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Digital technologies expanding creative possibilities in jewelry design

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Abstract

Purpose – This article discusses the changes that have arisen in the process of jewelry design through the introduction of new technologies - more specifically, 3D modelling and rapid prototyping. Opening new real and aesthetic possibilities, these technologies transform the methods of the designer within the jewelry production process and their interaction with other professionals that are part of the same process.

Design/methodology/approach – Through bibliographical and documental research, the main advantages of these technologies and the changes they bring in the creation and production of jewelry are raised. A case study of creating a conceptual piece of jewelry for a jewelry design contest was developed. The required high standard for design innovation in this contest was the argument for the exercising of possibilities offered by the use of new technologies.

Findings – The use of digital technology, such as 3D digital modelling and rapid prototyping, allows the jewelry designer to explore "new" real and aesthetic design alternatives, creating pieces with a degree of complexity that was not previously imaginable. In addition, this increases the amount of tools that enable designers to express their creativity and extrapolate the limits of design.

Originality/value – The record of the creation and production process of this conceptual piece of jewelry served as a reference for observation and contextual changes with the advantages that digital technology brings to the design of jewelry, giving the designer greater autonomy than traditional processes.

Keywords: jewelry design; new technologies; 3D modelling and rapid prototyping

Type of paper: Case study

1. Introduction

The introduction of digital 3D modeling and rapid prototyping, now known as digital manufacturing, has become a resource that has sparked great debate in the Brazilian jewelry sector based on expectations of production optimization and improvements in the quality of the parts produced using this technology. Moreover, as has happened in other projectual activities, such as architecture and graphic design, the introduction of computer technology within the jewelry industry brings about changes in the design process and expands the creative possibilities of the jewelry designer.

According to Benz (2009), the introduction of this technology to the industry began in late 1999, with a research agreement and technical cooperation between the IBGM (Brazilian Institute of Gems and Metals) and INT (National Institute of Technology). This agreement proposed to train workers in these technologies to meet the future demand of national jewelry companies. In this research, the importance of the technical field operator during the process of modeling and prototyping was realized, and CAD modeling courses were created. However, the programs that existed at the time were only somewhat intuitive, making the process of learning and modeling slow. With the adoption of a more intuitive 3D digital modeling program in 2002, such as the Rhinoceros, the designers of jewelry were the first to pursue their own specializations in this technology.

The first designers who adopted this new way of designing jewelry aimed to create a differential from the other designers offering services and training courses. Responding to an interview, Benz (2009), one of the first designers in adopting new technologies:

"Those who offer services outsourcing 3D modeling and rapid prototyping by subtracting the jewelry industry companies, say that they began prototyping their designs on the computer, because jewelry modeling companies could not understand them. They told the owners of the companies that making the designs was not possible, despite [the designer] delivering a very precise and technical drawing. To avoid this problem, [she] then decided to purchase a machine for rapid modeling subtraction (CNC) to provide a new service offering beyond creation and design, delivering the wax model, which could go straight into production without passing through the hands of these jewelry modelers" (Benz, 2009, p. 107).

As the CAM technologies were still difficult to access - especially in Brazil where they needed to be imported at prices that almost doubled the amount charged in Europe and the US - industries only began to adopt the technology later. The expectation of most of the industry turned to questions of production optimization by understanding the technology's "hard" side, of good physical capital and operations that could result from this. Consequently, in this context, skilled labor was expected to operate the machine, but it showed a certain expensiveness and "uncontrollable" measure, and this was against the productive goals.

According to Benz (2009, in 2007 there were about 18 rapid prototyping machines in the country, including both subtraction and addition. By 2009, this technology had nearly tripled. In addition, the workforce, which at first was expensive and "uncontrollable" with training new designers, mainly arising from these precursor stages with designers, longed to enter the jewelry market through the industry sector, accepting work for more affordable wages.

Initially, the subtraction technologies were introduced, such as, for example, numerical control milling cutters that remove wax plates, which required much control over the CAM material, were introduced. The training of CAM programs not on the training courses offered to designers were already being offered by suppliers of equipment and few designers had capital to invest in their own prototyping machinery. With this technology, it is necessary to take into consideration the surface quality and the grinding time especially, which would influence together the final cost for producing the 3D physical model. Many companies in these circumstances delayed its acquisition. Others who acquired it used it in a limited way, focusing on flat pieces with cut-outs and orthogonal recordings, unable or unwilling to develop three-dimensional shapes that were more complex.

The arrival of 3D printers for addition was seen as a more direct method for obtaining the three-dimensional physical models, but initially, the price of the machines, materials and final surface finishes were the major barriers to its spread in the jewelry industry in Brazil.

Both technologies have changed working relationships within the jewelry design process, especially in the scope of functions of the designer and his relationship with the goldsmith and producer. Recently, these technologies have become more stable. Lastly, the issue of training the designer and the changes in the product development process are beginning to emerge as a bottleneck for the introduction of this technology. Thus, the industry increasingly seeks designers who hold such knowledge.

For Böhm (1998),
“3-dimensional computer aided design produces objects in virtual reality which can be contemplated and modified in all 3 axes of space. [...] A CAD workshop at the Fachhochschule, Pforzheim has proven the enrichment of design opportunities afforded to design students. Complex objects with either organic or geometric structures can be created with reasonable efforts. The surfaces of a jewellery item can be affected easily in so many

variations that this is similar to adding a new dimension to jewellery design” (Böhm, 1998, p. 9).

This article seeks to understand the current changes caused by the introduction of 3D modeling and rapid prototyping in the design process of jewelry, inserted into the production process of companies in the Brazilian jewelry industry, while also seeking to expose the impacts and challenges that these technologies bring to the activities of the jewelry designer and his training.

This study is based on literature review and experiments in education in the field of jewelry design. As a resource to experience and expose the issues involved in using these new technologies, the case study of developing a piece that focuses on the use of these technologies for a jewelry design competition was conducted. In this case, it is shown that despite the introduction of technologies recognized for their precision, the design process still has a subjective and intuitive character. Characterized as "wicked problem" (Rittel & Webber, 1973) the process of design is influenced by personal decisions and the context of each project. Thus, we emphasize the importance of the training of the designer and its relationship with, and dependence on, processes specific to the design in which it is inserted. From the perspective of technology sector policies, they were alerted to the problem of concentrating simply on the acquisition of new technologies without proper investment in the training of qualified personnel and the observation and study of the processes of introducing new technologies.

2. Changes in the process of Jewelry Design

“As in other design fields, digital technology has had a significant impact on the way jewellery designers conceive, display, and produce their work today. Software now allows designers to develop and visualize their designs in three-dimensional, virtual space.” (Daab, 2008, p. 8).

