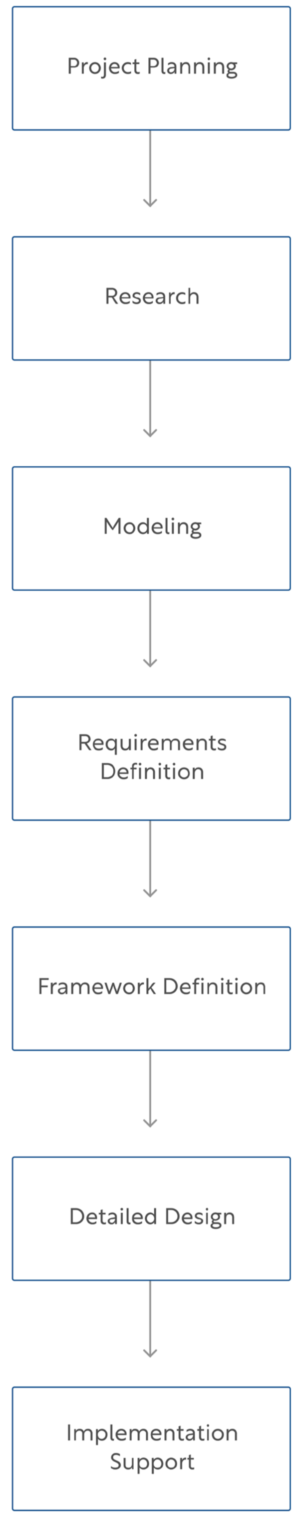
Data analysis and subsequent modeling also contribute to an appropriate **definition of requirements**. In this step, the intention is to determine the implications of the data collected on the functionality and design of the product (Goodwin, 2009). Naturally, this definition should also take into account business objectives and strategic constraints.

The newly understood requirements feed into another stage of **framework definition**. At this stage, first sketches of the shape and behavior are explored and presented, still without much detail, so that the parties involved can begin to visualize the project's paths. Then, in the **detailed design** step, designers specify what will be delivered at a ready-for-development level of fidelity. According to Goodwin, to anticipate extreme use cases and follow best practices, designers also rely on the collaboration of developers, engineers, and other specialists, and on usability tests, at this stage.

The final step of Goodwin's design model is **implementation support**. To exemplify it, the author makes an analogy with the routine of an architect who says that her work only ends when constructions are complete. At this stage, designers seek to assist the development teams with any doubts and additional specifications about the delivered project. This step is critical for the product's quality for avoiding design decisions made without the people responsible for them.

Goodwin also notes that a given design process does not determine the quality of what will be delivered and the team's efficiency by itself. On the contrary, management practices related to team structure, speed, communication with stakeholders, and collaboration deserve attention, as they will certainly affect the results. Lastly, despite presenting a linear unfolding initiated by robust planning, research, and modeling stages, the author admits the eventual need of "taking shortcuts", depending on the context and expectations regarding the product's release: "Some organizations (such as start-ups in search of additional funding) may believe getting a best-guess product out the door is more important than taking the time to understand their users and customers in any depth, so there are ways to jump to design with little or no time spent on research" (Goodwin, 2009, p.10).

Our foray into interaction design might also benefit from discussing the discipline's paths and models more recently proposed by academics and professionals. Currently, interaction design is ubiquitous, especially among technology companies that market digital products and services.



However, according to Sharp et al. (2019, p. 13), it is not only these naturally technological companies that have been interested in interaction design services. Today, banks and financial institutions, government agencies, retail companies, and various services see the value of the discipline and its potential for differentiation in a context of extreme digital competitiveness. Moreover, although "interaction design" is the commonly used umbrella term to describe the field — encompassing its methods, theories, and approaches — we can easily find a variety of nomenclatures with specific emphases. Among them, UI Design (user interface design), web design, product design (digital product design), and UX Design (user experience design) (Sharp et al., 2019, p. 9).

With the consolidation of UX and the focus on designing for the user experience, there has also been a clear shift in the discipline towards an approach centered on the actual users of the product. Although designers ordinarily think of their projects in functional and aesthetic terms, the search for commercial differentiation and for constantly delivering a "better brand experience" have reinforced the thesis that focusing on users and their emotional needs and expectations guarantee a better return to business (Garrett, 2010, p. 13).

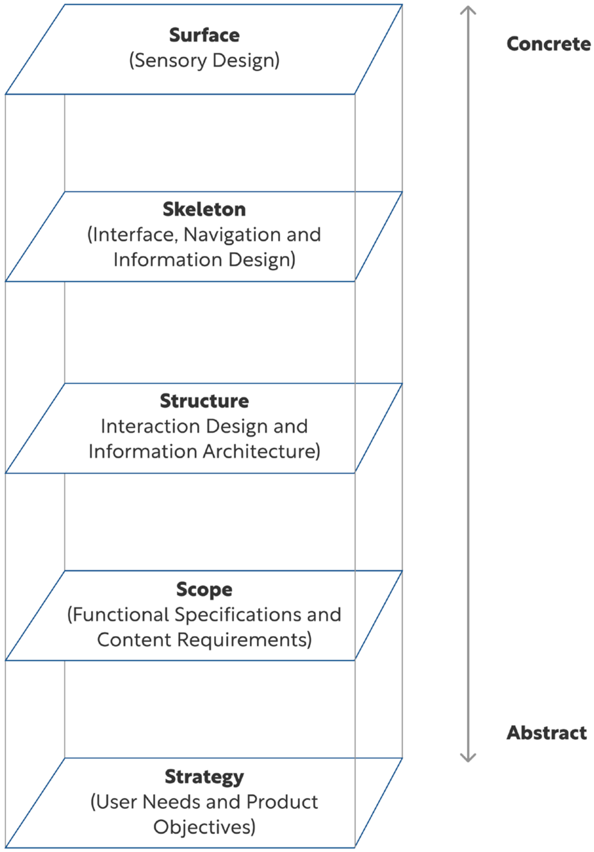
In this sense, several authors have been producing content on the most useful ways to direct creative processes towards better user experiences. For example, Garrett (2010, p.6) defines user experience simply as the experience that a given product promotes for people who use it in the real world. Accordingly, the author understands the design process as the conscious and intentional activity of defining the relevant aspects of a set of five complimentary planes that make up what is being received and interpreted: the **surface**, the **skeleton**, the **structure**, the **scope**, and the **strategy**.

On the surface, regardless of whether we are dealing with a product with informational or functional appeal, we are interested in articulating the sensory choices that manifest the intended experience. For example, at this level, the user will see a series of pages on a website made up of different images and texts. Some images will be illustrations, while others will be photographs that may link to other specific pages.

Just below the surface, the **skeleton** of the product represents the concrete placement of its various components, such as buttons, controls, images, and blocks of text. In addition, the organization might reflect an intended logic. For instance, the skeleton can be designed to optimize the content or shed light on specific points. Moreover, according to Garrett (2010, p. 20), the skeleton is nothing more than a concrete expression of the **structure** of the interactive product, which represents the general navigation and categorizations that determine the product's final appearance, despite not being necessarily visible.

Figure 25 (**previous page**): Reproduction of Goodwin's model (2009, p. 10).

The **scope** represents the "list" of elements and functionalities



Picture 26 (top): Reproduction of Garrett's model (2010, p. 6).

that should be considered in the product design and, thus, articulated by the superior planes. For example, some e-commerce sites allow users to save their favorite items to a list to refer to in the future. Whether or not to include this functionality is a matter of scope.

Finally, the **strategy** plane covers business intentions, desires, and requirements discovered through user research. As discussed in previous models, we can think of these strategy elements as a series of sentences or principles that the designed experience will attempt to communicate.

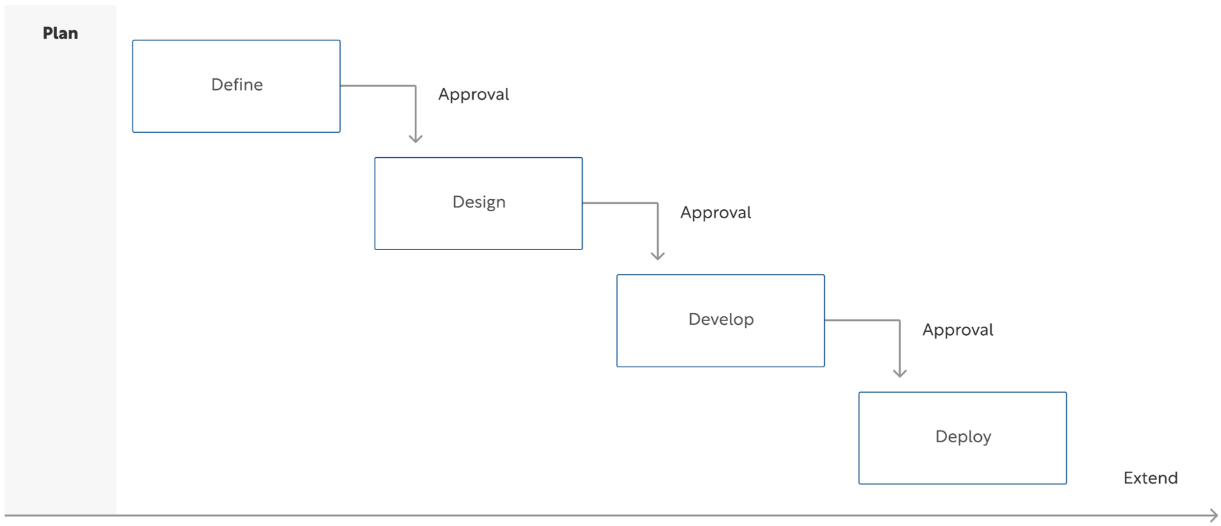
Garrett (2010, p. 24), at last, suggests a design process that navigates through the five planes, from the bottom to the top — starting with the strategic definitions until the creation of the surface. However, the author also recognizes that it is impossible to delimit a specific order for the activities to occur. "Dependencies run in both directions, with decisions made on upper planes sometimes forcing a reevaluation of issues on lower planes." he exemplified. Furthermore, the author explains that decisions made about each plane tend to respond not only to movements of the project itself but also to market competition, good design practices, and the available knowledge about users. All of these factors can change along the way.

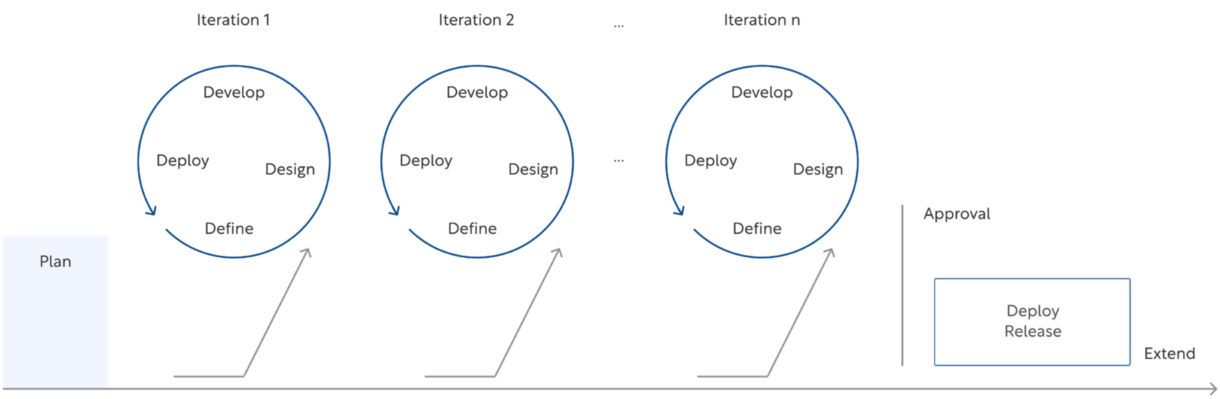
With a more market-oriented perspective, Unger and Chandler (2012, p. 3) define user experience design as "creating and synchronizing elements that affect the user experience with a particular company, product or service, to influence their perceptions and their behavior". Related to our previous discussions concerning the different ways to order the activities within an interaction design project, the authors also acknowledge the influence of factors such as structure and location of the team, technologies being used, and the desired level of collaboration. However, regardless of emphasis and ordering, Unger and Chandler (2012, p. 73) identify six essential steps common to most projects: **plan, define, design, develop, deploy and extend**.

In their proposal, designers begin by **planning** the overall strategy, the composition of the team, and the approach to be followed. Then, the relevant requirements and restrictions are **defined**. In the **design** stage, the visual and interactive aspects of the artifact are outlined, from simple concepts and sketches to detailed specifications. At the **development** stage, the designed artifact is tested and refined sufficiently to be **deployed**. At this point, details about product release and delivery schedules might be planned. Finally, the **extension stage** happens after execution and comprises the research and documentation of recommendations for future improvements and support.

Moreover, according to the authors, the steps proposed above can be organized in line with different procedural approaches — being **waterfall approaches** and **agile approaches** the two most common. In the first approach, the steps are treated as separate and distinct phases mediated by precise approval moments. "For example, the design phase does not begin in earnest until requirements have been approved by business stakeholders, who sign off on one or more requirements documents at the end of the define phase." (Unger & Chandler, 2012, p. 74). However, a fragility of the waterfall approach is that it assumes that each phase can be completed without causing modifications to the previous ones. That is, the activities of a specific design phase, for example, could not raise questions about the initial schedule or the requirements.

On the other hand, when they understand change as a constant in the project, product development teams benefit from more flexible approaches. In so-called agile approaches, the focus is on collaboration and quick creation at the expense of detailed documentation and excessive formality. By assuming great collaboration and closeness between team members, agile approaches reduce the need for robust documentation throughout each step. Naturally, though, such a shift from a linear and delimited approach — which favors long and detailed project time — to a faster approach — in which it is expected that quick decision-making and collaboration will provide satisfactory deliveries in less time — poses the need for designers to adapt



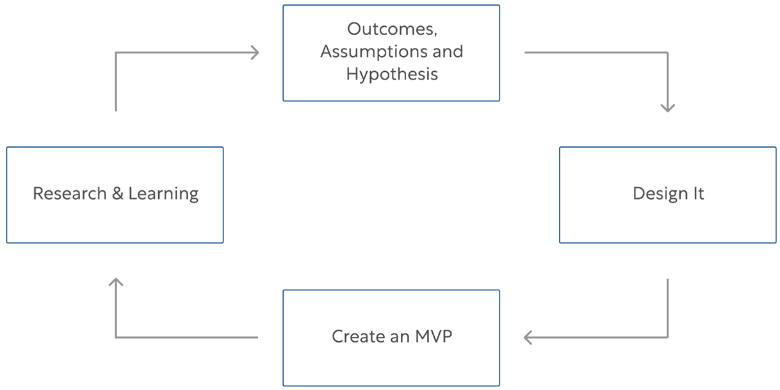


their creative process (Unger & Chandler, 2012, p. 73).

Being one of the current challenges for professionals of the field, the search for project agility and greater integration between the members of product development teams continue to instigate the proposition of new UX design models. Especially due to the growing absorption of these professionals by technology companies. For instance, Gothelf and Seiden (2016, p. 85) propose a four-step process model called Lean UX as a more recent contribution.

According to the authors, Lean UX is an approach based essentially on experimentation and learning. The work starts with **hypotheses** and assumptions to be investigated, or pre-established intentions. Based on these, the team ignites a quick **design** process intending to design an **MVP**[3] as a strategy of validation. At this point, experimentation takes place in various

3. A minimum viable product (MVP) is a version of a product with just enough features and details to be usable by early customers and stakeholders who can then provide feedback and suggest paths for further development.



ways, from usability testing to real-world product performance evaluation. Through these successive experiments, initial hypotheses are evaluated, improved, or discarded, providing insights and **learnings** to be incorporated into the project until a satisfactory version is produced (Gothelf & Seiden, 2016, p. 80-81).

Also according to the authors, in such an approach, discovery initiatives happen continuously, instead of being limited to an initial moment of the process. Accordingly, other design activities, such as the generation of alternatives, creation of research models, prototyping and evaluation with users, continue to be carried out but organized in a way to enable the intended pace.

In a recent book aimed at multidisciplinary technology teams, Cagan (2017, p. 26) also advocates a continuous and integrated interaction design process in which research activities (**discovery**) and **delivery** occur in parallel throughout the entire product development. As a characteristic of agile design processes, the author also argues that contemporary interaction designers should work side-by-side with developers and project managers,

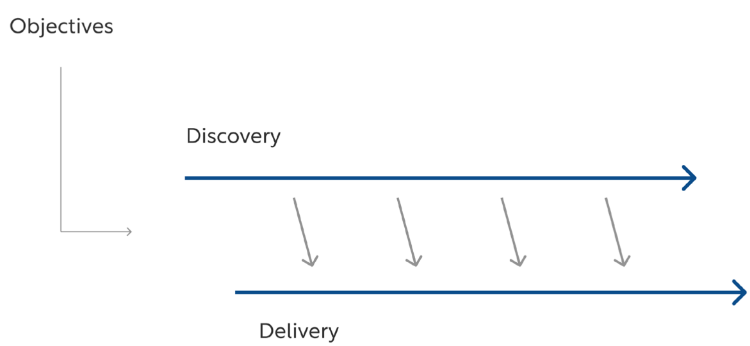


Figure 27 (previous page / top): The waterfall approach, based on the illustration created by Unger and Chandler (2012, p. 74).
Figure 28 (previous page / middle): The agile approach, based on the illustration created by Unger and Chandler (2012, p. 74).
Figure 29 (current page / top): Reproduction of the model created by Gothelf and Seiden (2016, p. 85).
Figure 30 (current page / bottom): The dual-track model as proposed by Cagan (2017, p. 26).

incorporating the design perspective into the other goals and overall team process.

For instance, throughout discovery, designers can take the lead and apply a myriad of user and stakeholder research methods and continually synthesize and present the insights discovered to the rest of the team. In parallel, these investigations can improve a series of aspects of the product being designed. Again, it is worth noting that the design activities discussed throughout this chapter continue to be carried out but at a different pace and organization.

After discussing a myriad of models for the creative process in interaction design, a last conceptual layer focused on generative creation and computational thinking will be added to support the holistic interpretation of our cases. Such discussion happens in the following subchapter.

We summarize the main contributions of this subchapter through the sentence and the board below.

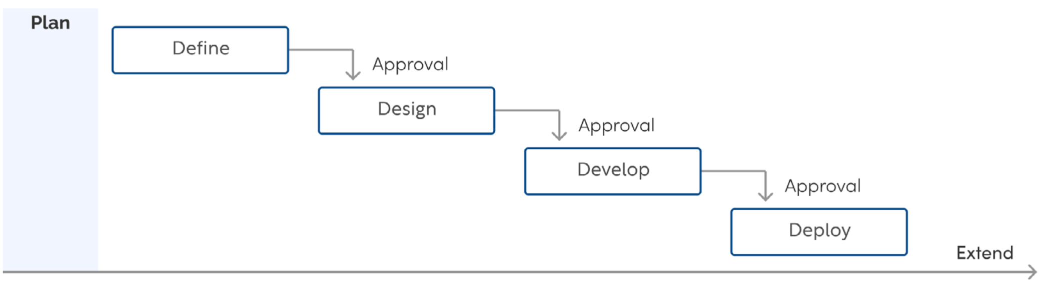
> **When designing interactive products** (Saffer, 2009; Goodwin, 2009; Sharp, Preece & Rogers, 2019), **professionals or teams may rely on creative processes that are either very structured, sequential — waterfall approaches and design-centered** (Saffer, 2009; Goodwin, 2009); **sequential but susceptible to experimentation and intercalation of steps** (Moggridge, 2007; Garrett, 2010); **or based on multidisciplinary collaboration, rapid iteration and experimentation — agile approaches or multi-track** (Unger & Chandler, 2012; Gothelf & Seiden, 2016; Cagan, 2017). **However, regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages: plan, define, design, develop, and deploy**(Unger & Chandler, 2012), **and the activities: designing alternatives, prototyping, evaluating, and discovering requirements** (Sharp, Preece & Rogers, 2019).

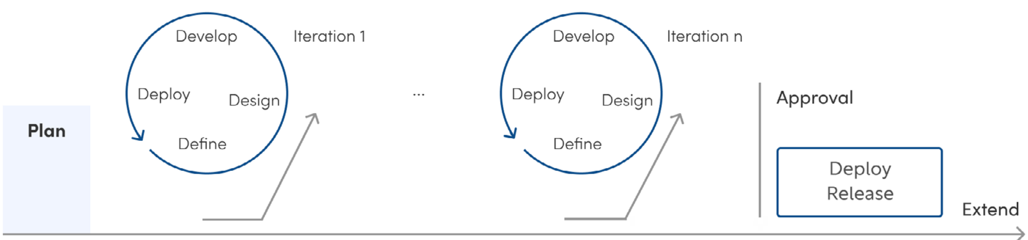
Board 2: Main Contributions of Subchapter 1.2 (Interaction Design)
Created by the author

Theoretical Contribution (TC.2)

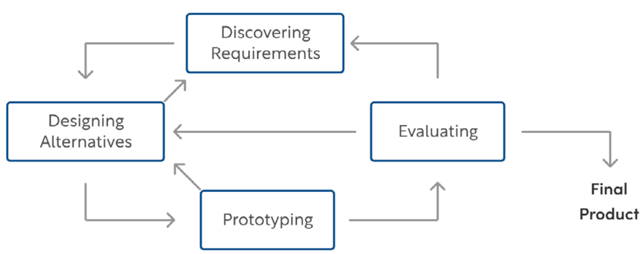
When designing interactive products (Saffer, 2009; Goodwin, 2009; Sharp, Preece & Rogers, 2019)**, professionals or teams may rely on creative processes that are either very structured, sequential – waterfall approaches and design-centered** (Saffer, 2009; Goodwin, 2009)**; sequential but susceptible to experimentation and intercalation of steps** (Moggridge, 2007; Garrett, 2010)**; or based on multidisciplinary collaboration, rapid iteration and experimentation – agile approaches or multi-track** (Unger & Chandler, 2012; Gothelf & Seiden, 2016; Cagan, 2017)**. However, regardless of specific constraints and the approach, when designing an interactive product powered by generative systems, designers undertake the major stages: plan, define, design, develop, and deploy** (Unger & Chandler, 2012)**, and the activities: designing alternatives, prototyping, evaluating, and discovering requirements** (Sharp, Preece & Rogers, 2019)**.**

Execution-related approaches for Interaction Design (Waterfall and Agile)





Common Activities



1.3 Generative Creation and Computational Thinking in Design

In 1964, Karl Gerstner (1930-2017) released his book Designing Programmes, one of the first texts dedicated to systematically approaching design. At that time, the author argued that problems could be more efficiently solved with a matrix of possible solutions — programs, instead of unique propositions. Essentially, Gerstner (1964, p. 21) considered impossible for designers to delimit, in an absolute way, all the relevant solutions of a design problem since conditions and the context might change fast and often. Still at the beginning of the computational era, Max Bense (1910-1990) also relied on research about computing and systematization as he was looking for ways to formalize aesthetic processes. Exploring a hypothetical concept of calculability of all elements, he worked centrally on the role of quantitative and objective analysis in the creations of shapes and on a design methodology strongly influenced by algorithms (Neves, 2015, p.533).

As computers became more accessible and straightforward during the XX century, computational tools and programming practices reached many industries and society's more popular layers. For designers, even though the adoption of these tools caused differences in the design process, it first represented a transposition of the usual media and routines to a digital context. The focus was on gaining precision and efficiency and not exploring new processual and aesthetic possibilities (Reas & McWilliams, 2010, p. 27). Behind the scenes, though, algorithmic explorations continued to advance due to scientists, designers, and artists who sought to extrapolate the most famous software tools and take computing as a fruitful creative material. These intentions motivated new artistic movements — such as the New Media Art scene —, the invention of innovative interactive interfaces and the creation of programming languages and platforms oriented to aesthetic purposes.

In this context, computational creation transcended a purely automating algorithmic approach and reached another, in which systems started to be employed in the creation of artifacts and experiences hardly obtained by traditional means. In other words, with its unique characteristics, attributes, and properties, the computer came to be seen as a creative medium in its own right and used to explore novelties (Reas & McWilliams, 2010, p. 31; Richardson, 2016, p. 16).

Furthermore, design has been relying on generative creation not only to produce innovative and hitherto unattainable shapes but also to rethink the traditional design process and explore other aesthetic possibilities. Since the early 1970s, when generative design began to be studied by pioneers such as architect John Frazer, alike approaches have attracted the attention of many academic researchers interested in design theory and of the CAD industry

(Computer-Aided Design), interested in selling parametric and optimization solutions (Krish, 2010, p. 90). Even though it was born within architecture, generative design can be, and is, explored in the creation of different types of physical and digital artifacts (Mountstephens; Teo, 2020, p.2). In reality, the reasons behind this adoption are based on the benefits of employing the method compared to conventional design approaches and not on its adequacy to a specific context.

Traditionally, a design project depends on the central role of designers (or the team) to execute it, from its initial conceptual stages to the finalization of the proposal. User needs and expectations along with technical and aesthetic requirements are continually and directly articulated to be contemplated by the designed product — a type of creative process that relegates the computer to the role of executing human decisions. In generative design, artifacts are produced by algorithms or autonomous systems, albeit partially, which can be fully automated or refined according to interventions made by human designers. The critical point is that computational intelligence is used as an active participant in the creative process and not only to support previous choices (Mountstephens & Teo, 2020, p.1). Nevertheless, due to the added computational complexity, there is a fundamental change in the

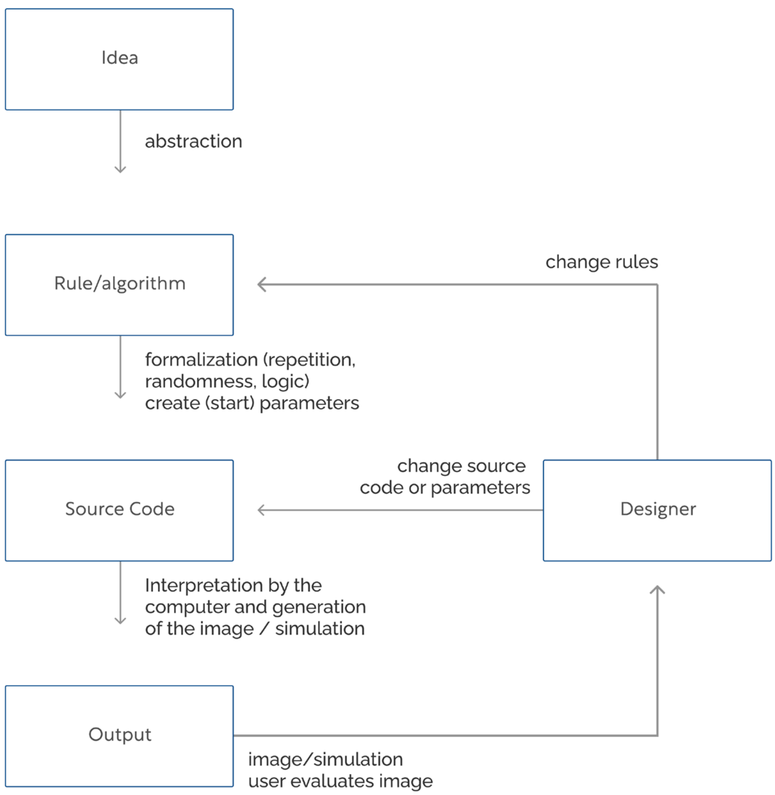


Figure 31: Reproduction of the model created by Groß et al. (2018, p. 504)

creative process: the designer is no longer an executor of tasks but a conductor. A role that Groß et al. (2018) refer to as an “orchestrator of decision-making processes”. According to the authors, this is what generative design is about: **“iteratively developing different processes and then selecting those that produce the most visually compelling results”**.

To illustrate this fundamental change, Groß et al. (2018) proposed a model for the creative process in generative design characterized by an emphasis on abstraction and on a different role for designers (Figure 31). The main change is that traditional craft recedes to the background, and abstraction and information become the protagonists. Thus, the relevant question is no longer ‘How do I draw?’, but ‘How do I abstract?’ (Groß et al., 2018, p. 504).

In opposition to the conventional process in which designers implement an idea directly, intervening and refining the artifact, when generative creation is employed, a process of abstraction is undertaken to transform the idea into an algorithm which is later translated into a source code, or program, to run and generate results. Being an “indirect” design process, as referred to by Omine (2014, p. 85), designers might participate at all steps through activities that encompass the creation of algorithms, writing of code, the evaluation of results, and the consequent refinement of programs.

As this is an unpredictable way to create, Groß et al. (2018, p. 507) also highlight the role of human designers in evaluating results and in the refinement of algorithms as the basis for an incremental and necessary improvement. Something particularly critical considering that replacing this evaluation strategy would require satisfactory automation of highly subjective and hardly quantifiable aspects, such as aesthetic preferences and choices (Mountstephens & Teo, 2020, p.5).

In contrast to the conventional approach, we do not directly put our hands on the image but instead change the underlying abstraction or individual parameters in the program and continue to refine each iteration until the desired result is achieved (Groß et al., 2018).

Besides being a central aspect of the above-discussed process, abstraction is also vital to computational thinking (or CT), a concept we will explore as a valuable additional theoretical layer to interpret this research’s object. After all, as already explored, generative creation is closely linked to computational processes.

Although there is no single definition for what this specific type of thinking is (Shute et al., 2017), informally, computational thinking describes the mental activities involved in formulating a problem in such a way that it admits computational solutions. Solutions that then can be performed by humans, machines, or both.

As an attempt to more formally define it, Kelly and Gero (2021, p.6) point out the existence of two distinct trends. In the first, authors seek to define computational thinking based on the type of reasoning involved in it. For instance, in one of her first publications on the subject, Wing (2006, p.33) defined computational thinking as solving problems, designing systems, and understanding human behavior through computer science concepts. Furber (2012) defines it as the method of recognizing computational aspects in the world around us and applying computer science tools and techniques to understand and argue about natural or artificial systems and processes. And for Denning (2009), in turn, computational thinking can be understood as a mental orientation to face problems as a process that converts an input into an output, associated with the search for an algorithmic process to do it.

The second trend defines computational thinking through the solutions it is capable of producing. For example, Yadav et al. (2014) describe the concept simply as a mental activity used to abstract problems and formulate solutions that can be automated. Wing (2011), in a second more recent work, defines computational thinking as the "processes involved in the formulation of problems and solutions so that these solutions can be represented and, consequently, carried out by information processing agents". Moreover, focusing on the elements and abilities that compose it, Bocconi et al. (2016, p. 18) define computational thinking as the "mental processes involved in solving problems so that they admit a computational solution that involves **abstraction, algorithmic thinking, automation, decomposition, debugging and generalization**", which they understand as the core skills or abilities of computational thinking. Finally, going partially in line with this proposition, Beecher (2017, p. 7) adds the concepts of **logical thinking, modeling**, and **evaluation** to the list.

The most crucial cognitive skill in computational thinking is **abstraction** (Kelly & Gero, 2021, p.6; Bocconi et al., 2016, p. 17-18). According to Grover and Pea (2013, p. 39), its importance as a key concept of computational thinking and as the element that differentiates it from other types of thinking is undisputed.

In essence, by abstracting, people express an idea in a specific context while suppressing details irrelevant to that context (Beecher, 2016, p. 56). In this way, it is possible to say that the ability to abstract is related to the act of choosing the correct details to be removed from a problem so that it can be better understood or represented (Csizmadia et al., 2015, p. 7). By placing 'How do I abstract?' as the central question of the creative process in generative design, for example, Groß et al. (2018, p. 507) illustrate the existence of an abstraction layer that thoroughly mediates it. For them, one of the biggest challenges for designers in this approach is abstracting vague ideas into formal computer-interpretable instructions.

In any case, when heading towards formalization, the abstracted idea needs to be transformed into an algorithm that, in turn, can be understood as "a set of steps to accomplish a task." (Cormen, 2013, p. 1) or, more rigorously, as “a finite, deterministic, and effective problem-solving method suitable for implementation as a computer program” (Sedgewick, 2011, p. 4). In essence, this abstraction followed by organizing an idea into a set of well-defined steps can be understood as **algorithmic thinking**.

