machines

Review

A Brief Review of Computational Product Design: A Brand Identity Approach

Athanasios Manavis *, Konstantinos Kakoulis and Panagiotis Kyratsis *

Department of Product and Systems Design Engineering, University of Western Macedonia, Kila, GR50100 Kozani, Greece
* Correspondence: manavis.athanasios@gmail.com (A.M.); pkyratsis@uowm.gr (P.K.)

Abstract: On the way to designing customized products as one of the core activities of Industry 4.0, the strategy of computational design emerges as a unique design process due to its flexibility and simplicity. More specifically, the aforementioned strategy is concerned with the study of brand identity and its description in the development of commercial industrial products. The proposed design approach is focused on the study of branded product forms following computational design methodologies, i.e., employing textual or/and visual programming languages. The paper presents an overview of in-depth research studies which deal with the systematic way of creation, evolution, and transformation of industrial products with modern digital tools. Through the review, 100 studies have been analyzed over the last 15 years. The background of this research includes definitions from the specific four pillars of the modern theory of industrial design, e.g., product design, digital design, visual representation, and product identity. Furthermore, the current paper combines the use of computational design with specific parameters of visual brand elements in order to develop a methodological tool for the mass customization of industrial products. Moreover, the proposed framework offers a great deal of flexibility in both design and manufacturing, while many design alternatives could become available in a very short time. Finally, the impact of this paper is the correlation between computational design techniques and the theoretical background of brand identity principles (i.e., shapes, geometries, styles, textures, colors, and materials) for inspiring novel ideas among engineers, designers, and marketers.

Keywords: computational design; product design; brand identity; design language; mass customization; Industry 4.0; design family

Citation: Manavis, A.; Kakoulis, K.; Kyratsis, P. A Brief Review of Computational Product Design: A Brand Identity Approach. *Machines* **2023**, *11*, 232. https://doi.org/10.3390/machines11020232

Academic Editors: Kai Cheng, Hamid Reza Karimi and Mark J. Jackson

Received: 31 December 2022
Revised: 28 January 2023
Accepted: 1 February 2023
Published: 4 February 2023

1. Introduction

Brand identity has an intense relationship with the visual representation of industrial products. More specifically, the visual aspects of the commercially branded artifacts are crucial parameters to end users' responses in correlation with the customers' purchase choice. A number of the aforementioned visual aspects include the shape, the geometry, the texture, the color, and finally, the material of the branded products. Moreover, product identity has a significant role in the marketing field and influences in its commercial success. Brand identity is one of the most important key factors of the product/user relationship. On the other hand, in the computational design approach, form follows mathematics and programming procedures [1–4]. The definition of the computational design approach describes a novel design methodology of using textual or visual programming interfaces in order to create and modify forms, shapes, geometries, textures, and colors. Computational design techniques support the designers in the ideation and development of a large variety of design forms. These specific tools allow the production of unusual product forms with simple design rules and parameters. That is why the design approach for mass customization has become a global trend in the contemporary industrial field [5,6].

Nowadays, design thinking methodologies and digital design technologies guide us towards Industry 4.0. Actually, Industry 4.0 includes a novel approach to automation development in design, based on digital and customization design tools such as computational design, algorithmic design, computer-aided design, digital design, generative design, and artificial intelligence (AI). The result of this theoretical overview represents the modern term of digital fabrication [7–10]. Digital fabrication is a design and production process that combines digital design and manufacturing techniques (e.g., additive and subtractive procedures). One of the main concepts of the digital fabrication methodology is that products are easily personalized by designers and customers at the same time. This consideration drives the main aim of modern product design in that personalized products are more treasured by end users, increasing their sustainability [11–14].

The current work deals with mass customization product design through computational design methodologies and techniques in order to develop innovative and unique forms. The perception of the brand identity approach links with the parametrization of the visible elements of specific branding strategies (e.g., shape, geometry, form, color, texture, type of assembly, packaging, etc.). The aforementioned design theory deals with a general design management framework for helping designers in translating all of the stakeholders' requisites into operative procedures for the development of more sustainable products. The core concept of the proposed design strategy is the customized design of products according to end users' needs and desires. The present paper depicts research studies that are related to the concept of computational product design, based on brand identity principles, in the last 15 years. The presented studies refer to four specific design pillars of modern product design: product design (PD), digital design (DD), visual representation (VR), and product identity (PI). Each design pillar includes three different core research areas. These proposed research areas are used for the in-depth understanding of the main research problem, the research goals, and finally, the research questions. More specifically, the research field of product design (PD) consists of the terms (a) industrial design, (b) concept design, and (c) product families. Then, the next pillar of digital design (DD) includes the scientific areas: (a) CAD-based tools, (b) computational design techniques, and (c) mass customization concept. The third pillar of visual representation (VR) is a combination of these specific areas: (a) the study of form, (b) design language, and (c) design style. Finally, the design pillar of product identity (PI) consists of the following terms: (a) visual identity, (b) brand identity, and (c) marketing aspects. The full concept of the research areas is depicted in Figure 1. As has already been noted, each research field includes three specific keywords, which support the correlation between the computational design field, the product design, the product identity, and finally, the visual representation aspects. The next section of the research work describes the four pillars of the research in more detail according to the literature survey.

The current paper aims to answer questions about the main research problem that characterizes the entirety of the research. More specifically, the research intends to find specific design parameters that can explain and develop product families under the main branding image of the archetype products. The proposed applications can be useful for designers and end users in that they are involved in following design procedures. The questions that the research aims to answer are:

- What defines the style of a product form?
- Which parameters determine a product's uniqueness and at the same time determine it being a part of a product family?
- How can the main aspects of a brand be converted into computational design parameters?
- What are the possible applications of such a product design approach?

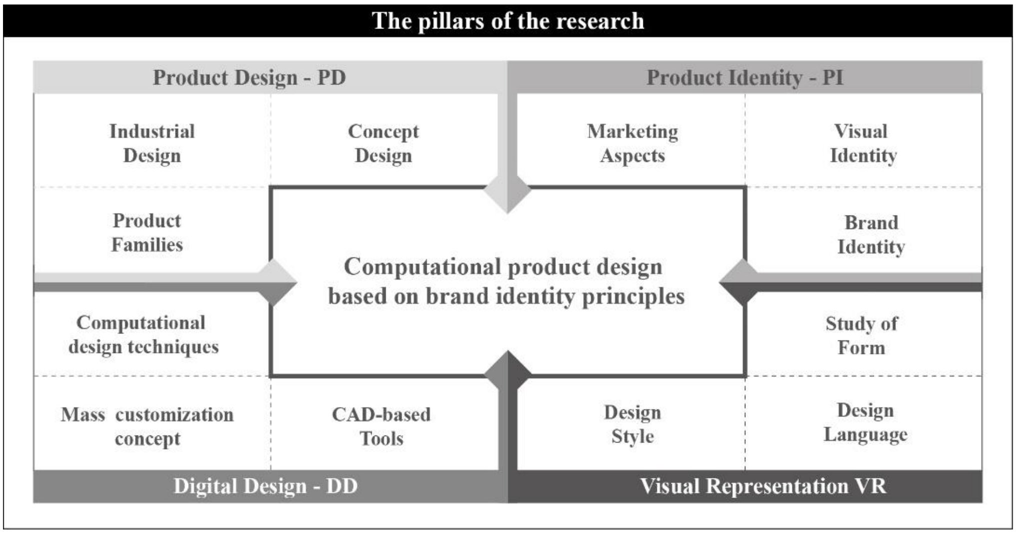

Figure 1. A schematic representation of the research areas.

Parallelly, the first research goal of this paper is to underline the great possibilities of computational design use in the improvement of branded product forms and applications through a systematic analysis of the referenced papers. After that, the second research goal of this paper is to inspire innovative ideas among designers, engineers, architects, programmers, and end users according to Industry 4.0 concepts.

2. Research Pillars

The product design approach, which includes theories and practices under the concept of Industry 4.0, is a great example of digital design and digital fabrication. Additionally, typical samples for digital product design and fabrication applications include all of the platforms that allow the end users to create their own products. The one and only design factor is the use of design parameters and rules under the main concept of the product shape, function, and aesthetics. Product personalization offers the end users the freedom to create their own design solutions as professional designers. Moreover, the aforementioned design process simulations (from the end users' point of view) work as a result of computational design tools and representation pieces of software. Some mainstream information on the novel product design methodologies that were used in the referenced studies is given below [15–20].

2.1. Product Design—PD

Design thinking is often presented as a specific methodology to solve problems. Furthermore, product design (according to design thinking principles) is a continuously iterative process that is user-centered. A great number of authors suggest three different categories for modern product design. These categories include all of the different perspectives from the industrial and business point of view to academic theory. The proposed design approaches are: (a) design as a creator, i.e., a generative thinking process, (b) design as a researcher, and (c) design as a differentiator. Another common theory in product design concerns the success drivers, which link to the new product development methodology (NPD). The crucial success drivers are separated into three different approaches:

- The success drivers of individual new product projects (the characteristics of the new product itself).
- The drivers of success for the business (including the organization's investment decisions).
- The methodology that the company has in place as a brand strategy for managing new product development (NDP).

On the other hand, product design has a great number of limitations. According to the theory, the concept of the margins has been addressed by two different directions: safety and design. More specifically, design researchers face limitations as a way of handling uncertainties during the design process. The design margins are considered in industrial practice as product parameters. It is crucial to note that, nowadays, product design is related to modern computational design approaches. More specifically, a significant number of products are based on automated design methodologies such as CAD-based (computer-aided design) use of APIs (application programming interfaces), and CAD-based use of graphical algorithm editors (e.g., Rhinoceros^{TM} and Grasshopper^{TM}). The aforementioned design (i.e., computational product design) method is the key concept of the proposed brief review.

