Direct digital manufacturing for 3D modelling and production of jewellery

Fabricação digital direta para modelação 3D e fabricação de joias

Henrique Almeida[1,2] | Liliana Vitorino[1] | Rita M. T. Ascenso[1,2] | Tatjana Spahiu[3]

[1] School of Technology and Management, Polytechnic Institute of Leiria, Leiria, Portugal.
[2] Computer Science and Communication Research Centre, Polytechnic Institute of Leiria, Leiria, Portugal.
[3] Faculty of Mechanical Engineering, Textile and Fashion Department, Polytechnic University of Tirana, Albania
Emails: henrique.almeida@ipleiria.pt; liliana.vitorino@ipleiria.pt; rita.ascenso@ipleiria.pt; tspahiu@fim.edu.al

abstract

The jewellery industry is facing significant market and customer challenges because it is still centred on traditional fabrication methods based on manual hand work. Except for a few international companies, most jewellery manufacturers do not apply advanced digital and/or physical technologies. The inclusion of new production methods, including 3D CAD and additive manufacturing processes, is one of the ways to overcome these challenges and limitations and increase its market and customer satisfaction. In this paper, advanced digital manufacturing technologies will be applied to design jewellery based on cultural heritage artefacts as the case of the Portuguese guitar. After that this are modelled as pendant, earrings, and ring. 3D modelling is an indispensable tool to design novel complex concept and through 3D printing the production is realized in a short time with least material waste.

Keywords: Digital manufacturing, 3D modelling, jewellery, heritage, artefacts

resumo

A indústria da joalharia enfrenta desafios significativos do mercado e dos clientes porque ainda está centrada nos métodos tradicionais de fabricação baseados no trabalho manual. Com exceção de algumas empresas internacionais, a maioria dos fabricantes de joias não aplica tecnologias digitais e/ou físicas avançadas. A inclusão de novos métodos de produção, incluindo CAD 3D e processos de fabricação aditiva, é uma das formas de superar esses desafios e limitações e aumentar seu mercado e a satisfação de seus clientes. Neste artigo, tecnologias avançadas de fabricação digital serão aplicadas no design de joias baseadas em artefatos do patrimônio cultural, como é o caso da guitarra portuguesa. Depois disso, são modelados como pingente, brincos e anel. A modelagem 3D é uma ferramenta indispensável para projetar novos conceitos complexos e através da impressão 3D a produção é realizada em um curto espaço de tempo com menos desperdício de material.

Palavras-chave: Fabricação digital, modelação 3D, joias, patrimônio cultural, artefactos

1- INTRODUCTION

Advancements of technologies are driving our life with everywhere application. Even in the jewellery industry the impacts include the designing and production process, which in its traditional way is handcrafting and casting. These changes are related with the use of 3D modelling of a new design, creating replicas of existing design by 3D scanning and its production by 3D printing (Gamov et al, 2018; Pipieri et al, 2016; Ferreira et al, 2012; Kazachkova et al, 2018). Due to complexity and size of the jewellery piece, the process of reproduction is not an easy task. Interactive systems which exploit the feature of the original model are used to create 3D models (Fudos, 2006). As in other industries, the use of 3D technologies has shown their advantages compared to traditional methods of production (Nicolantonio et al, 2019).

Computer aided design offers powerful tools for the designing process of jewellery by reducing costs and optimizing the whole production efficiency (Lin et al, 2018; Matos et al, 2016). Among 3D modelling software developed specifically for jewellery design, there are cases of implemented 3D modelling software applications. The packages of CAD jewellery offer detailed tools for designing and photorealistic images. These are a key element used for marketing and product assessment by avoiding the physical model. Jewellery design is a process of expressing creativity, during which several designs with minor changes are created. Generative design systems for jewellery applications can support designers to generate designs (Kielarova et al, 2015) and how industrial designers can use the field of parametric and computational modelling to foster their creativity (Demarco et al, 2019).