With possible direct implications for the design processes in which they participate, Reas and McWilliams (2010, p. 13) state that algorithms have four essential qualities:

1 - **There are many different ways to write an algorithm**, as there are different ways to write and organize instructions that lead to the same result;
2 - **An algorithm starts with assumptions** such as the types of data to be inputted that allow it to “focus” on a delimited aspect of the problem;
3 - **Algorithms also comprise decisions**, which are made throughout its execution, influencing the procedure; and
4 - **A complex algorithm should be broken down into smaller modules**, which allows the problem to be approached more carefully and correctly.

For design, although we are discussing algorithms in a specific generative context, we have already seen at the beginning of this subchapter that they are not a new concept. As put concisely by Omine (2014, p. 78-83), Karl Gerstner — one of the “most coherent theorists” of graphic design, promoted discussions on the subject since the middle of the 20th century, when he published his book Designing Programs (1964): “For Gerstner, even the typographic grid can be considered a program [and, consequently, an algorithm], as it works as a system that allows permutations in space”[4].

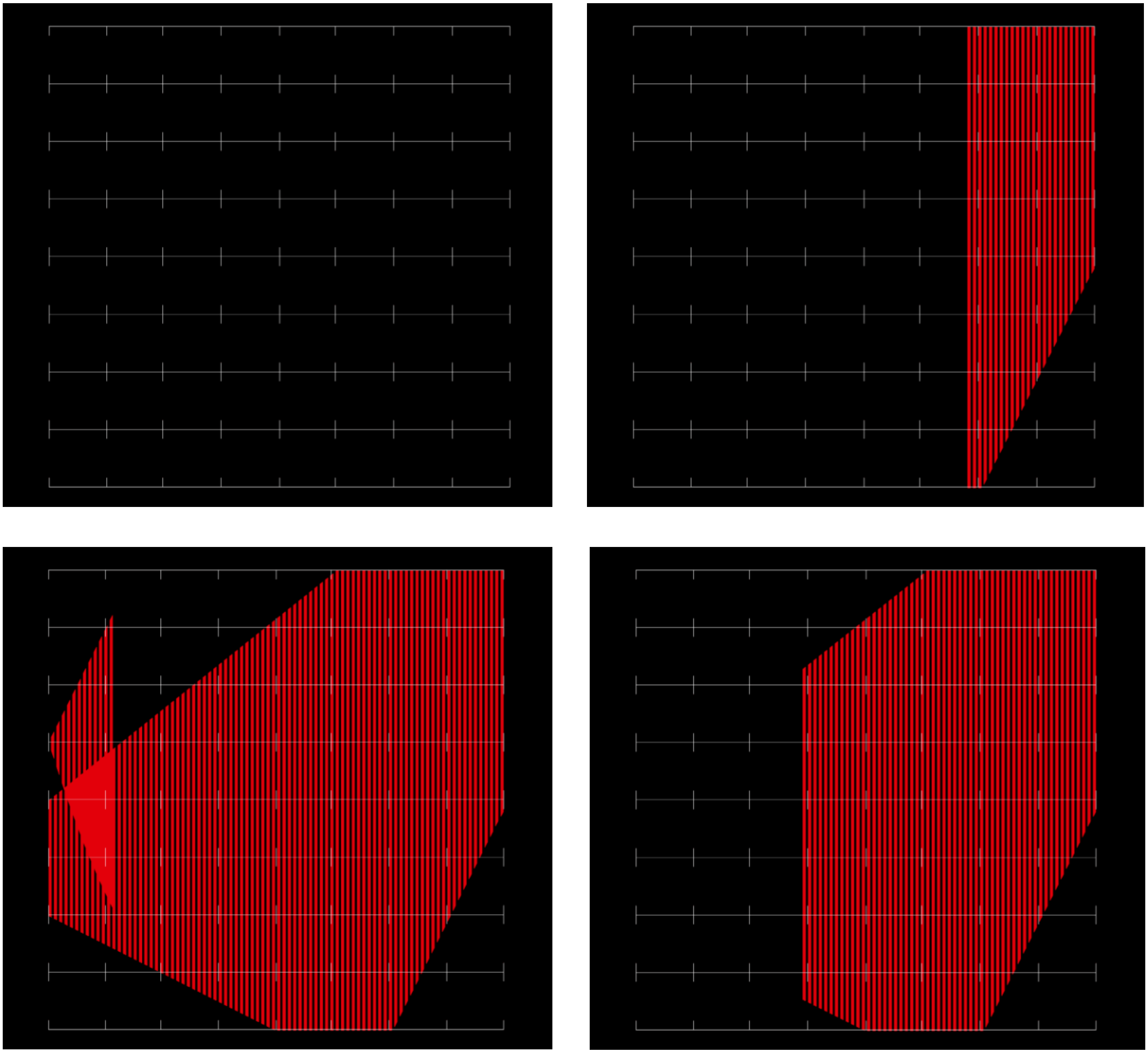
In contemporary works of many designers and artists, we can still find algorithmic thinking as an essential and characterizing element.

In his book Analog Algorithm (2019), for example, the German illustrator and graphic designer Christoph Grünberger experiments with a series of grid-based procedures to define a clear rationale for each of his works. For him, a rational and logical approach to design is not opposed to creative freedom, but an accelerant for the creative process. Such a belief motivated him to reflect on his career and present many examples of how algorithmic creation enables the production of an universe of possibilities after the establishment of a sufficient foundation — the grid (Figure 32) (Grünberger, 2019).

Another example of algorithmic application into design can be found in the visual identity the creative studio FIELD produced for the conference IBM Think 2020 (Figures 33 and 34). The studio relied on generative algorithms powered by data from many different musical instruments to deliver “a new kind of sound visualisation”, as referred to by them in their website. Therefore, graphic elements responded to instruments such as melody, vocals, machines, drum+bass, and space+details, becoming elements

4. Para Gerstner, até o grid tipográfico pode ser considerado um programa [e, consequentemente, um algoritmo], ao funcionar como um sistema que permite permutações no espaço.

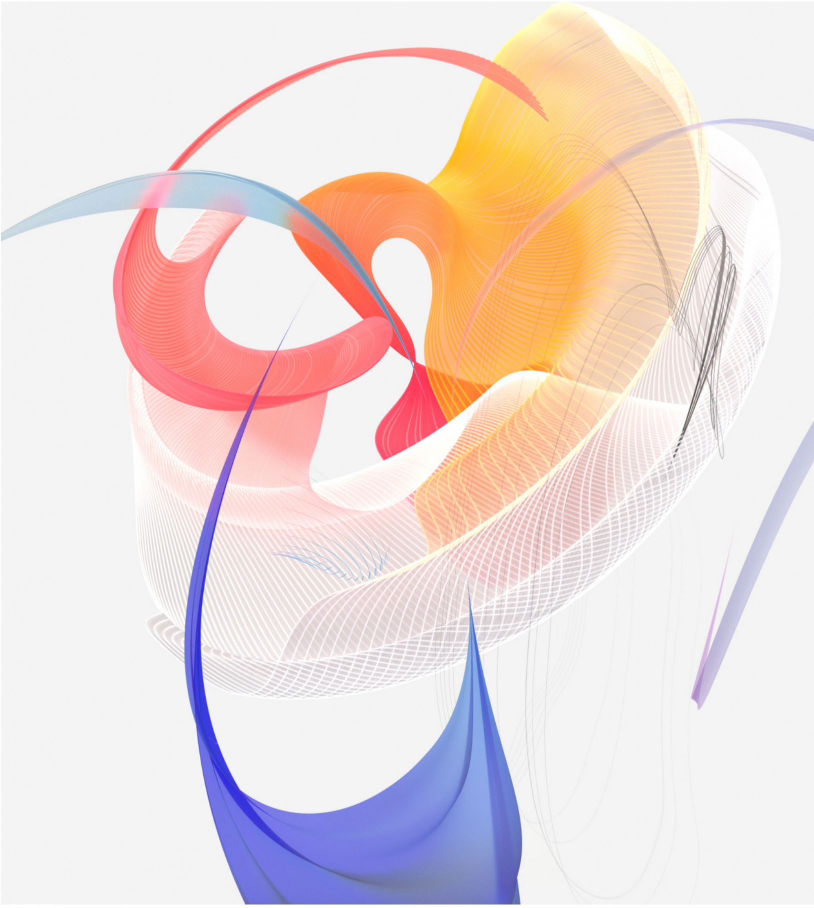
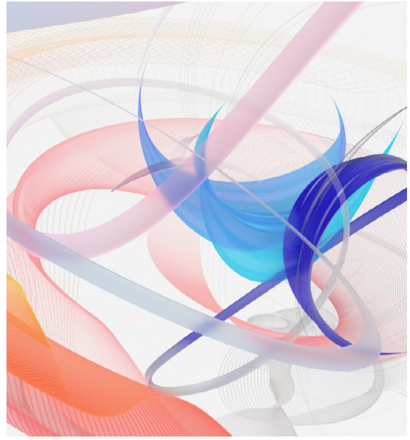
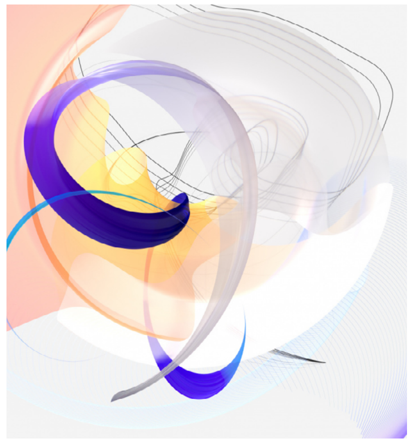
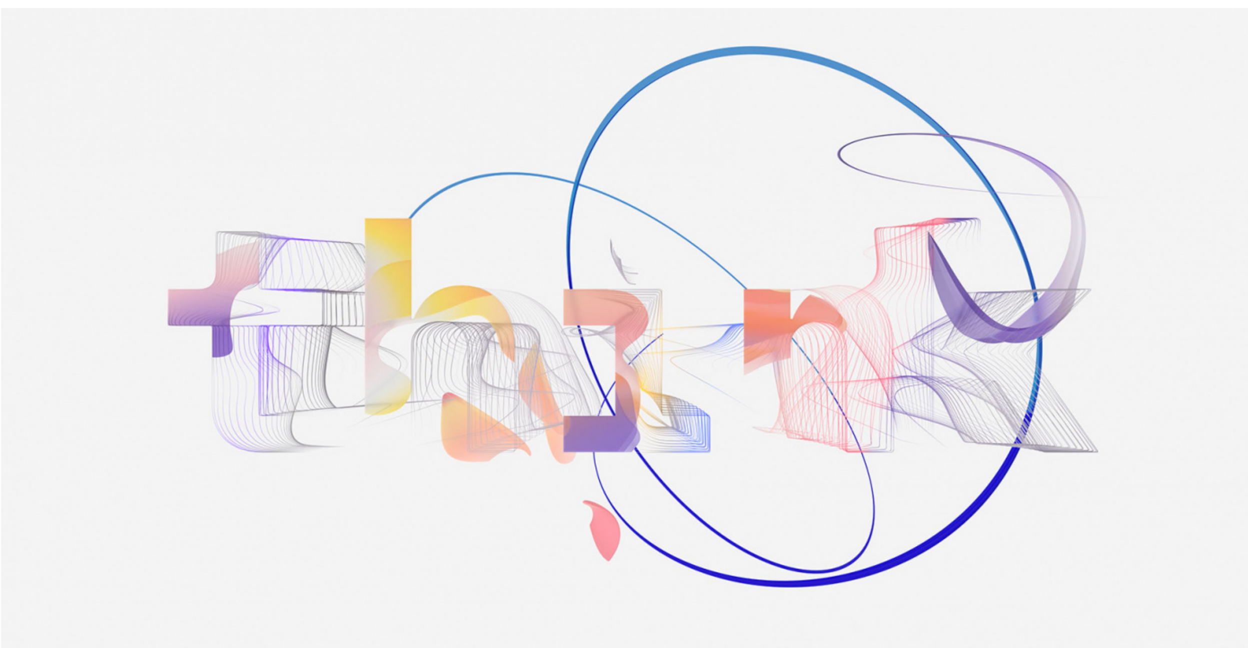
Figure 32 (nest page / top): Algorithmic visual experiments created by Grünberger for his book Analog Algorithm (2019).



to be applied as key visuals across all media for the event (Field, 2020).

Algorithms, though, are only part of solving the problems we are interested in. Since computational environments manipulate data through lines of code, algorithms must be translated into **programs** (review model by Groß et al. (2018)) so that they can, in fact, work. At this point, computational thinking reaches a very practical spectrum (Richardson, 2016 p. 20).

In addition to the computational-thinking skills already discussed, we program by employing frequent **debugging** and **generalization** processes as we seek to create efficient and correct programs to deliver the desired quality of **automation**. When **debugging**, we systematically analyze and evaluate programs or algorithms through testing, reviewing logs, and

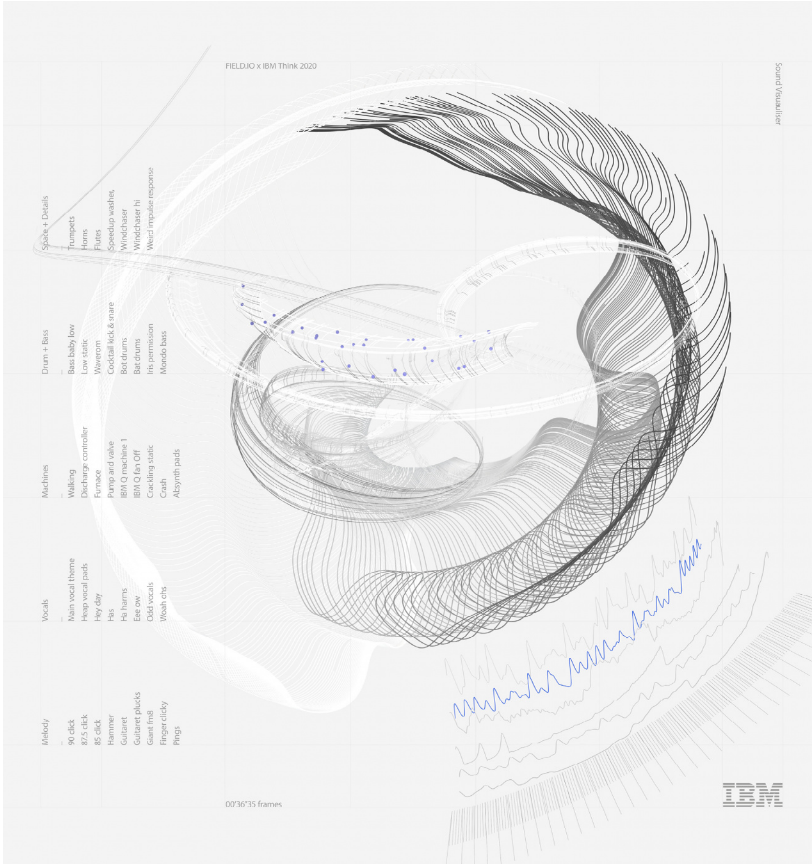


Figure 33 (previous page): Visuals created by FIELD for the IBM Think 2020.
Figure 34 (current page / top): A poster created by FIELD for the IBM Think 2020.

the intuitive application of **logical thinking** — that allows us to anticipate and verify results. Through **generalization**, we identify and base ourselves on patterns, similarities and connections that can help us write codes and compose the general strategy of what needs to be programmed. Finally, by **decomposing** a problem, or artifact, we can break it down into smaller elements and organize it in a way it can be understood and solved. This makes complex problems, whether related to writing a program or defining a design project, easier (Csizmadia et al., 2015, p. 7).

Moreover, to effectively write the program's **source code**, we can select the most suitable programming language, among the thousands of options that exist. To make this decision, we can rely on criteria such as the operating system or device on which the program will run; the desired aesthetic quality; and personal preference. Also, since there are several languages with different syntaxes, limitations, and modes of use, programmers reckon on the fact that their choice will naturally influence the style and possibilities of execution to make a conscious decision (Reas & McWilliams, 2010, p. 17). If in 1992, for example, to draw a line on the screen between the coordinates (10, 10) and (20, 20) using OpenGL it was necessary for the program to contain the following commands:

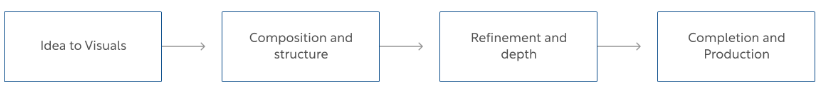
```
glBegin(GL_LINES);
   glVertex2f(10, 10);
   glVertex2f(10, 10);
glEnd();
```

Today, through sophisticated languages oriented towards aesthetic production, we can draw the same element using the commands:

`line(10, 10, 20, 20)`, in Processing; and
`ofDrawLine(10, 10, 20, 20)`, in openFrameworks.

With a notable focus on practice, programming and experimentation, Zhang and Funk (2021) proposed a four-stage creative process model for projects in which computing is the primary "material" (Figure 35). The stages are **idea to visuals; composition and structure; refinement and depth;** and **completion and production**.

The project begins with developing **visual concepts** that will serve as a starting point for the project. To this end, instead of conventional approaches such as creating mood boards and drafts, Zhang and Funk suggest that this process takes place in a very exploratory way, with successive programming experiments. By following this process of quickly alternating "between code and canvas," they claim that programmers will better understand how their programs and algorithmic choices determine each of



the aspects being "drawn" on the screen. Then, once the initial visual concepts are reasonably developed, the next step of the process is improving them by organizing the graphic elements and defining their interrelationships. At this point, it is possible to experiment with a series of **compositional** practices and concepts, such as repetition, variation, and randomness, and incorporate them into the generative algorithm. The intention is to start adding complexity to visual explorations.

In the **refinement and depth** stage, the intended elements and visual composition are properly programmed, as a structure for the code is also determined. At these moments, the execution of each of the graphical elements and compositional rules is defined along with the data necessary to make that happen. Therefore, functions for moving and positioning elements, controlling sizes, coloring, and employing user input data to control certain

Figure 35 (above): Illustration of the model proposed by Zhang and Funk (2021).

aspects are written.

Finally, in the **completion** stage, the program is prepared to produce the expected artifact. This means that if a movie or animation is being produced, the team will worry about correctly setting the frame rate per second and adjusting the program to synthesize the clips in the necessary resolution. On the other hand, if the outcome is a poster, they will probably be concerned about producing image files large enough to print with pixel-perfect quality. Moreover, at this stage, it might also be interesting to run the program on a mobile device, or over the internet, which will require specific adjustments.

Furthermore, Zhang and Funk (2021) argue that creative processes do not always start with an idea or concept to be elaborated. Counterpoint they explain through the discussion of two different approaches to ideation. In the first approach — **concept-based ideation** —, creative work begins conceptually, probably before computational tools are used. Since the main challenge in this approach is to turn an abstract idea, already in mind, into a satisfying computational result, one implication is that designers or programmers already have ideas and expectations about how the employed concept will be materialized. In the second approach — **material-based ideation** —, computing and programming are taken as the creative "material" we will be experimenting with to encounter concepts to be elaborated. More practically, this means that the creative work will gradually take a more

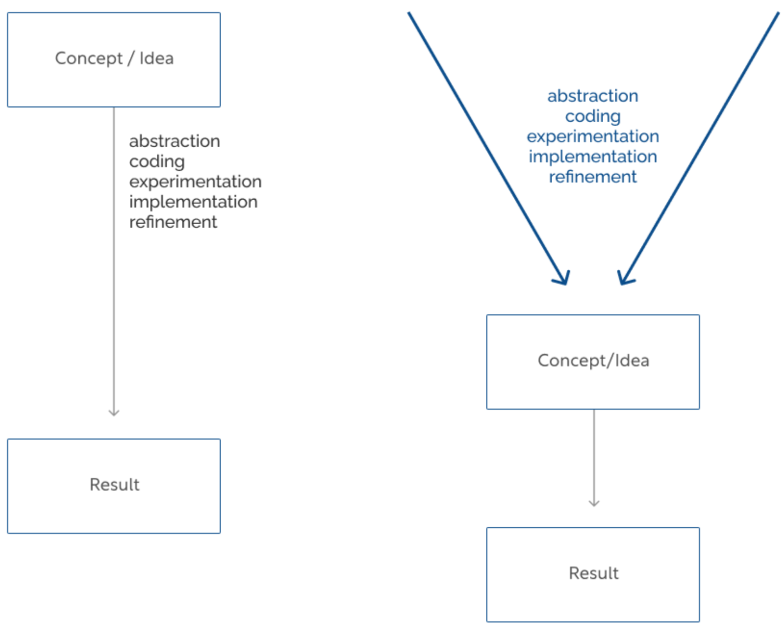
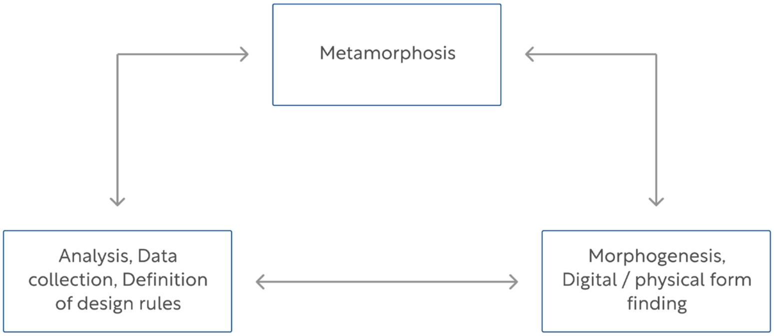


Figure 36: Illustration of the strategies of ideation proposed by Zhang and Funk (2021).



concrete shape and direction only after a series of experiments with different tools, processes, algorithms, and languages.

In short, while concept-based ideation sees computational material as a means of communicating a concept, the other sees it as the very concept that is going to be elevated and expressed. Zhang and Funk (2021, p.447) also complete their discussion by saying that such a strict delimitation between one approach and another does not happen in real life, but rather flexible creative work that constantly alternates between them.

In a way, the above-discussed distinction in the two approaches for ideation inherits elements from an earlier debate concerning the computer's role in creative activities such as design and art. As stated at the beginning of this subchapter, for a long time, computing was employed to gain precision and efficiency rather than exploring new procedural and aesthetic possibilities. A use, according to Reas and McWilliams (2010, p. 25), centered on the **production** of preconceived shapes and concepts. However, when employed with a **conception**-oriented perspective, the computer actively participates in developing the shape or concept in question.

For Agkathidis (2015, p. 14), for example, when used for **conception**, one of the main strengths of generative creation is its ability to offer new directions to design projects and break with predictable relationships between form and representation. Something that occurs because computational complexity is adopted as a co-drawer with whom designers "negotiate" creation. The author, here, refers to a morphogenetic approach, a conception model in which the computer, once fed with a specific set of **design rules,** conceives a series of artifacts that contemplate them (Figure 37).

Although it does not have a specific order, the process comprises three main steps. First, in a stage of **analysis, data collection, and definition of design rules**, the focus is on obtaining information about the various relevant aspects of the problem, such as context, program, structure, and performance, and defining the design rules that the system must consider. Then, in a stage of **morphogenesis**, the computer employs algorithmic

Figure 37 (top): Reproduction of the model proposed by Agkathidis (2015, p. 14).

processes to create the first versions of the expected results at a more superficial level of detail. Finally, in the last stage of **metamorphosis**, the proposed concepts are refined and adjusted on the computer to become the final results.

Accordingly, Grünberger (2019, p. 13) understands generative design as a practice in which control is relinquished in favor of results since the entire design process becomes subordinate to an autonomous logic or random seed. Because of this, the author states that designers start behaving not only as creators but mainly as interpreters and curators who must spontaneously evaluate and select shapes and patterns while ensuring that the process employed is adequate and compatible with the strategy of the project.

Finally, for those interested in optimization, significant advances in computational power have enabled design programs to make essential contributions in solving complex problems — for which the space of design solutions is vast and dynamic (Buonamici et al., 2021, p. 144). However, besides being used to conceive optimal alternatives for a given problem, adopting computing as a means can also point out new procedural and aesthetic paths and potentialize human designers' creativity (Buonamici et al., 2021, p. 144).

By relying on generative poetics, for example, several designers and artists have been engaging in political and experimental projects intended to motivate explorations of new languages and discussions concerning the impacts of technological transformations in our societies (Brain & Levin, 2021, p. 5).

> *"In computational art and design, many responses to the questions of what and why continue historical lines of creative inquiry centered on procedure, connection, abstraction, authorship, the nature of time, and the role of chance" (Brain & Levin, 2021, p. 4).*

In the end, such a paradigm shift clarifies the relevance of studying generative creation as an element capable of instigating novel practices and aesthetics to the field of design (Brain & Levin, 2021, p. 4).

We summarize the main contributions of this last subchapter through the sentence and the board below.

> **When comprising generative systems, designers' creative processes fundamentally change, as their role shifts from directly manipulating the product to curating and evaluating the computational processes that are supposed to produce it** (Groß et al., 2018; Grünberger, 2019). **This creative process would be: starting from an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output – what would possibly feedback the cycle. Moreover, designers would participate throughout the whole process** (Groß et al., 2018). **Due to the existence of a characteristic layer of abstraction** (Beecher, 2016; Csizmadia et al., 2015) — **as designers need to constantly think in terms of algorithms to create desired artifacts — the relevant question is no longer 'How do I draw?', but 'How do I abstract?'** (Groß et al., 2018)**, a statement that also illustrates a clear relationship between generative design and computational thinking** (Wing, 2011; Kelly & Gero (2021); Furber, 2012; Denning, 2009; Yadav et al., 2014; Wing, 2011; Bocconi et al., 2016) **— to which abstraction is also a central ability** (Kelly & Gero, 2021; Bocconi et al., 2016; Grover & Pea, 2013). **Nonetheless, the creative process does not always have a concept as a starting point for ideation** (**concept-based ideation**)**. It can also rely on many explorations with the material — programming and software tools — as a means to encounter more concrete concepts to be pursued as selected ideas** (**material-based ideation**) (Zhang & Funk, 2021).

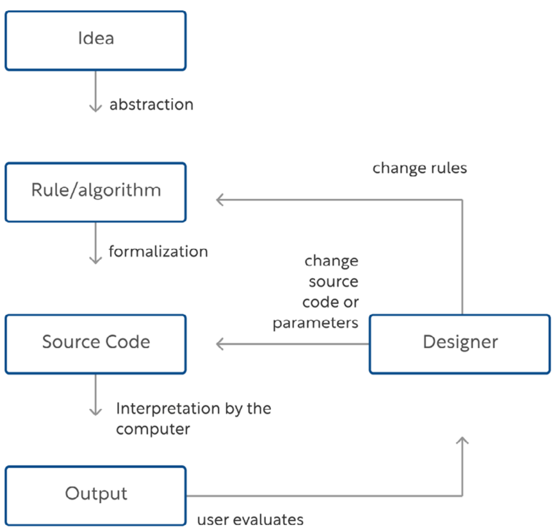
Board 3: Main Contributions of Subchapter 1.3

Created by the author

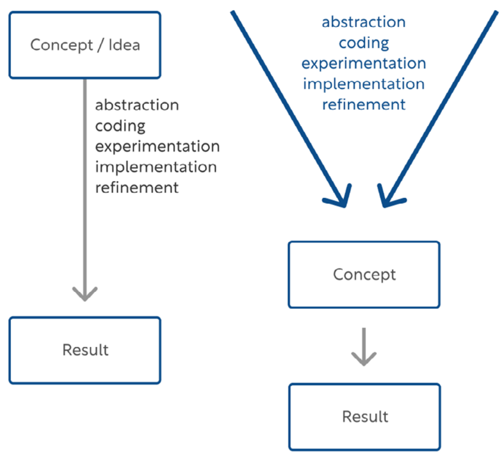
Theoretical Contributions (TC.3)

When comprising generative systems, designers' creative processes fundamentally change, as their role shifts from directly manipulating the product to curating and evaluating the computational processes that are supposed to produce it (Groß et al., 2018; Grünberger, 2019)**. This creative process would be: starting from an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output – what would possibly feedback the cycle. Moreover, designers would participate throughout the whole process** (Groß et al., 2018)**. Due to the existence of a characteristic layer of abstraction** (Beecher, 2016; Csizmadia et al., 2015) **— as designers need to constantly think in terms of algorithms to create desired artifacts — the relevant question is no longer 'How do I draw?', but 'How do I abstract?'** (Groß et al., 2018)**, a statement that also illustrates a clear relationship between generative design and computational thinking** (Wing, 2011; Kelly & Gero, 2021; Furber, 2012; Denning, 2009; Yadav et al., 2014; Wing, 2011; Bocconi et al., 2016) **— to which abstraction is also a central ability** (Kelly & Gero, 2021; Bocconi et al., 2016; Grover & Pea, 2013)**. Nonetheless, the creative process does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — as a means to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)** (Zhang & Funk, 2021)**.**

Models for Generative Design and for Ideation (concept-based and material-based)



(Groß et al. (2018)



Zhang & Funk (2021)

1.4 Main Contributions and Theoretical Proposition

This chapter went through the concepts, theories, and models that compose the foundations of our case studies.

In the first subchapter — Creative Processes in Design, we have defined creativity and the creative process and discussed a few models to describe it. More specifically, we learned that **"the creative process can be defined as a sequence of thoughts and actions that comprise the production of work that is original and valuable"** (Lubart, 2021, p. 3) and that such a sequence of thoughts and actions needs to be employed in the production of a valuable novelty (at least for the people involved in the process) to be considered a creative process. It would be a process of creation otherwise.

We also understood that **design thinking has relevant idiosyncrasies compared to conventional problem-solving approaches**, primarily due to the specific ways in which problems are ***framed*** and how **problems and solutions coevolve** throughout a project. Because of this, we relied on Lawson & Dorst's model (**formulate, represent, move, evaluate and manage** as main design activities) to understand specific aspects of how the creative process happens in design.

The following question arises as this first subchapter ends: "Now that we know what the creative process is — thus having the lens/structure through which cases will be analyzed — and how it can be adapted to a generalist design context, what would be the specifics involved in discussing it within an interaction design practice?"

As an answer to the question above, the second subchapter focused on moving the theoretical discussion into a more practical layer by enriching it with definitions and models of design processes proposed by interaction design researchers and practitioners. Since this study aims to interpret creative processes employed in the design of interactive products, discussing specific models and activities of **interaction design** was considered the natural next steps.

We learned that, despite encompassing different points of view and traditions, interaction design can be defined as **"the discipline that seeks to define the shape and behavior of interactive products, services, and systems"** (Goodwin, 2009, p. 5). Moreover, regardless of having diverse purposes, professionals answer questions such as the following ones when designing interactive products:

1. What activities will the product or service support, and how?
2. What information do users need at each point in that process?
3. What information does the system need from users and the context?
4. How is functionality segmented and manifested?

Furthermore, due to the somewhat generalist nature of interaction design, there are different points of view concerning what the discipline should be focusing on delivering, and what approaches should be used. For instance, it's not a consensus if interaction designers should be dedicating their efforts to making engineers' and scientists' inventions approachable; to crafting interactive products that behave in a useful way; or to coming up with solutions that not only are useful but mainly enhancers of human communication (Saffer, 2009, p. 4).

Concerning execution, the subchapter went through models of creative process that rely on more sequential approaches to design, such as the ones proposed by Sharp et al. (**discover, define, develop, deliver**) (2006), Saffer (**design strategy; design research; structured findings; ideation and design principles; refinement and prototyping, testing and developing**) (2009) and Goodwin (**project planning, research, modeling, requirements definition, framework definition, detailed design, and implementation support**) (2009), and others that comprise the sometimes random and interrelated nature of each one of the stages in the process, such as Moggridge's (**constraints, synthesis, framing, ideation, envisioning, uncertainty, selection, visualization, prototyping, and evaluation**) (2007).