Some examples of these design limitations are (a) tolerances, (b) overdesign, (c) bias, and (d) options. Finally, the keywords from the research of the PD point of view are product form design, shape design, design synthesis, product serialization, digital fabrication, emotional product design, CAD applications, Kansei engineering, product attributes, mass customization, and affective engineering. All of the aforementioned keywords will be used for the research in the stage of the literature survey [21–24].

2.2. Product Identity—PI

Today, product designers have been positioned between engineers and marketers. The core theory behind this is known as brand identity. The original definition of the brand links to the emotional feeling that the customers obtain from owning a product. There are three aspects that are important in what defines a brand: (a) a story, (b) a product (or service, graphic, event, etc.), and (c) an end user (or a customer). The correlation between the brand identity and the product itself depends on the creation of shape recognition for the end users from the designers. An overview that describes product identity includes three levels of abstraction from the tangible product:

- Layer 1, the product story (e.g., symbolism, mythology, legacy, etc.).
- Layer 2, the product image (e.g., origin, personality, style, designer's story, etc.).
- Layer 3, the product itself (e.g., functionality, ergonomics, production, etc.).

As a result, product design is one of the most successful tools to bring information or messages to end users. These messages link to end users according to three specific types of communication: (a) directly (e.g., shapes, geometries, etc.), (b) qualitative (e.g., design styles, textures, etc.), and (c) non-directly (e.g., colors, materials, etc.). The keywords from the research of the PI point of view are brand image, brand recognition, personalization, design similarities, style, aesthetics, and design sampling. The above keywords will be used in the literature survey [25–28].

2.3. Digital Design—DD

Recent research on digital design has been addressing a great number of new technological areas, such as computer aided design, parametric and meta-parametric design, computational design, virtual and augmented reality, and finally, artificial intelligence. Digital design tools are specific pieces of software and applications intended to aid designers in the development of innovative products. Furthermore, the computational design tools concern all the procedures that are related to the concepts of optimization, morphological analysis, and finally, 2D/3D shape generation. On the other hand, mass customization as a digital operation is a crucial procedure to satisfy target end users by offering personalized products or applications. More specifically, the term mass customization is a modern tool for offering increased status and value to brand consumers. A great number of researchers suggest seven levels of the mass customization concept:

- Product design according to customer needs.
- Product production based on a general prototyped design.
- Product assembly in different combinations based on end users' perspectives.
- Product customization on a specific standardized product.

- Service customization on a specific standardized service.
- Package design differentiation of the same product.
- Product design differentiation for alternative usages.

Finally, the authors collected a standard number of keywords from the DD point of view, in order to complete the literature survey. The keywords from the digital design research area are product form, design computing, parametric modelling, computer aided design, meta-parametric design, optimization, evolutionary algorithms, constraint-based sampling, function, structure, generative design, morphological analysis, computational design, and 3D shape generation [29–34].

2.4. Visual Representation—VR

Representation techniques can be used to visualize, develop, or advertise an abstract idea. Today, digital devices such as personal computers, tablets, and smartphones are used for design purposes, 2D and 3D modelling, and animation aspects. Furthermore, special digital design applications are widely used for 2D and 3D digital design under the main concept of the automatic production of drawings, photo-rendered images, and 3D models. The visual representation tools enhance the digital evaluation process according to a great number of evaluation tasks. In particular, research notes four different categories of evaluation:

- Analysis (e.g., structural, stress, thermal analysis, etc.) according to CAE (computer-aided engineering) tools.
- Simulation (e.g., simulation of assembly, the production process, and motion simulation) according to animated videos or/and applications.
- Evaluation (e.g., cost, ergonomics, and aesthetics evaluation) related to the usage of specific digital pieces of software or/and systems.
- Optimization according to CAD/CAM/CAE systems (including the computational design tools).

Finally, the keywords from the research of the VR point of view are geometric abstraction, design exploration, visual evaluation, sculpture generator, shape semantics, and shape grammar. All of the aforementioned keywords will be used for the research in the stage of the literature survey [35–40].

3. Literature Review

3.1. Methodology

In order to identify a complete set of scientific articles that focused on branded product computational design, the database platforms that were used were the Web of Science, Scopus, Google Scholar, etc. The aforementioned research method was conducted by first using appropriate keywords related to the main concept of the proposed brief research review. More specifically, the title of this investigation bridges terms and concepts of computational design, product design, and brand theory, as well as those terms related to the sub-topics in Figures 1 and 2. The selection of words chosen for the survey is then described.

The first research approach included the appropriate keywords related to the specific four design pillars (i.e., product design, digital design, visual representation, and product identity). This process identified more than 100 academic articles that have been published on digital product design strategy. Figure 2 shows the hierarchy of the keywords that were used in the first section of this research. Parallelly, the full set of 36 keywords is separated into three levels.

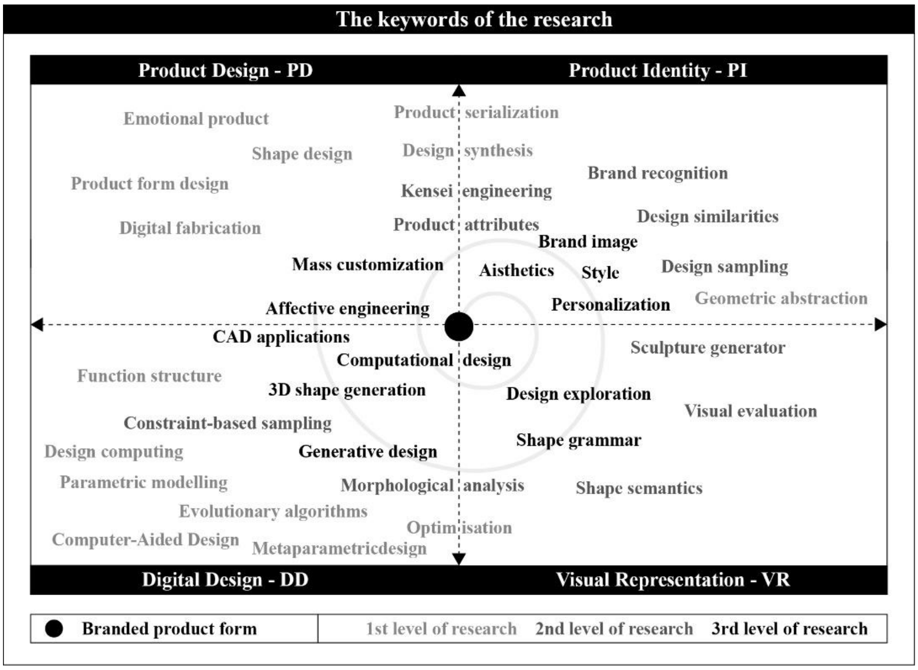

Figure 2. The three-level hierarchy of the research keywords.

The first level's terminology describes abstract theories and techniques that are linked with the basic definitions of the branded product forms. All of the terms in the first level are represented by a light grey color in Figure 2.

The second level of the research keywords concerns the more technical aspects of the branded product forms. More specifically, some of the technical terms that are mentioned are morphological analysis, visual evaluation, design similarities, and brand recognition. Finally, there are the search results in the third level, where digital-application-based keywords are listed. The spiral shape in Figure 2 concerns the core concept of the proposed research. All of the black-colored keywords are tangent to the spiral shape, which leads to the main research objective which is: computational design use in the development of product forms and applications through a systematic analysis of specific brand identities. The proposed three levels of the research will be mentioned by their titles (Figure 3):

- The 1st level as basic definitions of the branded product forms.
- The 2nd level as technical terminology of the branded product forms.
- The 3rd level as computer-based applications of the branded product forms.

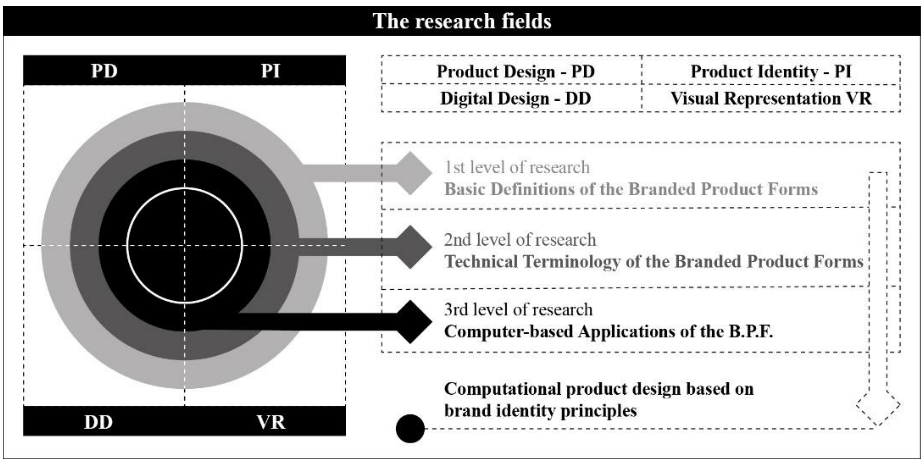

Figure 3. The research fields according to keyword categorization.