According to several authors (Andrade, 2002; Santos, 2003; Campos 2007), from the 1990s, with the actions of IBGM, design came to be regarded as part of the production chain of the jewelry industry. According to Campos (2007) formerly "the jewels were designed by the most experienced goldsmiths and for few designers, from courses in Fine Arts and Architecture, whose expertise was given within the companies where they worked" (Campos, 2007, p. 65-66). Santos (2003) also states that in addition to these artists, or the self-taught, it was very common to use the reproduction models of foreign magazines and catalogues that Andrade (2002, p. 15) still considered "less sophisticated copies of existing productions abroad". With that, the jewelry industry, "for many years remained refractory to design and the idea of hiring professionals to develop quality products and success" (Santos, 2003, p. 15). The opening of the Brazilian market in 1990 was the biggest reason for these changes.

Actions taken to encourage design provided great visibility for the foreign jewelry design public. For instance, there is the creation of national contests in jewelry design, and support for designers to participate in international competitions to design and present their creations at exhibitions in countries in Europe and fairs in the US. "In a few years we went from the creators and copiers, to being recognized worldwide by distinctive design, legitimately *'made in Brazil'*" (Andrade, 2002, p. 14). However, we are still not a major exporter of finished jewelry.

With this growth and recognition came the need to create specific training courses for the industry. In 2000, the first specialization in Jewellery Design in Brazil was created. With this, Brazil sought to unite the industry specific "traditional" training of projective methodology designers. Designers were being taught to design both through traditional graphical representation of the design by hand and by 3D modeling, in addition to notions of jewelry for professionals who would prefer to create their pieces directly with the metal. The designers formed by the course had "an idea of the two processes, but ended up designing their pieces by hand drawings, since both tools in the field, such as the domain of software, require daily use.
"When man mastered the technique of working with metals to create adornments, the figure of goldsmiths emerged as creator and executor of gem. As executor of his own creations, the goldsmith had no need to register them through drawings, but in some periods of history, such as the Renaissance, thanks to patronage, some known artists created drawings of jewelry to be executed by goldsmiths for royalty. During this time designing jewelry was born for execution" (Benutti, 2014).

According to Llaberia (2009), drawing on the production process of jewelry was already widely used in the 20s and even during the Art Nouveau period. One of the forerunners of design was Deraisme Georges (1859-1932), who began his training as an engraver and modeler and then as a designer, working for the great Fouquet and Rene Lalique. With his skill at drawing, Deraisme "added the 'know-how' and the knowledge of the production process. Thus, the drawings were no longer merely illustrations to relate directly to production" (Llaberia, 2009, p.134-135).

Llaberia (2009) commented that many used drawing to execute the design personally, while others used it as a record of the goldsmith hired by them to produce parts from these projects.

These drawings come to signify the craftsmanship and quality of jewelry work. In these cases, the participation of the goldsmith is critical to ensuring the possibility of constructing the piece, because the illustration is not a technical communication. Typically, these jewels are characterized by their traditional configuration, which means technical solutions to known jewelry. This eases the designer's work in regards to coordination with a goldsmith.

Currently, according to Llaberia (2009), principally for the designers who work within the industrial sector, and often do not have direct access to workshops, designing jewelry is used to translate two-dimensional form into the object to be produced, containing a representation all the elements of creation, and will be through direct communication with the modeler.

For this communication to occur without much trouble "the design of jewelry production obeys the rules of technical drawing and it depends on the fact that it is the language of communication within the industry (Llaberia, 2009, p. 132). Primarily as the designers' ventures on bolder paths in their design, support of the goldsmith starts to become urgent, and is necessary in order to minimize any problems between the articulation of the designer with the goldsmiths.

It must be noted, however, that what differentiates the designers of the past with designers nowadays, is that the design of jewelry is not restricted to designing a jewel, "nowadays, the process is linked to the knowledge of its user, realizing behaviors, interactions and modifications that will be performing in this respect "(Llaberia, 2009, p. 28). It also means that jewelry design earns innovation of meaning, reaching new target audiences, being less concerned with the value of the raw materials - precious metal, diamonds and gems – rather with those who seek to express their "personality" through new materials and innovative ways.

According to Campos (2007), the relative youth of jewelry design in Brazil protects the "historical weight of traditions, as in [most of] Europe. The secret seems to be exactly this lack of commitment to an image, in advance, which allows them to dare more"(Campos, 2007, p. 71).

With that, many times when presenting their ideas to the modeler, designers heard "everything on paper is possible" contending that that piece was impossible to create. As Böhm (1998) states, as jewelry design was limited by the structures and details that could be drawn by graphite or color pencil, even the three-dimensionality of a design – usually, in the jewelry industry, presented in the form of isometric perspective - was constrained by the limitations of two-dimensional graphics and the imaginative capacity of the human mind (Böhm, 1998, p. 9).

The authors Siu & Dilnot (2001) complement this affirmation, commenting that:

"Focused on creating jewellery objects on paper [...] designers manipulate basic drawing (design) tools (like rendering in pencil, or bush on paper) in relation to fundamental design principles (like the design elements of balance, unity, emphasis, pattern, movement and rhythm, proportion and scale, economy… etc.) in order to deliver jewellery designs which are both "specific" and "un-constrained". These designs are specific as to intention but they are un-constrained in the sense that the designer gives only a "partial" representation of the artefact: the design passed to the model-maker and the production unit is an "approximation" [...]; it is un-defined or ill-defined in terms of physical dimensions, technical setting of the process or even the required quality of the finished object" (Siu & Dilnot, 2001).

With this, many designers sought basic goldsmithing courses in order to "have better arguments" to defend their projects. Others ended up venturing to learn digital technologies, because they believed that they no longer needed modelers to materialize their creations.

This distinction in the processes of jewelry design made most companies separate from the activity of "design", the activity of "making" the jewel, as the knowledge required is very different and specific. Even among jewelry designers, there is a separation between those who create the pieces directly with metal and the design of jewelry. This separation is so profound that those who create the piece directly with the metal often do not call themselves jewelry designers, but jewelry makers.

Therefore, the creation of jewelry today (Table 1) can occur not only via:

- Three-dimensional mode in direct contact with the materials (precious metals, diamonds, gemstones and innovative materials), as jewelry maker;
- Two-dimensional mode, hand-drawn or digital;
- But, also in three dimensions, using CAD/CAM programs.

