International Journal of Modern Manufacturing Technologies
ISSN 2067–3604, Vol. XIII, No. 1 / 2021

# A COMPUTATIONAL STUDY ON PRODUCT SHAPE GENERATION TO SUPPORT BRAND IDENTITY

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***Abstract:*** Brand identity has a profound relationship with the product shape. The geometric form of a product is a key factor in the promotion of a holistic design identity to end-users. Furthermore, the preservation of brand identity according to shape changes is a crucial task in the concept development stage. Under this statement, the individuals of a specific product category reveal a great number of differences in their design – through such differences amongst them, similar characteristics can be identified. The exploration of form through the computational approach provides a means to systematize the design rules, which codify the formal inherent to a specific class (a product family under a specific design concept). The development of the computational model is based on a structured framework that provides a specific number of design steps: plan, sample, ontology, grammar, implementation, and evaluation. Using the case study of marble sculptures of the Cycladic Early Bronze Age, designer explores how to extend the role of branding beyond the prototype and official shape of these artifacts. This research presents a number of illustrative case studies of unique Cycladic-like forms from computational design point of view. The 3D models were developed under the proposed design framework principles. Finally, the manufacturing methods of the applications are about the 3D printing technologies and the 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.

***Key words:*** Study of form, brand identity, computational design, design tools, Cycladic marble sculptures.

## 1. INTRODUCTION

Style in product design development is a combination of form structures and brand identity elements. A great number of studies describe several classes of key form factors influential in product image, such as shape, geometry, textures, colors and materials. Furthermore, branded product identity becomes a holistic design strategy to increase competitiveness through marketing and promotion tools.

As reported by Boatwright et al. (2009) the identity of the brand must be inextricably linked to customers' needs and must be consistent with the company's capabilities and its branded products.

The design of aesthetic image of a digital model according to CAD approach, is defined by a set of parameters. Each design parameter represents a dimension in the branded design space. The parameters from computational point of view are connected with the form and image factors of the final product. According to Sequin (2005) computer-aided design tools (included computational design tools) are gradually also becoming more suitable for aesthetic engineering and for artistic shape optimization. One of the most crucial advantages of parametric modelling is the generation of shapes that conform to particular design styles using shape computation tools based on the mathematics of shape grammars. McKay et. al (2015) notes that the shape grammar investigations for industrial design applications have focused on the product shape development. Specifically, shape grammar methodologies are used for external design concepts. Furthermore, parametric modelling allows quick generation of a large number of design alternatives with specific aesthetic criteria.

The current paper presents a novel approach to analyze product appearance and explore similarities between industrial products. The approach is applied to examples of Cycladic marble sculptures as formed branding image. As reported by Hadji (2015) figurines constitute an abstract rendering of the human (usually female) form and are noted for their almost complete absence of facial features. Moreover, the form of figures and figurines has been well documented and studied in a wide range of approaches by archaeologists. These typological studies, seeking to analyze the canon employed in the manufacture of the figures and figurines. The outcomes are used to explore the design use of visual references to brand in product appearance. Results from the method's application validate the method in providing insights, in terms of specific similarities, in branded product appearance. Further interpretation is then used to recommend possible product design alternatives with respect to the use of visual references to Cycladic sculpturing branding image.