3.2. First Research Level—Basic Definitions

A variety of theories and practices are employed to explain the definitions for the branded product forms, but a number of the most apparently used theories are summarized in Table 1. More specifically, the authors created a list with the crucial keywords under the main concept of the correlation between product design, brand identity, and computational design. Table 1 presents all of the abstract terms and concepts that deal with the first level of research.

Table 1. Basic definitions.

Basic Definition	Explanation	Authors
Geometric abstraction	An abstract form is a simplified version of an original production model. There are some levels of abstraction (e.g., simplification, etc.) in order to support every design procedure. More specifically, simplification allows geometric features to be examined in isolation. Furthermore, the term abstract form relates to a great number of concepts, such as appearance, styling, design, shape, and profile.	Kang et al., 2019 [41] Orbay et al., 2015 [42]
Emotional product	An emotional product design deals with the creation of positive emotions. Moreover, the aforementioned design strategy builds emotional bonds between end users and products through specific attributes, aesthetics, ergonomics, and brand loyalty. It is important to note that emotional product design links with the theories of user experience and customer satisfaction in order to influence an end user's decision to purchase a product	Buker et al., 2022 [43] Francalanza et al., 2019 [44]
Shape design	The shape design of products has a profound relationship upon the way in which they are interpreted, approached, and used. In recent years, many researchers have focused on connecting terms and concepts such as: (a) product shape and (b) image vocabulary. The main reason for the proposed approach is product clarification from the end user's point of view.	Crilly et al., 2009 [45] Preference, 2021 [46]
Product form design	The most exciting way to solve problems creatively is evolution. Evolution in product design can extend new ideas to the innovation field. All novel ideas relate to product forms from the digital point of view (e.g., computational design, generative design, and parametric design).	Crilly et al., 2009 [45] Wang et al., 2020 [47]
Functional structure	Functional structures relate to the mechanical engineering area. Apart from that, new technologies offer a great number of advantages in product design engineering, such as design grammars, the bill of materials, technical drawings, and design alternatives. Nowadays, the potential value of functional structure studies drives the computational product design approach.	McKay et al., 2016 [48] Zhang et al., 2016 [49]
Product serialization	Product families have some common elements that are important to modern industry (e.g., mass customization). More specifically, serialized products share common technology, production procedures, and the same functions and aesthetic attributes. Moreover, the implementation of product families in the product development process is one of the most widely used strategies to face trends of mass individualization.	Zhang et al., 2022 [50] Mesa et al., 2018 [51] Schwede et al., 2020 [52]
Design synthesis	Modern digital tools of computational design offer great opportunities to designers. More specifically, nowadays, designers deliver initial shapes and after that, a specific design system can compute different or similar shapes. Finally, according to the design synthesis theory, a designer interacts with their creation in real time with the aim to finalize the output proposal.	McKay et al., 2020 [53]

Table 1. *Cont.*

Basic Definition	Explanation	Authors
Design computing	Sometimes, design computing is referred to as design science. In recent years, design computing has been linked directly to the term computational creativity. Computational creativity is the art, science, philosophy, and engineering of computational systems which, by taking on particular responsibilities, exhibit behaviors that unbiased observers would deem to be creative.	Gómez de Silva Garza, 2019 [54]
Computer-Aided Design	The advent of more sophisticated and advanced computer-aided design (CAD) software has increased the productivity of design engineers. Commercial CAD software is now filled with functions that were not available in the past decades. One such example is parametric modelling.	Shivegowda et al., 2022 [55] Kyratsis et al., 2021 [56]
Parametric modelling	Computational design is the procedure of using programming to create and modify form, structure, and ornamentation. Furthermore, parametric modelling allows the immediate generation of a large number of design alternatives. Apart from this, the authors categorize textual and visual programming languages in terms of the representation method and describe them with examples of applications. This means that designers are able to program (textual languages) or develop programs (visual programming) that, when executed, produce unique geometric models.	Leitão et al., 2011 [57] Celani et al., 2012 [58]
Evolutionary algorithms	Evolutionary algorithms are gaining increasing favor as computational intelligence methods and are very useful for holistic optimization problems. More specifically, generative design algorithms (GDA) are a fast-growing field that develops "design approaches that use algorithms to generate designs". Nowadays, researchers define some categories of design algorithms such as genetic algorithms, genetic programming, differential evolution, evolution strategies, and evolutionary programming.	Ang et al., 2006 [59] Greiner et al., 2018 [60] Hatchuel et al., 2021 [61] Slowik et al., 2020 [62]
Optimization	An act, process, or methodology of making something (such as a design, system, or decision) as fully perfect, functional, or effective as possible.	Sossou et al., 2018 [63] Nazir et al., 2019 [64]
Meta-parametric design	The meta-parametric design is described to have strong similarities to genetic programming (GP), whereby whole computer programs are generated by machines automatically. A significant tool of meta-parametric design methodology is Grasshopper. The Grasshopper models have three specific parts: the external parameters, the components in the graph, and the topological structure that associates with the components.	Meta, 2017 [65] Çalışkan et al., 2022 [66]

3.3. Second Research Level—Technical Terminology

In order to identify a comprehensive set of articles that focus on the technical terminology of branded product forms through computational design tools, the authors searched through a great number of core keywords under the main theme. More specifically, the authors noted the following technical terminology: shape semantics, morphological analysis, visual evaluation, product attributes, Kansei engineering, constraint-based thinking, design sampling, design similarities, and brand recognition.

Table 2 presents the definitions that were collected during the research under the second level—technical terminology.

Table 2. Technical terminology.

Technical Term	Explanation	Authors
Shape semantics	According to shape semantics theory, products are described in concepts of their core components (e.g., shape, color, texture, space, time, and motion), design principles (e.g., balance, unity, scale, and rhythm), and exterior style (e.g., a specific period design style). Furthermore, product sketches are more than abstract shapes; they carry semantic visual and technical information.	Echavarria and Song, 2015 [67] McKay et al., 2020 [53]
Morphological Analysis	The term "morphology" describes the structural relationship between the different aspects of the object under study. On the other hand, the term "morphological analysis" deals with a specific methodological tool for acquiring design knowledge. Hence, "morphological analysis" is creating an abstract design representation space and using this place to randomly generate potential shapes, volumes, and forms. It is crucial to note that the term morphology relates to a specific procedure, which combines the product's functions and ergonomic characteristics with the end users' experiences (actuators) according to product–user interaction (UI). Finally, "morphological analysis" is essentially a general method for non-quantified modelling.	Álvarez and Ritchey, 2015 [68] Arciszewski, 2018 [69] Fargnoli et al., 2013 [70]
Visual evaluation	Visual evaluation of product designs can be achieved using a great number of different ways and it plays a crucial role in the early stages of product design. Furthermore, visual evaluation is subjective, but all necessary measures must be taken to minimize any possible errors. Nowadays, the evaluation (or simulation) of specifically chosen form samples can be performed in any desired software, e.g., Grasshopper.	Muminovic et al., 2019 [71] Nisztuk et al., 2018 [72] Sileryte et al., 2016 [73] Luo et al., 2012 [74]
Product Attributes	A key aspect of enriching product information is extracting a large number of product attributes. The authors propose a natural language processing tool to measure the importance weight and sentiment score of product attributes. Moreover, the authors use aesthetic qualities to signify attributes that pertain to the beauty of design forms. The description of aesthetic qualities associated with visual form requires the quantification of attributes that are ambiguous and abstract.	Khan and Chase, 2016 [75] Sun et al., 2020 [76]
Kansei engineering	The basic principles of the Kansei method are the identification of product attributes and the correlation between these design features. In a number of cases, the term of Kansei is related to "emotional design". Moreover, the Kansei method refers to a relationship between the end user's senses (e.g., vision, hearing, smell, touch, etc.) and the product's factors (e.g., shape, color, performance, price, etc.).	Xue et al., 2020 [77] López et al., 2021 [78] Kobayashi and Shibata, 2018 [79]
Constraint-based thinking	The constraint-based design needs two specific research areas: a problem space and a solution space. The constraint-based thinking deals with the idea that constraints are opportunities to develop innovative solutions. The aforementioned strategy has four specific stages: (a) the limitations' identification, (b) the constraints' understanding, (c) product characteristics' mapping, and (d) the development of a simple product.	Agarwal et al., 2021 [80] Yang et al., 2022 [81]
Design Sampling	Design sampling is a methodology in which a designer is ready to generate or collect sketches to create a design space. The design field can be explored to retrieve the samples according to similar primitive shapes, such as circles, triangles, and ellipses, as constraints. These shapes are intended to inspire designers and can be employed during the design process. Nowadays, automated techniques search and generate a great number of design variations in order for a specific design space to be created. All of these tools are based on computational design techniques.	Gunpinar and Gunpinar,2018 [82] Dogan et al., 2019 [83] Khan, et al., 2017 [84]

Table 2. *Cont.*

Technical Term	Explanation	Authors
Design similarities	A lot of research relates the product brand and visual characteristics with the shape grammar theory. This specific set of geometric rules is used to create or compare designs (2D and 3D representations). The result of this procedure is the development of a group with similar shapes and geometries in order to further examine them.	Ranscombe et al., 2012 [85]
Brand recognition	The effect of brand recognition on customer preferences has been studied in depth for new product designs. On the other hand, customers' desire for consistency with the previous design style can play a significant role in brand recognition.	Burnap, et al., 2016, [86] Chang, 2008 [87] Orbay et al., 2013 [88]

3.4. Third Research Level—Computer-Based Applications

Castro e Costa et al. [88] presented the implementation of two prototypes for a tableware design system (TDS), whose objective was to enable designers to create customizable tableware collections. The TDS application was developed by parametric software tools such as Rhinoceros and Grasshopper. From the product design point of view, the final results of the TDS application were based on the shape grammar methodology against branding principles.