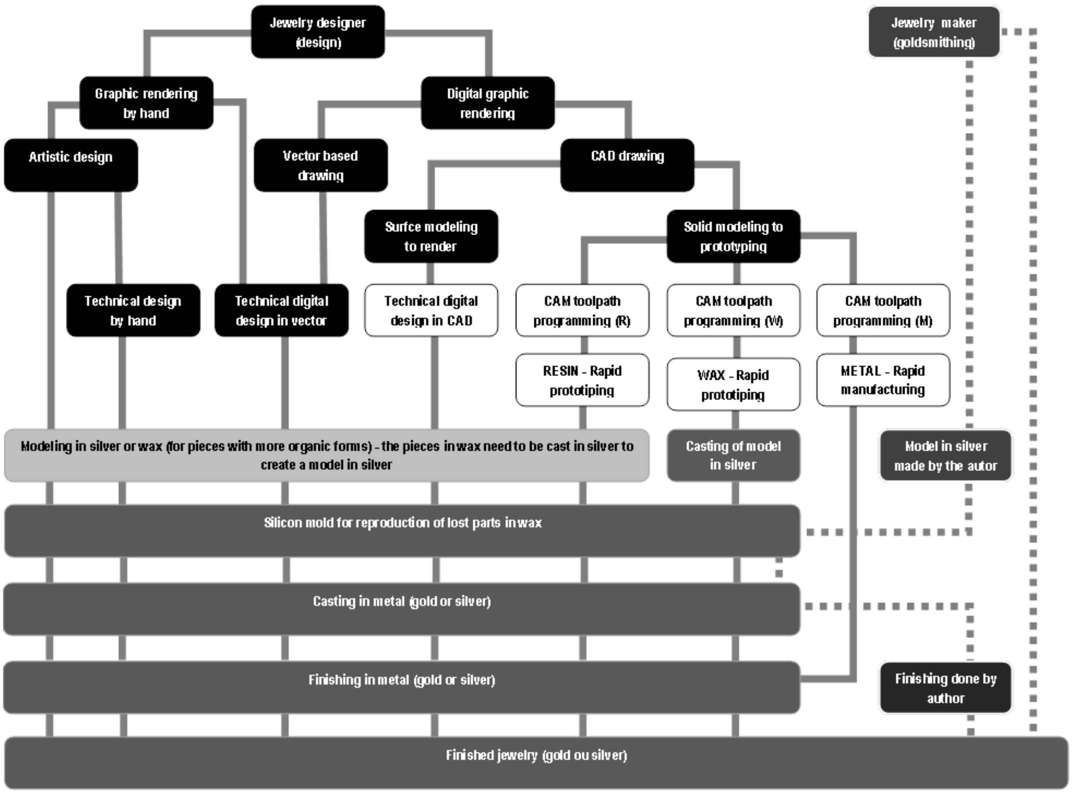


Table 1 – Processes of jewelry designer *versus* jewelry maker

Each type of creation process has advantages and disadvantages, in terms of both time and stages of execution, and in relation to technical knowledge representation and the production of jewelry.

A designer who has mastered only the techniques of graphic representation by hand, registers the design of a jewel through the artistic design (i.e. an isometric perspective of the jewel), and, depending on the industry for whom he designs, will also perform a technical drawing by hand - which can be freehand on graph paper or with callipers, rulers, bolometers and templates with the forms most commonly used by the industry. As is practice, to draw 1:1, few dimensions are included in this type of design. A designer who uses vector programs, such as Corel Draw or Adobe Illustrator, have usually projected directly through the technical drawing. The advantage of this technology is that forms can be copied and pasted, reduced and enlarged, distorted and quoted in easier and quicker ways. The drawings have more straight and "clean" lines, and if necessary can be used directly as a template for cutting metal plates by modellers.

The designers who master the CAD technologies of digital 3D modelling use more time in preparing their projects, but gain a photorealistic presentation of its parts. They also gain the possibility of choosing the best angle for the presentation of the piece - how it is constructed in a three-dimensional virtual space can show various "illuminations", different angles, different colors of gems and metal textures before choosing the most ideal. Furthermore, there is, as in the case of the technical drawing by hand or vector programs, the need to "guess" what will be seen from the technical drawing. While creating the views of an object with a simple geometry may not present great difficulties, in the case of an object with complex geometry and organic difficulties the difficulties can become gigantic. This then is another advantage of CAD programs that it automatically creates, with no problem of views not portraying the same way as stated in the other, which can hinder their interpretation by the modeller.

As this article has the theme of new technologies, this paper will focus on the changes that digital technologies for 3D modelling and rapid prototyping have brought to the process of the production of jewelry.

Based on the model created by Wannarumon & Bohez (2004) a working model of the designer was created, presented in Table 2, with the changes that occur when the creation process makes use of 3D modelling and rapid prototyping. Despite suffering minor variations with the strategies of each company, this model gives us an overview of the role of the designer in the production of jewelry process[1].

In the traditional process, when the designer draws a visual representation of the jewelry – which we call the artistic design industry - he earns, according to Siu & Dilnot (2001), "a perceptual freedom." Since not all the details and forms are determined, it is necessary that the modeler of jewelry then "fill" the missing parts, using "their interpretive skills and his knowledge of material to create the template for the production of silver [in series]" (Siu & Dilnot, 2001).

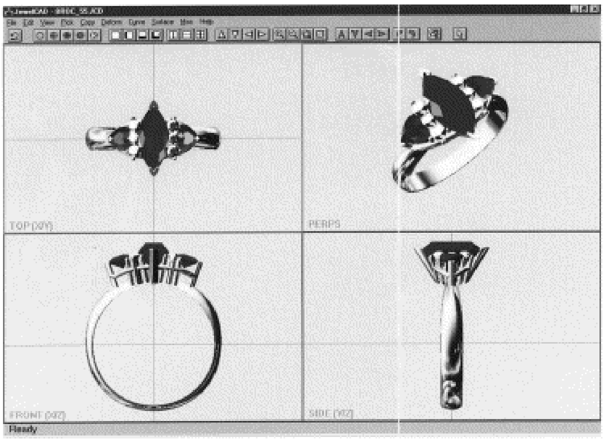
According to the authors, upon receiving the drawing, the modeller of jewelry is committed to translating this into an object through his craft, using his staffs' expertise along with their spatial vision, their manual dexterity and their practical knowledge of materials and processes. Even he cannot describe or document his "doing" or "knowing" craft in a more comprehensive way, all jewelry modelers know how to use the tools to achieve an effect, known as the degree of resistance, explained by molding matter and 'know how' to overcome possible practical problems. The process of doing it manually - and all transposition to be made - is a subjective interpretation individually related to perception, tacit experience, practical knowledge and "craftsmanship" that he does. To become a master in jewelry is therefore a difficult

[1] To facilitate the comparison of the performance of the designer in the two models of Table 2, highlighted in black are the actions performed by him, and in gray are the actions performed by other employees of the jewelry industry.

apprenticeship, through trial and error, a path of learning by taking no easy shortcuts in order to pass (Siu & Dilnot, 2001).