Moreover, with the consolidation of interaction design in the previous decade and the rise of UX (user experience) as the primary term to describe the practice and professionals in the field, many additional models have been proposed to guide designers' works within contemporary scenarios. **Agile approaches** (based on frequent collaboration and rapid development) began to be prioritized over conventional waterfall approaches, and this shift naturally influenced how designers were supposed to deliver their creations. To fit in this highly collaborative and practical contexts, designers have been relying on many recent models of creative process such as the ones proposed by Unger and Chandler (**plan, define, design, develop, and deploy**) (2012), Gothelf and Seiden (**hypothesis and assumptions; design it; create an MVP and research and learning**) (2016) and Cagan (**two continuous tracks of discovery and delivery**) (2017).

During *Generative Creation and Computational Thinking in Design,* we have established historical and conceptual parallels between generative creation, computational thinking, and design. Since generative design is recognized as a natural way to refer to generative systems being incorporated into a design practice, we began by investigating the possible ways to define it.

After discussing the fundamental differences between a generative design process and a conventional one (**the role of designers changes from performing tasks to orchestrating the decision-making process of the computer**), the definition proposed by Groß et al. (2018, p.5) was introduced: **generative design can be understood as "iteratively developing different**

processes and then selecting those that produce the most visually compelling results". Along with the definition, the authors also proposed a model of creative process composed by the stages: **idea**; abstraction into **rule/algorithm**; formalization through **source code**; and computational generation of the **output** through the interpretation of the source code. In this proposal, designers are still supposed to participate by refining and changing the rules behind the process being executed by the computer until something satisfactory is obtained — a process in which **abstraction** is one of the essential activities, as referred to by the authors.

After being understood as one of the most important elements within the creative process in generative design, further research on the **abstraction-based** nature of it became necessary. This gap was filled by research on **computational thinking**, to which abstraction is also a central element (Kelly & Gero, 2021; Bocconi et al., 2016). As stated by Shute et al. (2007), this form of thinking describes **the mental activities involved in the formulation of a problem in ways through which it admits computational solutions to be carried out by humans, machines, or both.**

Through further research, Bocconi et al. (2016, p. 18) identified the primary abilities involved in computational thinking and proposed a new definition encompassing them: **"computational thinking describes the thought processes entailed in formulating a problem so as to admit a computational solution involving abstraction, algorithmic thinking, automation, decomposition, debugging and generalization"**.

When implying that **'How do I abstract?**' is the most relevant question in the generative design process, instead of "How do I draw?", Groß et al. (2018, p. 507) are not only illustrating the existence of a layer of abstraction that intermediates the whole creative process but also establishing a clear intersection between design and computing in which generative design is positioned — something that suggests the need of concepts of both areas for a sufficient understanding of the creative process investigated. We also learned that, by abstracting, creators can design **algorithms, "a set of steps to accomplish a task"** (Cormen, 2013, p. 1), or more formally **"a finite, deterministic, and effective problem-solving method suitable for implementation as a computer program"** (Sedgewick, 2011, p. 17), which can be posteriorly translated into programs to be executed by computers in the generation of desired outcomes through a myriad of programming languages available.

Furthermore, despite being the only two forms of thinking to gain prominence since the beginning of the XXI century, **studies about how design thinking and computational thinking relate to each other are scarce** — perhaps due to the lack of consensus when it comes to defining them, or to the assumed differences between the problems each one of them is more suitable for (Kelly & Gero, 2021, p. 1). Nevertheless, as Kelly and Gero (2021, p. 7) suggest, **some tasks involve both computational and design thinking**, such as a web designer addressing the design of a website for a client or an engineer during a design activity of setting up parametric models.

Imagine our web designer begins addressing a client's brief by following a conventional design thinking approach (e.g., the double-diamond), thus spending some time researching stakeholders' expectations and final users' needs. Of course, this would expand the frame through which the problem will be understood by arising additional knowledge related to these contexts. However, suppose that, at some point in the process, the web designer needs to develop reusable components for the current set of pages of the website being created and the possible future ones. This designer would be abstracting this problem into a set of variables capable of determining which design aspects of the website should be componentized — and thus successfully applied to future sections of the website without further effort — and which not. Similarly, when engineers need to establish parametric design systems, computational thinking is necessary, as these parameters need to be abstracted from the problem and the context to synthesize maybe hundreds of alternative solutions. However, for these solutions to be abstracted into a set of parameters capable of modulating them, relevant knowledge about the context — such as users' needs and environmental restrictions — must be obtained so that the team can understand which variables will feed these parameters' creation.

It appears that in generative design, designers are constantly dealing with these two forms of thinking, as well.

Besides Groß et al. (2018, p. 504) a couple of other researchers have proposed models to describe the creative process in generative design, such as the ones created by Zhang and Funk (**idea to visuals, composition and structure, refinement and depth and completion and production**) (2021), and Agkathidis (**analysis, data collection, and definition of design rules; morphogenesis and metamorphosis**) (2015). Models also illustrate two different approaches to how the creative process happens in generative design: a **concept-based ideation approach** — in which the creative work starts conceptually, before execution, which means that designers might intuitively know how the idea will look, sound, or feel. — and a **material-based ideation approach** — in which programming is considered the creative material designers will be experimenting with to find the concepts they will pursue, which means that more concrete creative directions only are followed after several experiments with programming languages, tools, and software have been executed.

Finally, as last discussion about the third subchapter, it is worth noticing that a few different points of view exist when it comes to defining generative design and describing how generative designers work — perhaps due to the complex conceptual network involved in defining and describing an approach that is both recent (as a more popular practice) and multidisciplinary. As suggested by Brain & Levin (2021, p. 4), "in computational art and design, many responses to the questions of what and why continue historical lines of creative inquiry centered on procedure, connection, abstraction, authorship, the nature of time, and the role of chance".

As a preparation for our case studies, the following theoretical proposition (TP) has been elaborated through the synthesis of the contributions (TC.1, TC.2, TC.3) presented during this chapter:

> **When designing interactive products[5] powered by generative systems, designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.[6] Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.[7] Due to the existence of a characteristic layer of abstraction[8] — as designers need to constantly think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking[9] — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking[10]. Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation).[11] It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation). It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches[12]; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track[13]. Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy[14], and the activities designing alternatives, prototyping, evaluating, and discovering requirements[15].**

5. (Goodwin, 2009; Saffer, 2009; Sharpe, Preece & Rogers, 2019; Unger & Chandler, 2012; Gothelf & Seiden, 2016; Cagan, 2017)
6. (Groß et al., 2018; Grünberger, 2019)
7. (Groß et al., 2018)
8. (Groß et al., 2018)
9. (Wing, 2011; Kelly & Gero (2021); Furber, 2012; Denning, 2009; Yadav et al., 2014; Wing, 2011; Bocconi et al., 2016)
10. (Kelly & Gero, 2021; Bocconi et al., 2016; Grover & Pea, 2013)
11. (Zhang & Funk, 2021)
12. (Saffer, 2009; Goodwin, 2009)
13. (Unger & Chandler, 2012; Gothelf & Seiden, 2016; Cagan, 2017)
14. (Unger & Chandler, 2012)
15. (Sharp, Preece & Rogers, 2019)

Chapter 2

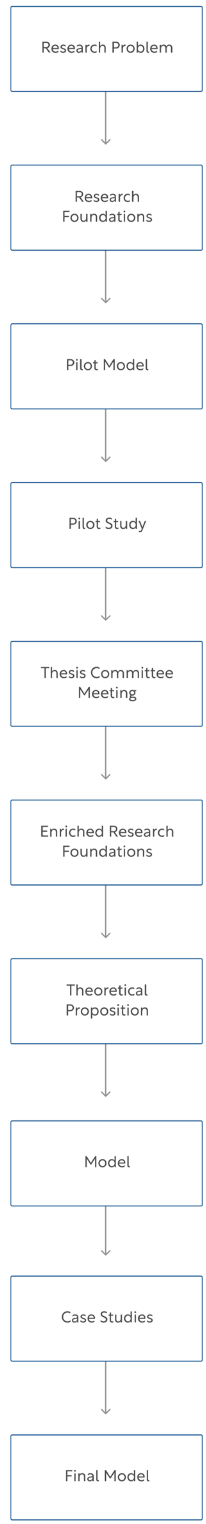
Method

2.1 Overview

As briefly presented in the introduction, the nature of this research is qualitative and based on a multiple cases study strategy. Such an approach was selected because of the exploratory nature of the question we are seeking to answer, its contemporaneous scope, and the impossibility of controlling the phenomenon being investigated. Stake (2000) refers to case study approaches as a good choice when the goal is generating understanding, experience, and conviction regarding a specific subject. Yin (2014), in turn, highlights the empirical nature of the strategy as he acknowledges its potential to investigate contemporary phenomena in their context.

Another significant motivator for this choice was the complex relationships involved in a study that aims to understand creative processes — it might raise a myriad of aspects related to the process, and to designers, their backgrounds, and beliefs. A multiplicity of variables should be taken into account at the same time that delimiting them might be complicated and undesirably reductive. That said, a holistic approach is favored (Yin, 2014).

Accordingly, Gray (2012) states that case studies are precious and valuable when the purpose is to explore questions in which relationships might be ambiguous and uncertain. However, the author acknowledges that the method relies on a deductive approach, which posed the need to previously elaborate a theoretical foundation to guide the collection and analysis of data. Such elaboration was also aligned with the flexibility inherent to this research style, allowing previously executed steps to be revisited and improved as case studies were conducted (Gray, 2012). For example, during the elaboration of the model, resorting to further literature has been necessary to obtain more relevant and recent contributions. Similarly, once case studies have been finished and their analysis has started, additional adjustments on the theoretical proposition and the model were necessary. Regardless, for explanatory purposes, the diagram on the right illustrates the method and execution of the research.



The research began with the construction of a theoretical foundation capable of sustaining the case studies. As referred to by Yin (2014), the intention was to select and organize the "study propositions" so that they could guide them. This process was undertaken through an exploratory literature review concerning the following topics: the creative process in design, interaction design, and generative creation and computational thinking in design. These topics were discussed throughout chapter 1 — research foundations — and synthesized into a theoretical proposition and model whose purposes were to support the confrontation of patterns during the case studies.

The studies mentioned above were executed with projects in which professionals or studios have designed interactive products powered by

1. https://caiobarrocal.format.com/codes-for-creativity

generative systems. Therefore, the pair designer-process, or team-process, was considered our unity of analysis. We decided so because we understood that information concerning these two main elements (creator and creative process) was necessary to answer the research question. A few additional selection criteria for cases were also established, as exposed in item 2.4.

To picture the creative processes undertaken during the projects studied, we relied on in-depth interviews with professionals and teams and on the analysis of final and partial deliverables created during the work. Moreover, to properly answer the research question, the following general goal has been defined:

To propose a model comprising relevant aspects of the creative processes undertaken by contemporary professionals when designing interactive products powered by generative systems.

Furthermore, to test the adequacy of our research tools and anticipate the quality of the analysis proposed, a pilot model has been created, applied into a pilot study, and results were discussed in a formal thesis committee meeting. Developments proposed by the committee are discussed in item 2.5.

Lastly, to guarantee reliability and easier access to the contributions made by this research, a digital database[1] containing the cases studied has been created.

2.2 Formulating the research question

A The very first activity of this work was to elaborate a research question (Yin, 2014) to delimit our focus and guide accurate data collection and analysis. Such a question is exposed right at the Introduction of this work.

2.3 Research foundations

An even better delimitation of scope and guidance was provided as the research foundations were created and used as the basis of our investigation. This foundation has been conceived as a three-layer conceptual network, encompassing references and models from the following subjects: **creative processes in design**, **interaction design**, and **generative creation and computational thinking in design**.

By approaching **creative processes in design**, we built the framework to describe and understand the investigated creative processes appropriately. Relying on authors such as Sawyer, Cross, Lawson, and Dorst, this research was framed as an investigation of creative processes in design, as models and theories concerning the creative activity and its specificities when in a design context were discussed. Then, we made our research corpus more approachable and enabled the interpretation of **interaction design**

Figure 38(previous page): Representation of the method followed during this research.

processes by relying on the field's literature to answer central questions, such as: "What is interaction design?", "What are the main approaches ?", "What is a conventional interaction design project like?" and "Which models have been guiding the creative activity of interaction designers, especially in the professional practice?". Lastly, by studying **generative creation and computational thinking in design**, we delimited the object of this study and discussed important theoretical propositions about the participation of generative creation in the design process.

Moreover, each of the subchapters of the research foundations was finished with a board and a sentence comprising its main contributions. These contributions were used as the basis of the theoretical proposition and the model transported to the case studies.

2.4 Unity of analysis, selection of cases, and corpus construction

After better delimiting our scope, we defined the criteria for selecting cases and constructing the corpus. Once this study seeks to understand and model the creative process involved in designing interactive products powered by generative systems, the **unity of analysis** (Yin, 2014) was considered the pair designer-process, or team-process. Research methods were then selected to elucidate them. Moreover, since this research's contributions rely on the **theoretical generalization** (Yin, 2014; Gray, 2012) of the phenomena investigated rather than on statistical inferences, cases were selected considering their quality as relevant data sources. Resorting to concepts such as **relevance**, **homogeneity**, and **synchronicity** to assess the quality of potential cases, we defined the following selection criteria (Bauer & Gaskell, 2000).

- **Cases must be contemporary**: attempting to capture how professionals are working right now and make an up-to-date contribution for the field;
- **The professionals or teams researched must have previous experience in the field and national or international relevance**: to assure relevance and wealth of detail by investigating creators with maturity and established practices;
- **The professionals or teams must be involved in the development and technical aspects of the algorithm systems**: attempting to uncover processes more probably influenced and characterized by generative creation;
- **Interaction between the product and users is taken as fundamental by the professionals researched**: so we can interpret processes in which interaction is an aspect designed.

Figure 39 (next page / bottom): the pilot model we used to measure the quality of our case studies strategy.

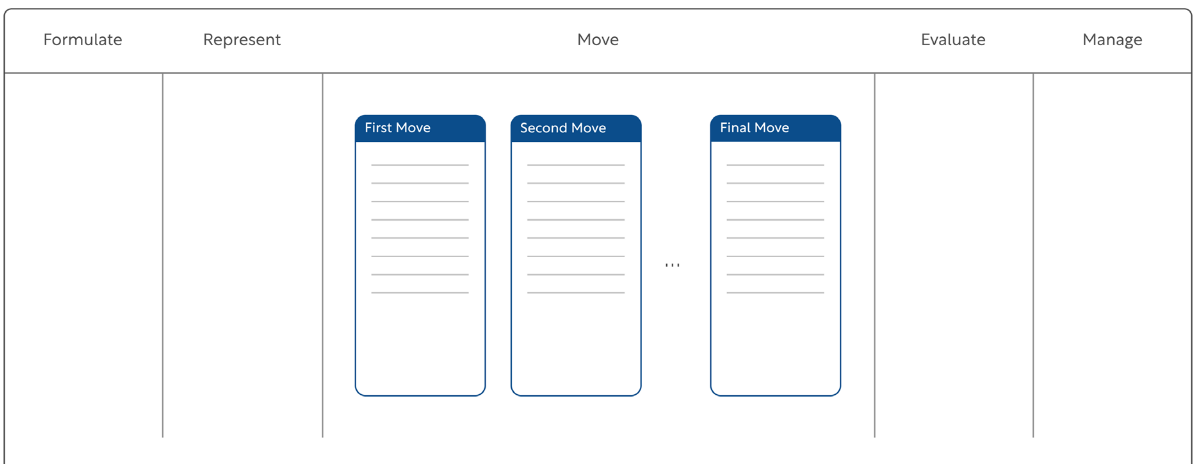
2.5 Pilot study and thesis committee meeting

Relying on definitions provided by the first research foundations, a pilot model was created and put into practice through a pilot case study, which allowed us to assess the adequacy of our research instruments for the problem and experiment with a few different analysis frameworks. The results of this pilot study have been discussed with the thesis committee in a regular meeting and their suggestions were incorporated into the process, resulting in the definitive versions of the research foundations, model, and research tools.

Despite acknowledging the fundamental differences between creative processes in which generative systems are used and conventional ones (Groß et al., 2018), we relied on a generalist design model to obtain insights and start shaping our conceptual framework and our research methods through practice. Therefore, to provide structure for a first mapping, we relied on the model proposed by Lawson and Dorst (2009, p.50) — in which the most relevant skills and activities of a successful design project are categorized into **formulate, represent, move, evaluate** and **manage** — to elaborate the following pilot instruments:

Pilot Model (PM)

The same generalist design model was used as the basis for the induction of hypotheses during the analysis of the pilot case. The following figure illustrates it.



(Lawson & Dorst, 2009)

Pilot Interview Script (PIS)

1: Formulate

–

1.1 - What were the intentions and provocations that motivated the project?
1.2 - What discussions came into play once the intentions were clear? What did you seek to define beforehand?
1.3 - Were there already limitations placed?

2: Represent

–

2.1 - Did the process also have manual steps, or was it all done on the computer?
2.2 - Have you built prototypes?
2.3 - How was the communication between you and those responsible for the development?

3: Move

–

3.1 - Before getting to the final idea, have you considered alternatives?
3.2 - And visually, how did you reach final results?
3.3 - I would like to understand the logic of the algorithm as well. Once it receives signals, how does it synthesize shapes?
3.4 - Any reference, author, artist or project was an important inspiration?

4: Evaluate

–

4.1 - Why did you choose to pursue this idea? What were the criteria?
4.2 - Why did you choose to employ generative approaches?
4.3 - When did you get satisfied and decide it was time to stop?
4.4 - If there was not a deadline, what would you have improved?

5: Manage

–

5.1 - How was the project executed? Main steps and challenges?

Our pilot case was the Brazilian application Heartbits, developed by Estúdio Guto Requena in collaboration with the production studio Midiadub. The results of this investigation (thoroughly discussed in subchapter 3.1) were presented to the thesis committee, and a few improvements were suggested based on the key findings below:

- The investigated process tends to be highly collaborative as designers, developers, and managers work together;
- The process is based on experimentation and rapid iteration. As referred to by interviewees, “agile approaches” were employed;
- MVPs and partial deliverables are constantly developed, discussed, and evaluated by the team as they evolve into the final versions;
- As a first important conclusion, the pilot model and first theoretical foundation were based on an approach to interaction design that was design-centered and delimited (waterfall approaches). Therefore, not so adequate to the study of a process that is notably contemporary and multidisciplinary. There was also a lack of conceptual references concerning the relationships between design thinking and algorithmic approaches (computational thinking), which diminished the interpretation of some aspects of the case;
- To provide greater maturity to the analysis and confrontation of patterns, more contemporary contributions from authors of generative design, generative creation, and computational design needed to be incorporated into this work.

Furthermore, the committee’s feedback motivated the revision of the research foundations, model, and research instruments. Such improvements are summarized by the initiatives below.

- Further research on contemporary interaction design models was made to provide additional references and more clarity concerning how recent trends and organizations influence the investigated processes. Accordingly, different models were included in the subchapter about interaction design, and recent changes in the discipline have been discussed;
- Additional research has also been done to enrich the foundations with discussions about the relationships between design thinking and computational thinking and the idiosyncrasies of design processes carried out with computational approaches. Therefore, recent contributions of models and theories have been incorporated into the subchapter about generative creation and computational thinking in design;
- Because the model used as the basis of the pilot model was not exactly oriented towards a collaborative and experimental creative process, the in-depth interview script has been re-elaborated and transformed into a more open inquiry guide. The intention was to rely on interviewees to describe their perception of the process and the significant steps and activities, leaving discussion and confrontation of patterns for posterior analysis. Moreover, the pilot model was also abandoned as an analysis tool.

Lastly, we decided to reanalyze Heartbits and maintain it as one of our cases by reckoning on the generalist data it provided.

2.6 Data Collection

To picture the creative processes undertaken, our revised data collection strategy relied on two main data sources: professionals (or teams) and the artifacts created by them. In-depth interviewing was the primary method selected for making sense of the studied processes. At the same time, the analyses of both final and partial deliverables were considered additional sources for a visual comprehension of essential changes, decisions, and influences.

Being one of the main data collection methods in qualitative research, in-depth interviews provide a detailed understanding of participants' beliefs, actions, motivations, and processes in their specific social contexts (Bauer & Gaskell, 2000). In addition, they give interviewers several techniques and opportunities to reach depth concerning the reasons, feelings, opinions, and values that permeate interviewees' choices, something important to the present study (Legard et al., 2003).

Acknowledging that researchers have an active role in developing data and meaning when conducting in-depth interviews, the following script has been elaborated to provide structure for thoughts and considerations while also leaving room for divagation and flexibility. It also aimed to emphasize depth, nuance and make interviewees comfortable enough to express thoughts in their own ways (Legard et al., 2003). Moreover, for better conduction, the script was elaborated after the foundations of this research and according to the framework of interview stages proposed by Legard et al. (2003).

Interviews were carried out in Brazilian Portuguese. However, the English version of the script is available below:

Interview Script (IS)

1: Arrival

–

- *Welcoming and icebreaker*
- *Acknowledgment*
- *Introducing the researcher*

2: Introducing the research

–

- *Overview of the research*
- *Researcher's background and motivations*

- *Introduction to the goals of our study*
- *Assure exclusivity regarding data usage.*
- *Ask permission to record audio and video*

3: Beginning the interview

–

- *Ask participants to briefly introduce themselves and comment on their relationship with generative creation*
- *Ask them to comment on the studio or production company they work for, if applicable*
- Ask for an introduction about the project studied: How and when did it start, and what motivated it?
- What did you try to decide beforehand? Were there requirements established?

4: During the interview

–

- How was the project team composed?
- In your understanding, how was the process of creating the project?
- What was the path towards this final idea? Both visually and technologically?
- Have alternatives been considered on this path? If so, why were they abandoned?
- (I would like to understand more about the technological apparatus of the project/installation) How does the system draw shapes? What were the languages or platforms used?
- What are the possibilities of interaction with the artifact? If applicable, how were the sensors articulated?
- Why did you choose to use generative creation?
- When did you decide that the project was satisfactory and that it was time to stop? What were the criteria?
- If there was a more extended deadline, what would have been improved?

5: Ending the interview

–

- (Finishing) How was the interaction between team members and clients during the project?
- Finally, what were the leading design and technological challenges faced? How were they overcome?

- Is there something you feel is important to share before we finish?

6: After the interview

–

- *Further acknowledgments*
- *Explain the expected contribution of the interview to the research*
- *Talk about the consent form to be sent and the collection of additional materials about the project.*
- *Next steps and farewell*

2.7 Model and analysis

The pattern-matching strategy was adopted for data analysis. In this way, a synthesis of predicted patterns — the model — was elaborated, representing what we expected to find during the field research, and posteriorly compared with patterns found through empiricism — case studies. Such a strategy relies on similarities in patterns to reinforce the model and on their divergences to pose questions and the consequent revision. This process is iterated until the model reflects the observed reality more accurately — favoring analytical generalization (Yin, 2014; Gray, 2004).

As discussed at the beginning of this chapter, the foundations of this research were used as the basis for the elaboration of a theoretical proposition (TP), which in turn resulted in the following model (M1) (Board 4) to be transported to the case studies. During them, each of the subpropositions was verified — being endorsed, partially endorsed, or refused — through empiricism to compose the final model (FM).

We discuss the final version of the model, improved through case studies, in chapter 4 — Results.

Board 4: Model
Created by the author

Subpropositions	Heartbits	Tocando Brasília	Futebol Arte	Atmosfera and Metaespaço
Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.				
Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.				
Due to the existence of a characteristic layer of abstraction — as designers need to constantly think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking.				
Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)				
It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track.				
Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements.				

Chapter 3

Case Studies

Four case studies have been executed during this research: a pilot study to test the adequacy of our data collection and analysis strategy and three subsequent ones.

The pilot study was carried out with Heartbits, a Brazilian application developed by Estúdio Guto Requena in collaboration with the production studio Midiadub. The app was created during the covid-19 pandemics in the first semester of 2020, and sought to mitigate the negative impacts of social distancing by promoting an affective experience between people, even if virtually. Therefore, the team relied on a generative system to deliver a mobile application for iOS and Android devices, capable of detecting the frequency of users' heartbeats and using it to create a unique video to be shared with friends and family. Founded in 2008 by Guto Requena, the Estúdio has been notably developing hybrid projects that range from the design of objects, spaces, and cities. The team has already won several awards for such efforts and lectured and exhibited works in more than 20 countries.

Then, we analyzed the project Tocando Brasília (playing Brasília), an interactive installation created by Alexandre Rangel for the exhibition "Brasília Mapping Festival 2019: #smartcities". Rangel is an experienced multimedia artist, software developer, and Ph.D. in Visual Arts, and, for the exhibition, he aimed to instigate moments of political awareness about the power relations inherent to "smart cities" by inviting the public to interact with an installation composed of city maps and musical outcomes.

The third study was executed with Samsung Futebol Arte (Samsung Art Soccer), a project created by Caio Velenosi. The project commissioned by Samsung sought to merge the technology of their to-be-released smartphone (Galaxy S4) with soccer movements. Therefore, generative visual pieces were produced by capturing and processing signals emitted by a Samsung smartphone incorporated into a ball. Velenosi is a developer who works with creative technology for more than ten years and is currently a technical director at MediaMonks, an international digital creative studio with more than 20 offices worldwide.

For the fourth case study, we investigated the installations Metaespaço and Atmosfera (Metaspace and Atmosphere), created by Dimitre Lima and Gabriela Castro for the Inventum 2019 — a science, technology, and innovation fair promoted by the Brazilian city of Pato Branco. The installations were generative technological interventions proposed by the duo to enrich the experience of the event, which lasted five days and had an estimated audience of 250,000 people. Both Dimitre and Gabriela have consistent experience working with art, design and technology, reflecting on a portfolio composed of projects commissioned by brands such as MTV, Red Bull, and Nike, and projects for museums and the public sector.

1. Based on an interview with Bruno Aricó and Camila Gonçalves on November 17, 2020, and on a follow-up interview with Bruno Aricó on February 15, 2021.

3.1 Heartbits

Heartbits [1] is a Brazilian mobile app developed by the Estúdio Guto Requena in collaboration with the production studio Midiadub. Released in the first semester of 2020 during the covid-19 pandemics, the app sought to mitigate the negative impacts of social distancing by promoting an affective experience between people, even if through the internet. The team relied on a generative system to deliver a mobile application for iOS and Android devices, capable of detecting the frequency of users' heartbeats and using it to create a unique video to be shared with friends and family. On the official website, the purpose of the application is expressed as:

> *Heartbits is an app that transforms your heartbeat into digital art.*
> *To share with those you miss.*

In addition to Midiadub, which took over the application's implementation, the project was carried out by a multidisciplinary team of the Estúdio. They were represented by **Camila Gonçalves**, the coordinator of the project, and **Bruno Aricó**, the technology specialist and creator of the generative algorithms used.

According to Camila, the initial idea for the app came from the team's motivation to engage in conceptual projects not necessarily associated with client brands. Furthermore, as the Estúdio already has a culture focused on the intersections of art, design, and technology and on projects based on biofeedback, another incentive was to look for additional applications for these generative systems they have been working with. These intentions gained more structure when the studio decided to participate in a Vogue call for action on Instagram, which invited designers to submit projects that could contribute to the situation of people during the covid-19 pandemic. At that time, Camila said that the problem took shape as discovering "if, with a generative, purely abstract art, we could send our heart to other people through a free app that everyone could download".

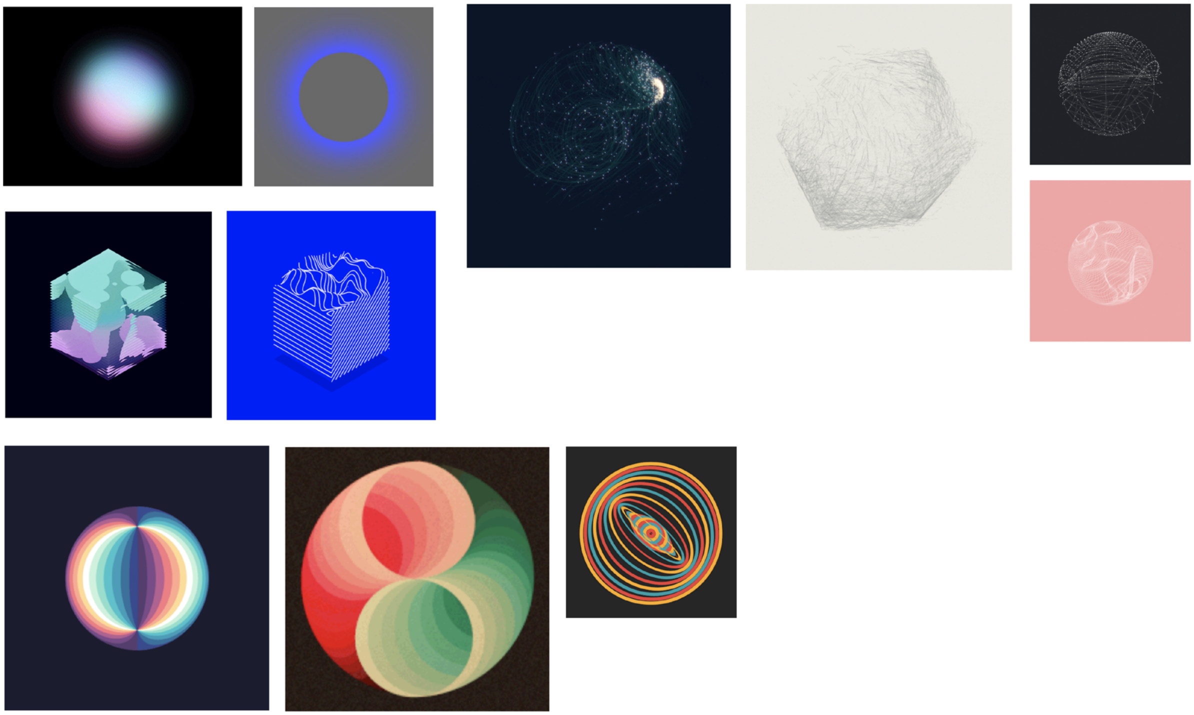
Once it was decided that the generative system would run on a mobile app for Android and iOS, other requirements were determined. According to Camila and Bruno, the team picked early on that they wanted to develop a free and accessible application that would not only appeal to visual but also sound and haptic sensibilities.

After the first definitions, moments of externalization and alignment were carried out through a series of recurrent virtual meetings — "very interactive moments", for which a frequency of one or two meetings per week was determined and in which primary references, drafts, and visual proposals of the interface and the generative shape to be designed were discussed.

This choice was also motivated by social distancing rules during the covid-19 pandemics.

In general, once the initial problem was framed and defined, the application's technological/algorithmic and visual aspects started being elaborated. According to Camila, although the intention of designing a system capable of presenting audio and haptic vibration was already posed, visual directions were still undefined. In this sense, the creative process consisted of parallel evolutions of a technical effort to develop the system to capture the heartbeat and a design effort to create the visual elements to be modulated by the produced system. Still, according to the project coordinator, the team began by collecting references from other creators and studios they liked. In "baby steps", as referred to by her, this process helped establish colors, typography, and the overall aesthetic directions of the application. For instance, because the project dealt with concepts of empathy, emotion, and feelings, Camila said it "made sense" to begin by searching for an "organic" and abstract shape to be modulated by the generative algorithm instead of something sharp.

Figure 40 (top): Digital sketches and mockups that were submitted to the Vogue magazine's calling.



According to Bruno, the collection of references mentioned above fed an interactive creative process. In his words, the process resembled "agile development", as it relied on constant research, collaboration, experimentation, and evaluation. Once the initial concept was defined, the process evolved around the main generative shape, as illustrated by the primary references and propositions presented on the board below. In general, the successive design propositions sought to define this main shape to assume the generative character of the algorithm and to illustrate the project's intentions.

In line with what Camila said about choosing a rounded and "organic" shape, the references above illustrate that such an investigation was indeed executed.

In general, the visual evolution followed a process of:

- searching for references centered on movement-related and geometric visual elements;
- beginning experimenting with potential shapes, textures, colors, and possible responses to the generative algorithm;
- defining the aspect of the principal shape and color palette;
- experimenting now with a more defined aesthetic direction, including textures and high-fidelity aspects; and

Figure 41 (top): Examples of references collected by the team of the Estúdio to start developing the generative shape.

- iterating and refining until the end of the project.