Castro e Costa et al. (2019) presented a method that describes the development of a generative design system for the mass customization of ceramic tableware, focusing on the implementation of generic shape grammar rules encoded into parametric models. The proposed application enables end-users to develop customizable tableware collection according to specific branding design parameters. The implementation tools of this application are Grasshopper™, Racket™, and Unity™ softwares. Similarly, Lopes Garcia (2018) described a grammar-based design tool (The ChairDNA Design Tool) for the concept phase of multipurpose chair design. The tool enables the generation of design through the addition/deletion of the chair parts and the manipulation of their parameters. The benefits of using ChairDNA as a design tool in early concept design phases are, according to the users: a) suggestion of unexpected solutions, b) easy to learn and use, c) easy generation of design families and/or design styles and d) generation of an editable 3D model in a great number of CAD applications. By using similar strategies, Novak (2021) proposed a novel CAD system to customize the 3D geometry of surfboard and stand-up paddle (SUP) board fins, featuring a simple interactive set of ten controls based on common features surfers use to describe fins. Moreover, the 3D visualization of the fin updates in real-time according to the implementation tools, Rhinoceros3D® and Grasshopper®. Harding and Shepherd (2017) defined an approach that called Meta-Parametric Design. Meta-Parametric Design is a new method of working with automation that helps design teams engage in wide design exploration, whilst retaining the cognitive benefits of an explicit representation. The proposed methodology combines graph-based parametric modelling with genetic programming. Kyratsis (2020) presented a specific number of case studies that are related to the automated procedure of creating complicated and unique 3D geometries and to the development of 3D patterns for 3D printing applications. The implementation tools of the proposed computational design case studies are Rhinoceros 3D® and Grasshopper®. Similarly, Gunpinar and Gunpinar (2018) proposed a generative design method, which consists of three algorithm steps and produces variations of a CAD model. The shape space for a product is defined by geometric parameters, parameter ranges, and geometric constraints. These shapes are intended to inspire designers and can be employed during the design process. Chen et al. (2008) presented a parametric shape grammar methodology to capture the constructional and aesthetical design principles of personal care bottles. These design characteristics drove to the development of a parametric tool for product development of similar bottles according to the specific principles. Kyratsis et. al. (2019) defined a new non-conventional methodology for form generation, focusing on the conceptual stage of design process. The proposed research presents illustrative design applications from the interior design perspective (i.e., furniture and decorative artifacts). Khan and Chace (2016) presented their framework for strategic style change using goal-driven grammar alternatives by using a mobile phone design example. From their point of view the proposed system offers advantages for style description and style change for a number of design domains that require frequent changes in style. Burnap et. al (2015) defined a methodology of predictive modelling of aesthetic styling in the automotive design process. The main core of the proposed framework is the human participation during the design decision process. Choo Ag et. al (2006) proposed a prototype software based on a system architecture for the integration of shape grammars with evolutionary algorithms. The final designs according to the application can be evaluated with respect to a single functional requirement (i.e. volume of the traditional Coca-Cola glass bottle). Sileryte (2016) presented an investigation about a design environment that it can be used to explore solutions after running an optimisation with Grasshopper-based geometry visualization dashboard. Figueiredo et. al (2013) proposed a research project, which aims to determine the influence of Alberti's treatise on Portuguese architecture. The final compilation of this information (alternative forms of temples) will ease the identification of possible deviations between Alberti theoretical design principles and automated digital design examples.

The implementation tools of the proposed methodology is Rhino3D™ and Grasshopper™ for computational design approach. Alcaide-Marzal et al. (2020) described a generative method for the exploration of product shapes in the conceptual design stage. The main core of this procedure is building a general parametric tool able to produce alternatives conceptual geometries for very different items, with minimum changes. The presented paper proposes an alternative way of generating novel structures and forms based on specific brand

principles (shape, geometry, textures, colors, and materials). The main theme of the proposed case studies is the holistic branding image of the Cycladic marble sculptures.
The aim of the present research is to develop an application with features found on computational design systems. Furthermore, according to the proposed application – the designers are able to create alternative product forms for a large number of applications from the product design point of view (i.e., jewelleries, toys, interior design artifacts).

## 2. APPLICATION DEVELOPMENT

### 2.1 Design workflow and application

The current research proposes a methodology for automatic creation of products based on specific brand elements. This procedure was developed according to the computational design approach by using parametric software. Finally, a case study presents the customization design approach of unique 3D and 2D geometries based on the concept of Cycladic marble figurines. The design workflow of the proposed methodology is divided into three sections: a) specification of original models and current brand image investigation, b) study of brand characteristics and shape grammar methodology usage for the transformation of brand visual elements (shape, geometry, textures, colors, and materials) into design rules and c) generation of the computational design model that it is based on parameters, which include all brand image references – at this stage designer translates the design rules to computational guidelines.
Using these three basic steps of the proposed methodology, a computational design application for the developing of brand image alternatives is created. Finally, every end user of this proposed methodology is ready to create novel design concepts for alternative products according to the original brand image. The application exports a great deal of file formats for product manufacturing purposes.
For instance, the proposed programme exports the STL format for 3D printing technologies (3D applications), the EPS format for laser cutting and engraving technologies (2D applications) and finally, the PNG image format for product photo renderings.
Figure 1 illustrates the design workflow and the application description.