Even in the case of the technical design, the designer quotes are often presented as "suggestions" since it is the modeller who dominates the ideal measurements of thickness of wires and plates, and it is that during the process of creating the piece that makes the best decisions materialize.

Nevertheless, when the jewelry is designed by 3D modelling, the designer
“Must also be a form-maker in a manner that is not required in the conventional design-by-drawing process. In the conventional process, the designer creates, in effect, only an image of the object to be made. Translation to actual form is made through the skills of the model-maker. This stage allows the model-maker to draw on a huge range of tacit knowledge regarding the materials and therefore to perform relatively efficient production-oriented translation of the designer's intent; in effect the goldsmith is the essential mediator between the designer and the production phase. But in the CAD/CAM systems, designers without sufficient making experience are required to determine not only impressions but also the precise dimensions of the jewellery object, i.e. they give, in effect, an “engineering” form to the images”. (Siu & Dilnot, 2001).



Design of Cartier no. R-6, 1969

Catalogue of Jewelry CAD/CAM

Figure 1- Traditional jewelry design, through artistic representation of the piece versus the design of jewelry using CAD programs (source: Siu & Dilnot, 2001)

As designers would have to accumulate functions and acquire new knowledge, Cooper (2005) in his article "*Current best practices in the use of various Rapid Prototyping systems*" raises the question of the necessity of the introduction of rapid prototyping in the jewelry industry and wonders if the professionals end up being overloaded within the production process. However, the advantages that it brings show that it is no longer possible to try to stop the uptake of these technologies.

For the same author, projectual technology through 3D digital modeling and rapid prototyping; "Can be fast, versatile, and relatively inexpensive, are readily available and are well understood by many of the engineers involved in jewellery and Silversmithing manufacture. They are, without doubt, quite sufficient to make prototypes rapidly, and definitely have no equal when it is necessary to make precisely engineered parts" (Cooper, 2005, p. 130 -131).

The advantages of this projectual technology through 3D digital modeling and rapid prototyping, compiled by a bibliographical and documental survey, bring changes to the creation and production of jewelry perceived through the experience of researchers, as can be seen in Table 2.

Advantages	**Author(s)**	**Change**
High accuracy in form modification in enlarging or reducing model size relative to the traditional ways	Siu & Dilnot (2001), Cooper (2005), Benz (2009)	In the design process of the jewelry through tools that allow greater precision and detail during the design; which was created by digital 3D modeling which the rapid prototyping machine will then reproduce.
Ease of modification through "reversible/repeatable" process	Siu & Dilnot (2001), Benz (2009)	
Repetition of 'standard' form, modules	Benz (2009)	
Execution of details	Benz (2009)	
Indicated for complex or intricate geometric forms	Cooper (2005)	
All views are modified together	Benz (2009)	The process of "reflection in action"; designer goes through a more accurate visualization of experienced options; the traditional design process and formal aesthetic decisions occur through undefined and precise imagery
Exchange and virtually experience multiple color combinations of metals and stones more easily	Benz (2009)	
Make further changes during the process of creation	Benz (2009)	
Permanent storage of product data, features and	Siu & Dilnot (2001)	

configurations		
Photorealistic rendering	Benz (2009)	in the communication of the proposal to the manufacturers/clients
Testing the product with the customer	Benz (2009)	
Fabrication of (currently multiple) parts into a single assembly	Cooper (2005)	in the process of the production of the item
Time compression in making master model, production mould and tooling	Siu & Dilnot (2001), Benz (2009)	

Table 2 – Advantages and changes that 3D modeling provides

3. The technology enabling the creation of new forms

According to Marshall (2008, p. 10), "designed objects created from the application of computer-based production methods that might offer possibilities for new forms of cross-disciplinary or hybrid art and design practice". With this technology, it has become possible to create experimental objects, which challenge existing expectations and established behavior by means of unconventional design Methodologies.

The author further states that digital 3D modelling can transform former design processes into new ways of working, and "might represent an expanded cultural field beyond each of the traditional disciplines" (Marshal, 2008, p. 78).

"The link established between design creation and technology allows us to think of this integrated, interrelated, interdisciplinary interaction and allows transdisciplinary scope to move towards breaking down barriers, thin borders, merge, hybridize, becoming another. These are complex relationships that explain the diversity and doubts regarding the area of operation" (Moura & Gusmão, 2008, p. 24).

It must be emphasized, however, that technology is just a tool that opens up new formal and aesthetic possibilities for the designer, but the creativity and inventiveness of a project mainly depends on the intention of the designer to be creative when making the project. New technologies make forms possible that could not even be imagined previously, let alone tried, but this does not automatically guarantee that everything produced by them will be unique and innovative. As Forty (2007) argues, it is not machines that cause "changes in design, but the use of the machine in specific economic and social circumstances. [...] Assign changes in design technology not only to understand the nature of both machines but the design in industrial societies "(Forty, 2007, p. 81).

Tschimmel (2003) talks about creative thinking in design supporting this idea by stating that creativity "is a result of intentional thinking" and "creative thinking does not take place, for example, when it is hampered by a lack of knowledge of the area by experience or by lack of motivation "(Tschimmel, 2003, p. 2).

According to Righi & Celani (2008, p. 3) "the tools and equipment used during the project interfere significantly with the design and consequently in obtaining solutions. The technology used to design interferes with the creative process."

Searching, for example, in architecture, where creativity and CAD technology has already been studied for some time, it can be seen that the simplified language programs, coupled with greater fluidity and intimacy in their use, secured the use of computational tools in this phase of design.

For Kowaltowski *et al*. (2006) The use of CAD systems in the design process in the development of architecture, in recent years, contributed to experimenting with more complex forms while there has been an increase in the complexity of proposed forms. We can conclude that where its representation and manipulation were facilitated, there was an increase in complexity in architectural designs.

“Even though the possibilities of CAD in the conception, development and representation of architectural design are still challenged by professionals and in teaching, there is great potential of these tools being used in the design process. The domain of resources becomes ever more present for creative and efficient use in architectural practice. There are many possibilities for project simulation, collaborative framework between the various professionals involved, experimentation with new and complex ways, structural representation and tests to be explored” (Kowaltowski *et al.*, 2006, p. 7)

According to Ferrari (2011) both the architecture and the jewelers show changes in their creative process through the use of digital technologies, not only as digital tools, but when explored in all its potential to produce two- and three-dimensional views.

However, the author points out that "it never hurts to emphasize that the computer cannot imagine, build pictures. The machine does not think that what it does in the real world is the thought of the artist working in four dimensions: functional, aesthetic, symbolic and technological" (Ferrai, 2011, p. 25).