Such a process is exemplified by the boards above (of references) and below (of designs proposed by the team in the middle of the process).

Board 5: Heartbits - Intermediate Deliverables
Created by the author

Board 6: Heartbits - Main Screens
Created by the author

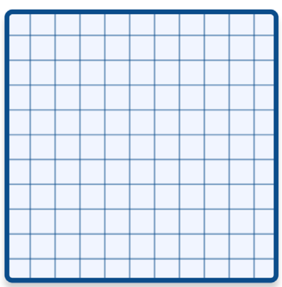
Technologically, according to Bruno, the evolution of the project consisted of figuring out a satisfactory sensor to capture the heart rate in a simple, practical, and cheap way and of elaborating an algorithm to accurately process the heart signals collected. Still, a substantial part of the technological developments consisted of continuous refinement of the programs involved in implementing the application, along with Midiadub.

Heartbits' visual interface is based on Unity, a framework used for creating digital games and developing multi-device visual and interactive experiences. Users' navigation begins on a screen with brief instructions. Then, users are directed to another screen that indicates how they should interact with the device's camera — the sensor. Once the system senses the positioning of the finger and starts to read the heart rate, it changes the screen state to one in which the detected rate is displayed in real-time (in BPMs), accompanied by a primitive shape that also reacts to the beats. After capturing and analyzing the heart rate, the system builds and presents a preview of the generative video. At this moment, users can choose whether to synthesize and record the video along with a text and whether to vary the composition's color palette, among other previously stipulated options. Finally, users have their video rendered and are invited to share it with friends and loved ones through their social networks or download it.

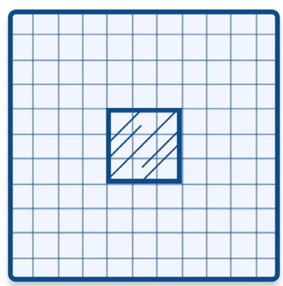
Once users ignite it, the generative system waits for the finger to be positioned on the device's camera. According to Bruno, the team decided to employ the camera as the sensor after researching and discovering a technique called photoplethysmography, through which optical devices (the camera) can be used to detect changes in blood volume of body tissues, allowing the system to measure the variation in heart rate and determine the user's frequency, in real-time. Moreover, choosing the camera was also advantageous because it is a cheap sensor, built-in into most of the smartphones.

Through photoplethysmography, pictures of the finger were

Board 7.1: Data Collection and Processing - Part 1
Created by the author



Representation of a frame captured by the camera, divided in pixels.



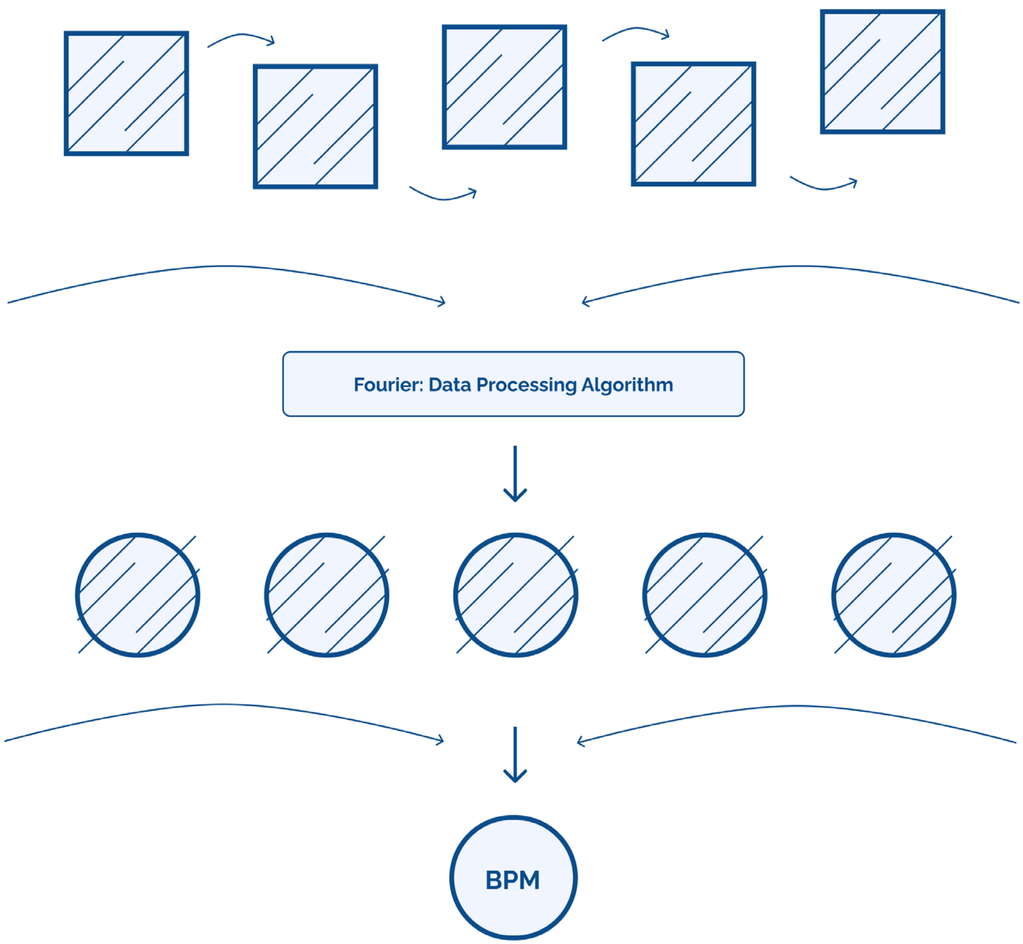
The system watches a central area of the picture, 30x30 pixels, and calculates the average of red values among the pixels that make it up.

continuously captured, meaning that successive arrays of pixels represented by their chromatic values were received by the computer. The system inferred the variation in blood flow by monitoring the intensity of red in a particular region of the image over time, as illustrated by the boards 7.1 and 7.2. Moreover, during analysis, signals were processed by a Fast Fourier Transform, an algorithmic technique in which input signals are normalized into a data range relevant to the phenomenon in question. For example, in the case of Heartbits, the Fourier algorithm transformed the red-related values received into "equivalent" values in a heart rate scale.

Lastly, after preparing the data, the generative system creates videos

Board 7.2: Data Collection and Processing - Part 2

Created by the author



by articulating the main visual aspects that compose them.

The circular shape was created in Unity, which includes a library of native functions to synthesize elementary shapes. In Heartbits, the ellipsoid was synthesized by one of these native drawing functions. The volume and toroidal aspect were also created by Unity, which allows the distortion of shapes through the manipulation of the vertices that make up their polygonal mesh (which describe three-dimensional objects). In this case, central vertices of the ellipsoid were expanded, which gave the shape the appearance of a "red blood cell". Colors and gradients were also aspects supported by Unity's native libraries. As stated earlier, there was no generative logic behind chromatic choices. When the analysis was finished and the video was presented, the system randomly colored it with one of the available palettes. Finally, according to the detected heart rate, the algorithm animated the shape by successively increasing and decreasing it. Although not precisely a sphere, it would be as if the shape had its radius increased and decreased, in the same detected frequency.

When asked when the app was considered satisfactory, both interviewees agreed that it happened when the app was visually appealing and accurate in terms of the heart rate detected. Such a process suggests that quality assessment was essentially defined by the deadline. Moreover, Camila added that the self-imposed one-month deadline was motivated by the uncertain duration of the social isolation at that time: "as we were in a context of not knowing how long the quarantine would last and if there would be lockdown or not, we thought it made sense to release an app that sought to bring people in social isolation together while they were in social isolation."

However, the coordinator acknowledged that a greater personalization of the experience through the insertion of photos, for example, and further testing with alternative shapes and color palettes, were aspects among the team's intentions for a possible second version. In addition, for Bruno Aricó, technical improvements in the accuracy of the sensor and in the algorithmic process that determined the heart rate would be relevant points for future versions. These aspects were considered satisfactory at the time though.

In general, from the initial concept, Heartbits' design process was conducted through three fronts: graphic and user-experience-related propositions; development of the generative system; and implementation for Android and iOS.

Tiago Toledo, the graphic designer of the project, conducted the first initiatives. Next, the project of the generative algorithm was carried out by Bruno Aricó. Lastly, the implementation of the application was carried out by Midiadub. It is worth noting that the choice of having a partner for development was due to the lack of internal expertise.

According to Camila and Bruno, the tight deadline and social isolation also motivated an interactive process in which visual, algorithmic, and technological efforts were constantly presented and discussed. A frequency of meetings was defined, occasions in which each of the fronts presented their progress, exchanged information, asked questions, and posed other possibilities for the entire team. For a relevant level of collaboration and constant cycles of conceptualization, development, prototyping, and validation, Bruno stated that the process resembled “agile development methods” — a standard project management methodology for tech-related projects based on rapid iteration and collaboration.

Analysis and Discussion:

When confronted with the subpropositions (SPs) of our model, the case suggested the following implications:

1- Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them (**Partially Endorsed**)

Bruno was responsible for designing the generative algorithms and transforming them into programs. The developer relied on computational processes to collect and process inputted data and transform it into the video. Such a statement suggests that direct manipulation receded to the background as the computer was literally producing final results. However, it was still used throughout the project to create reference boards, aesthetic guidelines, and design propositions.

As discussed previously, the creative process consisted of parallel evolutions of a technical effort to develop the algorithm to capture the heartbeat and a design effort to elaborate the visual elements to be modulated by the designed algorithm.

We considered SP1 partially endorsed by this case because instead of being abandoned for the exclusive curation of computational processes, direct manipulation still happened and contributed to the creative process, even if not being employed to produce the final artifact. More specifically, in Heartbits, such manipulation was used to constantly elaborate graphic guidelines to be achieved by the system.

2 - Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly

feedback the cycle. (Endorsed)

The steps mentioned above could be identified throughout the process, but not in a delimited way. After the first sessions in which the team settled aesthetic concepts to be pursued by the app, they carried out constant cycles of experimentation in which they co-created visual **ideas** through direct manipulation; experimented with synthesis through different **algorithms** and **programs**; and evaluated outcomes to figure out the **adjustments** to be incorporated in the next iteration. In short, all elements contained by the subproposition were executed through many explorations and evaluation by the team.

Therefore, SP2 was endorsed, but it is necessary to point out that stages of ideation, abstraction, formalization, evaluation, and refinement happened disorderly during the project.

3 - Due to the existence of a characteristic layer of abstraction — as designers need to think in terms of algorithms to create desired artifacts, there is a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking. (Endorsed)

As discussed previously, Heartbits essentially relied on two parallel efforts: one technical effort to figure out the sensor and data processing algorithms to be used, and a design effort to define the look and feel of the interface and of the shape that was going to be modulated by the generative system. Bruno was the actual programmer of the system behind the synthesis of the video, which implies that computational thinking was required. Still, through many explorations of visual and audiovisual references and co-design sessions, the team could frame the problem as an inquiry into the best ways to synthesize a given visual concept computationally. Such a mixed process suggests that abilities related to both computational thinking and design thinking were employed. Because of that, SP3 was endorsed.

4 - Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation). (Endorsed)

The problem tackled was framed by the team in terms of the experience they intended to deliver — its functional and aesthetic purposes. In this formulation, generative creation came as the chosen means to materialize a preconceived concept instead of being the material experimented with for ideation.

More specifically, visual concepts were elaborated to **define a shape and behavior to be modulated by the generative algorithm**. At the same time, programming and technological efforts aimed to enable the proposed experience in the best way. By exemplifying **concept-based ideation**, this case endorsed SP4.

5 - It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track. (Endorsed)

In general, the creative team iterated over a cycle of:

- proposing visual concepts;
- discussing the visual quality of these propositions;
- judging the feasibility of ideas according to the skills of the group;
- developing an MVP of the selected concepts;
- discussing results in relation to the guiding visual concept;
- adjusting the guiding vision, if necessary;
- and repeating this cycle, until satisfaction was achieved.

Collaboration was also a remarkable aspect, as the multidisciplinary team constantly got together to ideate, select ideas to pursue, and evaluate both visual and software propositions.

Since an approach based on multidisciplinary collaboration, rapid iteration, and experimentation was employed, SP5 was endorsed.

6 - Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements. (Endorsed).

The framing of the problem and definition of first intentions were accompanied by establishing functional, aesthetic, and technological requirements. In other words, **specific choices concerning the devices, input data, platforms, and programming languages** were put on the agenda beforehand. Such planning also established the intention **to develop free applications to run in Android and iOs**. Moreover, through a series of the development cycles already discussed, the team constantly defined their next steps and experimented with a set of design, development, and deployment alternatives. These cycles were also based on prototypes and MVPs that supported evaluation, as illustrated by the questions below:

a) Are the sensors accurately capturing real-world and user signals?
b) Is the system satisfactorily processing the input data so that it can be used?
c) Is the system synthesizing a visual message that we like and that is in line with our intentions?
d) Is the system synthesizing the artifact so that it runs satisfactorily on the chosen devices?

Because of the aspects discussed, SP6 was endorsed.

The implications discussed previously are summarized and illustrated through the filled model on the next page:

Board 8: Model confronted with Heartbits
Created by the author

Subpropositions	**Heartbits**
Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.	Partially Endorsed Direct manipulation was especially used to elaborate graphic elements to be achieved by the algorithm.
Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.	Endorsed Steps could be identified throughout the process, but not in a delimited way — stages happened disorderly and were shared collaboratively during the project.
Due to the existence of a characteristic layer of abstraction — as designers need to constantly think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking.	Endorsed A mixed process in which abilities related to computational thinking and design thinking were employed.
Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)	Endorsed. Concept-based Ideation Generative creation came as the chosen means to materialize a preconceived concept instead of being the material experimented with for ideation.
It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track.	Endorsed. Rapid Iteration, Collaboration and Experimentation The creative team iterated over cycles based on collaboration, fast proposition and constant evaluation.
Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements.	Endorsed Framing and definition of first intentions was followed by establishing functional, aesthetic, and technological requirements. . Still, through a series of development cycles, the team defined next steps and experimented with alternatives. These cycles were also based on MVPs that supported evaluation, as illustrated by the essential questions below: a) Are the sensors accurately capturing real-world and user signals? b) Is the system satisfactorily processing the input data? c) Is the system synthesizing a visual message that we like and that is in line with our intentions? d) Is the system synthesizing the artifact so that it runs satisfactorily on the chosen devices?

3.2 Tocando Brasília

Tocando Brasília[2] (Playing Brasília) was an installation created by Alexandre Rangel for the Brasília Mapping Festival #smartcities. The event happened on July 6th and 7th, 2019, in the National Museum of the Republic, in Brasília, and aimed to instigate reflections about the so-called smart cities and the perception of urban spaces through technological interventions. According to Camila Handam, one of the directors of the event, the primary purpose was to promote a dialogue between landscape architecture and the public space of cities through creative situations constituted by a lucid state of interactive content.

To Rangel, the project has been a materialization of a myriad of aspects inherent to his work. The artist has been familiar with computing and digital media since very young. When he was about ten years old, he had the opportunity to take a few programming courses. Since then, he has been dedicating his career to the intersections of art and the production of digital and audiovisual content (e.g., interactive CD-ROMs, interactive installations, mapped projections, and web programming). After obtaining his Bachelor's Degree in Visual Arts, Rangel started to combine his artistic and technological affinities more intensely. Notably, his interest in audiovisual production led him to elaborate a software tool focused on video editing in real-time. Called 'Quase-Cinema' (almost cinema), the tool dedicated to enabling live video performances was first proposed as an undergraduate thesis and received important updates as time went by.

During his Master's degree, Alexandre dedicated himself to researching artistic-based educational initiatives, intending to empower people to express themselves through audiovisual content. Therefore, the artist resumed his work with the 'Quase-Cinema', and relied on it as the basis

2. Based on the interview with Alexandre Rangel on May 11, 2021.

Figure 42: A picture of the interface of 'Quase-Cinema'.

of these educational and creative initiatives.

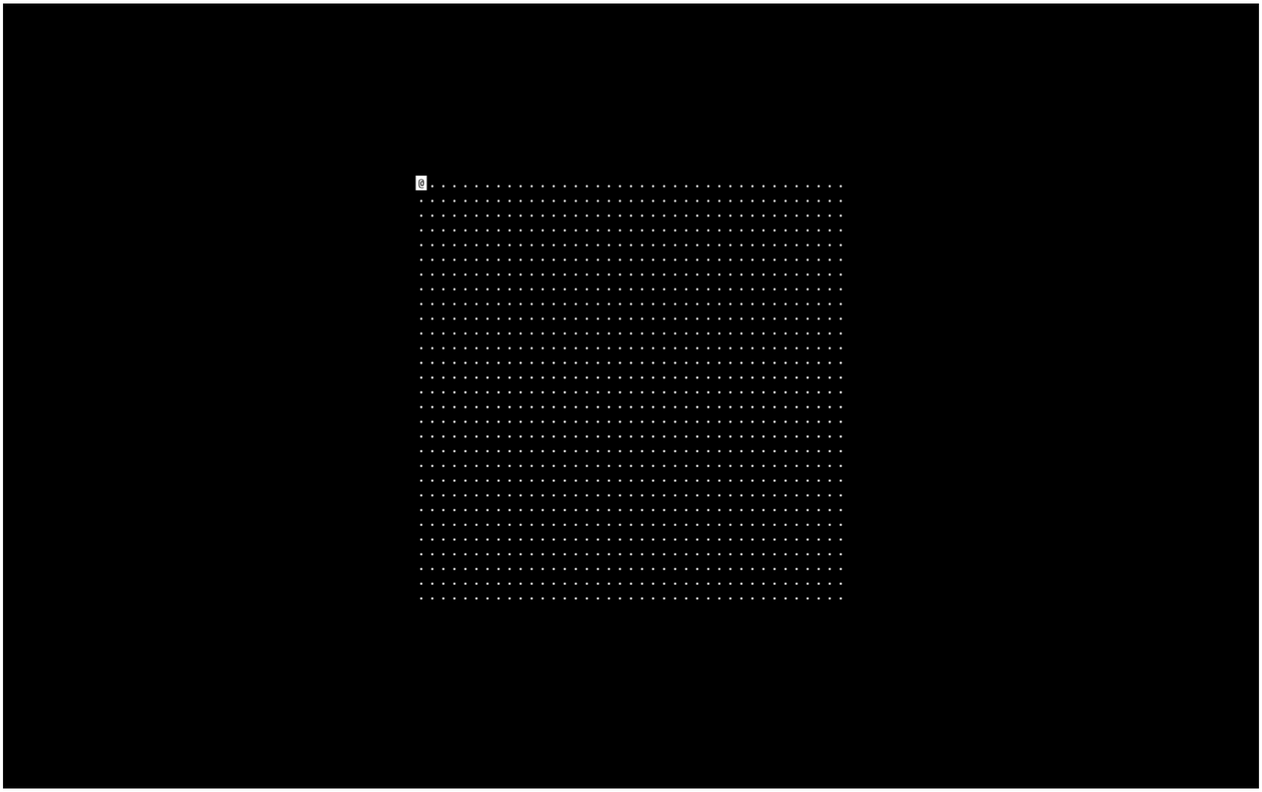
The project 'Tocando Brasília' was born from experimentation. At first, Rangel sought to go beyond the domains of projects he had been developing in his master's degree as a way to oxygenate his creative practices. "To expand horizons", as referred to by him. From this process of looking for new creative paths, two exceptionally motivating milestones for the origin of Tocando Brasília have been highlighted by the artist: to have discovered the live coding practice through programming languages such as Ixi Lang and Orca.

Live coding is a practice in which performers modify and adapt software tools they have developed for multimedia presentations as they unfold. In this sense, the very act of programming becomes a critical component of the program's execution. Created to run in a live coding context, Ixi Lang consists of an environment oriented to producing generative music, allowing performers to execute commands capable of modifying the source code: reordering, shuffling it, and, consequently, resulting in new musical compositions.

According to Rangel, his "discoveries" revealed a possible non-linear route for computer programs, another way of programming that instigated him to perceive computing as a means and an end. Interested in this "metaprogramming", the artist learned the programming language Orca, which Rek and Devine created to be a flexible live coding environment. Defined as an "esoteric" language by its creators, Orca enables the creation of procedural sequencers by displaying to users a two-dimensional matrix in which letters of the alphabet can be arranged to represent computational operations. In addition, the environment easily integrates with other visual and sound software tools (e.g., Ableton, Renoise, VCV Rack, and SuperCollider), which allows Orca-produced signals to be transformed into different outputs. With Orca, Rangel could represent programs as visual compositions, having these "two-dimensional sculptures" as novel interfaces in which commands are not necessarily interpreted from left to right and top to bottom but more flexibly.

Still challenged by concepts of rigidity, programming, grid, and deconstruction, Rangel brought to the creative process his fascination with the architectural plan of Brasília. According to him, such an initiative characterized by a rigid system of rules, blocks, regular demarcations, and attributions to urban life has been fascinating and intriguing him for a long time. Tocando Brasília was born from this mixture.

Intending to tension the normalization of life in the city and the decisions that culminated in its organization, Alexandre sought to recover a sentiment of "something different [...] this questioning". Therefore, the artist developed a structure whose interface merged the map of Brasília with the coordinates of blocks — extracted and interpreted as musical notes via Orca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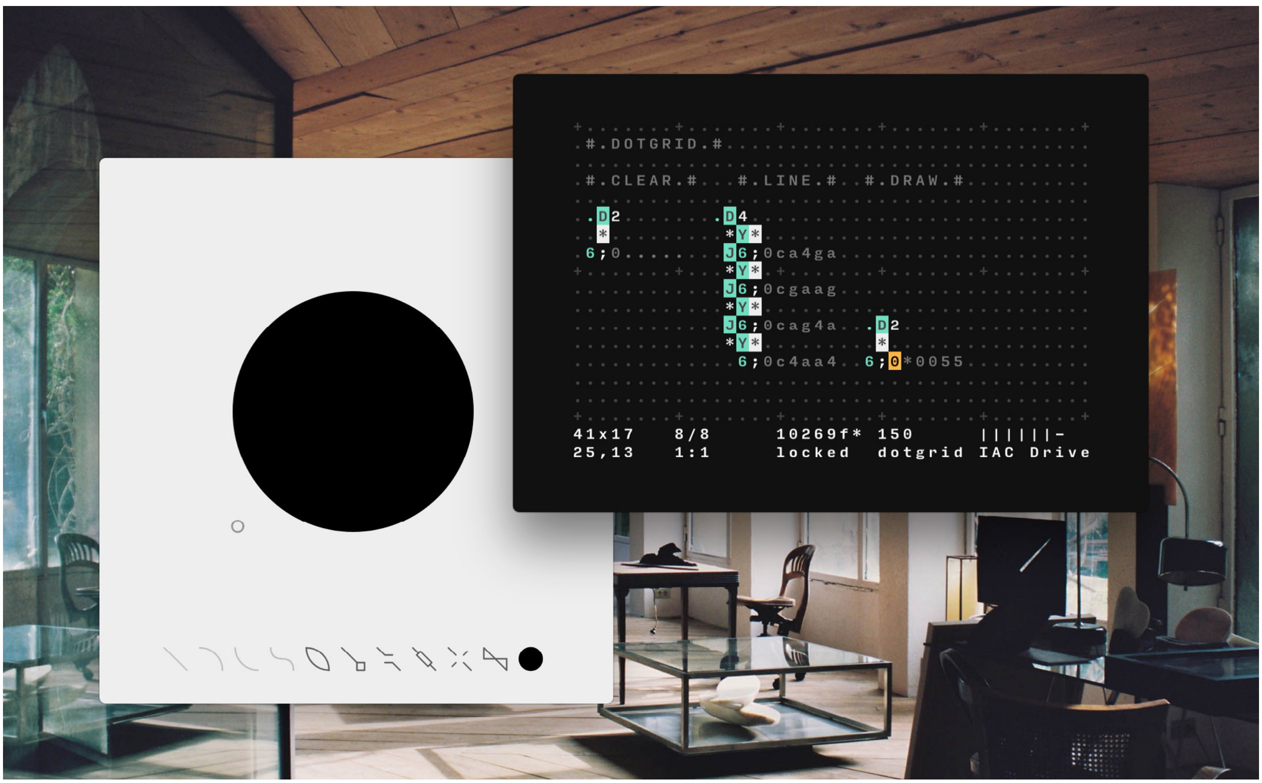
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Figure 43 (previous page / top): Orca's interface.
Figure 44 (previous page / bottom): Example of an Orca program and its visual outcome.
Figure 45 (current page / top): Examples of the interface of Tocando Brasília and the devices that supported the installation (gamepad and TV).

commands — and user's participation through a video game controller. In addition, the system recurrently projected texts about the original project of Brasília, written by the architect and urban planner Lúcio Costa, into the screen. "Another layer of meaning", according to Rangel.

The dynamics of the installation refer to a mix between Space Invaders and Tetris. Through the gamepad, users command a cursor that emits "pulses" as it moves. These pulses, emitted by the cursor, touch the coordinates of the blocks, interpreted as Orca commands, and "destroy" them, causing sounds to be cast. "What is it I am experiencing?", "Do I have a goal?", "Do I have to destroy the blocks, or do I have to avoid destroying?" and "What is this sound I am making?" were some of the questions Rangel sought to provoke.

The experience was complemented by a timer that switched the maps in the background and additional commands that users could execute through the gamepad, such as changing the displayed sector and the music style. According to Rangel, the experience was designed as "a computer program, on top of a map of a city that was also programmed and planned", which allowed users to feel like an architect, building and destroying.

Still according to Rangel, his work's experimental nature reflects the constant search for subversive ways of using software tools, in other words, finding creative uses beyond those originally proposed. Experiments such as spreadsheets to control musical software, among other attempts, characterize the artist's style. In the case of Tocando Brasília, Rangel started with "an idea of putting the programming software to control maps and sound". An initiative that became more concrete as the artist decided to carry out tests with a webcam as an input sensor to power an Orca program (Figure 46):

> *I created this blank Orca programming window, and I made another software that interpreted the input of the webcam's data and transformed the shadow and light of what the webcam was seeing into random letters,* [...] *I put this inside Orca's programming, without having any idea what was going to happen, either visually or sonically. I thought: 'look how interesting, the webcam* [...] *can send me two hundred and fifty-five letters, but let me just restrict on the letters that are equivalent to musical notes, from A to G'.*

With this test, Rangel figured out that a vast amount of commands does not cause an overload or interruption of Orca programs since only the interpretable part is executed. Furthermore, through successive tests, he managed to establish a spectrum of predictability for the interactivity of his program: on one extreme of total predictability, users could, for example, "press the keyboard, do 1 + 1, and get 2"; on the other, "the craziest thing could happen, like a dance in front of the webcam being transformed into a thousand programming commands".

This negotiation between predictability and unpredictability, as referred to by Rangel, also illustrates a difference between art and design that he brings as a dialectical element to his projects. "Design is the most predictable, the most objective, in the sense of having a goal [...]", while art points to the "unpredictable, uncontrollable", capable of evoking "a different perspective". After building this spectrum, Rangel said that the question was finding a middle ground between total predictability and chaos. Something

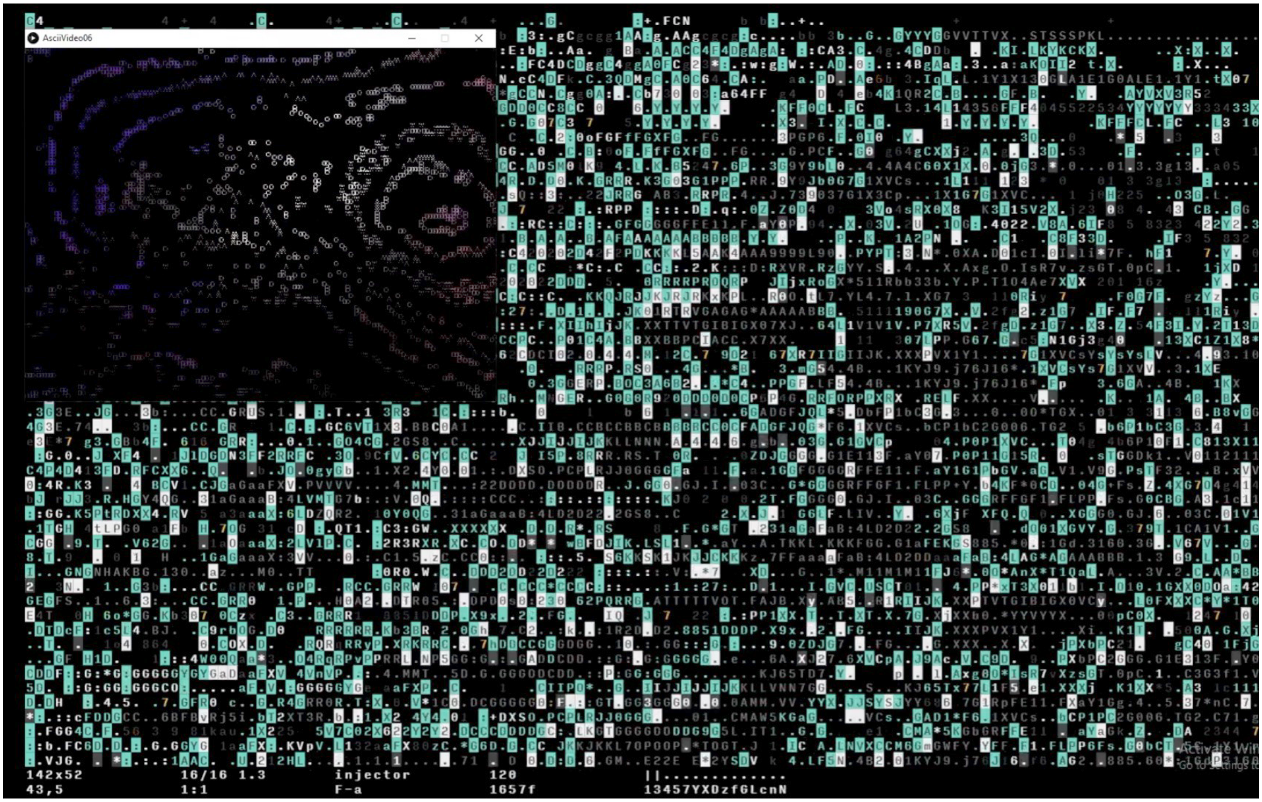
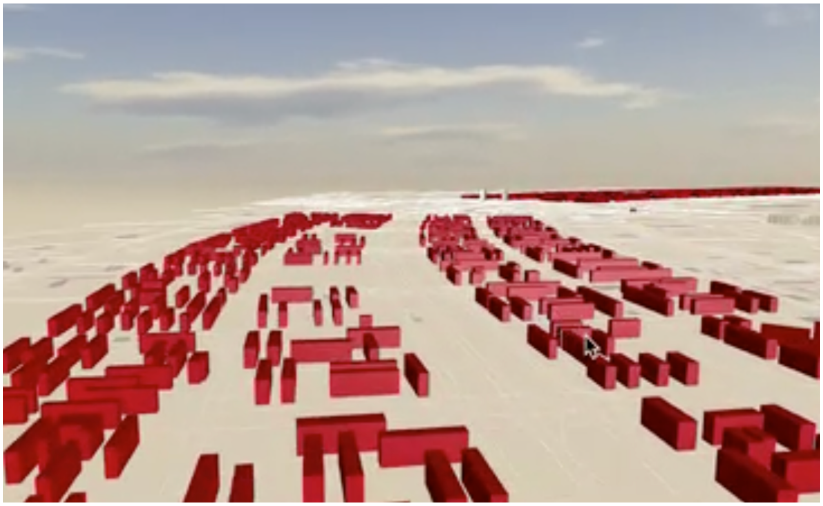


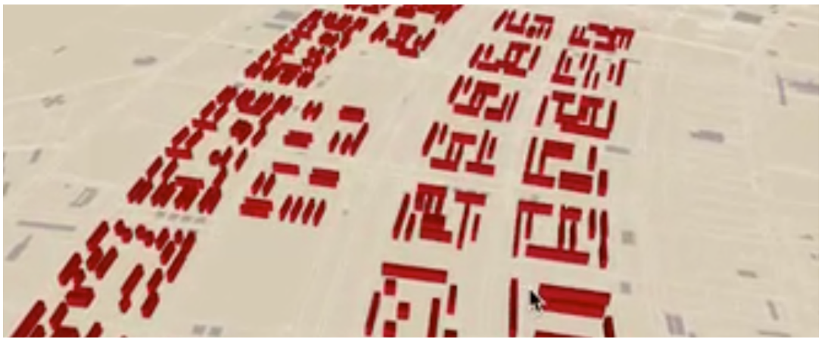
Figure 46 (top): One of Rangel's tests with a webcam as a sensor to feed an Orca program.