Parallelly, Lopez Garcia et al. [89] developed a parametric design tool for the concept of multipurpose chair design. The proposed application was developed by specific grammar-based rules that relate to chairs' design styles. The main structure of the ChairDNA application has been orientated towards generating a large variety of designs within a product class. Furthermore, the benefits of using the ChairDNA application design tool in the early concept design phase are (a) the suggestion of unexpected design solutions, (b) it is easy to learn and use, (c) easy generation of design families and/or design styles, and (d) generation of editable 3D model in a great number of applications.

Novak [90] proposed a novel CAD system to customize the 3D shape of a surfboard. Moreover, the 3D visualization of surfboards updates in real-time according to the implementation tools of Rhinoceros, Grasshopper, and Shape Diver. More specifically, Shape Diver is a web-based application for final product alternatives and the creation of manufacturing file exports. Furthermore, the aforementioned application provides customized parameters and solutions from the end user's point of view.

Lopes and Leitao [91] proposed a solution to the problem of computational product design under the main concept of mass customization named Rosetta. It allows users to explore different perspectives of products and design forms, in order to find a combination that is most suitable for the main design problem. Moreover, Rosetta is a predefined programming interface that: (a) is focused on generative design, (b) integrates with a great number of CAD applications, and (c) accommodates different programming languages.

From the aesthetic engineering point of view, Sequin underlines a methodological framework in that it deals with examples of abstract geometrical sculptures or/and the shape optimization of constrained curves and surfaces. According to Sequin [92], computer-aided design tools (including computational design tools) are gradually becoming more suitable for aesthetic engineering and for artistic optimization. From this point of view, Sequin underlines a methodological framework that deals with examples of abstract geometrical sculptures and/or the shape optimization of constrained curves and surfaces. The key concern being offered for the conceptual design phase is that it is fast enough to allow true real-time interactivity (e.g., of Rhinoceros, Grasshopper, and Shape Diver).

On the other hand, Chen et al. [93] described a unique case study that has been developed for personal care bottles. They present a parametric shape grammar model in order to capture the visual features of the branded bottles. Computations with the rules were used in order to generate four new designs according to the design principles.

Sun and Huang [94] explore how to realize parameterization by studying the software of Grasshopper in order to design a series of specific products. According to the authors, in the design process of serialized products, designers must pay attention to the three design principles: (a) a unified and innovative solid structure of the archetype product, (b) a significant theme concept, and (c) a distinctive sense of the product series. The proposed case study deals with a series of bottles of water with a great number of different skin forms under the main concept of the water ripple as relief patterns.

Burnup et al. [86] developed a web-based application for measuring changes in ten different styling attributes of four automotive design enterprises (e.g., Audi, BMW, Cadillac, and Lexus). The authors tried to measure the design freedom from the designer's point of view and at the same time, the brand recognition from the user's point of view.

Following this, Shih-Wen et al. [95] proposed a study in order to analyze product styles by applying algorithms and Kansei theory. The proposed research transforms the emotional conceptions of end users into linguistic variables. The main reference product was a coffee machine with all the basic components (e.g., the coffee maker, carafe, housing, reservoir, base, carafe body, and handle). Finally, the authors developed an application that allows end users to create their own design styles of coffee machines according to specific design rules and parameters.

Khan and Awan [96] presented a generative design technique called "space-filling-GDT (Sf-GDT)" for the creation of unique designs. The aforementioned application has the ability to design variant optimal design alternatives for a given CAD-based model. From these product alterations, end users can select a unique product form based on their aesthetic preferences. The same authors proposed their framework for strategic style change using goal-driven grammar alternatives by using a cell phone design example. From their point of view, the aforementioned design system offers advantages for style description and style change for a number of design domains that require frequent changes in styles.

Khan and Chase [75] proposed a methodological framework according to design grammar-based rules in order to develop the exterior plastic components of cell phones. More specifically, the utility of the grammar transformation framework was tested with specific examples of mobile phone designs in correlation with all the proposed design style description schemes.

Moreover, Khalili-Araghi and Kolarevic [97] developed a customization system that could provide customer participation and automatic design validation in the housing industry. The proposed system used BIM software in order to interact with a parametric model for automatic design validation against dimensional constraints. The main contribution of the research is to examine the challenges associated with customer participation and the complexity of dimensional customization in the housing industry.

Wonoto and Blouin [98] presented a structural optimization case study that allows for the inclusion of complexity using Grasshopper and Matlab. The process includes specific automated updates of a great number of design features: structural size, shape and topology, material properties, and loading conditions.

Finally, two more case studies from the application point of view are the examples of Figueiredo et al. [99] and Alcaide-Marzal et al. [28] First, Figueiredo et al. proposed a research project, which aimed to determine the influence of Alberti's treatise on Portuguese architecture. The correlation between the archetype models of Alberti and the digital alternative forms drives their comparison in order to create unique branded copies. After that, Alcaide-Marzal et al. described a generative method for the exploration of product shapes in the conceptual design stage. The method is based on three concepts: the notion of grammars to capture product appearance, the implementation of sketching transformation rules to produce design variations, and the use of a parametric modeler to build shapes.

Table 3 presents the most brand-related applications according to the product references such as the product types, the design methods, and implementation tools.

Table 3. Computer-based applications.

Authors	Application Description	Implementation Tools	Product Design Based On	Product Reference
Castro e Costa et al., 2019 [100]	The authors present a methodology "the tableware design system" which describes the development of a computational design system for the mass customization of ceramic tableware based on specific shape grammar rules.	Rhinoceros Grasshopper Unity	Product design focused on the implementation of generic shape grammar rules encoded into parametric models.	Tableware
Lopez Garcia, et al., 2018 [89]	The authors describe a grammar-based design tool for the concept phase of multipurpose chair design (The ChairDNA Design Tool).	Rhinoceros Grasshopper	The specific application enables the generation of alternative models of chairs according to the manipulation of their grammar-based parameters.	Chair
Novak, 2020 [90]	The author proposes a novel parametric-based system to customize the 3D geometry of a surfboard and stand-up paddle (SUP) board fins.	Rhinoceros Grasshopper Shape Diver	The author developed an application that uses a simple interactive set of ten controls based on common features that surfers use to describe fins.	Surfboard
Lopes and Leitao, 2011 [91]	The authors propose the Rosetta Application. Rosetta is a programming environment that is compatible with several CAD applications for mass-customized product design.	Unspecified programming language	Rosetta ensures that a single program can be used to create identical geometric models in different CAD applications.	Product form
Séquin,2005 [92]	The author presents a methodological framework for abstract product form representations.	Methodological framework	Product design for aesthetic engineering and for artistic optimization.	Abstract sculptures
Chen, et al., 2004 [93]	The authors describe a grammar-design-based methodology for defining particular brand interties for self-care bottles.	Shape grammar methodological tool	Packaging design based on shape grammar rules and design parameters that are related to visual aspects of bottles' shapes.	Bottle
Sun and Huang, 2019 [94]	The authors propose application cases for serialization design using parametric tools.	Rhinoceros Grasshopper	Packaging design based on patterns and motifs as visual references.	Relief patterns
Burnap, et al., 2016 [86]	The authors developed an application in order to measure brand recognition according to the morphological characteristics of vehicles without logos or others brand aspects.	Browser-based WebGL renderer	Product design based on the morphological characteristics of vehicles (e.g., grill shape, grill size, headlight shape, fog light shape, etc.).	Vehicle design
Wen et al., 2010 [95]	The authors propose an application in order to develop coffee machine alternatives. The application was constructed to enable designers to simulate consumer logic.	MATLAB	Product design based on coffee machine attributes (e.g., coffee maker, carafe, housing, reservoir, base, carafe body, and handle).	Coffee machine

Table 3. *Cont.*

Authors	Application Description	Implementation Tools	Product Design Based On	Product Reference
Khan and Awan, 2018 [96]	The authors developed a design application called Sf-GDT for product forms development. The application allows for the automatic generation of design variations.	Unspecified programming language	Computational product design based on specific morphological and ergonomic characteristics of the reference product.	Test models of speakers, motorbikes, and lamps
Khan and Chase, 2016 [75]	The authors present a methodological framework for cell phone design according to design grammar-based rules.	Methodological framework	Product design for the exterior attributes of cell phones.	Cell phone
Khalili-Araghi and Kolarevic, 2020 [97]	This research is targeted at the provision of the dimensional mass customization of housing.	REVIT	Computational design based on dimension constraints of housing models.	Housing models
Wonoto and Blouin, 2018 [98]	The authors present an application for structural optimization according to specific design attributes.	Rhinoceros Grasshopper MATLAB	Computational design based on structural optimization theory.	Structural forms
Figueiredo et al., 2013 [99]	This research is targeted at the unique architectural design style of Alberti. The application was constructed to enable designers to create their own prototypes.	Rhinoceros Grasshopper	Computational design based on architectural constraints of Alberti's design style.	Digital temples
Alcaide-Marzal et al., 2020 [28]	The authors proposed a generative design technique focused on obtaining a high number of valid aesthetic proposals for product design.	Rhinoceros Grasshopper	Product solutions as 3D sketches using combinations of basic shapes arranged in simple and schematic product structures.	Various industrial products

Figure 4 summarizes the usage of computational design tools according to the creation of branded product forms. From 2000 to 2015, a great number of methodological tools (Meth & M) were used to support computational thinking approaches (e.g., shape grammar theory, etc.). Apart from that, the well-known software MATLAB (MAT & T) had a significant role in the aforementioned procedures. It is important to note that some authors do not specify the computational design tools from their point of view (Un). Finally, in the last five years, Rhinoceros (Rh & R) and Grasshopper (Gh & G) have been used as the main basic computational tools. On the other hand, the applications' development deals with specific pieces of software, web-based platforms, and programming languages, e.g., Shape Diver (Sh & S), Revit (REV & V), Unity (U), and WebGL^{TM} (W).