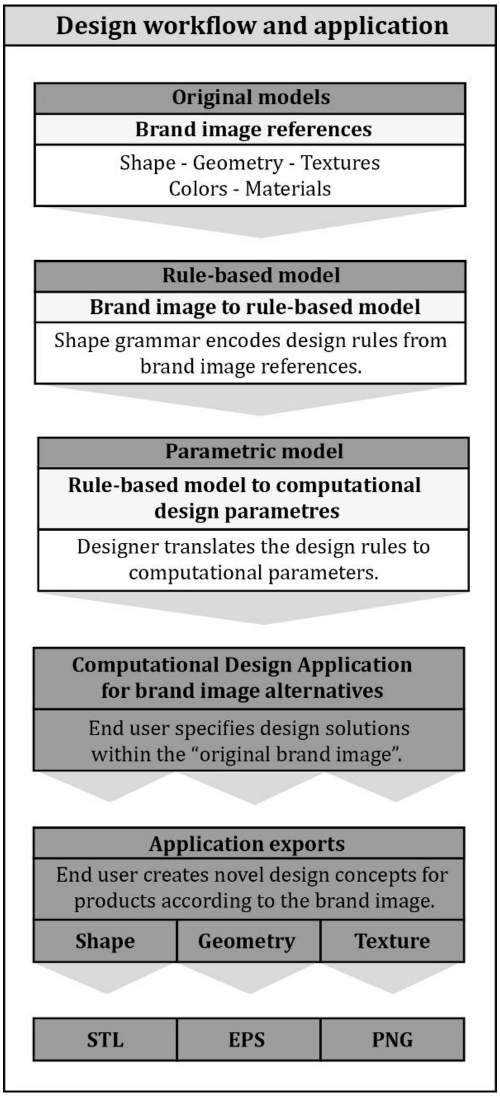

Fig. 1. Design workflow and application

### 2.2 Implementation tools

In the implementation of the design system named 'Product Shape Generation to Support Brand Identity Elements', three different software environments were used, one for each separate stage. The proposed software environments were:

- **Rhinoceros3D™** for the CAD models visualization during the design procedure.
- **Grasshopper3D™** for CAD-based 3D forms/models creation based on a number of parameters incorporated (CAD model parametrization).
- **Shape Diver™** web-based application (https://shapediver.com) for final product alternatives and the creation of manufacturing file exports for each product. Shape Diver® is an online application that it provides customized parameters and solutions from end user's point of view.

Figure 2 illustrates the implementation tools sequence for the parametric application development.