4. The creative process through these new technologies

We now present a practical case study in which 3D modelling was employed by the authors in the creative realisation of a piece of conceptual jewelry for the 2012 edition of the contest AuDITIONS Brazil of Anglogold Ashanti which is engineered through digital technologies. Understanding the power of design in the modernization of the value of their product chains, gold, a commodity that gains more value through human beings turning it into a piece of jewelry, the mining company began promoting this contest since 1999. They were always focusing on encouraging "artists to express themselves through innovative and sophisticated jewelry that goes beyond the boundaries of design" (Anglogold, 2008).

As the theme of the contest was "Brazilianness", the proposal of jewelry to represent the multiculturalism of the Brazilian people through the book Casa Grande & Senzala emerged, evoking the idea proposed by Gilberto Freire of Brazil as a mixed tropical paradise, where you would find the meeting of races and cultures from Europe, Africa and America and materializing the concept of multiculturalism through iconic forms of major African and Portuguese jewelers.

Searching for reference images of colonial Brazil (Figure 2) showed the jewelry worn by the slaves and the masters of slaves, and also the icons of Portuguese and African jewelry.

Figure 2 - Images of inspiration for the Casa Grande & Senzala earring.

The goal would be to generate an immediate identification of the proposal by those who judge the project and later by those who saw the piece. The main concept adopted was duality and composition between European Portuguese and African cultures represented by gold and polished diamonds, respectively. The starting point for the design of two initial ideas, starting in the 3D digital modelling program Rhinoceros:

- The first idea was to unite the two cultures in symmetrical earrings and reversing the references - i.e., instead of "textured" ring and gems in earrings of European origin, creating rings of "gems" by working on an internal metal pendant in the form of a teardrop. However, as can be seen in Figure 3 below, the project was never even finished because the result was not communicating the proposal. References to the Portuguese and African jewelry were lost, they were disfigured, and the piece had become just a stone earring with a metal pendant in the middle.
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The facilities offered by digital modelling technology: *i*. ease of propagation and reduced forms to the shape of cutting diamond, *ii*. the accuracy of positioning them in a perfectly circular shape and, *iii*. the possibility of a quick and accurate view of the final aesthetic outcome of future piece (Figure 3) allowed the idea to be discarded quickly.

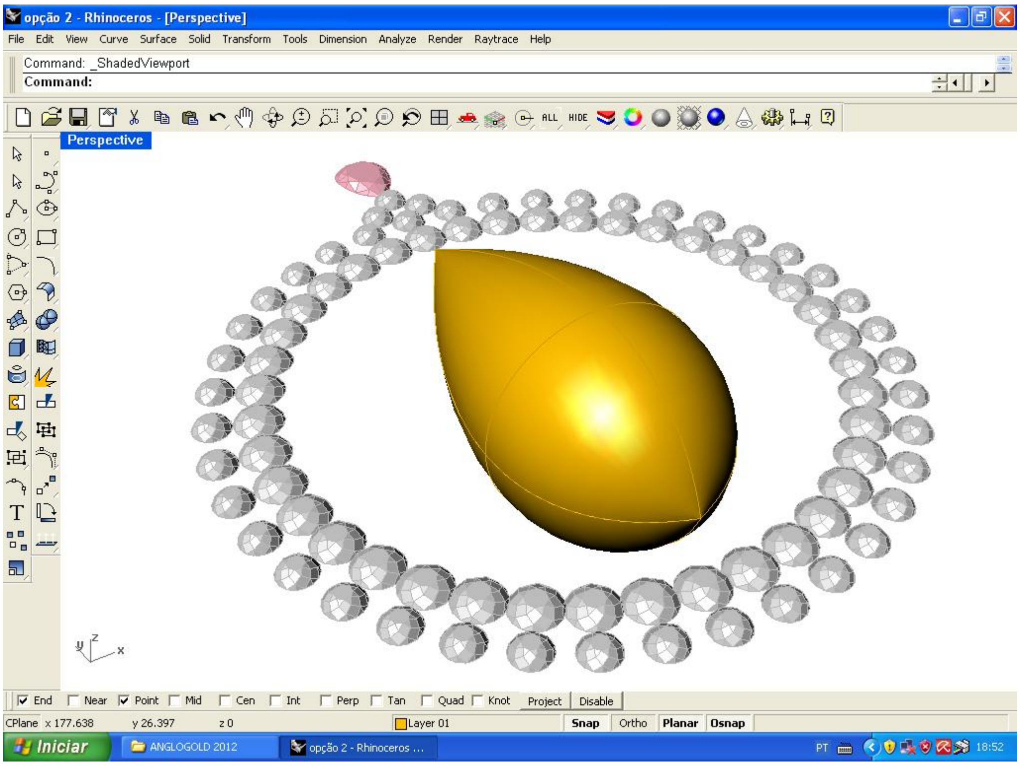

Figure 3 – The first layout option for the Casa Grande & Senzala earring.

- Taking advantage of the ready built forms of gems in the form of a bright and stone drop in the library of Rhinoceros, after which we had changed the ranges and combinations, we began to create a second option of an asymmetrical earring, or the ring on one side, and the stone earring the other (Figure 4). In addition to better expressing the idea that every Brazilian has a European culture and African culture in the construction of their Brazilianness (the contest theme), the cultural references remained easier to identify. The concept of multiculturalism would be enhanced by a change between the "head" and the rest of the earring. On the right earring, the head was the ring and the emphasis was given to the iconic shape of the Portuguese jewelry; while the left earring head was the ring of gems, giving greater emphasis to African jewelry through the hoop "carved" in low relief. They then required only reducing the drawings from the rest of the earring and mirrors vertically.

Taking advantage of the shape in diamond cutting created for the previously discarded option, instead of giving the copy command in circular form, it was given the copy command following a line circumscribing a central drop-shaped gem.