Recently, 3D printing also known as Additive manufacturing technology has been used to print objects from a digital template, using several materials, including metals, among hundred other materials, plastic, metal, nylon (Mpofu et al, 2014). Application of 3D printing technology enables jewellery production with complex shapes and high quality. In fact, the quality is mainly related to the type of 3D printing technology used for the production. There are several technologies for 3D printing but the one used for jewellery production are direct printing and indirect printing for mould production (Ferreira et al, 2012). Direct printing is jewellery production using metal 3D printers. Among the 3D printed technology DMLS (Direct Metal Laser Sintering) or Selective Laser Melting are power bed fusion techniques (Redwood, 2020) that creates finished products by reducing steps of the process involved in jewellery production (Ferreira et al, 2012). Moreover, the software used to create the model for 3D printing offers the options to modify the infill percentage. Low percentage means cost reduction of the materials used for jewellery production (EOS Solutions, 2020). Materials like precious metals such as Gold, Silver, Platinum and Palladium, etc., can be used for printing jewellery products. However, power bed fusion techniques are expensive to be used widely (Ferreira et al, 2012; SPILasers, 2020). A common technique used by 3D printing for jewellery production is Lost Wax Casting. Creating a duplicate of the 3D model with thermoplastic wax, them a mould is created using it. After that, the 3D wax/resin model is melted, and the liquid metal is poured into the mould. The process continues with steps of finishing and polishing of the jewellery. Application of 3D modelling and 3D printing with FDM technology for accessories even in fashion design courses (Kwon et al, 2017) are seen as a potential to use 3D printing for product customization (Pasricha and Greeninger, 2018), and reduce the cost of

jewellery products (Allodi, 2019) which because of its complexity in the conventional jewellery manufacturing tends to be higher (Cooper, 2016).

The numbers of companies that have embraced 3D modelling and 3D printing in their businesses have increased. Nervous System is a design studio that is based on natural design processes and adapting the logic of development into a computational tool. Using 3D printing technology, apart from the jewellery, there are several products offered by this company as dresses, shoes, etc. (Nervous System, 2020). Inspirations for jewellery designing taken by architecture are the case of the Radian Company, which uses 3D printing and innovative materials to create artistic design of jewellery products (Radian, 2020). The LuzMea Project presents an interesting way of designing by simulating the geometry of a paper crumpled by hand forces to produce jewellery (Luxmea, 2020).

Since the focus of the case study is to use an icon of cultural heritage, and since these icons may be of any size, shape and material, one must address 3D scanning systems capable of creating a 3D model from the desired icon. Current 3D scanning systems can generate data representing the shape of the model and represents a crucial step in the quality of the raw point data determining the quality of the resulting surfaces of the 3D model. There are non-destructive methods, which measure only the exterior surface of the object, and non-destructive methods, which also capture the interior geometry of the part. Non-destructive methods also comprise non-contact methods, where light (light fringes or lasers), sound, magnetic fields or photogrammetry are used, and contact methods, where the surface is touched by using mechanical probes. Each method uses a specific interaction process with the surface or volume of the object and each method has strengths and weaknesses, which require that the data acquisition system be carefully selected.

With the combination of both digital and physical manufacturing technologies, it is possible to design any cultural icon as a jewellery piece. In order to describe the adopted methodology, a case study will be presented beginning with 2D images until defining the 3D model.

2- A CASE STUDY - THE PORTUGUESE GUITAR

Culture can be defined as "a set of ideas (values, attitudes and beliefs), practices (of cultural production) and artefacts (cultural products, texts)" (Hanitzsch, 2007). It is the cultural and natural legacy that we receive from previous generations (as our family) and it is "a precious and irreplaceable resource, essential to personal and collective identity and necessary for self-respect" (Lowenthal, 2005). Heritage has the role to create character, identity and image of a location (Petronela, 2016). Cultural heritage is concerned in preserving the memory and identity of communities (Cerdeiras et al, 2019).