Based on this particular finding (i.e., the increasing use of computational tools in product design), the authors have already proposed a series of case studies in order to reinforce this design trend. More specifically, Manavis et al. [101] developed the CbVBI methodology (computational design based on visual brand identity), which deals with novel ideas for product development. The core concept of the proposed design tool is the automatic generation of furniture under the theme of DIY. (do-it-yourself) design strategy. More specifically, the authors suggest two different strategies for the implementation of the CbVBI methodology: (a) an application based on textual script using Solidworks and VisualBasic and (b) an application based on graphical algorithmic design using Rhinoceros3D and Grasshopper. Moreover, Manavis et al. [102] depicted extended case studies. The aforementioned work aimed to develop a new methodology for product generation, focusing on the product's image. The core idea was a combination of two different approaches: the computational design and the branding theory of the DIY concept.

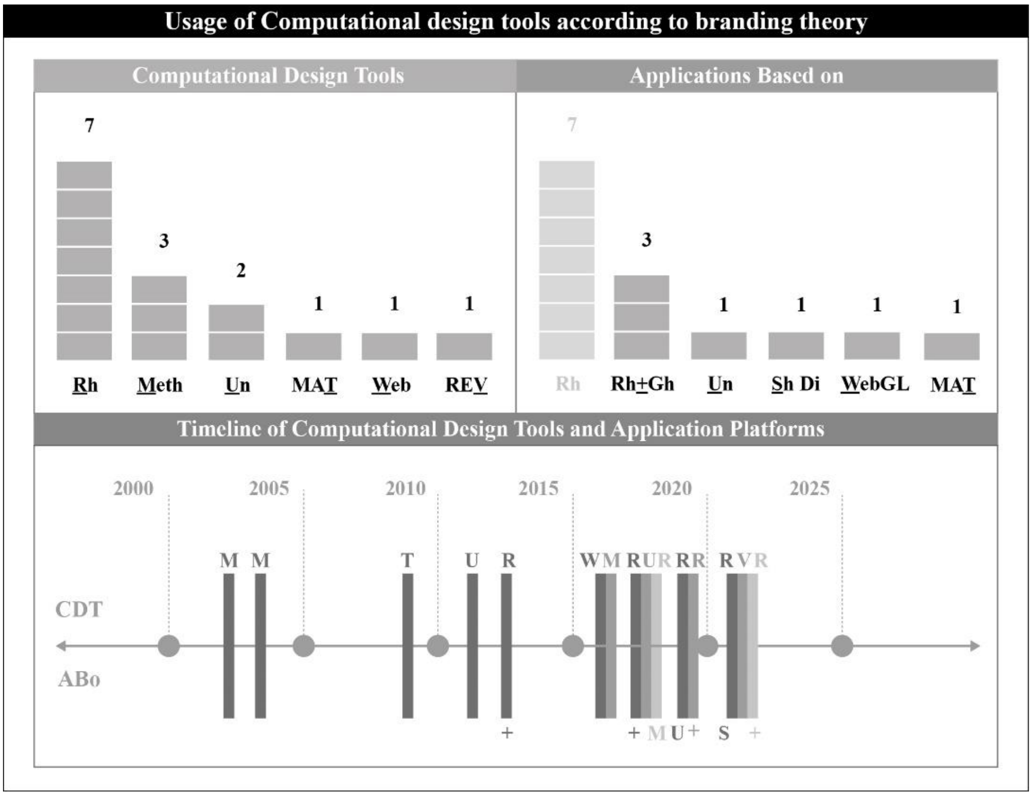

Figure 4. Usage of computational product design according to branded forms.

Finally, Manavis and Kyratsis [103] presented a number of illustrative case studies of unique Cycladic-like forms from the computational design point of view. The 3D models were developed under the proposed design framework principles. This research presented the manufacturing methods that can be used, i.e., 3D printing technologies, laser cutting, and engraving CNC machines. Some examples of the proposed applications are a building block toy, a necklace jewel, and a souvenir for decoration.

3.5. Summary of Key Research Streams

The key areas of research on computational product design based on branding identity are organized using an evolutionary dashboard. Figure 5 presents a correlation between the research papers, the research fields, and the levels of the investigation. More specifically, Figure 5 presents an overview where only the scientific papers mentioned in this paper are recorded. The positions of the proposed references in the table indicate their relationship with respect to the research gap located in the center. The key theory behind the research gap is to explore how a design process can serve an important function in telling the story of the brand according to the visual elements.

As a result, the proposed work discovers a gap in the middle of all the aforementioned aspects. More specifically, the three levels' cross-section (the research's gap) aims to use a computational-based application in order to develop branded forms according to specific parameters and design rules.

It is important to note that the proposed dashboard illustrates all the referenced papers. More specifically, the works' placement follows the following rules:

- Close to center > third research level > black fonts
- Around the center > second research level > light grey fonts
- Far from center > first research level > white fonts

- Too far from center—introduction's references > dark grey fonts

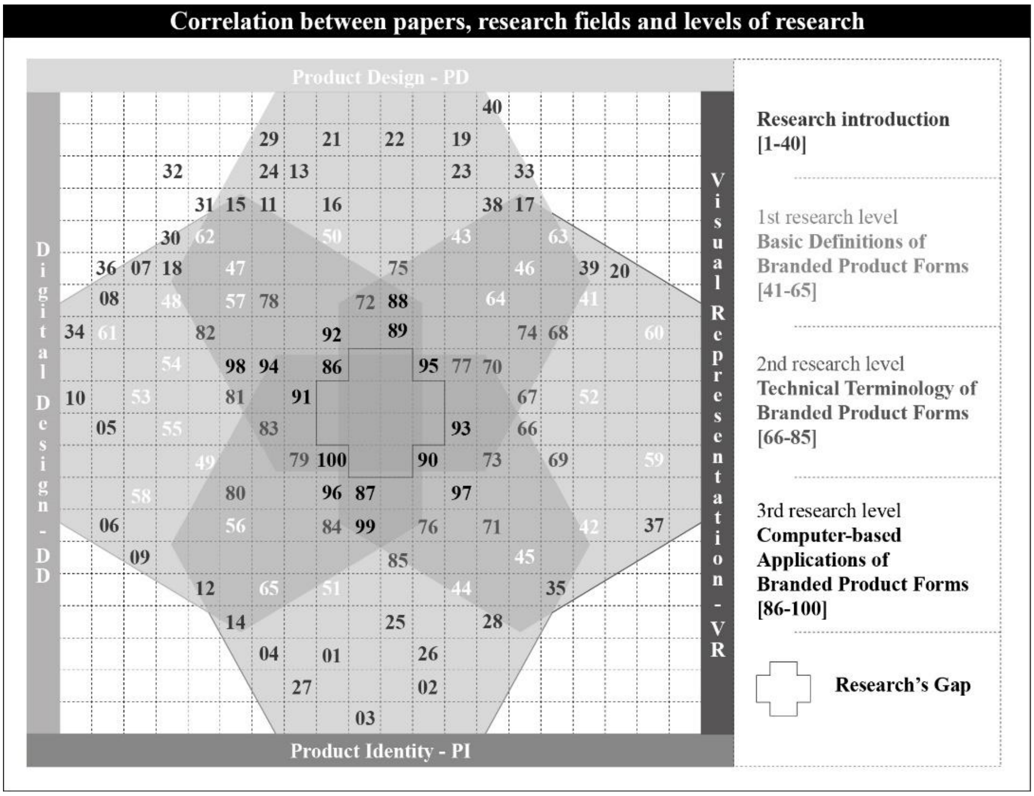

Figure 5. Correlation between papers, research fields, and levels of research [1–100].

4. Conclusions and Suggestions for Future Research

The literature discussed in this research paper managed the correlation between three disciplines: product design, brand identity, and computational design. Moreover, the current paper provided an overview of the three research areas of the branded product forms: basic definitions, technical terminology, and computer-based applications. It is crucial to note that the proposed literature highlights how the computational design of branded artifacts is different from other product procedures, e.g., design thinking, digital design, etc. Furthermore, the aforementioned research gap was linked directly to the implementation of computational design in the product design area. In addition, a great number of case studies in the product design industry use mainstream CAD tools in order to develop specific forms and structures. On the other hand, computational design tools have been completely linked to design processes in architecture in recent years. It is true that the correlation between architectural design and generative design is accepted by a great number of engineers. From this point of view, the research gap (Figure 5) indicates the very wide area of product design in relation to the absence of computational design tools.

The presented research work bridges two different design aspects according to the bibliography: the technical issues and their relationship with the aesthetic attributes of the branded products. All of the presented references highlight the very helpful modern tool of computational design in the use of product design.

Another proof of the importance of computational design usage in product design applications is the development of specific design tools (e.g., web-based design apps and pieces of software) under the concept of mass customization.

The proposed solution from the authors' point of view is computation design usage in order to create, develop, and build unique branded forms.

The key theory behind the proposed research model is that the product is important in telling the story about the brand by delivering a brand promise. The main core of this research is to explore how a design process can serve an important function in telling the story of the brand.