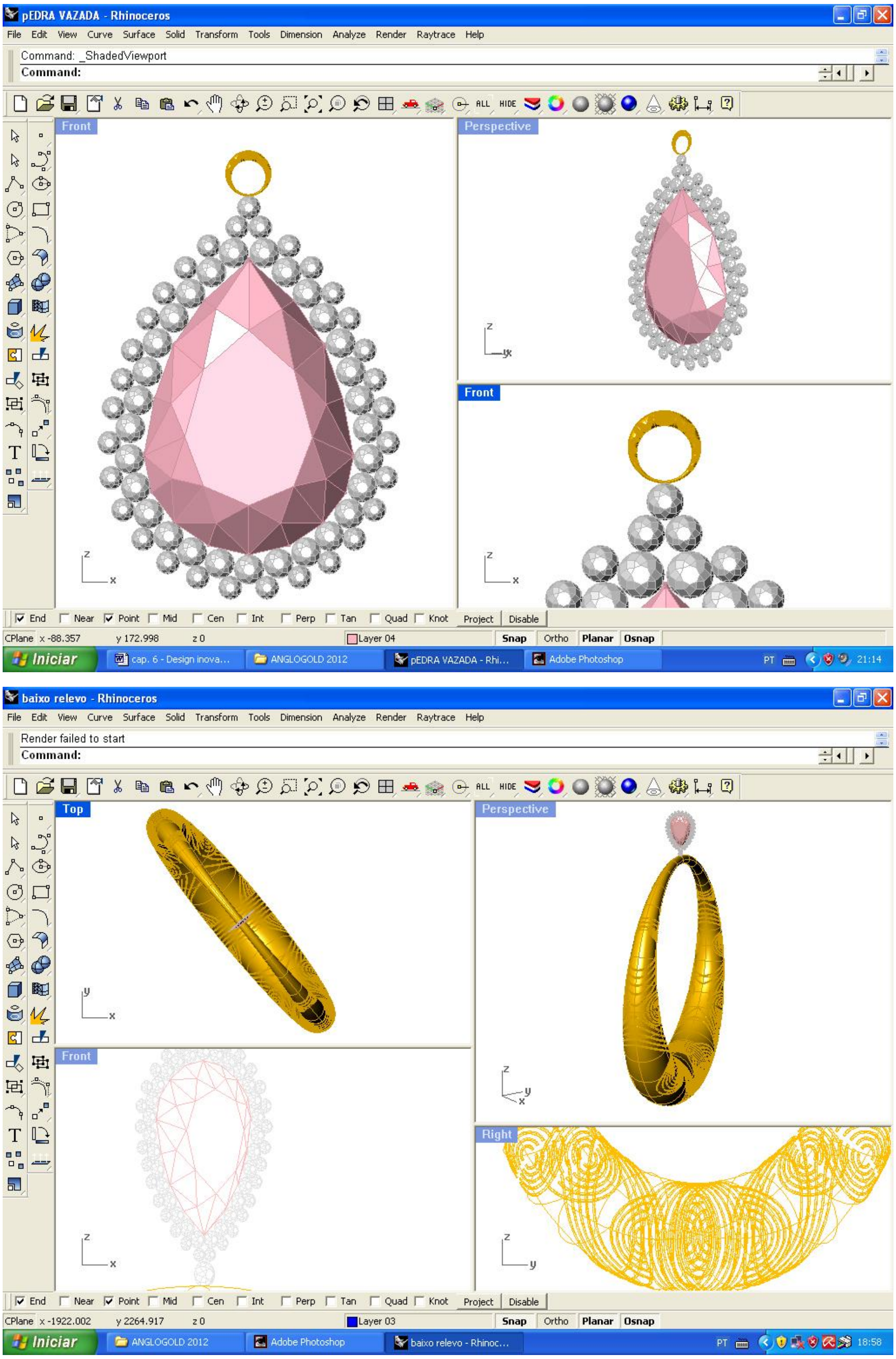

Figure 4 – Second option for the layout of the Casa Grande & Senzala earring.

The construction of the precise low reliefs in the ring was also only possible due to the use of 3D digital modelling. From the construction of a smooth loop (Figure 5, phase 1) designs were created in the desired shape along two dimensions (Figure 5, step 2). After these two-dimensional drawings were "extruded", vertical planes that cut the ring (Figure 5, step 3), and through a simple command (trace of intercession line) lines were created where the various plans and drawings of the ring were cut (Figure 5, step 4). From these lines, "pipelines" of the same diameter (Figure 5, step 5) were drawn to later "remember" the volume of the ring thus creating the low relief all at the same thickness.

Another advantage of using this method of creation is that the construction of each phase can be saved in different layers; they can all be stored to be reworked later. To help view the Design, the layers can be hidden and brought back when you want to visualize them.

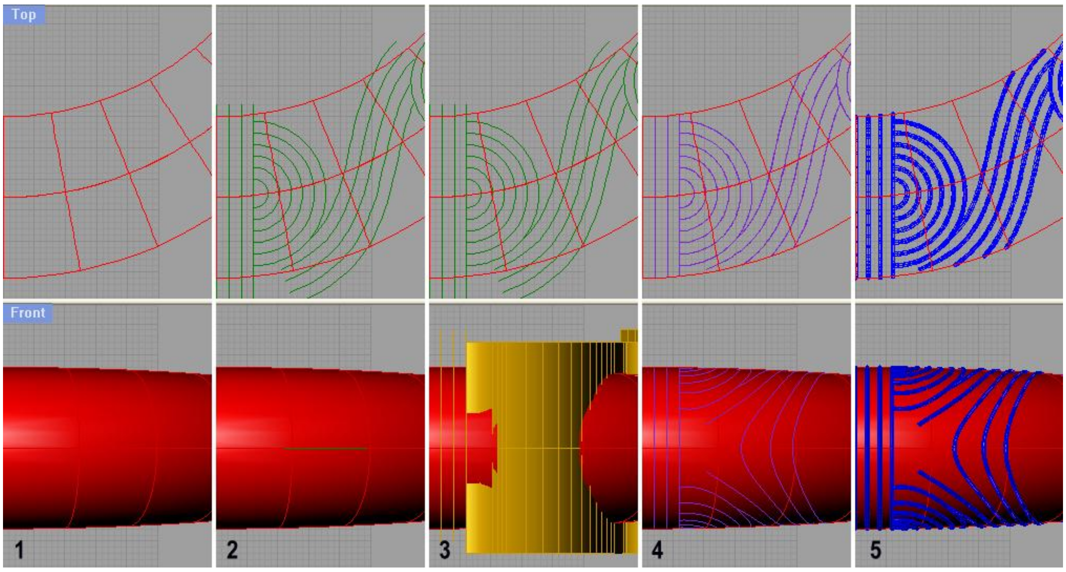

Figure 5 – Construction of low relief on the ring.

To emphasize the gold, and its array of colors using different alloys, the ring would be made in yellow gold, the "diamonds" in white gold with a pink gold central gem, resembling a pink sapphire, ruby or even, depending on the tone of gold achieved, traditional jewelry gems of the world. In addition, after these materials have been defined, their characteristics were digitally applied to each of the structures of the pieces so that when rendering the image, it gives the desired impression. In addition, spotlights were added to reproduce the glare and reflections from the gems and the white and yellow gold. As the program creates an instant display after changing any factor, the designer makes the final decision (Figure 6), not upon a mental image, but through multiple viewing options, which can be saved and replayed by the command "undo" that allows you to quickly reverse / repeat an action.

Figure 6 – *Render* of the layout for the Casa Grande & Senzala earring.