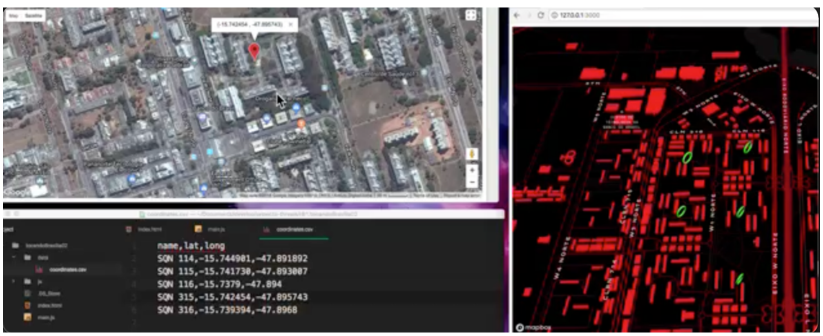
that, in Tocando Brasília, resulted in the gamepad being chosen as the primary interface. "The person immediately thinks: 'Oh, I am controlling this cursor that is destroying the buildings. I do not know what is happening [...], but this relationship, at least — left, right, up and down — I have'". Rangel often resorts to balancing control and non-control to promote involvement, mystery, and interest.

Although some requirements and motivations have remained constant since the beginning of the project, the interface took on very different "looks". The artist saw the city's blocks, neighborhoods, and buildings as easily abstractable into music because of their very regular project. Therefore, starting from the idea of assigning sounds to the city of Brasília, Rangel attempted to turn the city's geography into a kind of score users could play by hovering over the elements.

The interface's appearance in these early explorations resembled the interface of Google Earth, but without the maps underneath it. "Just the 3D models", as referred to by Rangel (Figures 47, 48 and 49). Moreover, despite having changed towards the final version, it maintained the logic of hybridizing general geographic coordinates with coordinates of buildings, getting the letter that represented each one of them — commonly between A and G—, and, finally, interpreting these letters as corresponding musical notes.

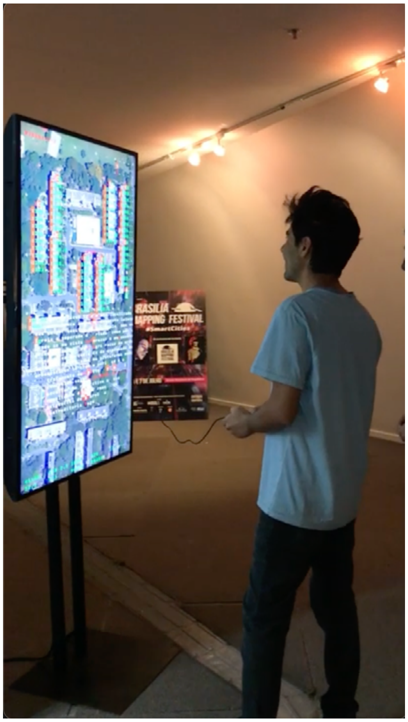






What led the artist to keep elaborating the look and feel of the interface was precisely the level of predictability and control he hoped to convey. Linking sonification to mouse movements entirely controlled by the user would not result in a sufficiently exciting and surprising experience since this interaction is highly intuitive for users of digital devices. Moreover, while working on the visual interface, Alexandre abandoned the three-dimensional aesthetic in favor of a "vintage" aspect. He said such an association was natural after proceeding with the gamepad and the Orca interface.

Figure 47 and 48 (current page / top): Rangel's first experiments for the interface of Tocando Brasília.
Figure 49 (current page / middle): First experiments having the map of the city as the main interface (on the right) and a playable musical score.
Figure 50 (next page / top): Example of the interactive dynamics of Tocando Brasília, based on a gamepad.

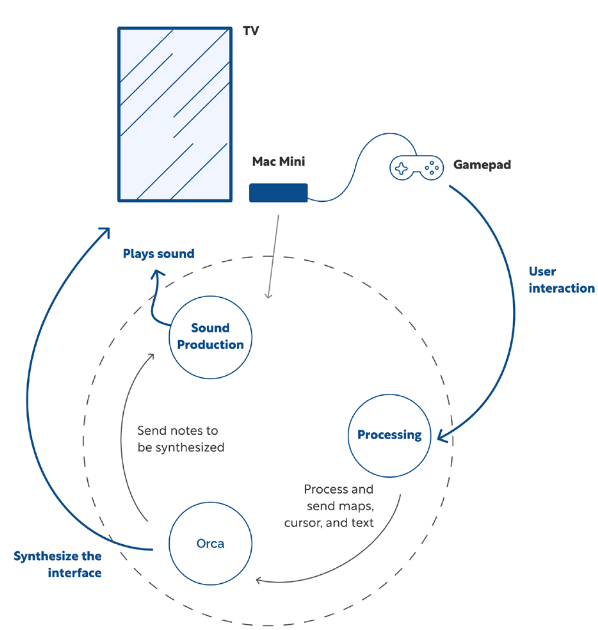


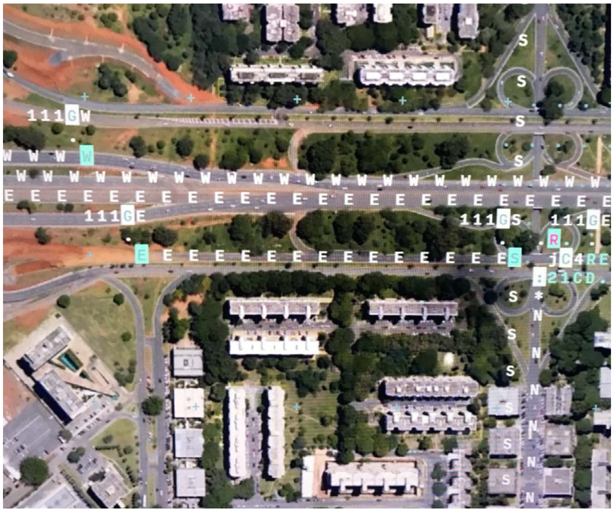
In the end, Tocando Brasília took shape as an interactive installation, mediated mainly by a gamepad. The structure consisted of a vertically-placed TV connected to a Mac Mini computer which, in turn, was connected to the video game controller. Moreover, three software tools were used: on a first level, a program written in Processing was responsible for receiving the gamepad commands, selecting Lúcio Costa's maps and text excerpts, and sending all this information to Orca. Then, Orca was responsible for synthesizing the visual and interactive experience by displaying the maps, coordinate letters and the text excerpts that would be turned into music. Finally, Orca sent musical notes — in MIDI — to a music production software (e.g., Ableton Live or Helm) running in the background.

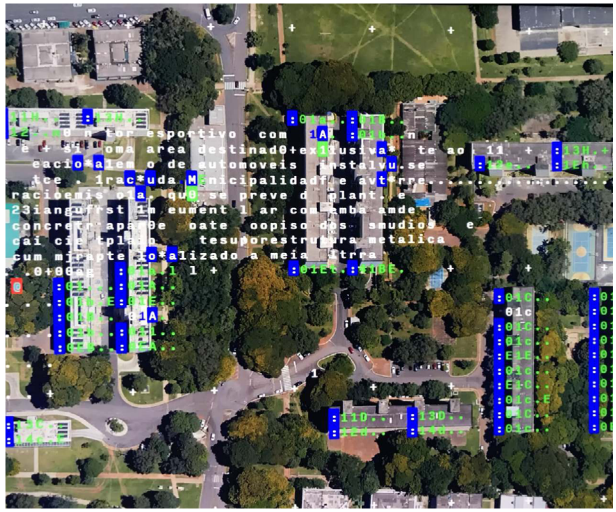
In short, the music production software was responsible for synthesizing the sound of the installation, Orca was responsible for synthesizing the interface and supporting intended interactions, and Processing was the engine that commanded the scene changes, placed Lúcio Costa's texts on the screen, and received, interpreted and executed gamepad commands.

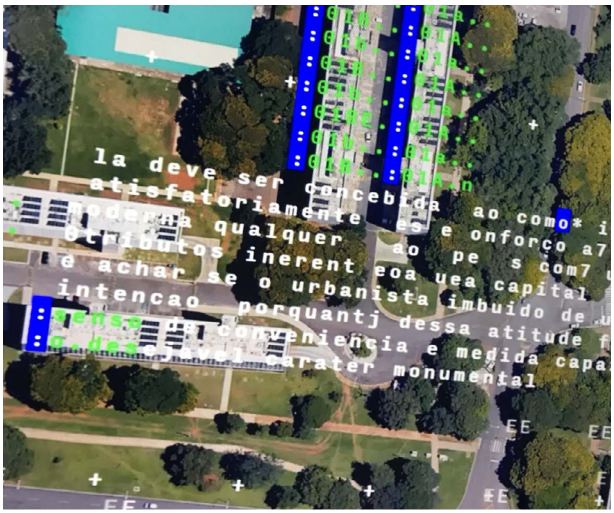
While the reasons behind using Orca have been explored, Rangel chose Processing because of the simplicity it allows interactivity-related operations and commands to be created. Accordingly, that is the reason why it is "one of the first tools", as referred to by him, when dealing with similar

Board 9: Tocando Brasília - Data Flow
Created by the author





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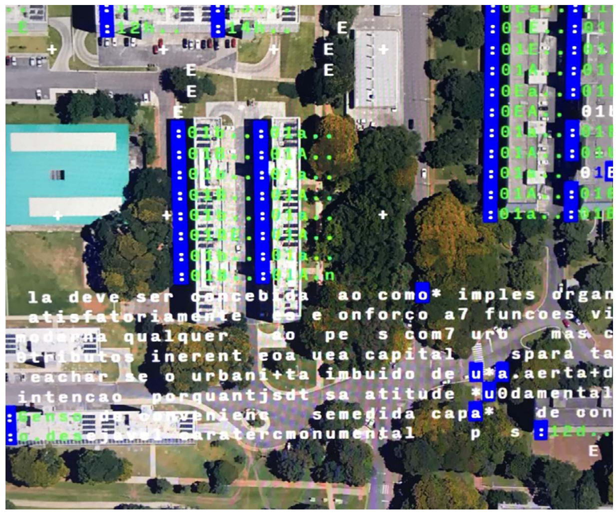
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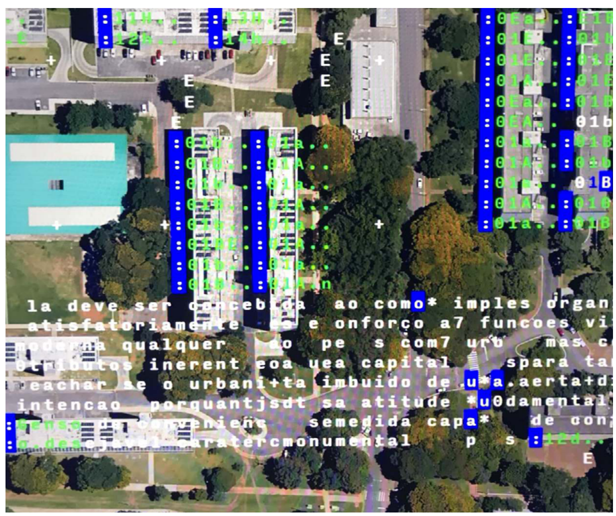
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projects: "It is a software that I can more easily put pieces together with. It has a lot of these libraries to make one software talk to another". Generative creation, in turn, was employed by Rangel, as it commonly is in many of his works, because of the originality and unpredictability it provides. According to him, the possibility of making and running software capable of producing unexpected results to visitors on different occasions is an aesthetic quality he esteems. "Almost as if fate was working there", in his words.

Rangel considered the project satisfactory when it caused "enthusiasm" in him. When asked how and when he decided to stop, he pointed out that he usually finishes his more artistic works when delighted with the results achieved. In his words: "It is this fascination, right? When we see and actually say: 'Wow, it is fun [...], it is cool'. And I see myself recording movies, publishing [...]". Nonetheless, despite getting satisfied at that time, the artist admitted that he would continue developing Tocando Brasília if he had more time and resources: "I would like to have a version of it that could run online, for example".

Finally, according to him, the project's biggest challenge was establishing connections between the many software tools involved in the work. Something he figured out after spending "half of the time studying and researching" the UDP protocol, "a way to make software tools talk to each other".

Analysis and Discussion:

When confronted with the subpropositions (SPs) of our model, the case suggested the following implications:

1 - Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them (Endorsed)

Rangel puts programming and his software experiments in the center of the creative process as they intermediate and influence aesthetic choices and support ideation, elaboration, and execution. As he referred, the process relied on "openness" to the possibilities offered by the software tools and programming languages he could get to know.

Visual references were not manually elaborated by the artist, who let experimentations point out aesthetic paths. Since the analysis suggested that direct manipulation was indeed abandoned as results

Figure 51 (previous page): Photos of the interface of Tocando Brasília and its layers: the map, orca letters, cursor and Lúcio Costa's texts.

obtained through programming and software were constantly evaluated and refined in the same medium, SP1 was endorsed.

2 - Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle. (Endorsed)

We could identify moments related to each of the steps mentioned above throughout the process.

The idea was shaped after cycles in which Rangel elaborated concepts through programming or playing with software; he had a "click", in his words, as he saw connections between his experimentations and the structure of the city Brasília. Then, still through cycles of experimentation, he programmed and connected all the interfaces to properly develop the concept, which implies that **ideas** were necessarily abstracted into **algorithms**, formalized via **source code**, and **run**. Output **evaluation** was also essential as partial results and intermediate versions were often abandoned or pursued as a means for taking the project to the end.

SP2 was endorsed, but it is necessary to point out that stages did not happen linearly. On the contrary, moments of ideation, abstraction, formalization, evaluation, and refinement happened disorderly during the project.

3 - Due to the existence of a characteristic layer of abstraction — as designers need to think in terms of algorithms to create desired artifacts, there is a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking. (Endorsed)

The creator employed abilities related to computational thinking as he programmed the software tools needed for the execution of the installation. Fundamentally, to create an executable and satisfactory program, one needs to articulate abilities such as debugging, algorithmic thinking, generalization, and automation. However, more than that, Rangel relied on the very nature of computing and software to experiment with and express his ideas, which suggests a creative process in which computational thinking is deeply embedded.

On the other hand, to propose the whole experience of Tocando Brasília, Rangel had to frame the problem as some sort of equation in which he had to balance aesthetic intentions, possibilities of execution, and involvement of users. This consideration reflected on the constant experimentations with interactive inputs and refinement until a desired experience of use was achieved. Because of the experimental nature of the process, as referred to by the artist, another design-related aspect is that problem and solution did coevolve, something illustrated by the different interfaces and inputs presented by the first versions of the work.

The above-discussed mixture of abilities endorsed SP3.

4 - Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation). (Endorsed)

Rangel relies on a creative praxis that seeks to go beyond common uses of software and programming. He is “always focusing on exploring computing itself as the means”. Such a premise motivates the author to “go beyond aesthetics”, and sometimes even to let it aside completely to evoke curiosity and mystery.

Material-based ideation was favored in Tocando Brasília, as illustrated by the software-based network of concepts that resulted in the final work. By highlighting the discovery of live coding and, more specifically, of Orca as the aesthetic foundations of the installation, Rangel demonstrated how software experimentations guided his creative process instead of being employed as a means to achieving a preconceived concept.

We considered SP4 endorsed, as well.

5- It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track. (Endorsed)

Being stated as “open” and “experimental” from the beginning, Rangel’s creative process relied on unordered and interspersed experimentations to elaborate the idea, figure out the input format and dynamics of interaction, and define the look and feel of the installation. Such a process was repeated until a satisfactory interface was built.

Therefore, the case not only endorsed SP5 but also endorsed that an experimental approach was preferred.

6 - Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements. (**Partially endorsed**)

It is worth noting that the experimental nature of the project and the lack of client requirements made stages related to planning and defining less emphasized, which does not imply that they did not happen. As discussed in our foundations, throughout any design process, moves and next steps are intuitively planned and defined as the project is carried out, even if not during delimited stages dedicated to it.

Regardless, Tocando Brasília was indeed carried out through the exploration of alternatives and a relevant process of prototyping that fed technical and aesthetic evaluations. However, instead of belonging to a delimited stage of testing, in which validation was executed according to pre-established criteria, **prototypes were constantly built as partial versions of the interface. Attempts**.

Moreover, as stated by Rangel, **both the level of predictability and the intended familiarity with the interactive dynamics were evaluation criteria**. When designing the structure and defining how users would use it, the artist experimented with different inputs and algorithms to enable interactions that were not chaotic but also not predictable. Because of that, SP6 was endorsed. However, again it is necessary to point out that the flexible brief of the exhibition made abilities related to planning, defining, and discovering requirements less prominent as delimited stages.

Board 10: Model confronted with Tocando Brasília
Created by the author

Subpropositions	**Tocando Brasília**
Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.	Endorsed Direct manipulation was abandoned as results obtained through programming and software were constantly evaluated and refined in the same medium.
Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.	Endorsed Steps could be identified throughout the process, but not in a delimited way — stages happened disorderly during the project.
Due to the existence of a characteristic layer of abstraction — as designers need to constantly think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking.	Endorsed The creator employed abilities related to computational thinking as he programmed the software tools needed for the installation. He also relies on the very nature of computing to experiment with and express his ideas. On the other hand, to propose the whole experience of Tocando Brasília, Rangel had to balance aesthetic intentions, possibilities of execution, and involvement of users.
Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)	Endorsed. Material-based Ideation By highlighting the discovery of live coding and, more specifically, of Orca as the aesthetic foundations of the installation, Rangel demonstrated how software experimentations guided his creative process instead of being employed as a means to achieving a preconceived concept.
It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track.	Endorsed. Based on Experimentation Being stated as an "open" and "experimental" from the beginning, Rangel's creative process relied on unordered and interspersed experimentations to develop the project.
Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements.	Endorsed Tocando Brasília was carried out through the exploration of alternatives and a relevant process of prototyping that fed technical and aesthetic evaluations. Moreover, both the level of predictability and the intended familiarity with the interactive dynamics were evaluation criteria. The flexible brief of the exhibition made abilities related to planning, defining, and discovering requirements less prominent, but they naturally happened.

3.3 Futebol Arte

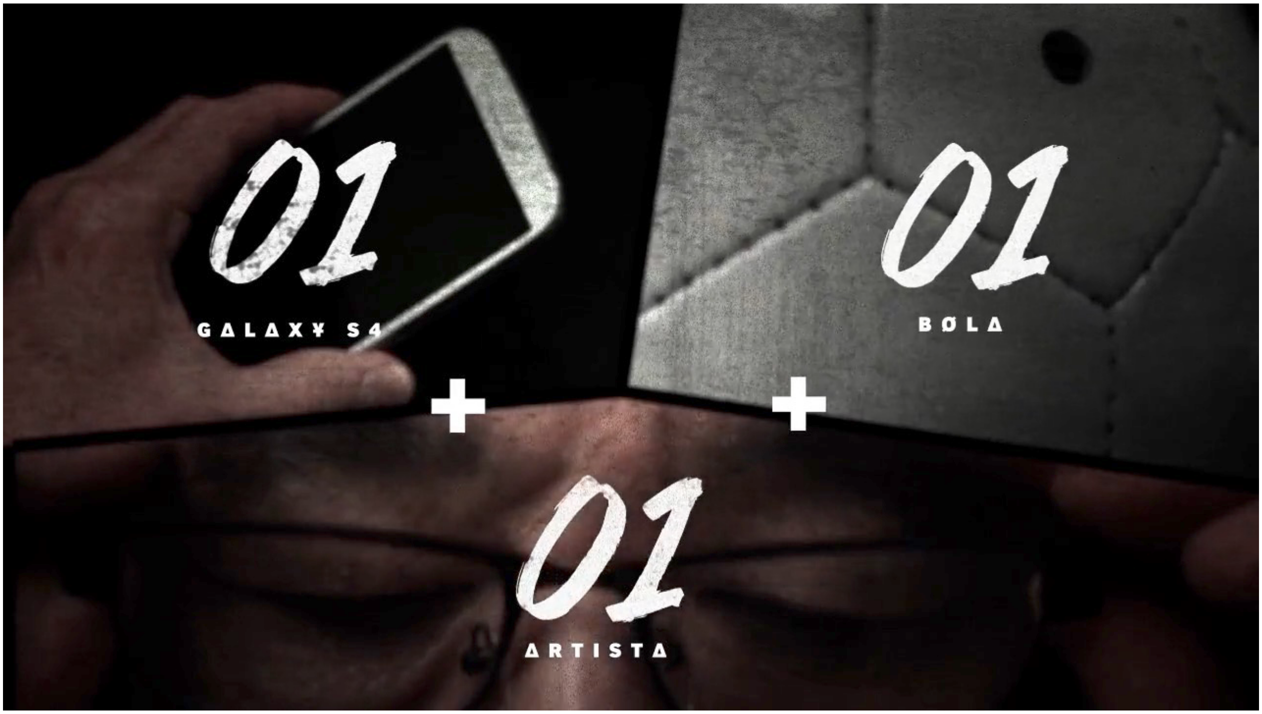
Futebol Arte [3] (Art Soccer) was developed by the production studio Cricket Brasil — currently a part of the international company MediaMonks — as a publicity campaign for the release of Samsung's Galaxy S4 smartphone. The project explored the movements of a soccer ball during kick-ups to synthesize generative art pieces. Caio Velenosi, responsible for developing the software tools employed in the project, was an interactivity developer at Cricket Brasil at that time.

Velenosi has been working with software development for more than ten years and has started to explore the field when he was a teenager. The discovery of generative creation came as Velenosi got involved with projects related to web interactivity. One thing led to another, as the interviewee said: "in this process of working with Flash, web, [...] I ended up discovering creative coding and this part that involves generative design, visual computing, even physical computing, integration with sensors, with external systems and everything else". Since then, Velenosi has been working at the intersection of technology and design, developing experimental installations and interactive experiences that often employ generative creation. "I had the opportunity to work on different projects, from urinals that did guitar solos to kinetic installations", he added. Moreover, before getting involved with the elaboration of interactive and experiential installations, he also worked with developing more business-oriented tools, such as ERPs[4].

After some years of existence, Cricket Brasil became the Brazilian unit of the international producer MediaMonks. With the transition, Caio continued to progress in the area as he joined the new unit's team as a senior developer. Today, he holds the position of technical director at the company. According to him, "MediaMonks is probably the largest digital producer in the world today, in terms of offices and number of people." The multinational company operates in several segments, "from platform systems and more business-oriented long-term projects to movies, animation, and games [...]. Practically all segments..." , explained Velenosi. In addition to these, MediaMonks also produces projects the company calls experiential, a category that embraces physical computing projects, new technologies, extended reality, virtual and augmented realities, and physical installations.

Before being incorporated into the MediaMonks structure, "Cricket was one of the main production studios working with experimental projects" within the national market, according to Velenosi. Since 2012, the agency has carried out projects for large clients, such as Billboard, C&A, Samsung, and Globo. According to him, this relevance led the agency to be incorporated into MediaMonks as one of the main units dedicated to experimental projects. "In the Netherlands, MediaMonks was already starting to work with experimental projects. And then, when we joined, we were able to expand it a lot".

3. Based on the interview with Caio Velenosi on May 19, 2021.
4. A type of software focused on enterprise resource planning.



Futebol Arte was commissioned by Leo Burnett — an advertising agency that provided services for Samsung at that time. "They came to us with the intention of doing something different for the release of the smartphone and to try to do something that was more creative," Velenosi said. Along with the brief, according to him, came the idea of incorporating soccer-related concepts into the project's creative equation: "The idea of the soccer ball came to us, like: [...] 'How can we make a soccer ball with a smartphone turn into art, into something tangible?'. From there, the challenge became figuring out "the physical feasibility — how to put a cell phone inside a ball —, and software requirements — how to turn it into something relevant, visually attractive and all that" concluded the developer.

Since the team started with the intention of capturing and processing data of the soccer ball's movements, a first challenge was to enable the integration of the smartphone with the ball. Humorously, Caio noted that the ball ended up being "very difficult to play", since a large foam coating for protection was necessary: "We could not use a common ball. So we had to find a supplier who made them by hand, learn how to sew the ball to be able to put the cell phone inside it, and everything else".

Alongside this integration effort, another challenge for the team was connecting and sending data collected by the phone to the computer. Briefly, Velenosi said that the idea was to "read phone sensors [...] inside the ball, communicate data via Wi-Fi with a desktop computer, and use accelerometer and gyroscope data to do a visual translation to generative art pieces".

Figure 52 (top): Frame of the official video of the project illustrating the integration of the phone into the ball.

To tackle the challenges mentioned above, the team was composed of four members. Besides Caio Velenosi — developing the software to synthesize the generative pieces — other members were dedicated to project management, graphic design, and electronics. “A management person, supervising; a creative person, to help validate the artistic part, especially the color palette; and an electronics person, who was responsible for [...] building the electronic part, [...] adapting the entire cell phone inside the ball”, said the developer. It is worth noting that the openness and familiarity among them were identified as essential factors for the project. According to Velenosi, working with the same team for over a year on previous initiatives made it easier for a “common ground, where everyone was satisfied”, to be found.

In general, the project was characterized by successive experiments concerning data collecting and processing. In Velenosi’s words, a process of understanding the problem and “understanding what you have in hand to work with it”. It was these various attempts and questions, according to him, that took the project from beginning to end: “Okay, [let us] put the cell phone inside a ball. How do you put it in there? How do you hold it? How do you guarantee it will not break on the first kick? [...] What information can we get from the cell phone? How is this information affected by being inside a ball?”...

These various questions and considerations characterize what Velenosi calls an iterative process. In short, the team executed one step after the other, constantly evaluating and refining what was being produced. A dynamic the developer believes is irreplaceable when dealing with interactive and experimental works: “Since the beginning, I had the phone in my hand, analyzing the numbers and how the computer was translating it”.

However, despite the exploratory nature of figuring out how to turn kick-ups into generative pieces, the spectrum of possibilities was somehow reduced due to the need to adopt the Galaxy S4 as a sensor. According to Velenosi, his motto of “understanding what you have at hand” to deal with problems led the team first to investigate which data they could satisfactorily collect through the phone. Basically, because the device was going to be inside the ball, the first sensor eliminated was the camera. Then, the remaining options were the accelerometer, gyroscope, barometer, GPS, Bluetooth, and Wi-Fi. According to Caio, Bluetooth and Wi-Fi are good options. However, they commonly require “a whole environment to be set” with routers or other receptive devices to infer the position through triangulation, which made the team abandon them. Moreover, since the campaign could be presented indoors, the GPS was not considered accurate for mapping the movements. Lastly, because of a similar lack of accuracy in mapping short movements, without “expressive rises and falls” and differences in atmospheric pressure, the barometer was, too, eliminated.

In the end, the team decided to use the accelerometer and the

Figure 53: Frames of the official video showing the process of incorporating the cell phone into the ball.

gyroscope to obtain data about gravity, acceleration, speed, and rotation.

According to Velenosi, after defining which information they would collect, the project became a matter of looking at data and trying to figure out how to “translate it into the final product of the project, which was visual”. A process of “understanding the information you have, and based on it, go prototyping and refining [...]”.

Concerning the creative process and ideation, another important aspect, according to Velenosi, was that the brief of the project and the graphic designer of the team were essential for the quality delivered by suggesting aesthetic guidelines for the program to pursue in its execution: “the look we wanted to have [...], color palette, line style, texture, those things”. Still, the program’s writing and subsequent creation of generative art pieces followed an iterative and collaborative process.

From the first drafts to the final versions, there were subsequent negotiations between the visual expectation of the team and what would be possible to synthesize computationally, considering the expertise of members and the resources at the time. The creative direction suggested an aesthetic outcome for the software to reach, and the tech team provided clarity regarding what was possible to execute and what needed to be adjusted in the creative vision.

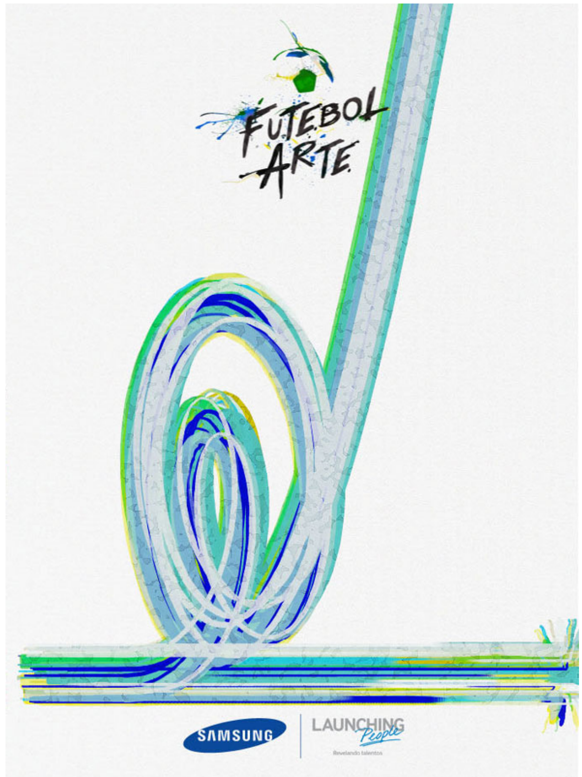
Despite these mentioned adjustments, Velenosi stated that the process undertaken could deliver a product close to what was expected, given, of course, necessary adaptations. Initially, the brief encompassed an oil painting texture to be synthesized by the program, which needed to be adapted due to the development deadline. “We ended up abandoning this look because of the deadline, development time, and everything else. It was not possible to reach that result in a way that would be good, but the client got satisfied with what we presented”, explained him. Another vital part of the creative equation was the frequent feedback provided by Samsung, which was possible because the team established a relationship where they reached out to feedback from the client when they had an interesting version to share. Then, expectations and impressions were collected and used as a basis for further refinement.

The inspiration for the visuals came when Velenosi was studying animation at college. “At the time, I was researching a lot about non-photorealistic rendering. [...] I found the work of an artist who was [...] simulating digital watercolor, and I spent a long time trying to unravel how the guy did it [...] It was one of my main references at the time”, according to him.

In his words, the project relied on three main computing elements in a “mixed process” to produce the generative works. At first, the data collected by the phone was processed and transmitted to the computer through a Processing application running on the mobile device. Then, another

Figure 54 (next page): Examples of final generative posters produced by the system of Futebol Arte.