The basic concept for this procedure is known as mass customization. As a result, the current work aims to propose a novel methodological tool according to computational design and branding principles. More specifically, the authors propose a tool that is separated into several aspects: (a) design DNA (a product's morphological characteristics), (b) translate (a product's features parameterization), (c) design phase (product concept development), (d) promotion (computational design-based tool for alternatives), and (e) market (product alternatives for end users). Figure 6 presents the interaction between the theory of customized branded products (e.g., status and values, consumer behavior, and brand management) and the proposed methodological tool. The appropriate result of this methodological tool is an automated way to design a great number of product variations (under the main theme of a specific brand) according to the end users' needs. The customers become design contributors via their participation in selecting parameters and thus strengthen brand identity principles through the product's shape and morphology. On the other hand, the limitation of the proposed procedure relates to the correlation between the technical issues of the product design with the translation of the visual branding elements. Probably, more research is needed on the use of grammar-shaped methodologies in relation to computational design tools for increased designing and manufacturing issues and for better incorporation of the branded elements into the novel forms of products.

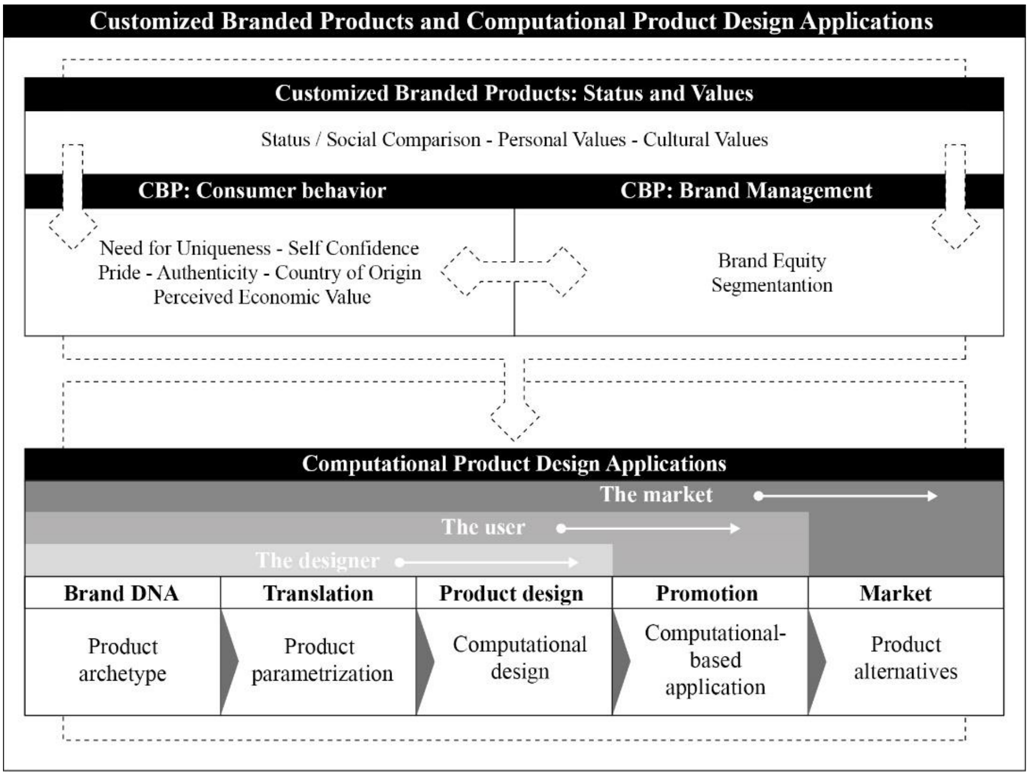

Figure 6. The proposed methodology for customized branded products via computational design.

Products become a very important touchpoint because they are the key physical representation of the brand, making intangible concepts real for the end user. Through this contemporary marketing approach, the proposed application can be very helpful for the designers and end users that are involved in the digital design procedures of customized products. Moreover, the aforementioned tool deals with a great number of possibilities for computational design use in the improvement of branded product forms.

Furthermore, the current approach to brand identity from the product design point of view focuses on the visible elements of any brand such as color, design, morphology, and shape that identify and distinguish the brand in end users' minds. Indeed, themes such as product qualities and the product's life cycle are not underlined in the proposed work but they are a great opportunity for future work, i.e., the correlation between the original branded products and the substitute products with different quality from the aesthetics design point of view.

Finally, the research is expected to contribute to the ongoing development of the computational design field under the concept of product design. Modern product design is on the verge of great evolution, with it being more than just an industrial procedural framework. Computational product design based on visually branded elements will become a new trend in design practice under the influence of digital mass customization.

Author Contributions: Conceptualization, A.M. and P.K.; methodology, A.M.; software, A.M.; validation, P.K. and K.K.; formal analysis, P.K.; investigation, A.M.; resources, A.M.; writing—original draft preparation, A.M.; supervision, P.K. and K.K.; project administration, P.K.; funding acquisition, P.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available in https://doi.org/10.3390/machines10111065, accessed on 30 December 2022.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Black, I.; Veloutsou, C. Working consumers: Co-creation of brand identity, consumer identity and brand community identity. *J. Bus. Res.* **2017**, *70*, 416–429. [CrossRef]
2. Coelho, P.S.; Rita, P.; Santos, Z.R. On the relationship between consumer-brand identification, brand community, and brand loyalty. *J. Retail. Consum. Serv.* **2018**, *43*, 101–110. [CrossRef]
3. Fu, H.; Jia, R.; Gao, L.; Gong, M.; Zhao, B.; Maybank, S.; Tao, D. 3D-FUTURE: 3D Furniture Shape with TextURE. *Int. J. Comput. Vis.* **2021**, *129*, 3313–3337. [CrossRef]
4. Montalto, A.; Graziosi, S.; Bordegoni, M.; Di Landro, L. Combining aesthetics and engineering specifications for fashion-driven product design: A case study on spectacle frames. *Comput. Ind.* **2018**, *95*, 102–112. [CrossRef]
5. Kyratsis, P. Computational design and digital manufacturing applications. *Int. J. Mod. Manuf. Technol.* **2020**, *12*, 82–91.
6. Efkolidis, N.; Minaoglou, P.; Aidinli, K.; Kyratsis, P. Computational design used for jewelry. In Proceedings of the 10th International Symposium on Graphic Engineering and Design, Novi Sad, Serbia, 12–14 November 2020; pp. 531–536. [CrossRef]
7. Buonamici, F.; Carfagni, M.; Furferi, R.; Volpe, Y.; Governi, L. Generative design: An explorative study. *Comput. Aided. Des. Appl.* **2020**, *18*, 144–155. [CrossRef]
8. Caetano, I.; Santos, L.; Leitão, A. Computational design in architecture: Defining parametric, generative, and algorithmic design. *Front. Archit. Res.* **2020**, *9*, 287–300. [CrossRef]
9. Uludüz, Ç.; Aydin, Ç. Machine as the Designer of Generative Solutions in Chair Design. *J. Comput. Des.* **2022**, *3*, 81–104. [CrossRef]
10. Tufarelli, M.; Cianfanelli, E. Generative Product Design Processes: Humans and Machines Towards a Symbiotic Balance. *Proc. Des. Soc.* **2022**, *2*, 1787–1794. [CrossRef]
11. Agustí-Juan, I.; Habert, G. Environmental design guidelines for digital fabrication. *J. Clean. Prod.* **2017**, *142*, 2780–2791. [CrossRef]
12. Kwok, T.H.; Ye, H.; Chen, Y.; Zhou, C.; Xu, W. Mass customization: Reuse of digital slicing for additive manufacturing. *J. Comput. Inf. Sci. Eng.* **2017**, *17*, 021009. [CrossRef]
13. Paritala, P.K.; Manchikatla, S.; Yarlagadda, P.K.D.V. Digital Manufacturing- Applications Past, Current, and Future Trends. *Procedia Eng.* **2017**, *174*, 982–991. [CrossRef]
14. Cohen, Y.; Faccio, M.; Pilati, F.; Yao, X. Design and management of digital manufacturing and assembly systems in the Industry 4.0 era. *Int. J. Adv. Manuf. Technol.* **2019**, *105*, 3565–3577. [CrossRef]
15. Möller, D.P.F. *Digital Manufacturing/Industry 4.0*; Springer: Cham, Switzerland, 2016; ISBN 9783319251783.
16. Zhou, K.; Liu, T.; Zhou, L. Industry 4.0: Towards future industrial opportunities and challenges. In Proceedings of the 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), Zhangjiajie, China, 15–17 August 2015; pp. 2147–2152. [CrossRef]
17. Torn, I.A.R.; Vaneker, T.H.J. Mass personalization with industry 4.0 by SMEs: A concept for collaborative networks. *Procedia Manuf.* **2019**, *28*, 135–141. [CrossRef]
18. Mourtzis, D. Simulation in the design and operation of manufacturing systems: State of the art and new trends. *Int. J. Prod. Res.* **2020**, *58*, 1927–1949. [CrossRef]
19. Camburn, B.; Viswanathan, V.; Linsey, J.; Anderson, D.; Jensen, D.; Crawford, R.; Otto, K.; Wood, K. Design prototyping methods: State of the art in strategies, techniques, and guidelines. *Des. Sci.* **2017**, *3*, e13. [CrossRef]