After the forms were defined, it was necessary to determine the size of the earring in relation to the face of someone to get an idea of "largeness" – this in both Portuguese and in African jewelry concepts. An image of a face of a woman was chosen and the earrings built in Rhinoceros were positioned at an angle that matched the position of the face. A montage of images in an image program was made, as in this example in Adobe Photoshop. As one of the categories for the selection of finalists is attractiveness - which is defined in this contest as the final visual impact of the piece - it was decided to not only make great earrings, but bring a lot of the concepts used in recent parades of the great fashion designers in the use of necklaces, brooches, bracelets and earrings the same as those used on the catwalks: the *oversize* (examples in Figure 7).

Figure 7 - Extreme oversized earrings (Michelle, 2010)

As you can see in the montage of pictures for the project (Figure 8), the transposition of the concept *extreme oversized*, brought a certain impact to the piece. As the earring was already digitally constructed three-dimensionally, it was only necessary to rotate and position the pieces so that they fit the render on the image of a selected face, thus creating a new rendering that can be "mounted" in this image. Two options were created through reduction and image magnification of earrings, in order to visualize the optimal size of the piece in relation to a person's face (Figure 8).

large ***extreme oversized***

Figure 8 – Options for proportion of the Casa Grande & Senzala earring.

For complete understanding of the project proposal, the board presentation (Figure 9) was sent to the contest, presented below, showing the earring worn by a person - to demonstrate the size ratio compared to a face - and the front view - where it can be seen that the elements are repeated with variations in size in the two earrings.

For the construction of this board, in addition to 3D (Rhinoceros) digital modeling, image editing (Photoshop) and two-dimensional vector graphics (Corel Draw) software programs were used, demonstrating that the more technology the designer learns, the better the chances of representing the idea.

Figure 9 – Board presentation of the Casa Grande & Senzala earring design.

After the proposal was chosen as one that would pass to the next stage of the competition, and would thus be transformed into metal, the whole basis of the virtual construction project created for the render was used. The drawing digitally modeled in 3D was handed to the jewelry company that would manufacture the piece with 400gr of pure gold (24K) made available by the organizers.

In addition, it was noted through the virtual model that the weight of the earring would be a problem. It was necessary to make it lighter, and again the technology of 3D digital modeling was important in allowing for a reworking of the respective lines of the earring, loop, small details along the notches on the front, and the earring gems, emphasizing the edges of polished stone (Figure 10). With this, the weight of the earring fell almost by half, still giving a finish of jewelry used in the "Haute Joaillerie".

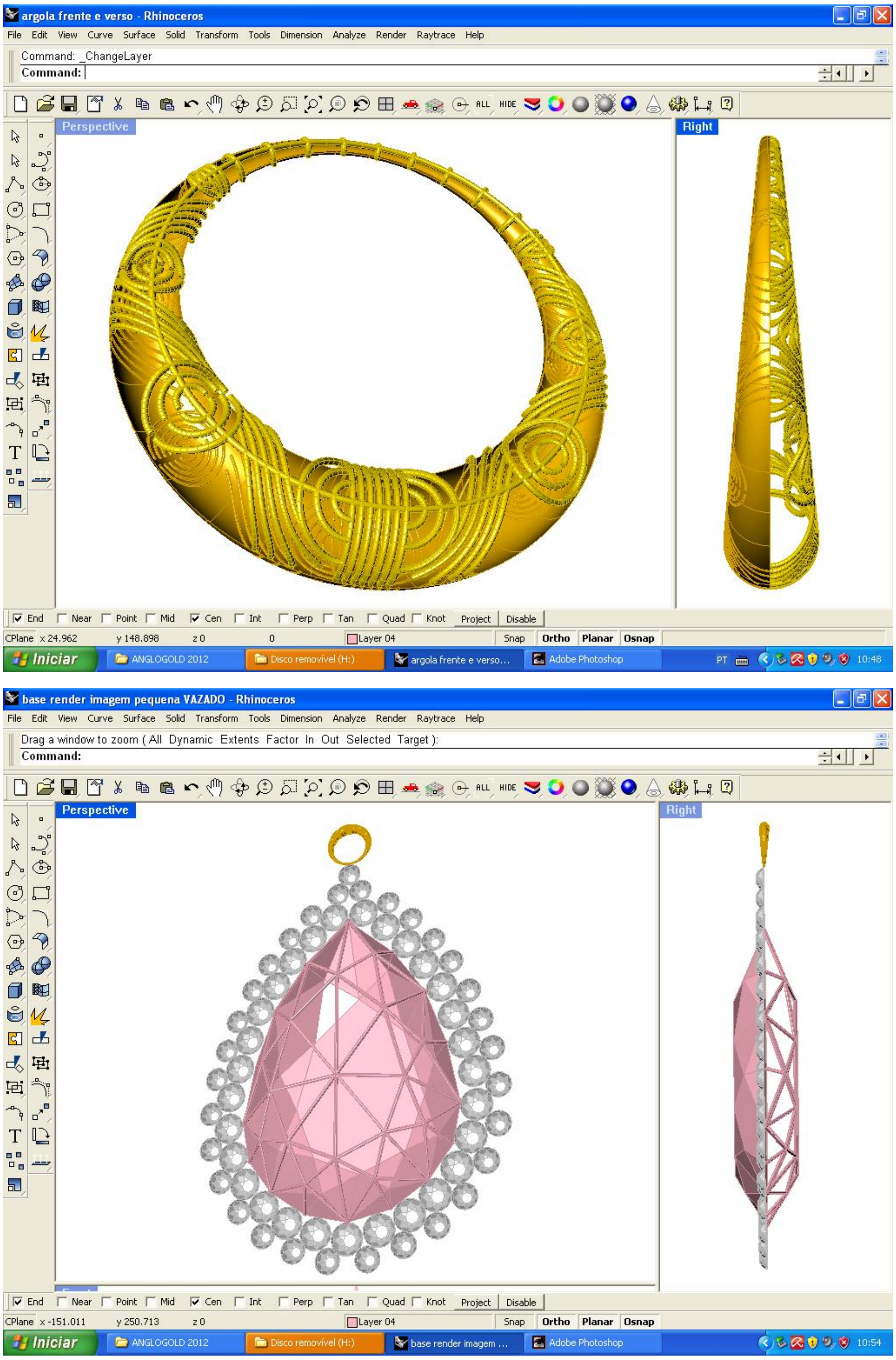

Figure 10 – Changes in the Project of the Casa Grande & Senzala earring.

With specific machinery (Perfactory® Aureus of ENVISIONTEC), the industry sponsor can print the piece in resin through rapid prototyping technology and from this merge the respective parts with the gold colors specified in the design: yellow, white and pink.