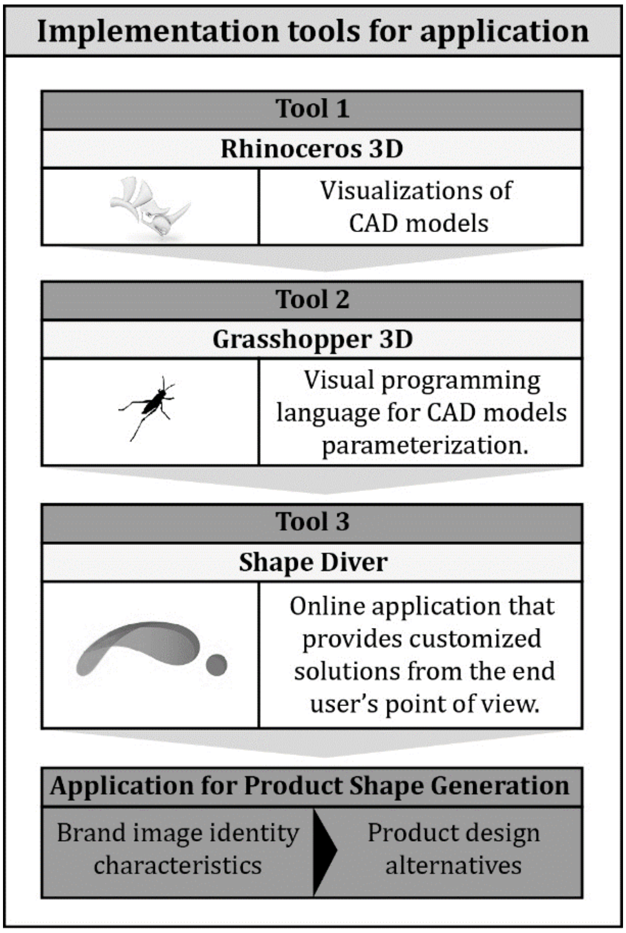


Fig. 2. Implementation tools for application

### 2.3 Case study principles – Cycladic figurines

Cycladic marble figurines from Early Ages are simply flat pieces of marble, shaped to give a vaguely anthropomorphic outline, and sometimes incised, generally on one surface only. Many of them have prong-like necks, but none have separate heads. It is notable to note that there are too many similarities into figurines forms between the varieties defined. This approach links to today's marketing and branding theory, according to concept design development based on visual elements (shape, geometry, textures, colors and materials).

Some similar figurine form examples that were used for the design rules creation are: A. Violin form, B. Notch waisted form C. Shouldered form, D. Tripartite form and E. Pebble form. Following this, the design of the figures was divided into three different sections: Section A – Neck, Section B – Shoulder, and Section C – Waist**.** Furthermore, all the sections of the original models were translated to primitive shapes according to shape grammar methodology, in order to develop the parametric model. The correlation between figurine elements and primitive shapes is:

- Section A: Neck – Circle
- Section B: Shoulder – Rectangle
- Section C: Waist - Triangle