The Portuguese guitar is a plucked string instrument with twelve steel strings, strung in six courses of two strings. It is one of the few musical instruments that still uses watch-

key or Preston tuners. It is associated with the musical genre known as Fado and is a cultural icon in the Portuguese culture. The Portuguese guitar is illustrated in figure 1, during the performance of Mariza on the 14th of March 2019 in the Coliseu dos Recreios in Lisbon, Portugal. Mariza is a world famous Portuguese Fado signer.

Fig. 1 | Portuguese Guitar shown in the background during the performance of Mariza (Radio Comercial, 2020).

For the design of a jewellery piece the inspiration is taken from the Portuguese guitar. In this case study, the design process may be done by two distinct methods, namely using a 2D image to either create a 3D mesh or for assistance in CAD modelling.

In the first method, the first step is the reverse engineering process, where the model is created by digitizing the existing model. From a single picture of the guitar, a 3D model is created by processing on Rhinoceros 3D modelling software (figure 2). A 3D mesh model is obtained by processing the image and the next steps such as cleaning and removing unnecessary data, noisy spikes, and smoothing are necessary in order to obtain an adequate 3D model (figure 3). After that, the created shell model is converted in a solid model and exported in ".stl" format for importing into the 3D printing software for production (figure 4).

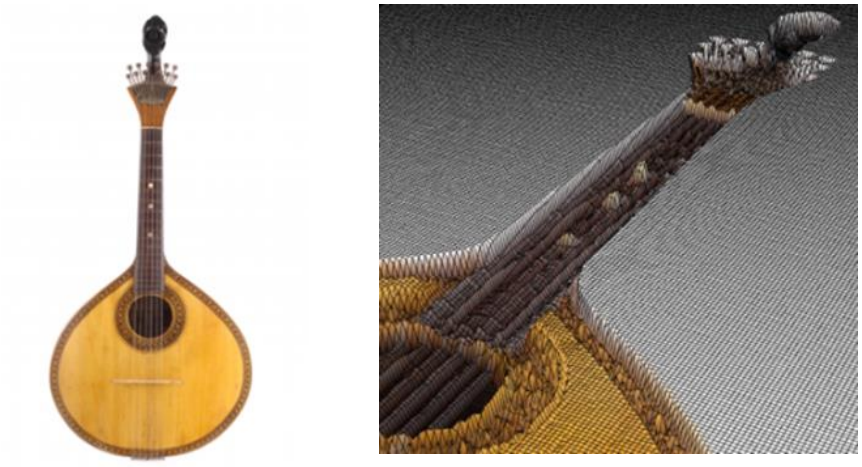

Fig. 2 | The Portuguese Guitar and illustration of the initial 3D mesh with textures in the Rhino software.

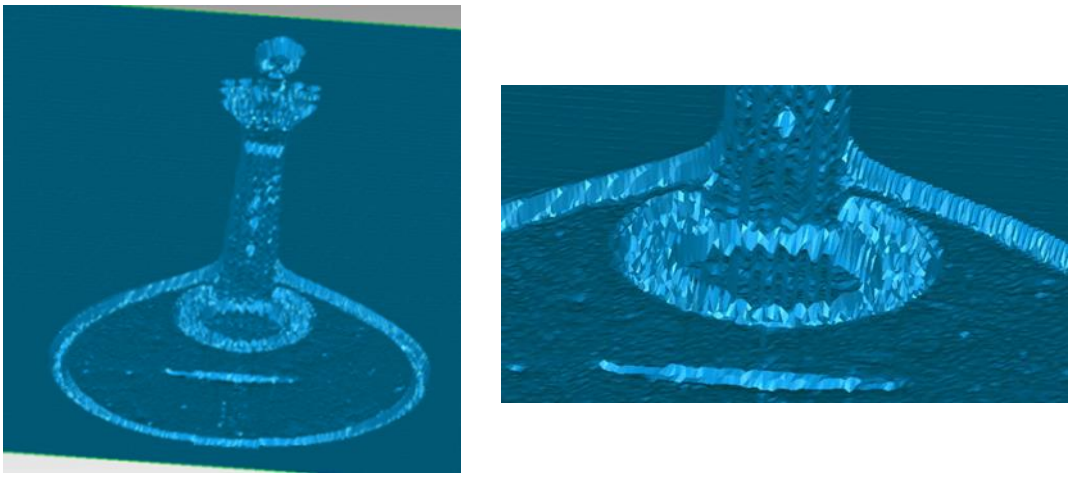

Fig. 3 | Illustration of unnecessary 3D data surrounding the guitar, along with noise data and spikes creating high irregularities on the surface software Rhino.