FUTEBOL
ARTE
SAMSUNG
LAUNCHING People
Revelando talentos


FUTEBOL
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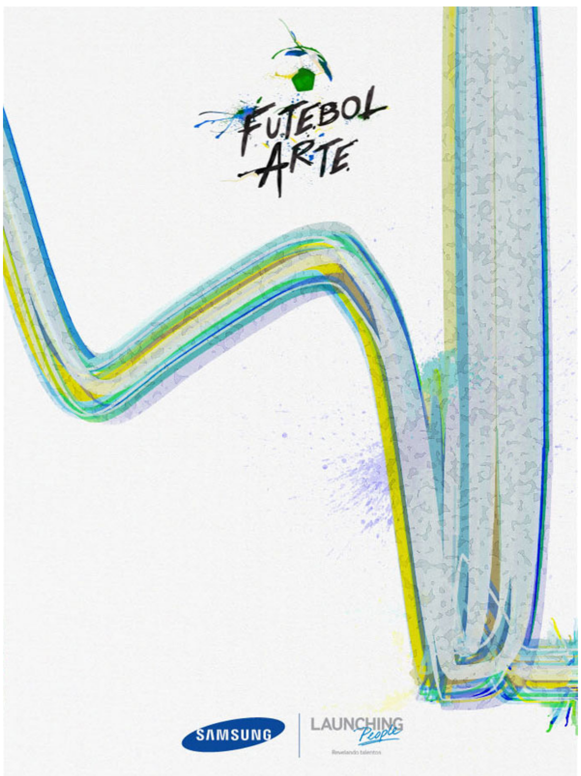
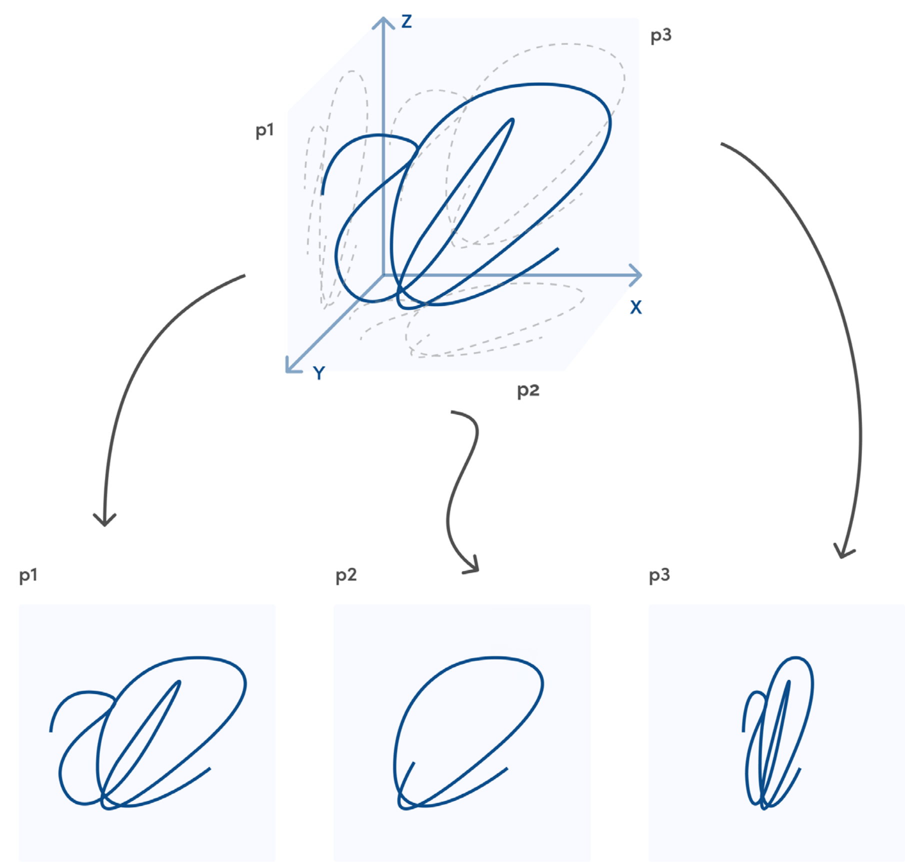
LAUNCHING People
Revelando talentos


FUTEBOL
ARTE
SAMSUNG
LAUNCHING People
Revelando talentos

application coded in Processing was responsible for receiving commands and executing instructions on the cell phone, such as starting and stopping data recording. Finally, visual synthesis was done through commands in Flash executed within Adobe Air. "At that moment, it was what I was most familiar with", explained Caio.

Once data was collected and sent to the computer, the generative algorithm drew shapes by mapping the ball's movement during kick-ups and translating it into visual aspects. We can understand this process as describing the position of a particle through the axes of the three-dimensional space and its variation over time. First, as illustrated in the board below, the movement tracked was projected into each of the three planes (p1, p2, p3). Then, the team evaluated results, and the most visually appealing projection was selected as the definitive piece.

Board 11: Futebol Arte - Drawing Process
Created by the author



Besides the affinity with the method, Velenosi chose generative creation as the main pillar of the project due to the lack of predictability in the data to be collected. In his words, "you do not have many alternatives because you are working with information you have zero control over." Here, the developer refers to the difficulty of determining pre-programmed commands triggered when specific values were detected caused by the unpredictability of the coordinates captured. As a complement to his reasoning, Velenosi also brought a counterexample:

> *We created an installation about two years ago for a film festival in Toronto, which was a tunnel, a metal structure that, when people crossed through, generated lights and had directional speakers. They played music according to your position* [...] *This project had nothing you could call generative.* [...] *The entire light scene was pre-programmed, the sounds were already pre-composed, I had already determined what it was like. So, the only thing you had was: trigger when the person is in position.*

In short, if the Toronto project discussed above could be solved by dividing the space into "slices" associated with certain lights and speakers, Futebol Arte was based on an object that could move in any direction. This is why it required a system capable of dealing with a lack of control and certainty.

> *I think this is one of the great things about generative art in general. To move between what is more art and what is more data visualization. And between these two extremes* [...] *there is a gigantic spectrum to explore, and that is the most interesting thing about it. In a project like this, in which we are working with random data, anything can happen, but we want to have a final result that is visual, that is aesthetically pleasing* [...] *So, let us control what we can: control the color palette, the stroke style, more or less how we want it to be* [...] *Within that* [...] *whatever comes will generate something. Some will look better, others will look less good, but it is part of the game.*

It is worth noting that the team also chose to capture kick-ups to establish a smaller scope for data processing. "We even thought about the possibility of a [soccer] match [...]. But, [...] since the ball had a whole internal structure to hold the cell phone, it was very heavy. Doing kick-ups was difficult. Imagine playing with it," explained Velenosi. In addition, he said that kick-ups evoked an individualist appeal and personalization that were desirable for the campaign: "I get the ball, I do the kick-ups, I have my art [...] The translation of the movements I made."

As part of the Galaxy S4 campaign, Samsung also presented Futebol Arte in a concept store at a shopping center in São Paulo. The intention was to have this physical place where people could go, do kick-ups with the ball and visualize the arts generated. "Some people in the audience were able to play and see their arts, which were displayed on the screens". On that subject, Velenosi said that there is always a satisfying reward in projects of this kind, which is the public's reaction: "There is a kind of magical characteristic of seeing something physical being translated into something digital and vice versa. [...] So it is always interesting to follow along, see the audience interacting and see the reactions, they are always very fun".

Since it was a part of an advertising campaign, the pace of the project was strongly dictated by the deadline and by client expectations. When asked when they decided to end the development of the project, Velenosi answered that it happened when the deadline was close and when the client agreed on the quality of what was presented. Thus, as he referred, it was a combination of "deadline, budget, result, and beauty".

However, despite the pragmatism concerning this moment of delivery, Velenosi said that "he would not have stopped it until today" if he had the opportunity to do so. "Mainly because of the look [...] I think it could get better," he explained. For him, the project could have taken other interesting paths if it had happened a few years later. "With tools, with techniques, and even visual background" to allow him to produce the desired results with the appropriate quality.

> *I think I would be able to produce a much more interesting final result in terms of visuals, algorithms, and data processing.* [...] *My mind was where I wanted to go, but the technical repertoire was not catching up yet.*

Regardless, Velenosi believes that they delivered the best results possible given the deadline and circumstances. According to the developer, the first big challenge was satisfactorily incorporating the phone into the soccer ball, which was solved after experimenting with different materials and sewing techniques. Another challenge was to "handle the information" coming from the phone, given the "very hostile environment". Here he refers to the data collecting complexities discussed previously.

> *When you talk about accelerometer and gyroscope data, it is very hostile.* [...] *The day I was the happiest was the day we executed a test: the guy* [...] *held the ball in his hand, I started recording, he walked 10 feet and stopped, and I stopped recording.* [...] *And when it generated* [*the image*], *it generated a straight line.* [...] *It generated something that made sense.*

Lastly, according to Caio, the great challenge was translating the captured movements into coherent visuals. They wanted to make it clear that visuals were determined by the movements captured by the phone. In his words,

Figure 55 (next page): Frames of the official video illustrating the translation of movements into the visual pieces.


FUTEBOL ARTE
SAMSUNG


FUTEBOL ARTE
SAMSUNG

“the idea [..] was to precisely show that [...] it was not random; that we were effectively using phone data”. Therefore, the tests performed went in the same direction.

In short, the “inevitably iterative” process mentioned by Caio started from a brief the developer captured through the question: “How can we make a soccer ball with a phone become art?”. For the campaign, the brief also outlined some important aspects that guided part of the creative process followed by the team. Finally, even though the definition of electronic apparatus and construction of the soccer ball involved research, the request to work with the Galaxy S4 as the primary sensor and integrate it into the ball resulted in a smaller scope of possibilities. Thus, the project started with a somewhat strict data capture scope and assumed investigative directions concerning the concept’s technical feasibility and production of visual outcomes.

Analysis and Discussion:

When confronted with the subpropositions (SPs) of our model, the case suggested the following implications:

> **1 - Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them** (**Endorsed**)
>
> Velenosi was the programmer of the project, who designed the algorithms and wrote the codes for final works to be produced. Computational processes were employed to collect and process data and to transform input into visual art. Because of that, direct manipulation was less emphasized as final results were essentially produced by the computer. However, we considered SP1 partially endorsed by this case because direct manipulation was still employed to create mood boards, visual inspirations, and aesthetic guidelines throughout the project. It still happened and contributed to the creative process, even if it did not produce the final artifact.
>
> **2 - Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.** (**Endorsed**)

Again, moments related to the postulated steps could be identified throughout the process. Since it was a publicity campaign, the client's expectations contributed to a reduced scope of **ideation**. In other words, the team has received beforehand a moderately elaborated **idea** as a brief of the project. Nevertheless, initiatives related to **abstraction** and **formalization** happened through iterations, since ideas were recurrently elaborated, presented, and implemented. Interestingly, a work dynamic between a graphic designer and a developer illustrated a creative process in which aesthetic goals were recurrently communicated to be abstracted into algorithms and programs by someone else. Finally, evaluation was habitual since the team and the client constantly discussed promising versions, which inspired improvements and further coding.

SP2 was endorsed, but again it is necessary to point out that stages did not happen linearly. On the contrary, moments of ideation, abstraction, formalization, evaluation, and refinement happened disorderly and collaboratively during the project.

3 - Due to the existence of a characteristic layer of abstraction — as designers need to think in terms of algorithms to create desired artifacts, there is a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking. (Endorsed)

The very nature of a tech project being carried out by a multidisciplinary team suggests the presence of abilities related to both design thinking and **computational thinking**. Programming, per se, requires computational thinking. In addition, we could identify a layer of design-related abilities because it was constantly executed in parallel with technical feasibility research and visual experimentation. As stated by Velenosi, the creative direction suggested aesthetic outcomes for the software to reach, and the tech team provided clarity regarding what was possible to execute and what needed to be adapted in the creative vision. Such a negotiation relied on design thinking and computational thinking to enable the discussion and incorporation of concepts into a single solution. From the early moments in which visual and software concepts started to be elaborated to the use of product design approach to produce a ball capable of smoothing impact and protecting a phone, this mixed approach supported the coevolution of problem and solution. Because of that, SP3 was endorsed.

4 - Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (concept-based ideation). (Endorsed)

Velenosi's team started from a concept illustrated by the project brief. The client wanted to release a campaign for the Galaxy S4 in which soccer was an inspiration. Explicit concept-based ideation was followed, as the central theme influenced aesthetic and technological explorations with the purpose of materializing preconceived motivations. Of course, material-based ideation approaches were used in specific parts of the project, especially in defining the final visual language synthesized via software. Regardless, we considered SP4 endorsed, as well.

5 - It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track. (Endorsed)

As referred to by Velenosi, he does not "see how a project of this kind could follow a process" that is not based on iteration and constant refinement. In this sense, the project was carried out through cycles of ideation, exploration of technical means, development, and refinement with the client. Because of an approach based on collaboration and multidisciplinarity, SP5 was endorsed.

6 - Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements. (Endorsed)

Despite assuming an experimental approach many times, especially concerning data collecting, algorithmic synthesis, and electronic structure, the Futebol Arte project was commissioned by a publicity agency, which implies that **requirements and constraints** existed. For instance, the relevance of requirements was illustrated by the presence of a management person in the team. Moreover, the necessity to rely on the sensors of the Galaxy S4 established additional constraints and requirements that needed to be considered when **planning** the project.

After research and exploration, the team managed to better **define** the project as a system capable of collecting and processing kick-ups data from a phone incorporated into a ball to draw generative art. Furthermore, visual ideation and software experimentation supported the team's work, implying that **design**, **development**, and **deployment** stages were executed. **Alternatives** were considered and abandoned due to constraints, as prototypes were discussed with the client, and **evaluation** was mainly concerned with the visual quality of the pieces and the accuracy and coherence of the data being collected and processed.

All these considerations endorsed SP6.

The implications discussed previously are summarized and illustrated through the filled model on the next page.

Board 12: Model confronted with Futebol Arte
Created by the author

Subpropositions	Futebol Arte
Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.	Partially Endorsed Direct manipulation was still employed to create mood boards, visual inspirations, and aesthetic guidelines throughout the project.
Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.	Endorsed Steps could be identified throughout the process, but not in a delimited way — stages happened disorderly and were shared collaboratively during the project.
Due to the existence of a characteristic layer of abstraction — as designers need to constantly think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking.	Endorsed From the early moments in which visual and software concepts started to be elaborated to the use of product design approach to produce a ball capable of smoothing impact and protecting a phone, this mixed approach supported the coevolution of problem and solution.
Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)	Endorsed. Concept-based Ideation Explicit concept-based ideation was followed, as the central theme influenced aesthetic and technological explorations with the purpose of materializing preconceived motivations.
It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track.	Endorsed. Rapid Iteration, Collaboration and Experimentation The project was carried out through cycles of ideation, exploration of technical means, development, and refinement with the client.
Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements.	Endorsed Futebol Arte was commissioned by a publicity agency, which posed requirements and constraints. Moreover, the necessity to rely on the sensors of the Galaxy S4 established additional aspects to be considered by planning initiatives. After research and exploration, the team managed to better define the project. Furthermore, visual ideation and software experimentation supported the team's work, implying that design, development, and deployment stages were executed. Alternatives were considered and abandoned, and evaluation was mainly concerned with the visual quality of the pieces and the accuracy of the data being collected and processed.

5. Based on an interview with Dimitre Lima and Gabriela Castro on June 06th, 2021.

3.4 Atmosfera and Metaespaço [5]

Dimitre Lima and Gabriela Castro met in Rio de Janeiro in an artistic residency. At that time, Gabriela maintained with Marlus Araújo the studio Mirabilis — a studio that employed design, architecture, and technology to design objects, installations, and digital experiences. Gabriela has a Bachelor's degree in architecture. However, since college, she wanted to get involved with projects that go beyond the traditional look and feel, something not always possible in conventional architectural works, according to her. Such motivation led her to work with scenography within a technological context at the Brazilian studio SuperUber. The studio values multidisciplinary production and incorporates technology into big clients' design, art, and architecture projects. For instance, when she was part of SuperUber, Gabriela designed scenographic projects for the Museum of Tomorrow in Rio de Janeiro and the creative conference Rio2C.

Dimitre Lima's relationship with such projects is also long. Lima has a degree in graphic design, but he always liked computer programming. Finding possible intersections, the designer and artist began to increasingly integrate his technological affinities to his projects to experiment with other means of expression and creative paths. With an extensive art, design, and technology portfolio, Dimitre has designed interactive and contemplative artifacts for relevant national and international clients such as MTV, Oi, Red Bull, Nike. Nubank, and also for the public sector.

After the period within SuperUber, Gabriela started to focus on her authorial work, which led her to create the Estúdio Mirabilis with Marlus Araújo — an initiative that made possible for her to deliver projects for museums and cultural institutions. The projects Atmosfera and Metaespaço were initially Mirabilis'. However, Dimitre joined the project's team due to a partnership with Gabriela and Marlus in the artistic residency.

The Brazilian city of Pato Branco commissioned Atmosfera and Metaespaço for the Inventum 2019, a science, technology, and innovation fair promoted by the city. The event took place between November 8th and 13th, 2019, receiving around 180,000 visitors.

According to the event's theme, Gabriela and Dimitre were challenged to create exclusive technological interventions for the fair space. The duo then considered the other installations and sessions promoted by universities, museums, and companies at the event and chose to differentiate themselves through the design of passage spaces.

In part, considering these transitory spaces, rather than rooms, sections, or demarcated places, came from the desire to propose an experience to be organically incorporated into the path of all visitors. Something that would help build the "climate" of the event. Dimitre said that part of this climate-building inspiration came from an event he attended to in the past:

I remember a music event [...] *that took place in 2004, in which you entered, and you could not see anything. There was an installation with many hoses, you could not see anything for a while and when you reached the other end, it changed... all the corners of the space were round, velvety, with different colors, with different smells, so you had an exact impression of transition. You are in one place, you arrive in another place, and the temperature is different. Everything is different.*

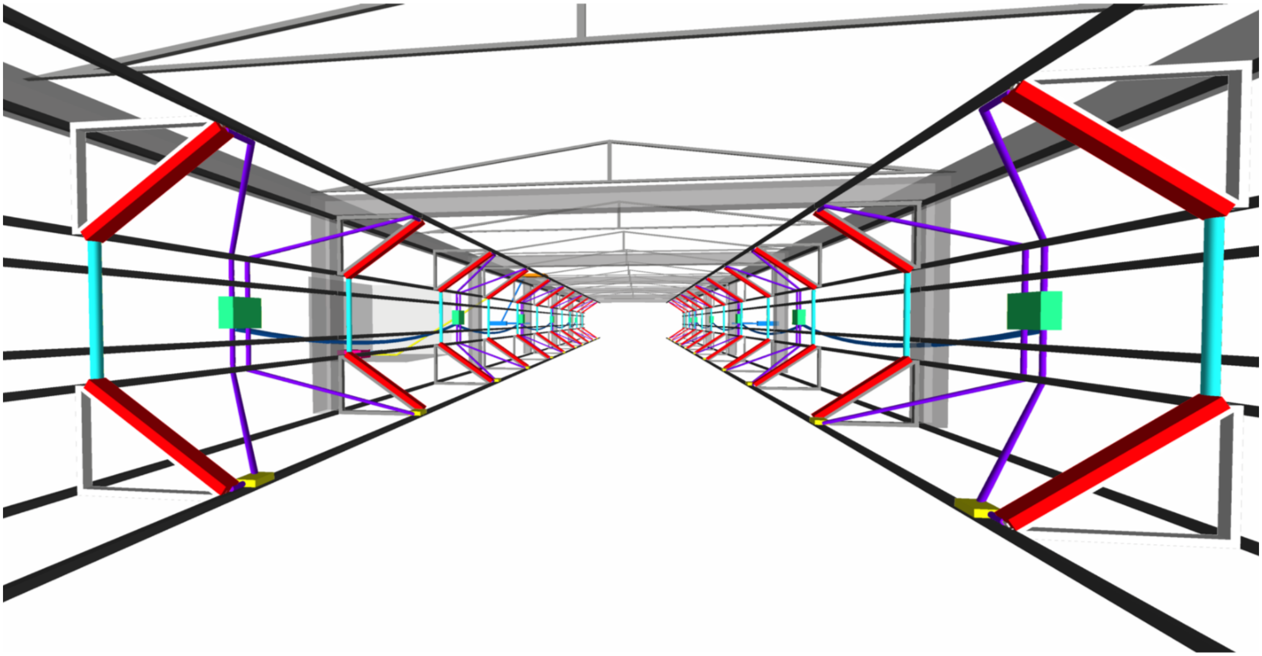
Furthermore, the size of the site was also a factor to take into account since the fair took place at an open convention space, with kilometers in length. For Dimitre, elaborating spaces of passage was a way to mix architecture with technology, and capture people's attention without requiring them to enter a room. For Gabriela, choosing spaces of passage was also a strategy to capture the disputed attention of visitors, who would still have a multitude of other "super interesting places" to see. Therefore, the duo chose to design an entrance. "A starting point," as referred to by Lima, to provoke a feeling of change in people who were crossing by.

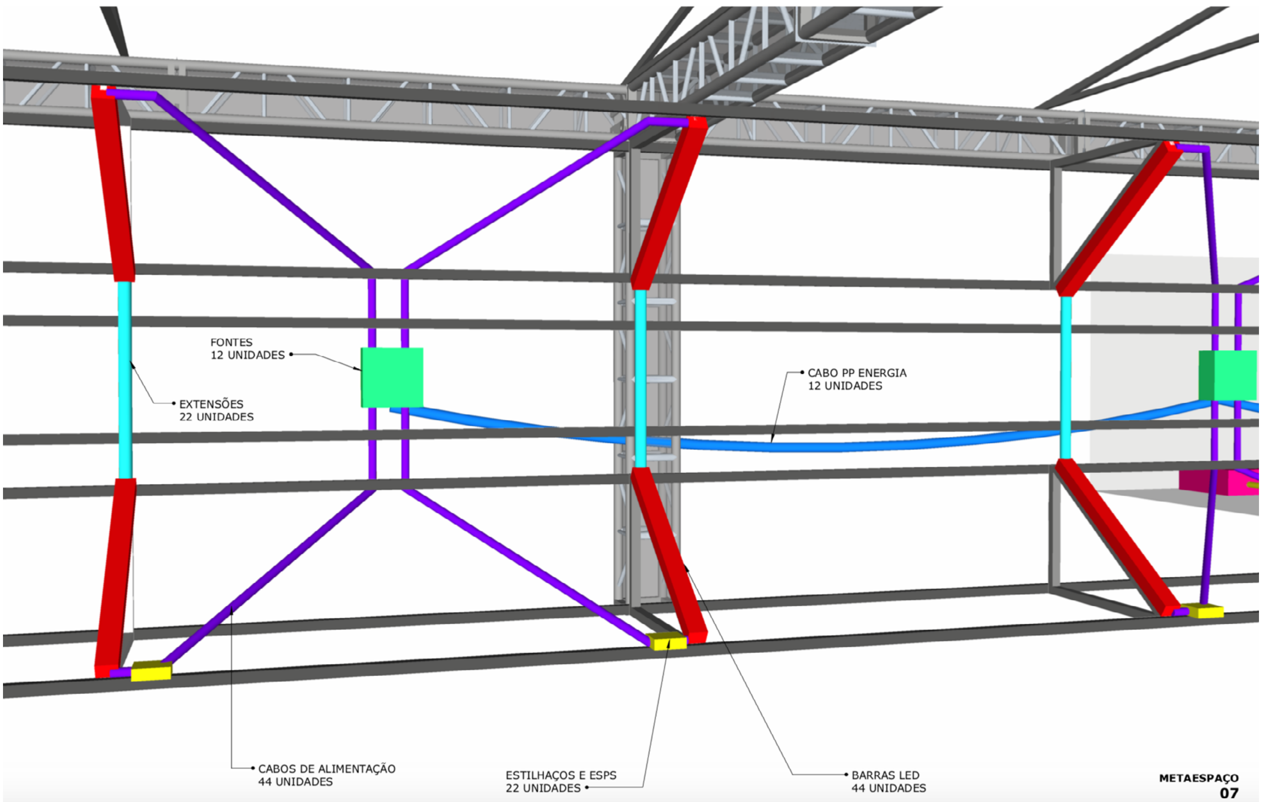
The first sketches submitted for the fair organization described an installation corridor, a structure of approximately 40mX8m that would be inserted right at the entrance to the space. "We were surprised because we designed a huge structure, and we never thought it would be approved. [...] But in the end, their question was: 'can we do 45 meters?'", explained Dimitre. Despite some bureaucracy, Gabriela highlighted the receptivity, interest, and artistic freedom promoted by the fair's organization as positive factors: "It is cool that they embarked on ideas they had never done before." To which Dimitre added: "Another surprising thing is that we [said]: 'We can do this installation, this one or this one,' and in the end, they said: 'okay, but we want the three of them'". Metaespaço and Atmosfera were two of these three installations produced for the Inventum 2019.

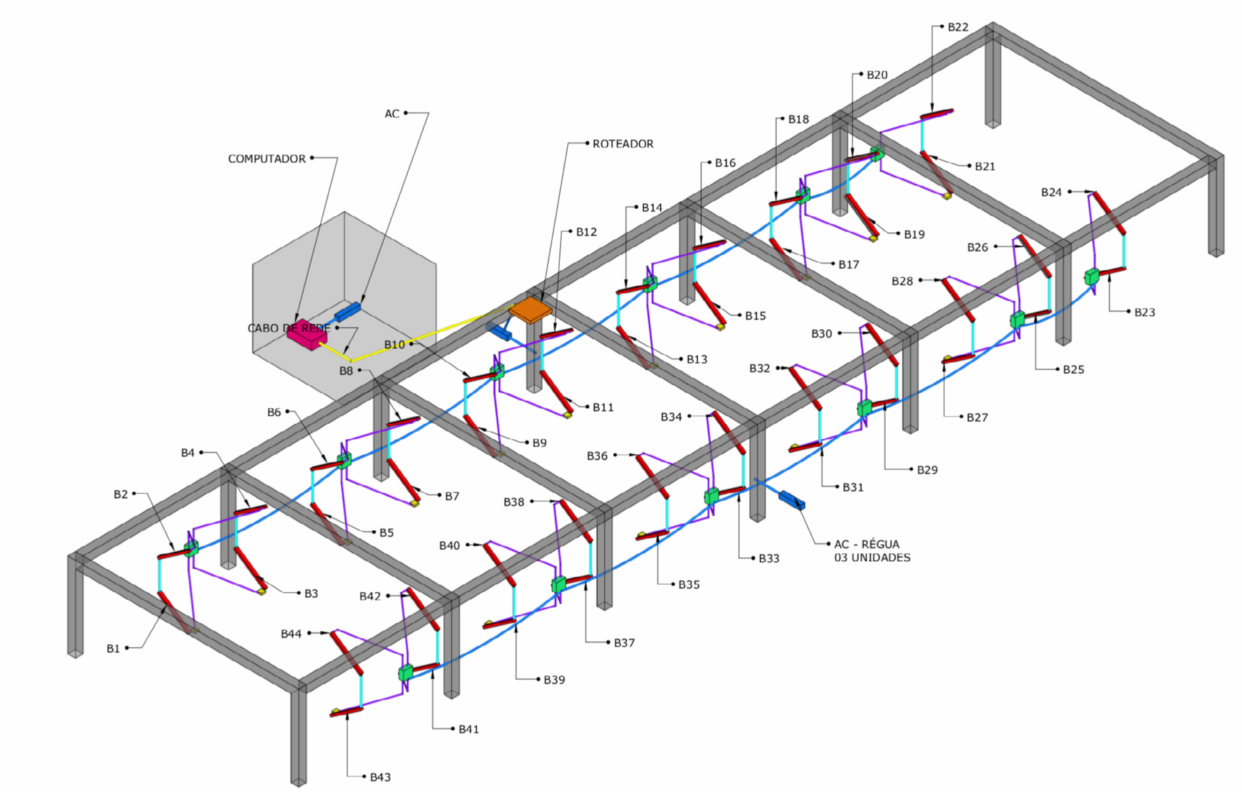
Intending to design interventions related to the event's theme, the duo started by searching for a "face" to technology. In other words, they were looking for visual concepts that would allow the installations to be perceived as technological artifacts, illustrating the event's purpose. One of the first obstacles faced by the duo, according to Dimitre, was precisely to define what technology aesthetically is: "we wanted it to have to do with technology, but at the same time, technology does not have a face. [...] The more advanced technology is, the more transparent. So we decided to appeal to what people see as technological."

In the archetypes shown in classic movies such as 2001: A Space Odyssey, Gabriela and Dimitre found inspiration and ways to make their intentions tangible: "We started researching the archetypes of cinema because there is a whole simulacrum of the face of technology. [...] In some

Figure 56 and 57 (next page): Models of Metaespaço's physical structure. View from the inside.




FONTES
12 UNIDADES
EXTENSÕES
22 UNIDADES
CABO PP ENERGIA
12 UNIDADES
CABOS DE ALIMENTAÇÃO
44 UNIDADES
ESTILHAÇOS E ESPS
22 UNIDADES
BARRAS LED
44 UNIDADES
METAESPAÇO
07



movies, even today, you have green screens with cursors and codes". Despite acknowledging that technology "can be anything", Gabriela added that resorting to this early-technology aesthetic worked as a "good reference to" define the look and feel of the installations.

Associated with the concept of passage spaces, the aesthetic explorations of Dimitre and Gabriela led them to design a spatial corridor, those corridors that have lights, a half-hex perspective, and a typical spaceship appearance, as defined by the duo. "It is not that there is a spaceship like that, but I think 2001 (A Space Odyssey) proposed this, and until today the cinema has not been able to detach from it", they acknowledged. According to Gabriela, to evidence a "high tech" look, they also decided to incorporate a "spatial window" into the corridor to put "the person in a completely different place". Such a window required not only a wide viewport but also appropriate content to be displayed. Thus, the entrance assumed the form of a spatial corridor, with two horizontal windows from end to end, in which the vivacious generative content was displayed.

Because they started working in São Paulo, Gabriela said an essential part of the creative process was sketching schemes and exploratory drawings for the installations: "since we were not in place, [...] we had to expand the imagination, testing, imagining scenarios". Naturally, though, many

Figure 58 (top): A model of Metaespaço's physical structure. View from above.

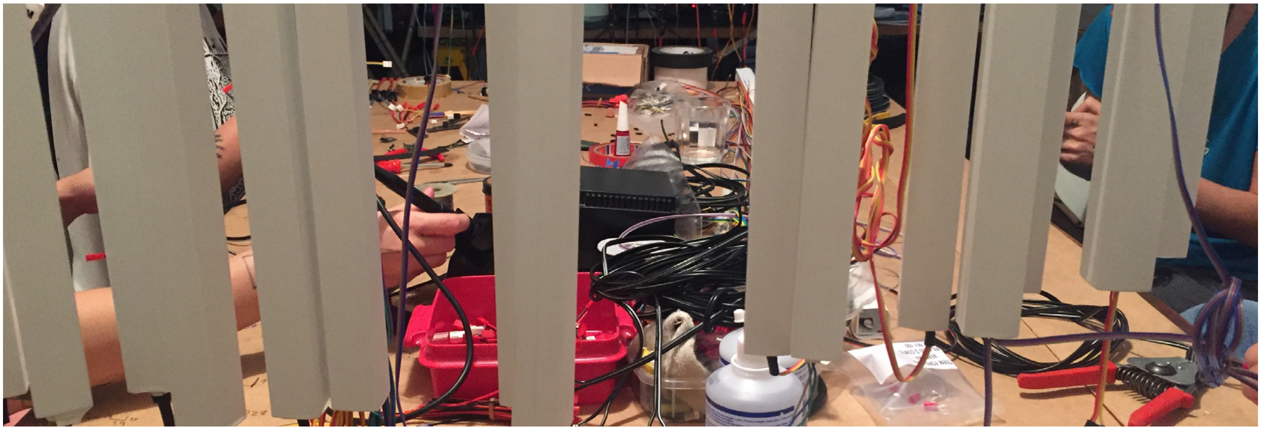


Figure 59 (top): A picture of the pre-assembling.
Figure 60 (middle): A picture of the setup of Metaespaço and the car the team rented.

adjustments became necessary when the team actually began building the structures. For Dimitre, for example, a significant element of the creative process was the adaptations that had to be made due to the various constraints that appeared during the setup.

Moreover, according to the duo, the involvement with the setup was something worthy of note. In Pato Branco, the team got into a daily routine of going to and from the fair to make sure everything was accordingly. Humorously, Dimitre said that they had rented a car to transport all the material. "About the setup, it is always intense [...] it is always impossible to predict how it is going to be. Sometimes we even stayed at dawn [...] to better tune the lights and everything else", added Gabriela.

Interestingly, the designer also said that he worked on the elaboration of the generative virtual content in parallel with the setup of the structures. According to him, "when the project is put together, you notice other things".

Therefore, he usually sets a worktable inside the installation to create the programs while being surrounded by the physical structure that is going to support them.

During the fair, the duo also stayed close to their installations to pay attention to how visitors interacted with them. Commonly, these observations ended up motivating minor adjustments and improvements for the following day.

Figure 61 (top): A picture of Metaespaço at night.
Figures 62 (bottom), 63 (next page / top) and 64 (next page / bottom): Photos from visitors interacting with Metaespaço.