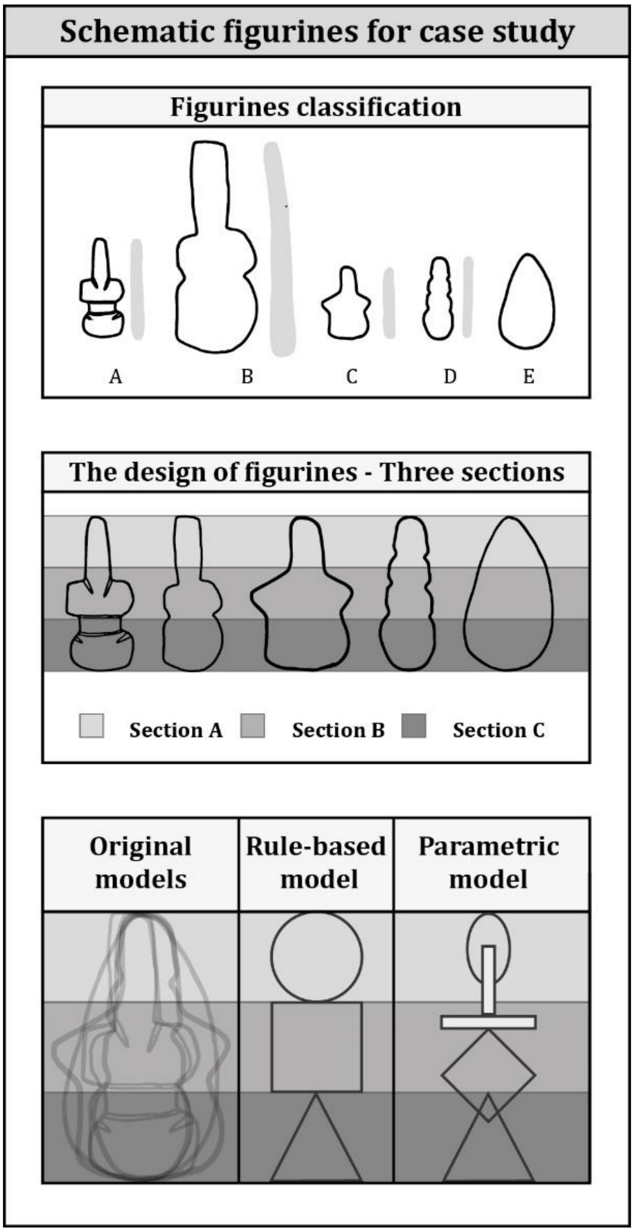


Fig. 3. Schematic figurines and case study principles

Figure 3 illustrates: (a) the figurines classification based on bibliography references, (b) the design of figurines according to "three sections" geometry approach and, (c) the design building sequence from the original model characteristics to the rule-based model and finally the model that provides the computational approach for case study implementation.

Computational design is the action of using a visual programming language with an aim to create and modify form, structure, and ornamentation.

Some of the benefits offered are, the precision, the automation, the generativity, the randomness, and the parameterization achieved. Figure 4 illustrates the parameterization of the brand image of Cycladic marble figurines.

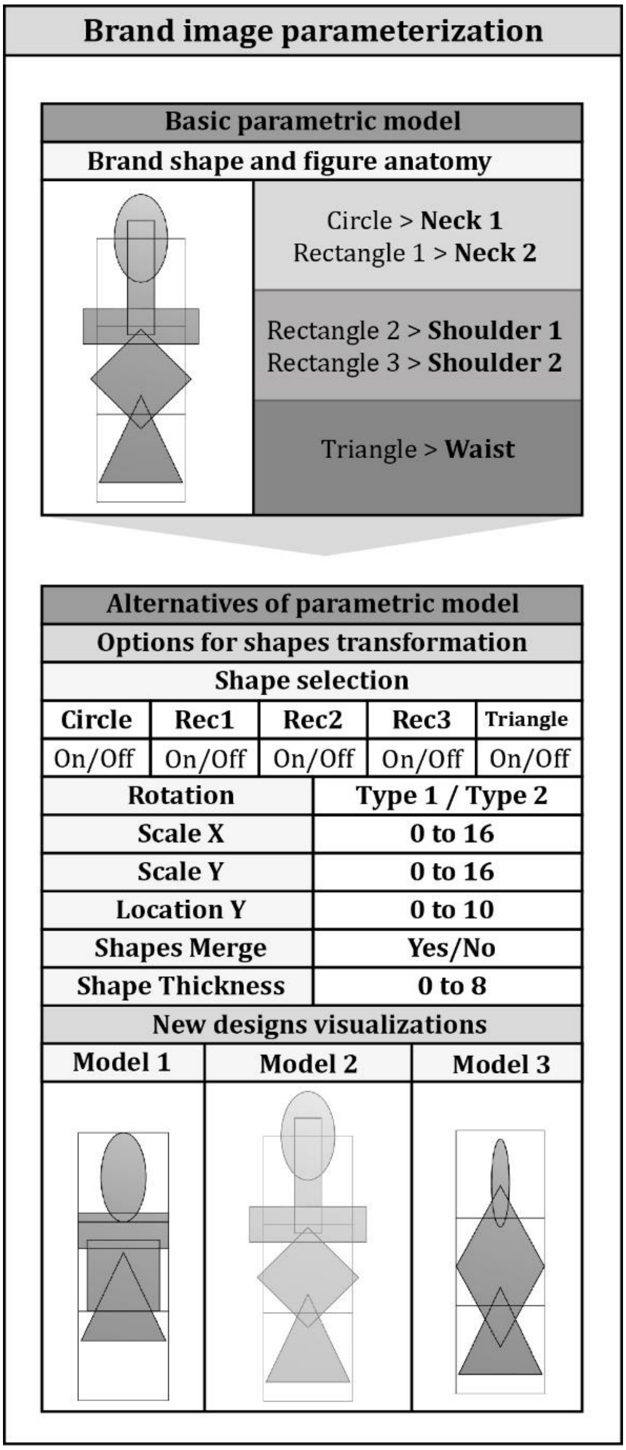


Fig. 4. Brand image parameterization

The case study presents an application for automatic creation of unique 2D and 3D geometries with the aid of Rhino3D™ (CAD software) and Grasshopper3D™ (Computational design Add-on). According to Figure 4, the figurine anatomy of the basic brand shape consists of a Circle and a Rectangle 1 (Section A), Rectangle 2 and 3 (Section B) and a Triangle (Section C). First, end-user choices the number of primitive shapes of the final object.