20. Oktan, S.; Vural, S. A teaching strategies model experiment for computational design thinking. *TECHNE J. Technol. Archit. Environ.* **2021**, *2*, 154–158. [CrossRef]
21. Micheli, P.; Wilner, S.J.S.; Bhatti, S.H.; Mura, M.; Beverland, M.B. Doing Design Thinking: Conceptual Review, Synthesis, and Research Agenda. *J. Prod. Innov. Manag.* **2019**, *36*, 124–148. [CrossRef]
22. Hernández, R.J.; Cooper, R.; Tether, B.; Murphy, E. Design, the Language of Innovation: A Review of the Design Studies Literature. *She Ji* **2018**, *4*, 249–274. [CrossRef]
23. Cooper, R.G. The drivers of success in new-product development. *Ind. Mark. Manag.* **2019**, *76*, 36–47. [CrossRef]
24. Eckert, C.; Isaksson, O.; Lebjioui, S.; Earl, C.F.; Edlund, S. Design margins in industrial practice. *Des. Sci.* **2020**, *6*, e30. [CrossRef]
25. Hestad, M. Approaching different design choices in the process of branding products Monika Hestad. In *Design Thinking: New Challenges for Designers, Managers and Organizations*; Gower Publishing Limited: Aldershot, UK, 2008; pp. 1–20.
26. Kaur, H.; Kaur, K. Connecting the dots between brand logo and brand image. *Asia Pac. J. Bus. Adm.* **2019**, *11*, 68–87. [CrossRef]
27. Bettels, J.; Wiedmann, K.P. Brand logo symmetry and product design: The spillover effects on consumer inferences. *J. Bus. Res.* **2019**, *97*, 1–9. [CrossRef]
28. Alcaide-Marzal, J.; Diego-Mas, J.A.; Acosta-Zazueta, G. A 3D shape generative method for aesthetic product design. *Des. Stud.* **2020**, *66*, 144–176. [CrossRef]
29. Pallant, J.L.; Sands, S.; Karpen, I.O. The 4Cs of mass customization in service industries: A customer lens. *J. Serv. Mark.* **2020**, *34*, 499–511. [CrossRef]
30. Shukla, M.; Todorov, I.; Kapletia, D. Application of additive manufacturing for mass customization: Understanding the interaction of critical barriers. *Prod. Plan. Control* **2018**, *29*, 814–825. [CrossRef]
31. Guo, S.; Choi, T.M.; Shen, B.; Jung, S. Inventory Management in Mass Customization Operations: A Review. *IEEE Trans. Eng. Manag.* **2019**, *66*, 412–428. [CrossRef]
32. Puig, J.; Carusi, A.; Cassinelli, A.; Pinel, P.; Hoel, A.S. A-me and BrainCloud: Art-Science Interrogations of Localization in Neuroscience. *Leonardo* **2018**, *51*, 111–117. [CrossRef]
33. Celani, G.; Veloso, P. CAAD conferences: A brief history. In Proceedings of the 16th International Conference CAAD Futures, Sao Paulo, Brazil, 8–10 July 2015; pp. 47–58.
34. McKay, A.; Chase, S.; Shea, K.; Chau, H.H. Spatial grammar implementation: From theory to useable software. *Artif. Intell. Eng. Des. Anal. Manuf. AIEDAM* **2012**, *26*, 143–159. [CrossRef]
35. Ahmad, S.; Chase, S.C. Style representation in design grammars. *Environ. Plan. B Plan. Des.* **2012**, *39*, 486–500. [CrossRef]
36. Alamerew, Y.A.; Kambanou, M.L.; Sakao, T.; Brissaud, D. A multi-criteria evaluation method of product-level circularity strategies. *Sustain.* **2020**, *12*, 5129. [CrossRef]
37. Chen, T.; Kornblith, S.; Norouzi, M.; Hinton, G.E. A Simple Framework for Contrastive Learning of Visual Representations. In Proceedings of the 37th International Conference on Machine Learning, ICML 2020, Virtual Event, 13–18 July 2020; pp. 1597–1607.
38. Saul, G.; Lau, M.; Mitani, J.; Igarashi, T. SketchChair: An all-in-one chair design system for end users. In Proceedings of the Fifth International Conference on Tangible, Embedded, and Embodied Interaction, Funchal, Portugal, 22–26 January 2010; pp. 73–80. [CrossRef]
39. Sanchez, M.; Fryazinov, O.; Vilbrandt, T.; Pasko, A. Morphological shape generation through user-controlled group metamorphosis. *Comput. Graph.* **2013**, *37*, 620–627. [CrossRef]
40. Dong, M.; Zeng, X.; Koehl, L.; Zhang, J. An interactive knowledge-based recommender system for fashion product design in the big data environment. *Inf. Sci.* **2020**, *540*, 469–488. [CrossRef]
41. Kang, N.; Ren, Y.; Feinberg, F.; Papalambros, P. Form + Function: Optimizing Aesthetic Product Design via Adaptive, Geometrized Preference Elicitation. *arXiv* **2019**, arXiv:1912.05047.
42. Orbay, G.; Fu, L.; Kara, L.B. Deciphering the Influence of Product Shape on Consumer Judgments Through Geometric Abstraction. *J. Mech. Des. Trans. ASME* **2015**, *137*, 081103. [CrossRef]
43. Buker, T.; Schmitt, T.; Miehling, J.; Wartzack, S. Exploring the importance of a usable and emotional product design from the user's perspective. *Ergonomics* **2022**, 1–12. [CrossRef]
44. Francalanza, E.; Borg, J.; Fenech, A.; Farrugia, P. Emotional product design: Merging industrial and engineering design perspectives. *Procedia CIRP* **2019**, *84*, 124–129. [CrossRef]
45. Crilly, N.; Moultrie, J.; Clarkson, P.J. Shaping things: Intended consumer response and the other determinants of product form. *Des. Stud.* **2009**, *30*, 224–254. [CrossRef]
46. Lu, P.; Hsiao, S.-W.; Wu, F. A Product Shape Design and Evaluation Model Based on Morphology Preference and Macroscopic Shape Information. *Entropy* **2021**, *23*, 1065. [CrossRef]
47. Wang, T.; Zhou, M. A method for product form design of integrating interactive genetic algorithm with the interval hesitation time and user satisfaction. *Int. J. Ind. Ergon.* **2020**, *76*, 102901. [CrossRef]
48. McKay, A.; Stiny, G.N.; De Pennington, A. Principles for the definition of design structures. *Int. J. Comput. Integr. Manuf.* **2016**, *29*, 237–250. [CrossRef]
49. Zhang, L.; Yang, Q.; Zhang, K.; Liu, J.; Feng, C.; Hou, W.; He, X. Research on the integration of industrial design and mechanical product design. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *772*, 012100. [CrossRef]
50. Zhang, S.; Liu, S.; Su, J.; Zhou, A.; Wang, S. An evolutionary design method of product form inspired by spider-webs. *Comput. Aided. Des. Appl.* **2022**, *19*, 1–25. [CrossRef]