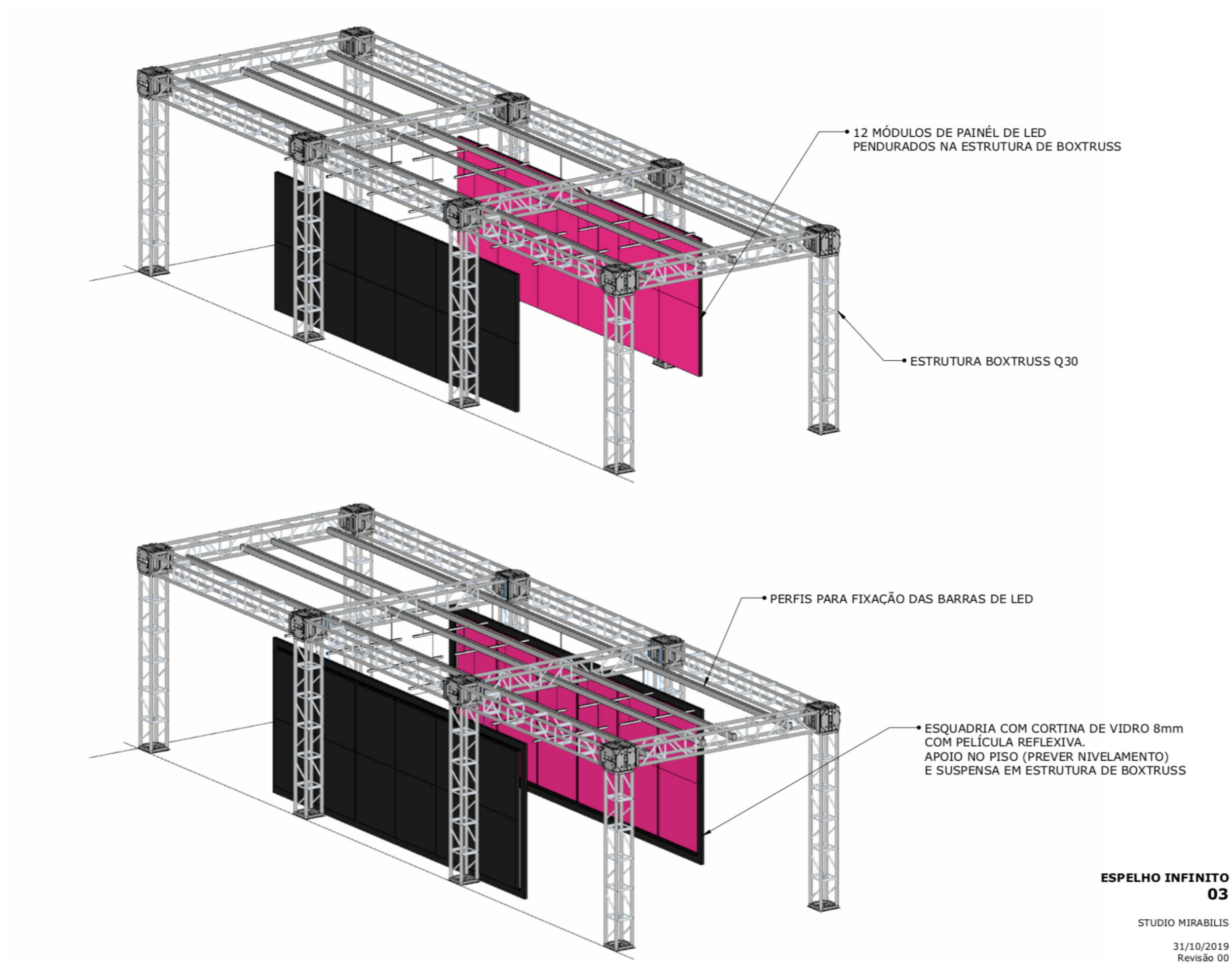

inventum

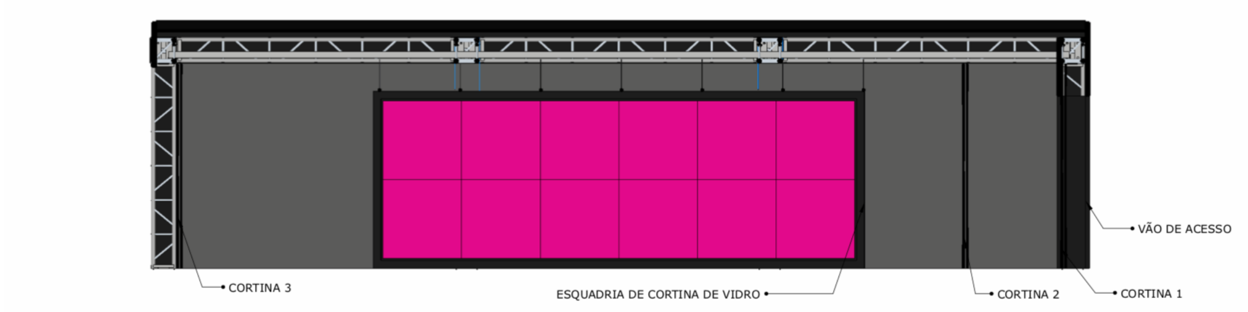
At approximately 300 meters from Metaspaço, the creative and aesthetic paths taken by Gabriela and Dimitre also resulted in the design of a second corridor installation, the Atmosfera. Still working with the concept of passage spaces, this second project was a much smaller corridor than the first one, connecting two other spaces at the fair.

According to Dimitre, the intention of Atmosfera was still "to hijack people's attention almost without meaning to", but through the creation of "a space of reflections where the virtual content would blend with real content". Therefore, relying on LED panels and a mirrored curtain attached to the corridor's structure, the team materialized thoughts about how reflected elements can be exciting compositions when more attention is paid to them.

According to Dimitre, although not everything turned out as planned, many adjustments were successfully incorporated into the project's creative equation, "becoming a language". The bluish aspect, for example, was accidentally caused by the too-blue mirrored film they bought to create

6. C++ is a programming language created by Bjarne Stroustrup as an extension of the C programming language. Stroustrup's general intention was to incorporate object-oriented programming into the C language.





the installation. As he referred, when the reflection got amplified, this blue tone multiplied and became bluer. According to the designer, though, the installation was successfully built despite the adjustments that needed to be made and relying on “simple” content.

The virtual content of the two installations was generative and synthesized in real-time by programs written in openFrameworks — a programming framework for aesthetic purposes based on C++[6].

For Metaespaço, Dimitre drew on some of his previous explorations with simulations of sinuous particles, which moved and behaved like “a shoal of abstract objects”. “Tadpoles”, as referred to by him, However, an important insight came when he realized that the same sets of particles left trails resembling electronic circuits if programmed adequately. In his words, it was on the frontier between biology and technology that he found central inspirations for the installation:

> *I started to experiment with these shoals, creating tracks. And when I narrowed their angle, they automatically looked like electronic circuits, so it was super fun for me to work on the edge.*

By working with this organic-electronic aspect, the duo also saw how to incorporate the fair theme into the visual language of their installations. “The city surprised me because they invested a lot in their technological hub [...] Thus we also had this idea of using shapes that resembled pulses, electronic signals, and electronic boards within this digital content”, said Gabriela.

Concerning interactivity, Dimitre and Gabriela decided not to connect sensors to the synthesis of generative content. Instead, they chose to tackle the interactivity through the careful design of the structures involved and the anticipation of how people could connect with their physical and virtual elements. According to Gabriela, they established “a conversation between the space [...] and what was being generated”. For example, the main challenge in creating the generative content for Metaespaço, according to Dimitre, was working with such a wide window, which required the designer to program a set of repeatable scenes to be replicated and articulated

Figure 65 (previous page / bottom): Models of Atmosfera’s physical structure with the LED panels. Texts in the figure are in Portuguese.
Figure 66 (current page / top): Model of Atmosfera’s physical structure with the LED panels. Different view. Texts in the figure are in Portuguese.

Figure 67 (top): Photo of Dimitre and Gabriela inside Atmosfera. It is worth noting the blue tone discussed by them in the interview.

throughout the viewport. To properly create the repeatable scenes, he built several three-dimensional models of the structure to try to predict the appropriate relationships of size between the content and the visitors.

For the generative content of Atmosfera, in turn, the duo resorted to wireframe representations and vector graphics of older displays, still exploring computer simulacra and their evolution. "Deformed spheres with polygons" were spread over the screens to resemble "bacterium, amoeba flying", which Dimitre exemplified through the aesthetics of the old covers of Kraftwerk. Along with the generative content, the physical effect caused by the arrangement of the mirrors inserted visitors into a "repeating cloud" in which the above-mentioned abstract shapes blend with visitors' silhouettes.

According to Dimitre, generative creation was also the best choice for the problem as it allowed him to create "software of 10, or 15, megabytes", capable of producing original content in real-time, without ever repeating itself: "It is fun this possibility for you to create the seed of how something happens, but not exactly knowing all the possibilities". Moreover, for dealing with programmatically produced content, Dimitre and Gabriela could easily adjust and improve the generative content to match the physical structure and the environment: "there was not a day that we did not have adjustments".

As Gabriela referred, such a process based on a series of refinements is associated with a perception that “these works [...] never end”. In fact, according to the duo, the main criteria for the end of the project were the deadline, access to materials, and the availability of other teams involved in the setup.

Finally, complicated by bureaucratic procedures required by the city hall, the logistical processes of hiring a team, importing electronic parts, and financing the project were placed as the duo’s main challenges. Gabriela and Dimitre said that they spent quite some time without having a contract signed, which became an obstacle for the investments that needed to be made. “We are a small studio. We do not have working capital [...] to hire people at risk for an installation that we do not have the contract signed for yet”, Gabriela explained. For instance, bureaucracy also forced the pair to give up another project, which Atmosfera replaced. The initial idea for the second corridor installation was to make a fiber-optic structure, for which the team manufactured a component, in China. However, the complications involved in importing the technology made them give up this first idea for the project.

Analysis and Discussion:

When confronted with the subpropositions (SPs) of our model, the case suggested the following implications:

1 - Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them (Endorsed)

The production of the generative content of the installations was indeed carried out through experimentation with programming and software tools. As stated by Dimitre, final versions were influenced by early investigations with generative particle simulations, which were refined and adapted to blend with the physical structures of the project. Moreover, when he ran some programs and realized that the same set of particles could be employed to create virtual “electronic circuits”, he achieved a more concrete idea to pursue. These considerations imply that the role of “curator of computational processes” was indeed assumed.

However, we considered SP1 partially endorsed because direct manipulation was used throughout the project. In this case, it was employed in the production of models and of the physical structures into which generative content was incorporated to compose the final experience.

2 - **Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.** (**Endorsed**)

Dimitre and Gabriela constantly relied on a conceptual network that inspired both their physical and software efforts. From the moment the challenge was accepted, the duo envisioned the experiences they intended to evoke in visitors and had them as the basis for **ideation**. Hence, concepts such as technology, electronics, cybernetics, space, and the universe ignited their experimentation with physical structures and **abstraction** into **algorithms** and **programs**.

The conclusion above implies that their work involved the abstraction of ideas, formalization into source code, and production of final results. Lastly, **evaluation** was also constant, as exemplified by the moments in which Dimitre said that he kept programming and adjusting software during and after setup until they were satisfied with the results.

We considered SP2 endorsed but also acknowledge that stages (ideation, abstraction, formalization, evaluation, and refinement) did not happen linearly.

3 - **Due to the existence of a characteristic layer of abstraction — as designers need to think in terms of algorithms to create desired artifacts, there is a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking.** (**Endorsed**)

Metaespaço and Atmosfera were materializations of a project that relied essentially on architectural design and programming. As referred to by Gabriela, they managed to establish "a conversation between the space [...] and what was being generated".

Abstraction was central to the process as aesthetic intentions were constantly incorporated into the displays of the installations through software-based efforts. Dimitre was the actual programmer of the projects, which implies that abilities related to computational thinking were employed. In its architectural design initiatives, the project went through many explorations of look and feel as structures were envisioned as part of the fair. A myriad of sketches and models assisted the team in their framing efforts, and solution and problem coevolved as constraints related to technological and material capabilities were figured out. Naturally, these design-related initiatives inspired and influenced the production of generative content.

Because of that, SP3 was endorsed.

4 - Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (concept-based ideation). (Endorsed)

Atmosfera and Metaespaço were born from a brief that was flexible: the duo was challenged to propose novel technological interventions to blend with the other attractions of the fair. The concepts related to crossing, technology, sci-fi, and electronics were figured out as experimentation took place. Such a process suggested the employment of material-based ideation.

However, if we analyze direct manipulation separately of the computational synthesis of generative content, we might see that programming took place when more concrete concepts were defined. When Dimitre started experimenting with generative algorithms to create the virtual content of the installations, there were already some guiding concepts of look and feel put as goals for the programs to reach. In other words, from the beginning, his programming experiments aimed to produce technology-themed visuals for a "space window" and a room with mirrors.

Therefore, we considered SP4 endorsed as the process relied on both approaches for ideation. More specifically, generative creation was employed following a concept-based strategy.

5 - It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track. (Endorsed)

When referring to it as a work "that never ends", Gabriela illustrated a creative process that relied on constant experimentation and refinement. The duo maintained a routine in which sketching, prototyping, evaluation, and adjustments were the basis of creation for both manual elaboration and development of computational processes.

When mentioning the many adequacies they had to do in the physical structures during setup, and that generative content was produced as the installations were built, **a design approach based on rapid iteration, experimentation, and collaboration was favored**. Because of that, SP5 was endorsed.

6 - Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements. (**Endorsed**)

Despite acknowledging that an experimental approach sustained the development of the installations, Gabriela and Dimitre undertook a process in which **planning** and **definition**-related activities seemed to lead **design** and **development**.

Design, development, and deployment happened through the already discussed experimentation cycles. Accordingly, **alternatives** and **prototypes** were generated throughout the project, as the duo explored the more promising ways to build Atmosfera and Metaespaço. Lastly, as already discussed, such explorations were mediated by constant **evaluation** concerning the quality of the content synthesized and the overall ambiance inspired by the installations.

All these considerations endorsed SP6.

The implications discussed previously are summarized and illustrated through the filled model on the next page.

Board 13: Model confronted with Atmosfera and Metaespaço

Created by the author

Subpropositions	**Atmosfera and Metaespaço**
Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.	Partially Endorsed The role of "curator of computational processes" was assumed. However, direct manipulation was used in the production of models and the physical structures of the installations.
Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.	Endorsed Steps could be identified throughout the process, but not in a delimited way — stages happened disorderly and were shared collaboratively during the project.
Due to the existence of a characteristic layer of abstraction — as designers need to constantly think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking.	Endorsed Metaespaço and Atmosfera were materializations of a project that relied heavily on architectural design and programming. Dimitre was the actual programmer of the projects, which implies that abilities related to computational thinking were employed. In addition, in its architectural design initiatives, the project went through many explorations of look and feel as structures were envisioned as part of the fair.
Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)	Endorsed. Concept-based and Material-based Ideation The process relied on both approaches for ideation. More specifically, though, generative creation was employed following a concept-based strategy.
It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track.	Endorsed. Rapid Iteration, Collaboration and Experimentation When mentioning the many adequacies they had to do in the physical structures during setup and that generative content was produced as the installations were being built, a design approach based on rapid iteration, experimentation, and collaboration was clearly favored.
Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements.	Endorsed Gabriela and Dimitre undertook a process in which planning and definition-related activities seemed to precede the installations' design and development. Design, development, and deployment happened through experimentation cycles. Accordingly, alternatives and prototypes were, as the duo explored the more promising ways to build Atmosfera and Metaespaço. Such explorations were mediated by constant evaluation.

Chapter 4

Results

4.1 First move: framing initiatives, creation of foun dations, and the pilot model.

4.2 Second move: pilot study, feedback from thesis committee, and adaptations.

4.3 Third move: case studies

Results were organized into three research moves for better exposure. The first one represents the opening initiatives of this work — our primary assumptions, attempts of problem framing, and the rationale behind the pilot model. Then, as a second move, we reviewed and discussed the improvements made in the model and in our foundations motivated by the pilot study and suggestions of the thesis committee. Lastly, as a final move, we cross-analyzed our cases and confronted them with the first model to deliver the intended contributions of this work.

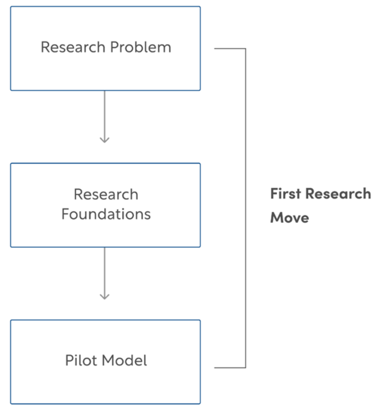
4.1 First Move

We began by making attempts on how to frame this research's problem. After a few explorations, we could define the criteria for building the corpus and the foundations to provide the necessary answers. To delimit the conceptual network of the study and start outlining a model, we created a foundation comprising the themes of **creative processes in design, interaction design, and generative creation and computational thinking in design**. As extensively discussed, each of these thematic subchapters went through concepts and models proposed by authors of the respective field.

As first results, the initiatives mentioned above provided us with concepts and general knowledge concerning creative processes and interaction design. Furthermore, they offered formal propositions regarding the analysis and understanding of generative systems' roles in interaction design. In essence, the first initiatives provided learnings such as:

- Concepts about creativity and a couple of generalist models for describing and analyzing creative processes;
- The main components of the creative activity in a design context;
- Resources to begin describing and interpreting the creative processes investigated through the above-mentioned generic models and contributions related to interaction and generative design.

According to what was exposed in the second chapter — method, these contributions were synthesized into the pilot model and pilot interview script, ultimately representing how they were taken as initial attempts for interpreting our corpus.



Figures 68 (current page / above): Illustration of the first research move.
Figures 69 (next page / bottom): Illustration of the second research move.

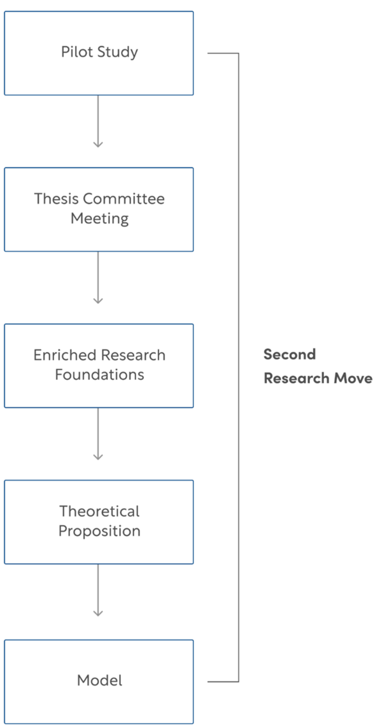
4.2 Second Move

The pilot model and interview script were put to verification through our pilot study. As exposed in chapter two — method, this validation-oriented study pointed out improvements that needed to be made. These changes were still discussed within a regular thesis committee meeting, which resulted in the definition of further practical initiatives to enrich the research foundations and build more appropriate data collection instruments. Such a shift was also documented in the second chapter.

By delving deeper again into the relevant themes of, new contributions were brought to the conceptual framework of this work. More specifically, we aimed to increase relevance through the addition of up-to-date propositions. As discussed in the second chapter, the revised foundations granted us many theoretical contributions (TC1, TC2, TC3), which in turn supported the elaboration of the following guiding theoretical proposition (TP):

When designing interactive products[1] powered by generative systems, designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.[2] Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.[3] Due to the existence of a characteristic layer of abstraction[4] — as designers need to constantly think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking[5] — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking[6]. Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation).[7] It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation). It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches[8]; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track[9]. Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and

1. (Goodwin, 2009; Saffer, 2009; Sharpe, Preece & Rogers, 2019; Unger & Chandler, 2012; Gothelf & Seiden, 2016; Cagan, 2017)
2. (Groß et al., 2018; Grünberger, 2019)
3. (Groß et al., 2018)
4. (Groß et al., 2018)
5. (Wing, 2011; Kelly & Gero (2021); Furber, 2012; Denning, 2009; Yadav et al., 2014; Wing, 2011; Bocconi et al., 2016)
6. (Kelly & Gero, 2021; Bocconi et al., 2016; Grover & Pea, 2013)
7. (Zhang & Funk, 2021)
8. (Saffer, 2009; Goodwin, 2009)
9. (Unger & Chandler, 2012; Gothelf & Seiden, 2016; Cagan, 2017)



deploy[10], and the activities designing alternatives, prototyping, evaluating, and discovering requirements[11].

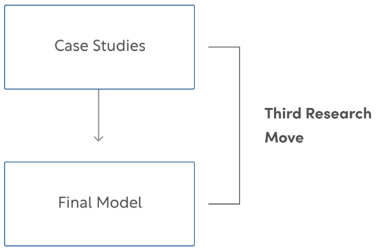
10. (Unger & Chandler, 2012)
11. (Sharp, Preece & Rogers, 2019)

Finally, as another round of synthesis, the theoretical proposition was employed in the elaboration of the model, illustrating the results of what we considered being the second research move.

Board 4: Model
Created by the author

Subpropositions	Heartbits	Tocando Brasília	Futebol Arte	Atmosfera and Metaespaço
Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.				
Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.				
Due to the existence of a characteristic layer of abstraction — as designers need to constantly think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking.				
Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)				
It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track.				
Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements.				

4.3 Third Move



Figures 70 (top): Illustration of the third research move.

The third move consisted of our case studies and their implications for the components of the model. Ultimately, by cross-analyzing cases, we could obtain insights about what was practiced in real-life and confront the theoretical patterns expressed by the model to establish a more accurate version of it.

In this sense, the revised model and the hypotheses inducted through it are the final contributions of this work.

The first subproposition — **Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them** — dealt with a significant difference between conventional processes in design and those that involve the use of generative systems.

When stating that such a difference exists due to a shift in the role of designers — from executors to curators of processes —, Groß et al. (2018) and Grünberger (2019) also suggest that direct manipulation recedes to the background, as the design process becomes principally intermediated by generative systems. However, when taken to our cases, SP1 was partially endorsed because the professionals and teams investigated notably relied on direct manipulation throughout the process despite letting the production of final artifacts be carried out by generative systems. The table on the bottom (Board 14) recaps how SP1 was perceived in each of the cases.

The observations suggested that direct manipulation was still critical to the creative process, despite eventually giving room for generative systems. Furthermore, **direct manipulation was notably employed in projects that needed to match a particular brand or aesthetic direction**.

Board 14: Confrontation of Subproposition 1
Created by the author

Subpropositions	**Heartbits**	**Tocando Brasília**	**Futebol Arte**	**Atmosfera and Metaespaço**
Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.	Partially Endorsed Direct manipulation to elaborate graphic elements to be achieved by the algorithm.	Endorsed Programming and software experiments intermediate ideation, elaboration, and execution.	Partially Endorsed Direct manipulation in the creation of mood boards, visual inspirations, and aesthetic guidelines.	Partially Endorsed Direct manipulation in the creation of mood boards, models and physical structures.

More specifically, the cross-analysis suggested the following possible involvements of the abovementioned approach in the design of interactive products powered by generative algorithms:

- Direct manipulation to elaborate aesthetic guides for algorithmic efforts (e.g. Heartbits and Futebol Arte);
- Direct manipulation to communicate intentions and the state of the project (e.g. Heartbits, Futebol Arte, and Atmosfera and Metaespaço);
- Direct manipulation to elaborate additional non-generative physical and digital elements of the interface/structure (e.g. Heartbits, Tocando Brasília, Futebol Arte, Atmosfera and Metaespaço).

When **taken as an aesthetic guide for algorithmic efforts**, direct manipulation was regularly employed in producing visual references, mood boards, sketches, and models to guide the development of the generative system. Such practices tend to be related to concept-based ideation for the presence of preconceived thoughts that are translated into visual representations prior to implementation.

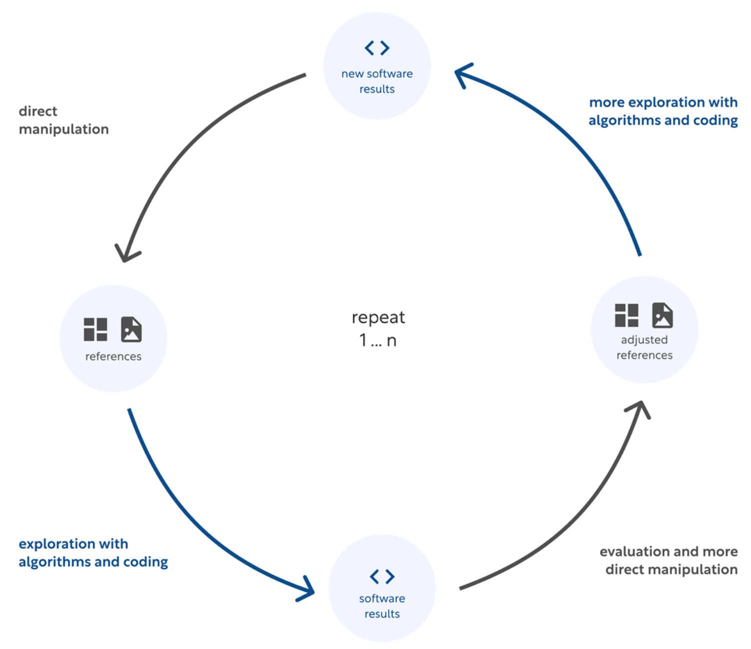
Regardless, it is worth noting that direct manipulation did not necessarily precede programming and software-based experimentation even when employed as aesthetic guides for technical efforts. Just the opposite, the analysis of cases revealed that it was incorporated into the processes according to what was proposed by the experimental and collaborative approaches we also investigated (SP5), being carried out along with development efforts in cycles of experimentation. We illustrated this dynamic through board 15.

Direct manipulation also **supported report and communication initiatives** when alignments were necessary and the state of the project needed to be demonstrated, whether due to client requirements or team dynamics. Manifestations of this category could be found in the development of mockups and models to communicate the intended structures of the interfaces and the overall look and feel of the generative content, as we illustrated through board 16.

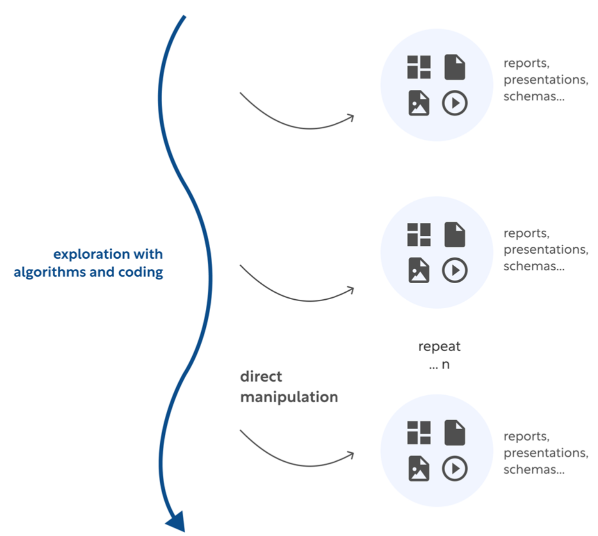
Lastly, direct manipulation was also **employed in designing non-generative sections or parts of the product**, which naturally influenced the making of generative content (Board 17). For the design of Atmosfera and Metaespaço, for example, direct manipulation was used to conceive the physical structure of the installations, which, in turn, motivated the team to make specific decisions concerning what was going to be produced by the algorithms.

Whether supported by direct manipulation or not, the need to abstract concepts into algorithms or to facilitate this process still emphasizes the fundamental change postulated by Groß et al. (2018) and Grünberger (2019) — from 'How do I draw?' to 'How do I abstract?'. However, to better

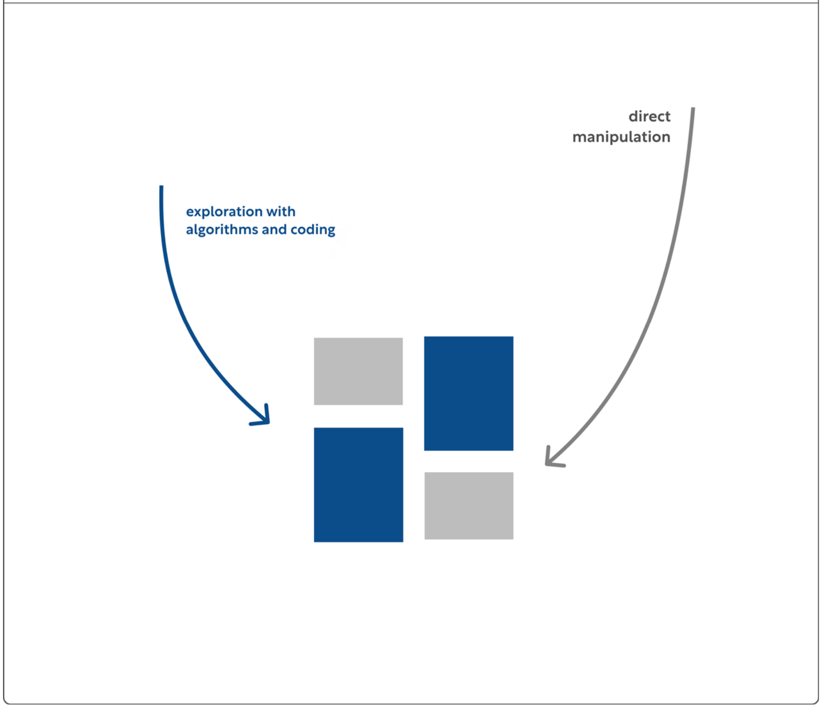
Board 15: Direct manipulation as an aesthetic guide for algorithmic efforts
Created by the author



Board 16: Direct manipulation to support report and communication initiatives
Created by the author



Board 17: Direct Manipulation to designing non-generative sections or parts
Created by the author



reflect what was practiced and consider direct manipulation as a possibly vital participant of the creative process, SP1 can be rewritten as the following: **Designers have their creative process fundamentally altered, as they are no longer supposed to produce artifacts exclusively through direct manipulation, but primarily through mediating the elaboration, curation, and evaluation of the computational processes that are supposed to produce them**.

With the second subproposition — **Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle —**, we essentially attempted to understand how the elements proposed were manifested in the creative process investigated.

When taken to our cases, the second subproposition was endorsed by moments and initiatives related to each of the steps. However, despite being illustrated as a somewhat sequential process by Groß et al. (2018), it is worth emphasizing that such initiatives happened disorderly.

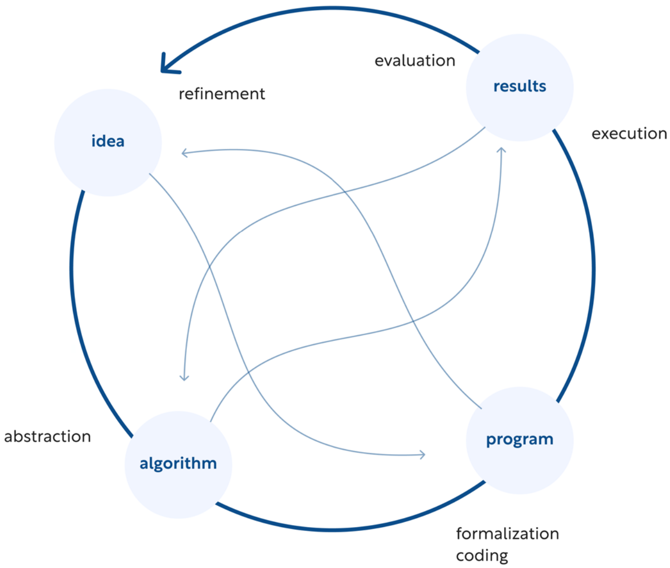
Moreover, the aspects we learned when investigating professionals' practice suggested a collaborative and multidisciplinary nature of real-world projects, which could be integrated into the model to reflect reality better. Tocando Brasília was the only project conducted individually. The others were conducted in collaborative and multidisciplinary ways, varying in how each of the disciplines of the team related to each other. For example, in Futebol Arte, Velenosi was responsible for programming the generative algorithms while being influenced by the creative direction in terms of what they wanted the system to deliver. As discussed in the case in question, constant negotiations between the fronts characterized the creative process. Similarly, in Heartbits, the team was organized into three different fronts: one focused on graphic design, another focused on building the generative algorithms to deliver the intended aesthetic experience, and the last front focused on implementing the applications for Android and iOs. As expected, in these scenarios, the postulated initiatives of ideating, abstracting into algorithms, coding, evaluating outputs, and refining were shared and influenced by the people involved.