Afterwards, the user is able to insert specific numerical values for the parameters required by the web-based application of the software (Shape Diver™). Each shape includes the same types of parameters. The parameters are:

- **Rotation:** Type 1 rotates the shape to 0° and Type 2 rotates the shape to ±45°.
- **Scale X:** The shape is increased or decreased on the X axis (values are from 0 to 16).
- **Scale Y:** The shape is increased or decreased on the Y axis (values are from 0 to 16).
- **Location Y:** The shape is moved up or down on the Y axis.
- **Merge:** The final combination of shapes is merged. The end-user has two choices in this parameter: Yes or No.
- **Thickness:** The end user adjusts the thickness of the object (the suggested values are from 0 to 8).

All the numerical values and the values ranges are generic units. The reason of this decision connects to the concept stage of this research proposal. Furthermore, the application is proposed to end-users, who are not familiar with the design parameters. The final user feels free to create his unique "Cycladic Figurine" according to his own aesthetical approach. The proposed procedure was developed in Grasshopper3D™ visual language. All results were presented in Rhino3D™ environment for visual investigation from the designers' point of view. Finally, the export file (.gh format) was imported to Shape Diver™ application. The final application includes all customized parameters and solutions. The end user access and interact with the Cycladic Figurine Creator via the Shape Diver™ platform, which is an online 3D product configurator.

Figure 5 illustrates the final stage of the complete procedure and presents three alternative designs (models 1, 2 and 3) from three original types of Cycladic figurine from the Early Ages (models A, B and C according to Figure 3). This approach emphasizes the development of a complete family of geometries according to all branding and design rules that they were developed from the designer. The alternative types of figurines that are proposed from the current application are different kind of prototypes, with an aim to explore aesthetics and technical characteristics from the end-user' point of view.

It is concluded that the presented application can lead to a holistic tool that allow non-designers to create different types of structures by using appropriate brand parameters and basic geometries.