Fig. 4 | 3D digital solid model with a clean and smooth surface ready for redesigning into a jewellery piece.

The second method is 3D modelling of the guitar model. Here we present a free 3D modelling software that can be used for modelling. Using geometric shapes and modifying templates part of the library of the program, the obtained 3D model is depicted in figure 5. Moreover, this model is then used to design jewellery pieces such as earnings and rings (figure 6).

In the case of objects with complex geometries 3D modelling requires a lot of efforts this compared to active or passive scanning methods.

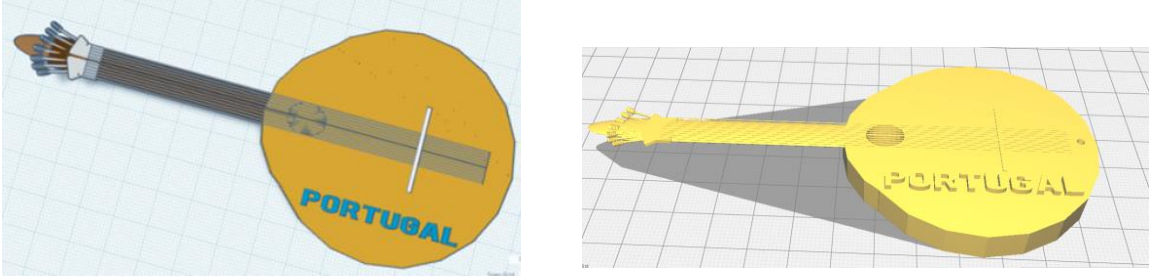

Fig. 5 | Guitar model designed on 3D software.

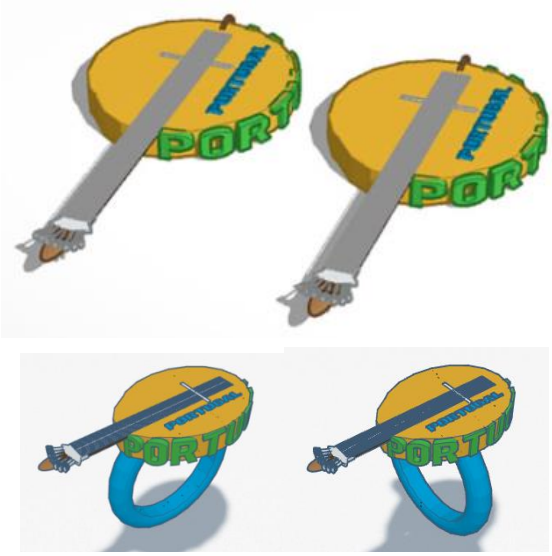

Fig. 6 | 3D models of earrings and rings created with the guitar model.

3. CONCLUSIONS

The jewellery industry is facing significant market and customer challenges because it is still centred on traditional fabrication methods based on manual hand work. The inclusion of new production methods, including 3D CAD and additive manufacturing processes, is one of the ways to overcome these challenges and limitations and increase its market and customer satisfaction. Advanced 3D CAD systems allow designing novel complex concepts while additive manufacturing systems allows obtaining any product of any complex geometry. The combination of these technologies also allows reducing production time, energy and materials, and consequently, production costs.

In this paper, advanced digital and physical manufacturing technologies will be applied to design jewellery based on cultural heritage artefacts which it allows arising the value of heritage cultural reproducing (new) cultural symbols. The Portuguese Guitar was used for the case study being a Portuguese cultural icon known worldwide. The process initiates with photogrammetry of the model, then undergoing several design steps until obtaining a 3D solid model for the design of the jewellery piece.

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