The table below (Board 18) recaps how SP2 was perceived in the cases.

Board 18: Confrontation of Subproposition 2
Created by the author

Subpropositions	**Heartbits**	**Tocando Brasília**	**Futebol Arte**	**Atmosfera and Metaespaço**
Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.	Endorsed Steps could be identified throughout the process, but disorderly and shared among the team.	Endorsed Steps could be identified throughout the process, but disorderly and based on experimentation.	Endorsed Steps could be identified throughout the process, but disorderly and shared among the team.	Endorsed Steps could be identified throughout the process, but disorderly and shared among the team.

Board 19: Generative Design Process
Created by the author



More specifically, the cross-analysis suggested that concepts are defined, abstracted, formalized, turned into results, evaluated, and refined through a series of possibly disordered iterations, as illustrated by the board above (Board 19). Naturally, the results obtained could also motivate changes in the idea itself.

In order to capture the flexible, disordered, and possibly collaborative nature of the creative process investigated — thus better reflecting the practice —, without excluding those projects carried out individually, we can rewrite SP2 as follows: **Such a creative process relies on activities that can be interspersed and shared collaboratively, related to ideating, abstracting ideas into algorithms, translating algorithms into programs, obtaining and evaluating computationally-generated results, and refining the computational process to deliver the expected quality**.

We brought the third subproposition — **Due to the existence of a characteristic layer of abstraction — as designers need to think in terms of algorithms to create desired artifacts, there is a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking** — to the studies to understand the validity of the connections between computational thinking and design thinking as foundational elements of the processes studied. To this end, we resorted to the field's literature to learn about the essential activities and aspects related to the two forms of thinking. Subsequently, they were investigated in terms of how they were manifested and related to each other.

When confronted with practice, the subproposition was endorsed due to the presence of practical abilities and concerns related to design thinking and computational thinking in the processes investigated, and because there was a clear connection between them. The table on the bottom recaps how SP3 was perceived.

More specifically, the analysis suggested the following major activities for how each form of thinking was manifested:

- **Design Thinking** was used for framing the problem; elaborating sketches, representations, and models of the structures (digital or physical); conducting research-related abilities focused on technical feasibility and aesthetic possibilities; creating aesthetic references for the algorithmic synthesis; and envisioning context of interaction and environment to induce the indented experiences.
- **Computational Thinking** for describing the problem's context in terms of input, output, and necessary data; describing aesthetic production in algorithmic terms; decomposing instructions into aesthetic elements; adapting existing programs to be reused; handling data collection and processing, and debugging programs to process signals accurately and produce results satisfactorily.

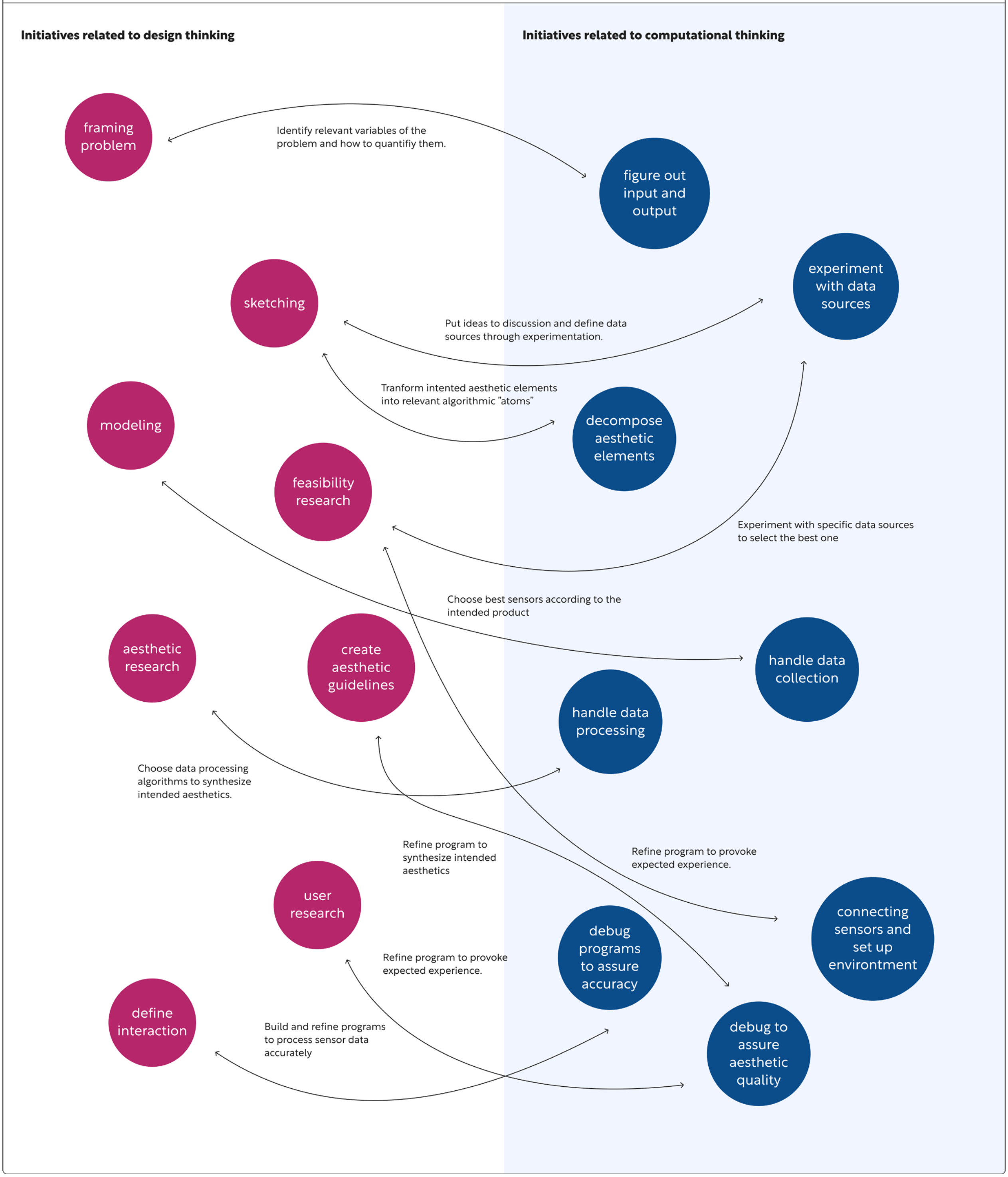
Board 20: Confrontation of Subproposition 3
Created by the author

Subpropositions	**Heartbits**	**Tocando Brasília**	**Futebol Arte**	**Atmosfera and Metaespaço**
Due to the existence of a characteristic layer of abstraction — as designers need to think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking.	Endorsed A mixed process in which aesthetic initiatives were constantly explored and taken as guides for algorithmic efforts and vice versa.	Endorsed Process based on constant experimentations with software, aesthetic references, inputs and outputs.	Endorsed A mixed process in which aesthetic initiatives were constantly explored and taken as guides for algorithmic efforts and vice versa.	Endorsed A project that relied on architectural design and programming. "A conversation between the space [...] and what was being generated".

Furthermore, because our cases relied on a mixed approach for creation in which exploratory research and propositions determined the goals of computational processes and vice versa, it seems valuable to suggest that designing successful interactive products powered by generative systems requires professionals or teams capable of mastering abilities related to computational thinking and design thinking. The board on the next page (Board 21) illustrates a few initiatives related to design thinking and computational thinking and the possible connections between them.

Therefore, we can rewrite the third subproposition to strengthen the relevance of computational thinking and design thinking as foundational elements of the creative process as follows: **Due to the existence of a characteristic layer of abstraction — as professionals need to think in terms of algorithms to enable the design of desired artifacts —, the creation of successful interactive products powered by generative systems depends on professionals or teams capable of mastering abilities related to both computational thinking and design thinking**.

Board 21: A few initiatives related to design thinking and computational thinking and their connections.
Created by the author



With the fourth subproposition — **Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)** —, we intended to investigate the prominence of an experimental approach to generative-design-related projects, as proposed by many authors of the field.

When taken to the cases, though, experimental approaches to ideation were not always favored, especially in projects associated with brands or explicit constraints. The table on the bottom of the page recaps the main insights about how SP4 was perceived.

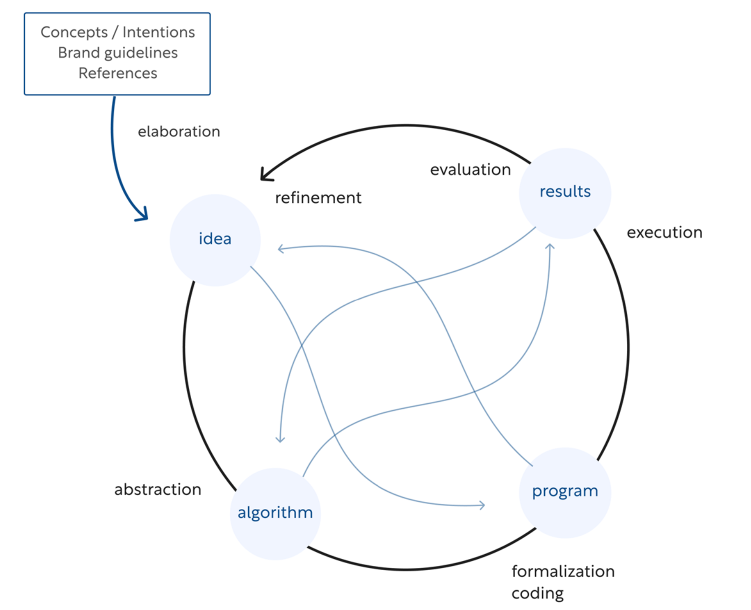
SP4 was endorsed because it could satisfactorily classify the dynamics of ideation followed. More specifically, categorizing these strategies into concept-based and material-based ideation offered a simple way to infer what contributed the most to the idea resulting in the final product. For instance, this thought allowed us to learn that concept-based ideation was favored when projects were supposed to attain a particular aesthetic guideline or produce a specific aesthetic quality. This conclusion suggests that somewhat beforehand-defined projects will likely rely on concept-based ideation, while experimental and artistic initiatives with fewer restrictions concerning delivery might be better suited for material-based ideation.

When proposing the thoughts of concept-based and material-based ideation, Zhang and Funk (2021) acknowledged that despite helping let us reason about the motivations behind a project, such a delimitation does not exist in real-life. Instead, projects comprise a mixed process in which professionals employ the two strategies on different occasions to deliver outcomes. Accordingly, we could observe this tendency in the cases studied. For example, in Futebol Arte, a central concept (soccer, movements, data from Galaxy S4) ignited the process and guided the team's work. However, other aesthetic concepts were obtained and pursued after technical and algorithmic explorations. For explanatory purposes, the two boards on the next page (Boards 23 and 24) illustrate the strategies mentioned above, separately:

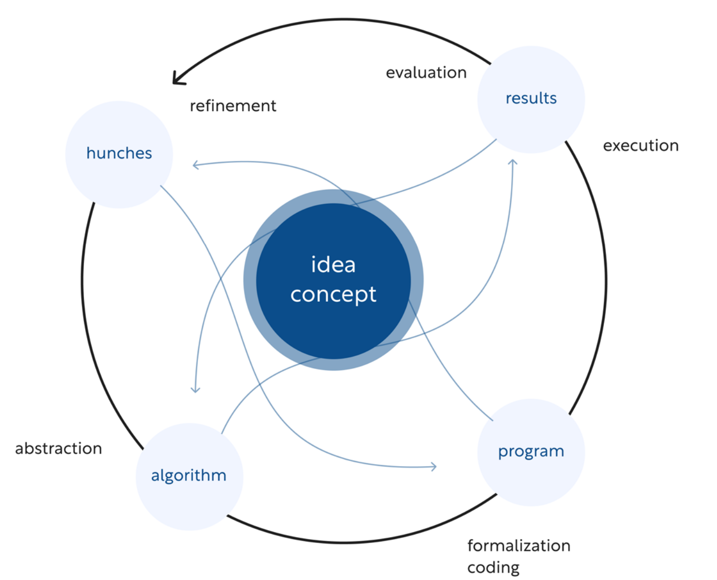
Board 22: Confrontation of Subproposition 4
Created by the author

Subpropositions	Heartbits	Tocando Brasília	Futebol Arte	Atmosfera and Metaespaço
Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)	Endorsed Concept-based: The problem was framed by the team in terms of the experience they intended to deliver — its functional and aesthetic purposes.	Endorsed Material-based: Rangel relied on experimentation and let this practice point out to concepts to be pursed.	Endorsed Concept-based ideation was followed, as the theme and brand requirementes influenced aesthetic and technological explorations.	Endorsed Concept-based: Generative creation was employed to enrich an experience that was already being imagined by the team.

Board 23: Concept-based Ideation
Created by the author



Board 24: Material-based Ideation
Created by the author



Lastly, despite being endorsed, we can rewrite SP4 to contemplate the abovementioned aspects and reflect reality better: **Two complementary ideation strategies might also enable and compose the creative process. First, professionals follow concept-based ideation when they choose to elaborate aesthetic concepts as guides for what will be synthesized by the system. Thus, directing algorithmic and programming efforts. In addition, they can work the other way around when constraints are more flexible and rely on material-based ideation to let many explorations with programming and software (the material) point out concrete concepts to be pursued**.

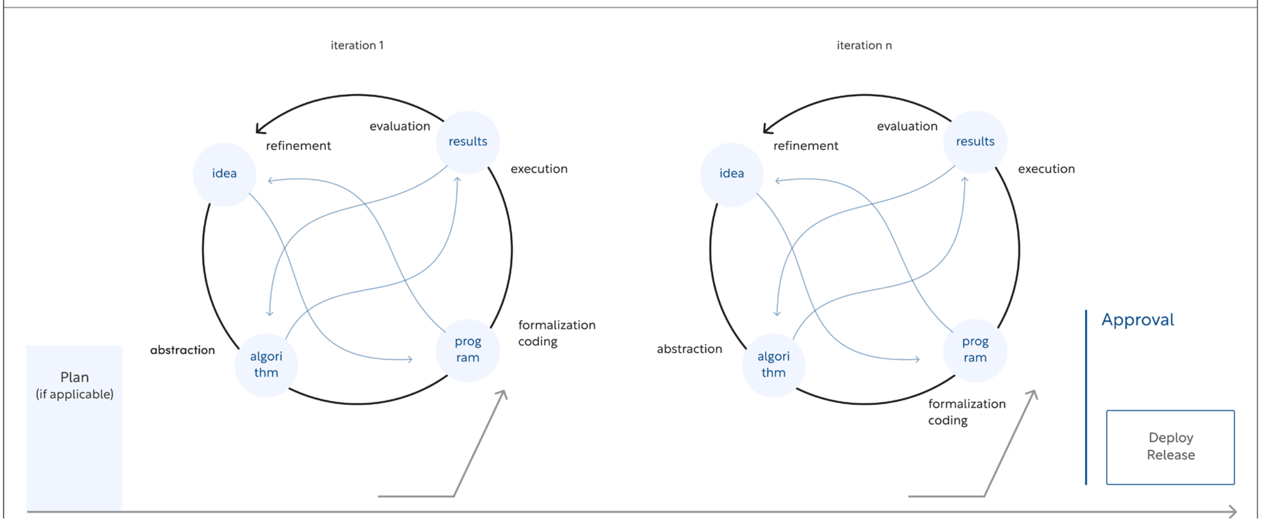
Through SP5 — **It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track** —, we aimed to obtain insights about which project management approaches are consciously or unconsciously chosen by professionals and teams of the field. Accordingly, we intended to enrich the model with insights related to how real-life projects are managed and how the activities and initiatives are organized.

We considered SP5 endorsed and emphasized experimental and agile approaches after observing that all of our cases were carried out through initiatives that happened disorderly. Moreover, when it was not carried out individually, projects were executed collaboratively either through multidisciplinary efforts or dedicated fronts. Lastly, the aforementioned approaches were also reinforced because interviewees referred to them as the natural choice when developing similar projects. The following table (Board 25) recaps how SP5 was perceived in each of the cases.

Board 25: Confrontation of Subproposition 5
Created by the author

Subpropositions	**Heartbits**	**Tocando Brasília**	**Futebol Arte**	**Atmosfera and Metaespaço**
It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track.	Endorsed Based on multidisciplinary collaboration, rapid iteration and experimentation, resembling agile methods.	Endorsed "Open" and "experimental" from the beginning. Creative process relied on unordered experimentations.	Endorsed Cycles of ideation, exploration of technical means, development, and refinement with the client.	Endorsed Cycles of sketching, prototyping, evaluation, and refinement were the basis for manual elaboration and creation of programs.

Board 26: Conduction through collaborative and iterative approaches
Created by the author



In addition to being suggested by the analysis of our cases, collaborative and experimental approaches are also favored by contemporary authors and practitioners of interaction design, as discussed in subchapter 1.2. Therefore, to comprise the questions discussed above and picture a creative process more oriented towards practice (as illustrated by the board below), we can rewrite SP5 as follows: **Concerning the conduction of projects, contemporary professionals and teams prefer to carry them out through approaches that are multidisciplinary, collaborative, experimental, and based on non-delimited cycles of propositioning, evaluating, and refining. Examples of the aforesaid approaches are agile methods and multi-track development.**

Finally, the sixth subproposition — **Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements** —, was endorsed due to the identification of activities and concerns related to the categories above throughout our cases. However, it is worth noting that delimited moments of planning and defining were less emphasized when happening in a less constrained context. We stated this because, in Tocando Brasília, Rangel's experimental approach to developing the installation and the exhibition's flexible brief allowed him to work freely. Imposing an organization in stages could be, then, misleading.

The table on the end of the page (Board 27) recaps how SP6 was perceived in our cases.

Furthermore, due to a context in which design-related and computing-related abilities are extremely connected to each other, the analysis of cases suggested that the proposed stages of design and development could be integrated into a single category of **design and develop**, comprising not only the respective initiatives of each one of them but also the mixed activities and decisions that are simultaneously and collaboratively made.

More specifically, the practical initiatives on the next pages (Board 28) have been identified and were grouped to be taken as examples of relevant tasks and activities. To enhance comprehension, they were classified according to the categories postulated by the subproposition. **However, it is worth noting that, despite being represented as a table, the following elements can be reordered, skipped, postponed, or advanced, and that they do not necessarily represent only the categories they are associated with.**

Board 27: Confrontation of Subproposition 6
Created by the author

Subpropositions	**Heartbits**	**Tocando Brasília**	**Futebol Arte**	**Atmosfera and Metaespaço**
Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements.	Endorsed The team covered all the stages through a series of collaborative development cycles.	Endorsed Stages covered through experimentation. Abilities related to planning and defining were less prominent, but they happened.	Endorsed The team covered all the stages through iterative development cycles.	Endorsed The team covered all the stages through a series of the experimental cycles.

Board 28.1: Examples of Relevant Initiatives - Part 1
Created by the author

Categories	Initatives	Activities
Planning	Establish deadlines and milestones (if necessary); Establish team organization and work dynamics (if necessary); Receive client brief or guides from other involved agencies...	Discovering Requirements
Define	Define generative logic and the functioning of the system; Define interactive dynamics (if necessary); Define the devices that will be used to enable the experience; Define overall look and feel (if necessary); Define which data will be collected to feed the generative system (if necessary); Define acceptance criteria (if necessary); Define output (images, videos, real-time interactive system, animation, sound...); Define programming-related specifics (e.g. programming language and software tools) that will be used; Define electronic-aspects (e.g. sensors, displays, audiovisual infrastructure) that will be used (if necessary)...	
Design and Develop	Elaborate models and sketches (if necessary or desired); Experiment with aesthetic guidelines and intentions (e.g. visual, sound, haptic) (if necessary or desired); Experiment with shapes, sounds, behaviors and other relevant aesthetic elements to be modulated by the system; Experiment with autonomous logics and random seeds to power the generative system; Experiment with existing software tools or previously created programs; Experiment with sensors and algorithmic strategies for data processing; Generate partial versions or representations for evaluation; Pursue promissing versions through refinements and abandon undisered ones; Test MVPs in the field to evaluate the quality of the proposition (if necessary); Figure out equipments, computers, lights and other electronic aspects (if necessary); Experiment with different libraries for synthesizing shapes and behaviors; Adjust aesthetic visions (if existing) based on programming and electronic constraints; Push programming and electronic efforts through aesthetic visions; Set up physical structures involved in the product (if applicable)...	Design Alternatives and Prototype

Board 28.2: Examples of Relevant Initiatives - Part 2 Created by the author		
Categories	Initatives	Activities
Deploy	**Evaluate and refine according to relevant criteria, such as:** **Accuracy of sensors for data collection;** **Adequacy of data processing algorithms;** **Aesthetic quality of outputs generated;** **Technical quality of outputs generated according to constraints;** **Coherence between the data collected and aesthetic synthesis;** **Adequacy of generative content to the non-generative physical and digital parts;** **Adjustments for presentation (e.g. execution time, repetition rate)...**	Evaluate

To consider the improvements discussed, we can rewrite SP6 as follows: **Regardless of specific constraints and the approach, when designing an interactive product powered by generative systems, professionals rely on initiatives related to planning, defining, designing & developing, and deploying to carry out their projects. Moreover, they execute practical activities adapted to the context such as designing alternatives, prototyping, evaluating, and discovering requirements.**

Finally, through the confirmations and revisions driven by our case studies, we could elaborate the final version of the model, incorporating the key takeaways provided by the investigation. This model is available on the next page (Board 29).

By transporting the model to our case studies and confronting it with the data uncovered, we learned aspects that motivated its revision and enabled the interpretation of the creative processes studied. Concisely, this research pointed out the following aspects about the creative processes employed by contemporary professionals in the design of interactive products powered by generative systems (the process):

- **The process still relies on direct manipulation as an important contributor for delivering the intended design** and facilitating the abstraction of aesthetic aspects into algorithms. This insight suggests that direct manipulation enables the proposition of designs and helps

Board 29: Final Model
Created by the author

Original Subpropositions	Revised Subpropositions
Designers have their creative process fundamentally altered, as their role shifts from directly manipulating artifacts to curating and evaluating the computational processes that are supposed to produce them.	Designers have their creative process fundamentally altered, as they are no longer supposed to produce artifacts exclusively through direct manipulation, but primarily through mediating the elaboration, curation, and evaluation of the computational processes that are supposed to produce them.
Such a creative process involves reaching an idea; abstracting it into an algorithm, translating it into a program to be executed; and obtaining and evaluating the output — what would possibly feedback the cycle.	Such a creative process relies on activities to be interspersed and shared collaboratively, related to ideating, abstracting ideas into algorithms, translating algorithms into programs; obtaining and evaluating computationally-generated results, and refining the computational process to deliver the expected quality.
Due to the existence of a characteristic layer of abstraction — as designers need to constantly think in terms of algorithms to create desired artifacts, there's a relationship between this specific creative process and computational thinking — to which abstraction is a characterizing aspect, which implies that designers are required to rely on abilities related to design thinking and computational thinking.	Due to the existence of a characteristic layer of abstraction — as professionals need to think in terms of algorithms to enable the design of desired artifacts —, the creation of successful interactive products powered by generative systems depends on professionals or teams capable of mastering abilities related to both computational thinking and design thinking.
Concerning its execution, the creative process in question does not always have a concept as a starting point for ideation (concept-based ideation). It can also rely on many explorations with the material — programming and software tools — to encounter more concrete concepts to be pursued as selected ideas (material-based ideation)	Two complementary ideation strategies might also enable and compose the creative process. First, professionals follow concept-based ideation when they choose to elaborate aesthetic concepts as guides for what will be synthesized by the system. Thus, directing algorithmic and programming efforts. In addition, they can work the other way around when constraints are more flexible and rely on material-based ideation to let many explorations with programming and software (the material) point out concrete concepts to be pursued.
It can also be conducted in ways that are either more structured, sequential, and unidisciplinary — waterfall approaches; or based on multidisciplinary collaboration, rapid iteration, and experimentation — agile methods or multi-track.	Concerning the conduction of projects, contemporary professionals and teams prefer to carry them out through approaches that are multidisciplinary, collaborative, experimental, and based on non-delimited cycles of propositioning, evaluating, and refining. Examples of the aforesaid approaches are agile methods and multi-track development.
Regardless of specific constraints and the approach, when designing an interactive product, designers undertake the major stages plan, define, design, develop, and deploy, and the activities designing alternatives, prototyping, evaluating, and discovering requirements.	Regardless of specific constraints and the approach, when designing an interactive product, professionals rely on initiatives related to planning, defining, designing, developing, and deploying to carry out their projects. Moreover, they execute practical activities such as designing alternatives, prototyping, evaluating, and discovering requirements to design the artifact properly.

professionals navigate the fundamental differences stated by Groß et al. (2018) and Grünberger (2019);

- **Direct manipulation is especially useful when the project needs to attain specific aesthetic guidelines — contexts in which it can be used to create aesthetic guides for algorithmic efforts**. In other words, to preconceive concepts to be produced through the development and execution of generative systems;

- **The process comprises activities related to ideating, abstracting ideas into algorithms, translating algorithms into programs, obtaining and evaluating computationally-generated results, and refining, as stated by Groß et al. (2018), that happen interspersedly throughout the process**, instead of being executed in a specific order or in specific moments. Moreover, when carried out by a team, these activities might be shared collaboratively or organized in fronts;

- **The process is carried out through cycles of experimentation, evaluation, and refinement,** similarly to contemporary models proposed by authors of the fields of interaction design and digital product development.

- **The process might be carried out collaboratively by a multidisciplinary team,** so activities and abilities are shared among the people involved and organized according to specific intentions or constraints.

- **The process might be powered by two complementary strategies of ideation — concept-based and material-based—**, which can be selected according to the constraints of the project and the style of the team.

- **The process involves activities such as the ones grouped into the table Examples of Relevant Initiatives (Boards 28.1 and 28.2)**, which can be reordered, skipped, postponed, or advanced, and represent categories beyond the ones they are associated with in the same table.

- **The process notably relies on activities, abilities, and initiatives associated with both design thinking and computational thinking**, which suggests that mastering these two forms of thinking might contribute to more mature projects

- **The process relies on a significant practical connection between design and development initiatives**, which suggests that separate "stages" or "fronts" to organize initiatives might be misleading. Instead, it is more accurate to think in terms of a unified category of activities we can call **design & develop**.

Chapter 5

Final Considerations

This work sought to answer the following question: **What are the main aspects of the creative processes employed by contemporary professionals for designing interactive products powered by generative systems?**

The question reckoned on the idea that differences between design processes in which generative creation is employed and conventional ones are relevant and valuable to be understood as contributions for the design field. Therefore, to answer it, we relied on the investigation executed to encounter insights capable of enabling the characterization of the process investigated.

5.1 General considerations

Our final model provided answers to the research question by presenting aspects of the process verified through case studies. In addition, it illustrated how contemporary professionals are executing the practice we are interested in, contributing with insights about the aspects mentioned by the question.

To answer the question more concisely, we rely on the following conclusion composed by the revised subpropositions of our model:

> **Designers have their creative process fundamentally altered, as they are no longer supposed to produce artifacts exclusively through direct manipulation but primarily through mediating the elaboration, curation, and evaluation of the computational processes that are supposed to produce them. Such a creative process relies on activities that can be interspersed and shared collaboratively, related to ideating, abstracting ideas into algorithms, translating algorithms into programs, obtaining and evaluating computationally-generated results, and refining the computational processes to deliver the expected quality.**
>
> **Accordingly, due to the existence of a characteristic layer of abstraction — as professionals need to think in terms of algorithms to create or enable the design of desired artifacts —, designing successful interactive products powered by generative systems requires professionals or teams capable of mastering abilities related to both computational thinking and design thinking. Moreover, two complementary ideation strategies might also enable and compose the creative process. First, professionals follow concept-based ideation when they choose to elaborate aesthetic concepts as guides for what will be synthesized by the system. Thus, directing algorithmic and programming efforts. In addition, they can work the other way around when constraints are more flexible and rely on material-based ideation to let many**

explorations with programming and software (the material) point out concrete concepts to be pursued. Concerning the conduction of projects, contemporary professionals and teams prefer to carry them out through approaches that are multidisciplinary, collaborative, experimental, and based on non-delimited cycles of propositioning, evaluating, and refining. Examples of the aforesaid approaches are agile methods and multi-track development.

Finally, regardless of specific constraints and the approach, when designing an interactive product powered by generative systems, professionals rely on initiatives related to planning, defining, designing & developing, and deploying to carry out their projects. Moreover, they execute practical activities adapted to the context such as designing alternatives, prototyping, evaluating, and discovering requirements.

The following objective for this research was also defined: **To propose a model comprising relevant aspects of the creative processes undertaken by contemporary professionals when designing interactive products powered by generative systems.** We considered it achieved as the final model was elaborated and presented, containing the aspects and insights summarized in the board 29.

Finally, we understand that the contributions of this work find support in academic literature and in the reality of the investigated professional practice, therefore, **they have validity and expand the scientific literature** of the relevant fields.

5.2 Limitations of this work

This research executed some initiatives in order to deliver scientific rigor and make meaningful contributions (Yin, 2014; Gray, 2012; Bauer & Gaskell, 2000; Legard et al. 2003), as detailed in chapter 2 - method. Regardless, it is necessary to critically evaluate its quality concerning its validity and reliability (Yin, 2014).

First, we understand that no major threats to **reliability, internal validity**, and **external validity** were identified.

We attempted to provide **reliability**, thus facilitating that our study can be re-executed with the same cases producing equivalent results, by making this research's process very clear. To this end, the procedure we followed was made explicit concerning how we dealt with the method and elaborated the data collection instruments, the changes motivated by the pilot study and thesis committee, and how data was analyzed and turned into conclusions. We also were careful in clarifying how each of the theoretical contributions we relied on became relevant elements such as questions, components of the model, the theoretical proposition, and conclusions.

Second, **internal validity** is not considered a relevant test for this work because we did not intend to infer causal relationships between variables, but rather relied on an exploratory strategy to induce insights and hypotheses about our object. Regardless, in order to assure greater coherence between the data collected during the investigations and how it was analyzed, this work would benefit from involving participants in the interpretation of data to judge the accuracy of the patterns found.

We also attempted to provide **external validity**, thus producing results that can be generalized "beyond the immediate study" (Yin, 2014), by dedicating considerable time to declare a scope through framing initiatives that resulted in the research question and in the first propositions we followed. By making explicit through our question that the scope investigated is composed of projects that are contemporary and executed by professionals of the field, we narrowed our focus and produced results more probably generalizable. It is also worth noting that, due to the qualitative nature of this work, when we mention generalization, we mean **analytic generalization**.

Finally, we understand that **construct validity** might be "threatened" due to unforeseen questions concerning the selection of cases. When testing construct validity, researchers want to make sure "a sufficiently operational set of measures" (Yin, 2014) is declared for planning and conducting the study. However, despite attempting to provide uniformity to the study and diminish "subjective" interpretations of central concepts (e.g. creative process, design process, and generative creation) by defining selection criteria (as declared in chapter 2 — method) and building a comprehensive foundation, we acknowledge that further delimitations might be considered relevant by other researchers, thus posing the need for improvement.

5.3 Insights for further research

Certainly, further research on many concepts related to this work would be beneficial for the fields of interaction design, computational and generative design, and even computer science. However, we will attain to point out aspects we believe are crucial for expanding the relevance of this work, thus grasping the creative process investigated. Those will be:

- Computing techniques professionals use to synthesize foundational aesthetic elements such as shapes, textures, and movements;
- Specific autonomous logics commonly employed for powering generative systems and their influence on the creative processes;
- The differences between processes carried out by single individuals and teams when designing interactive products powered by generative systems;
- How production happens in specific devices and with specific technologies

and programming languages;
- How generative creation is being perceived by and has been applied in the market.

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