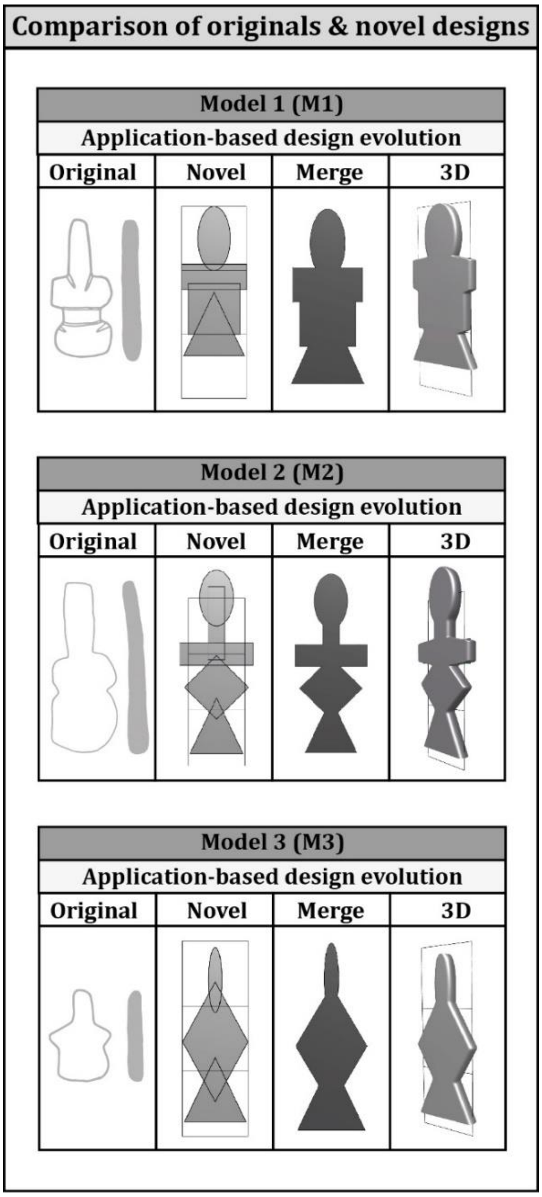


Fig. 5. Comparison of originals and novel designs

## 2.4 Exported product design applications

The research presents the whole process of one and only case study of a new Cycladic figurine. The final produced geometry of the figurine is a non-conventional representation of a unique shape, that includes the basic visual branding characteristics from the original sculptures. The numerical values of all design and branding parameters are presented to Figure 6.

In more details:

Model 3 (M3) includes three specific shapes: a circle for neck, a rectangle for shoulders and a triangle for waist. Next, the end-user inserts new values, thus a new structure is created. The main characteristic is that the new Cycladic figurine (M3) is very close to the main branding image of the original.

The values for the Model 3 geometry are:

- **Section A – Neck:** Shape=Circle, Rotation=Type 1, Scale X=2, Scale Y=10, Location Y=-3
- **Section B – Shoulders:** Shape=Rectangle, Rotation = Type 1, Scale X=7, Scale Y=12, Location Y=-2.
- **Section C – Waist:** Shape=Triangle, Rotation=Type 1, Scale X=9, Scale Y=12, Location Y=1

The thickness of the object was set to 2 units. Furthermore, Figure 6 presents the 3D-CAD visualization of the final produced model.

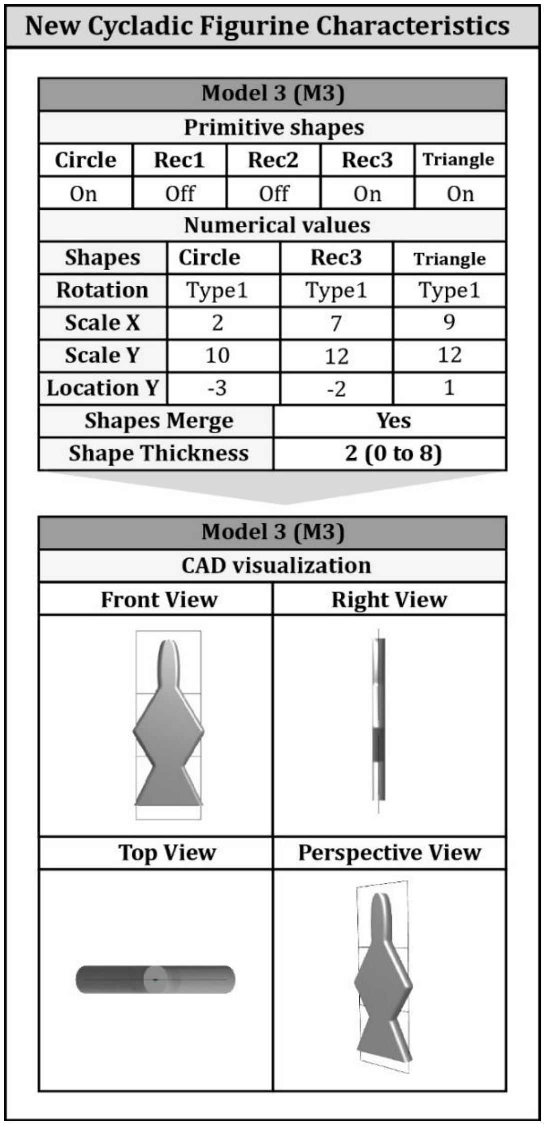


Fig. 6. New Cycladic figurine specifications

Finally, the proposed methodological framework exports two types of file formats in order to development three kind of product design applications. The file formats that they are produced from the procedure are:

- **STL format**: it describes only the surface geometry of the three-dimensional figurine. this export is recommended for 3D printing usage.
- **EPS format:** it is a graphics file format that is great for designers who need to create 2D models from laser cut and engraving machines.