In Figure 11 one can see how the piece of metal does not differ in any of the renderings created on 3D modeling software. Only the hooks at the top of the earring, placed for reasons of weight, to generate greater comfort and safety for that part used in the catwalk parade of the contest submission.

Figure 11 – Accompanying photo sent to the company for the approval of the designer.

5. Conclusion

This research has allowed the contextualization of the various advantages of using new 3D digital modelling technology and rapid prototyping in jewelry design through a case study of developing a conceptual piece with a high standard of innovation.

New technologies enable (1) better accuracy, (2) execution details with greater accuracy, and (3) reduction of production time. Other advantages made clear with the use of these technologies were, for example, (4) the possibility to make changes and (5) photorealistic experimentation during the process of creation, (6 and 7) storage and use of previously created forms and commands through the reduction and enlargement, as in the case of heads of earrings (Figure 12), etc.

Figure 12 – Detail of earring heads in metal.

These technologies have also allowed; (8) during the execution of the project problems in part weight to be identified, and also to be able to propose its reduction through the use of edges in the gem drop shape, simulated pink gold and the filigree ring in yellow gold . These forms would be extremely difficult to weld. Furthermore, filigree work on the back of the ring - which reproduces the design in low relief on the front of the same part (Figure 13) - would be impossible to carry out so accurately with the use of traditional jewelry technology, which is (9) a form of extreme complexity.

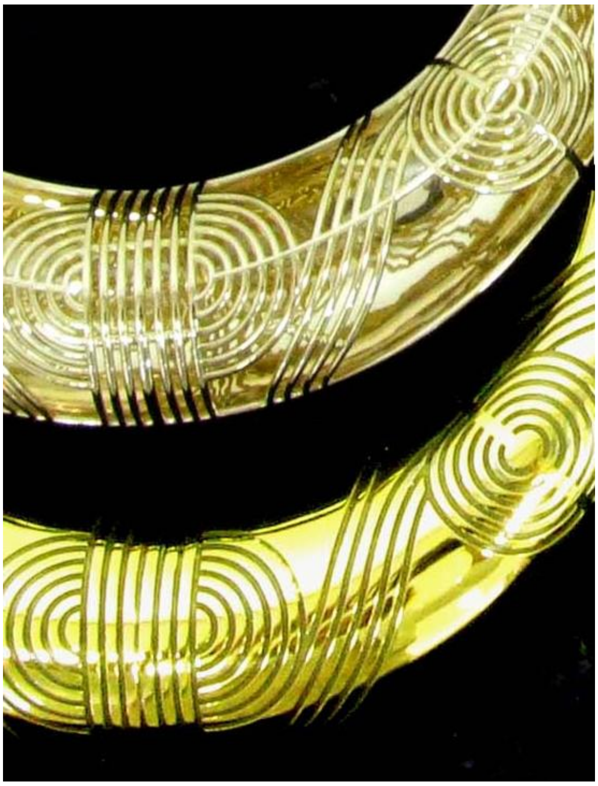

Figure 13 – Detail of the loop in metal.

Beyond the technical advantages presented above, the 3D digital modelling and rapid prototyping in jewelry design enables the designer to expand their creativity, not having to worry about the limits that would be imposed during traditional jewelry design. For example, many corners of the gemstone teardrop, in pink gold or white gold, simulated polished diamonds themselves (Figure 14). If not using the 3D digital modelling and rapid prototyping, the production process (especially in relation to the numerous weld edges) would be very laborious, decreasing the chances of finding any industry to transpose the project to the metal. Thanks to this new technology, the simulated gem pink gold teardrop was printed in resin and a unique piece in white gold simulating polished diamonds was printed in groups, reducing the number of welds on the part.

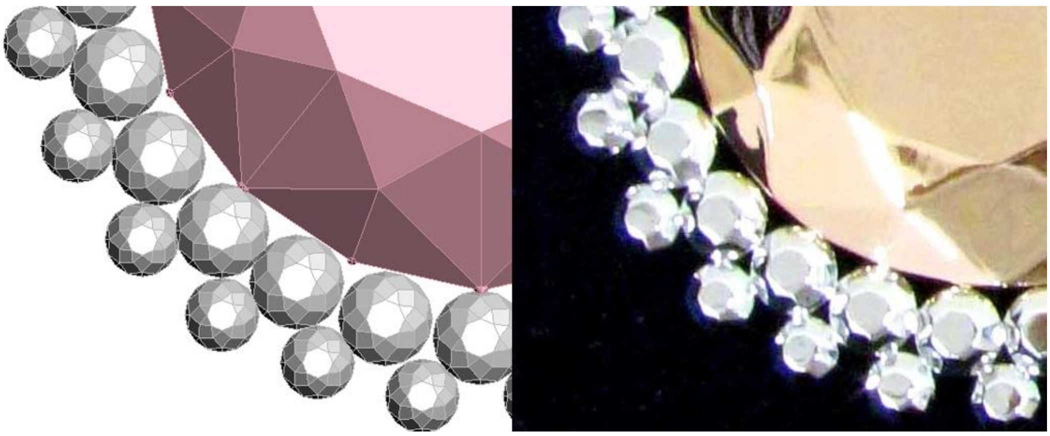

Figure 14 – Detail of gem and Diamonds simulated in gold.

The Casa Grande earring succeeded in uniting the tradition of Portuguese and African jewelers with the technology and modernity of 3D digital modelling and rapid prototyping, representing the multiculturalism of Brazil where black and European beauty coexist harmoniously (Figure 15).

Figure 15 – catalogue photos (Anglogold Ashanti, 2012) and the parade of finalists pieces in the AuDIITIONS 2012 collection (Anglogold Ashanti, 2013).

Through this example, one can see how the use of digital technologies such as 3D digital modelling and rapid prototyping allows the jewelry designer to explore "new" formal and aesthetic alternatives, creating pieces that were not previously imaginable. Furthermore, it was realized that these technologies allow the designer to more intensively use the "dynamic process of learning" (Neumeier, 2010), not only during the creation of a jewel, but also during its production process. The weight "problem" identified during the production process allowed the designer, looking for a solution, to add to the initial design filigree work and cast the edges of the simulated gemstone pink gold spaces, which increased the beauty of the final piece.

The subjectivity of the process performed by the designer was empowered by new technologies. Various paths and decisions made by the designer were possible due to the cited advantages of these technologies. Nevertheless, this mostly points to direct conversions between the 3D digital design, the physical 3D printed model and the traditional process of casting as the main benefit to the autonomy of the designer. The technical advantages brought by new technology keep the design process full of open paths, subjective personal decisions and intuitive, thanks to the improved accessibility of these technologies.

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