51. Mesa, J.; Esparragoza, I.; Maury, H. Developing a set of sustainability indicators for product families based on the circular economy model. *J. Clean. Prod.* **2018**, *196*, 1429–1442. [CrossRef]
52. Schwede, L.N.; Greve, E.; Krause, D. Validation Concept for the Investigation of Effects of Modular Product Families. *Proc. Des. Soc. Des. Conf.* **2020**, *1*, 2395–2404. [CrossRef]
53. Mckay, A.; Chase, S.; Garner, S.; Jowers, I.; Prats, M.; Hogg, D.; Hing, H. Design Synthesis and Shape Generation. In *Designing for the 21st Century*; Ashgate Publishing Ltd.: Farnham, UK, 2020; pp. 308–325. [CrossRef]
54. Gómez de Silva Garza, A. An introduction to and comparison of computational creativity and design computing. *Artif. Intell. Rev.* **2019**, *51*, 61–76. [CrossRef]
55. Shivegowda, M.D.; Boonyasopon, P.; Rangappa, S.M.; Siengchin, S. A Review on Computer-Aided Design and Manufacturing Processes in Design and Architecture. *Arch. Comput. Methods Eng.* **2022**, *29*, 3973–3980. [CrossRef]
56. Kyratsis, P.; Tzotzis, A.; Manavis, A. *Computational Design and Digital Fabrication*; Springer: Singapore, 2021; ISBN 9789813344655.
57. Leitão, A.; Santos, L. Programming Languages for Generative design Visual or Textual? In Proceedings of the 29th eCAADe Conference Proceedings, Ljubljana, Slovenia, 21–24 September 2011; pp. 549–557. [CrossRef]
58. Celani, G.; Eduardo Verzola Vaz, C. CAD scripting and visual programming languages for implementing computational design concepts: A comparison from a pedagogical point of view. *Int. J. Archit. Comput.* **2012**, *10*, 121–137. [CrossRef]
59. Ang, M.C.; Chau, H.H.; McKay, A.; De Pennington, A. Combining evolutionary algorithms and shape grammars to generate branded product design. In *Design Computing and Cognition'06*; Springer: Dordrecht, The Netherlands, 2006; pp. 521–539. [CrossRef]
60. Greiner, D.; Periaux, J.; Quagliarella, D.; Magalhaes-Mendes, J.; Galván, B. Evolutionary Algorithms and Metaheuristics: Applications in Engineering Design and Optimization. *Math. Probl. Eng.* **2018**, *2018*, 2793762. [CrossRef]
61. Hatchuel, A.; Le Masson, P.; Thomas, M.; Weil, B. What is generative in generative design tools? Uncovering topological generativity with a C-K model of evolutionary algorithms. *Proc. Des. Soc.* **2021**, *1*, 3419–3429. [CrossRef]
62. Slowik, A.; Kwasnicka, H. Evolutionary algorithms and their applications to engineering problems. *Neural Comput. Appl.* **2020**, *32*, 12363–12379. [CrossRef]
63. Sossou, G.; Demoly, F.; Montavon, G.; Gomes, S. An additive manufacturing oriented design approach to mechanical assemblies. *J. Comput. Des. Eng.* **2018**, *5*, 3–18. [CrossRef]
64. Nazir, A.; Abate, K.M.; Kumar, A.; Jeng, J.Y. A state-of-the-art review on types, design, optimization, and additive manufacturing of cellular structures. *Int. J. Adv. Manuf. Technol.* **2019**, *104*, 3489–3510. [CrossRef]
65. Harding, J.E.; Shepherd, P. Meta-Parametric Design. *Des. Stud.* **2017**, *52*, 73–95. [CrossRef]
66. Çalışkan, O.; Barut, Y.B.; Ongun, G. Parametric Urban Design Thinking: Shared Patterns in Design by Algorithm and Design by Drawing. *J. Plan. Educ. Res.* **2021**. [CrossRef]
67. Echavarria, K.R.; Song, R. Studying shape semantics of an architectural moulding collection: Classifying style based on shape analysis methods. In Proceedings of the 2015 Digital Heritage, Granada, Spain, 28 September–2 October 2015; pp. 53–60. [CrossRef]
68. Álvarez, A.; Ritchey, T. Applications of General Morphological Analysis. *Acta Morphol. Gen.* **2015**, *4*, 1–40.
69. Arciszewski, T. Morphological Analysis in Inventive Engineering. *Technol. Forecast. Soc. Change* **2018**, *126*, 92–101. [CrossRef]
70. Fargnoli, M.; De Minicis, M.; Tronci, M. Design Management for Sustainability: An integrated approach for the development of sustainable products. *J. Eng. Technol. Manag.* **2014**, *34*, 29–45. [CrossRef]
71. Muminovic, A.J.; Saric, I.; Mesic, E.; Pervan, N.; Delic, M. Research about characteristics of designs from industrial designers and product designers. *Period. Eng. Nat. Sci.* **2019**, *7*, 860–869. [CrossRef]
72. Nisztuk, M.; Myszkowski, P.B. Usability of contemporary tools for the computational design of architectural objects: Review, features evaluation and reflection. *Int. J. Archit. Comput.* **2018**, *16*, 58–84. [CrossRef]
73. Sileryte, R.; D'Aquilio, A.; Di Stefano, D.; Yang, D.; Turrin, M. Supporting Exploration of Design Alternatives using Multivariate Analysis Algorithms. In Proceedings of the Symposium on Simulation for Architecture and Urban Design (SimAUD), London, UK, 16–18 May 2016; pp. 215–222.
74. Luo, S.J.; Fu, Y.T.; Korvenmaa, P. A preliminary study of perceptual matching for the evaluation of beverage bottle design. *Int. J. Ind. Ergon.* **2012**, *42*, 219–232. [CrossRef]
75. Khan, S.; Chase, S.C. Strategic style change using grammar transformations. *Artif. Intell. Eng. Des. Anal. Manuf. AIEDAM* **2016**, *30*, 488–506. [CrossRef]
76. Sun, H.; Guo, W.; Shao, H.; Rong, B. Dynamical mining of ever-changing user requirements: A product design and improvement perspective. *Adv. Eng. Inform.* **2020**, *46*, 101174. [CrossRef]
77. Xue, L.; Yi, X.; Zhang, Y. Research on optimized product image design integrated decision system based on Kansei engineering. *Appl. Sci.* **2020**, *10*, 1198. [CrossRef]
78. López, Ó.; Murillo, C.; González, A. Systematic literature reviews in kansei engineering for product design—A comparative study from 1995 to 2020. *Sensors* **2021**, *21*, 16532. [CrossRef] [PubMed]
79. Kobayashi, M.; Shibata, F. Reuse of kansei evaluation results for the aesthetic design of different types of products. *Comput. Aided. Des. Appl.* **2018**, *16*, 150–160. [CrossRef]
80. Agarwal, N.; Oehler, J.; Brem, A. Constraint-Based Thinking: A Structured Approach for Developing Frugal Innovations. *IEEE Trans. Eng. Manag.* **2021**, *68*, 739–751. [CrossRef]

81. Yang, J.; Mo, K.; Lai, Y.-K.; Guibas, L.J.; Gao, L. DSG-Net: Learning Disentangled Structure and Geometry for 3D Shape Generation. *ACM Trans. Graph.* **2022**, *42*, 1–17. [CrossRef]
82. Gunpinar, E.; Gunpinar, S. A shape sampling technique via particle tracing for CAD models. *Graph. Model.* **2018**, *96*, 11–29. [CrossRef]
83. Dogan, K.M.; Suzuki, H.; Gunpinar, E.; Kim, M.S. A generative sampling system for profile designs with shape constraints and user evaluation. *CAD Comput. Aided Des.* **2019**, *111*, 93–112. [CrossRef]
84. Khan, S.; Gunpinar, E.; Moriguchi, M. Customer-Centered Design Sampling for CAD Products Using Spatial Simulated Annealing. *Proc. CAD* **2017**, *17*, 100–103. [CrossRef]
85. Ranscombe, C.; Hicks, B.; Mullineux, G. A method for exploring similarities and visual references to brand in the appearance of mature mass-market products. *Des. Stud.* **2012**, *33*, 496–520. [CrossRef]
86. Burnap, A.; Hartley, J.; Pan, Y.; Gonzalez, R.; Papalambros, P.Y. Balancing design freedom and brand recognition in the evolution of automotive brand styling. *Des. Sci.* **2016**, *2*, e9. [CrossRef]
87. Chang, C.C. Factors influencing visual comfort appreciation of the product form of digital cameras. *Int. J. Ind. Ergon.* **2008**, *38*, 1007–1016. [CrossRef]
88. Orbay, G.; Fu, L.; Kara, L.B. Shape spirit: Deciphering form characteristics and emotional associations through geometric abstraction. In Proceedings of the ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Portland, OR, USA, 4–7 August 2013. [CrossRef]
89. Garcia, S.; Menezes Leitão, A. Shape grammars as design tools: An implementation of a multipurpose chair grammar. *Artif. Intell. Eng. Des. Anal. Manuf. AIEDAM* **2018**, *32*, 240–255. [CrossRef]
90. Novak, J.I. A parametric method to customize surfboard and stand up paddle board fins for additive manufacturing. *Comput. Aided. Des. Appl.* **2020**, *18*, 297–308. [CrossRef]
91. Lopes, J.; Leitão, A. Portable generative design for CAD applications. In Proceedings of the 31st Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA), Banff, AB, Canada, 13–16 October 2011; pp. 196–203. [CrossRef]
92. Séquin, C.H. CAD tools for aesthetic engineering. *CAD Comput. Aided Des.* **2005**, *37*, 737–750. [CrossRef]
93. Chen, X.; McKay, A. Package shape design principles to support brand identity. In Proceedings of the 14th IAPRI World Conference on Packaging, Stockholm, Sweden, 13–16 June 2004; pp. 1–14.
94. Sun, B.; Huang, S. Realizing product serialization by Grasshopper parametric design. *IOP Conf. Ser. Mater. Sci. Eng.* **2019**, *573*, 012078. [CrossRef]
95. Hsiao, S.W.; Chiu, F.Y.; Lu, S.H. Product-form design model based on genetic algorithms. *Int. J. Ind. Ergon.* **2010**, *40*, 237–246. [CrossRef]
96. Khan, S.; Awan, M.J. A generative design technique for exploring shape variations. *Adv. Eng. Inform.* **2018**, *38*, 712–724. [CrossRef]
97. Khalili-Araghi, S.; Kolarevic, B. Variability and validity: Flexibility of a dimensional customization system. *Autom. Constr.* **2020**, *109*, 102970. [CrossRef]
98. Wonoto, N.; Blouin, V. Integrating grasshopper and matlab for shape optimization and structural form-finding of buildings. *Comput. Aided. Des. Appl.* **2018**, *16*, 1–12. [CrossRef]
99. Figueiredo, B.; Castro e Costa, E.; Duarte, J.P.; Krüger, M. Digital Temples: A Shape Grammar to generate sacred building according to Alberti's theory. In Proceedings of the Future Traditions—1st eCAADe Regional International Workshop, Porto Porto, Portugal, 4–6 April 2013.
100. E Costa, E.C.; Jorge, J.; Duarte, J. Comparing digital tools for implementing a generative system for the design of customized tableware. *Comput. Aided. Des. Appl.* **2019**, *16*, 803–821. [CrossRef]
101. Manavis, A.; Tzotzis, A.; Tsagaris, A.; Kyratsis, P. A Novel Computational-Based Visual Brand Identity (CbVBI) Product Design Methodology. *Machines* **2022**, *10*, 1065. [CrossRef]
102. Manavis, A.; Efkolidis, N.; Kakoulis, K.; Kyratsis, P. The "Do-It-Yourself (Diy)" Brand Design Strategy Through Computational Design Tools. *Int. Symp. Graph. Eng. Des.* **2022**, 687–696. [CrossRef]
103. Manavis, A.; Kyratsis, P. A computational study on product shape generation to support brand identity. *Int. J. Mod. Manuf. Technol.* **2021**, *13*, 115–122.