Figure 7 illustrates the three different kinds of product applications according to the produced shape of the “new Cycladic sculpture”.

The first product application is a building blocks toy according to the main geometry of the statue. The suggested example is based on CNC laser cutting techniques – in order to create wooden structures for product design purposes. In this step, the end-user is able to set two new parameters. The parameters relate to a) the thickness of the whole geometry and b) the thickness of the layers.

The second product application is a 3D model structure for jewelry design purposes. In this case – the proposed application is creating an STL file. The end user has two new options about the customization of his own product: a) the diameter of the hole that it is important for the chain adding or the string adding and b) the thickness of the whole geometry.

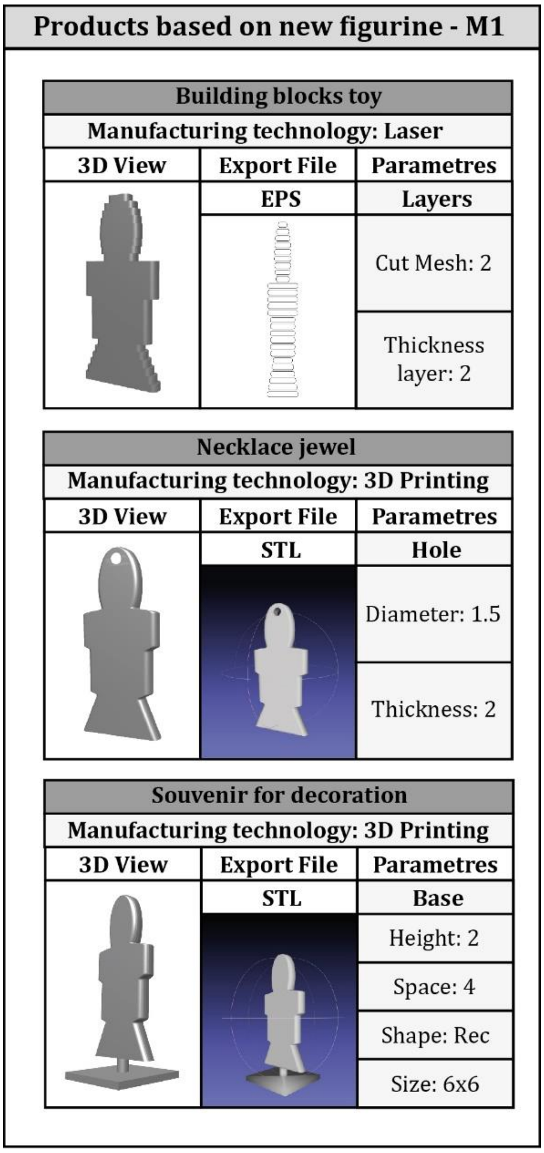


Fig. 7. Products based on new figurine specifications

The third product application is similar to the second one. The end-user is able to create his own souvenir according to the Cycladic figurine shape. In this case, the user has the responsibility to fill four new parameters that they are very important for production of the final STL file: a) the shape of the base, b) height of the base, c) the size of the base and d) space between the statue and the base.

## 3. CONCLUSIONS

In the present work, the development of a computational design application is being demonstrated, for the automated product design generation based on visual branding aspects. More specifically, this paper combines the use of the computational design methodologies and the visual branded elements (i.e., shapes, forms, colours, textures and functions) for developing innovative and unique design 3D concepts under the main theme of Cycladic marble figurines. The proposed approach was applied to a series of schematic anthropomorphic figurines and the outcome was used to explore the strategic use of visual references to brand in product appearance.

The purpose of this paper is to explore, how to develop a series of products, under a holistic brand identity, by using the application of Grasshopper$^{TM}$. Finally, the proposed methodology offers a great number of advantages in the 3D modelling design of product families.

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Received: March 12, 2021 / Accepted: June 15, 2021 / Paper available online: June 20, 2021 © International Journal of Modern Manufacturing Technologies