ADD WHAT? A REFLECTION ON THE APPLICATION OF ADDITIVE MANUFACTURING FOR THE CREATION OF JEWELLERY

M.F. VERSTEEG[1], E.L. DEN BESTEN[2]

[1]*Technical University Eindhoven (the Netherlands), m.f.versteeg@tue.nl*

[2]*Technical University Eindhoven (the Netherlands), e.l.d.besten@tue.nl*

***Abstract**: In this paper we reflect on additive manufacturing from a jewellery perspective. We first describe the technology and its merits. We then factually assess how the technology is applied in a given collection of printed jewellery. To conclude we identify tendencies, explain current applications and sketch future perspectives in terms of changes and threads.*

Keywords: *additive manufacturing, jewellery, craftsmanship, digital production, personalisation*

1. Introduction

Over the last decades the technical possibilities and the availability of additive manufacturing (AM) have grown enormously. Due to its small size jewellery can relatively easy be printed and therefore seems to be perceived as a good medium to explore and exploit the opportunities of additive manufacturing. This has resulted in an enormous amount of printed jewels. For example, entering the query '3d printed jewellery' in Google results in over 7 million hits (dd 22-6-2014). But to what extent has additive manufacturing truly innovated the world of jewellery?

This paper aims:

- To identify characteristics of printed jewellery: who are the creators? Which technologies and materials do they use?
- To interpret directions within printed jewellery and reflect on them.
- To sketch a future perspective and identify challenges within the field of additive manufactured jewellery.

1.1 Approach

When talking about printed jewellery in general, we would run the risk of getting stuck in generalities. It is for this reason that we wanted our research to focus on a random yet limited selection of works. First we analysed the *Around the Future*-collection as composed by Cappellieri et al. (2014). In order to verify the outcome of that analysis, we composed a second collection by taking the first 45 Google-image hits on the search term '3D printed jewellery' (Versteeg and Den Besten, 2014). While composing this collection we took the following rules into account:

- Use a computer that didn't previously execute a query in the direction of (3D printed) jewellery, to avoid biased results caused by the Google-algorithm that takes earlier searches into account.
- No examples from the homepage of designers and/or producers of printed jewellery, only from blogs, reviews, newspapers, etc. By concentrating on secondary sources we assume to get examples that were considered to be 'worth mentioning' for other than pure commercial reasons.
- No more than one design per designer, as the designs are often strongly related in terms of used materials, technology, shape and concept.
- No renderings, only designs that actually have been printed.

By means of desk-research and contact with the creators we collected the following information for each design: title, country the design originates from, name of creator and/or studio, his/her educational background, material and production technique. The outcome of the analysis of the two collections strongly overlapped[1]. To prevent confusion the rest of this paper is based on the collection we put together ourselves and will be referred to as *our study collection.*

Our study collection obviously is not all-embracing, as that would be impossible regarding the amounts of printed jewellery available on the market. Yet it as a sample of printed jewellery conceived by individual creators, studios and small brands. Large(r) and more commercial brands are no part of this research.

During our research we found interesting examples of printed jewellery that are not in *Our study collection*. We decided not to add them, as that would blur the boundaries of the collection and impose our (tacit) assumptions. Instead we put them away and used them at the end of the process to verify and improve our findings.

1.2 Outline

A basic understanding of additive manufacturing is needed to assess printed jewellery; we therefore start this paper with a description of the technology, its background and its merits (paragraph 2).

To get a first understanding of the characteristics of *Our study collection* we used *Freed*, a software tool that enables the visual organisation of designers' digital work in order to reflect on its internal relations. (Mendels, 2013). The organisation of *Our study collection* based on factual information gives interesting insights in for example the dissemination of certain AM-technologies within jewellery and differences between the world of jewellery as we know it and the new practice that stems from digital production technology (paragraph 3).

Up to this point the focus is on *Our study collection* as a whole and its internal structure based on factual information. In paragraph 4 we look at the individual designs and more subjective attributes like form, uniqueness and role of craftsmanship. On the one hand we aim for objectification by underpinning these attributes with technological influences (as deducted from paragraph 2 and 3). On the other hand we identify aspects of the 3D printing in relation to jewellery that hold promising opportunities and leave room for future explorations.

2. Additive manufacturing

Additive manufacturing technologies build 3-dimensional products layer-by-layer. Contrary to most production technologies which subtract material, additive-manufacturing technologies do add material. Each printed object starts with a computer-aided design (CAD) file.

2.1 Short history

Over the past three decades additive manufacturing has gradually developed from a tool to quickly make models during the design process into a technology that "has the potential to revolutionize the way we make almost everything", as president Obama stated in the 2013 State of the Union (Obama, 2013). The process was called Rapid Prototyping. The name referred to its purpose of the time: quick and relatively cheap production of prototypes in order to evaluate the geometry of a design. Later on it was also labelled Rapid Tooling, as it became possible to make moulds, which allowed for production of test-series to

---

[1] A graphical comparison of the factual characteristics of the *Around the Future* collection and *Our Study Collection* can be found on http://www.brech.nl/wp-content/uploads/2014/09/Comparison-.pdf

evaluate the functional properties of a design. Over the last decade technology has improved to a level where it became possible to use it for actual production: Rapid Manufacturing.

Figure 1: Left: first generation MakerBot Thing-O-Matic, Right: fifth generation Makerbot Replicator

At the beginning of the 21st century additive manufacturing also found its way to amateurs and became labelled '3D printing'. Lowcost printers like *RepRap*, *Ultimaker* and *Makerbot* enabled printing at home. At first these were only available as Do-It-Yourself-kits. Nowadays more and more plug-and-play printers enter the market, with casings resembling those of 2D desktop printers. Figure 1 illustrates this development. For those who do not own a 3D printer themselves, online services like *Shapeways, Materialise* and *Freedom of Creation* offer the opportunity to upload a 3D model and get the print delivered at home. Physical hubs like *Makerspace* and *Fablab* allow individuals to go to the nearest printer to print their own designs.

Parallel to the developments mentioned above, there is a growing awareness of the potential impact of additive manufacturing. Rifkin (2011) identifies additive manufacturing as an important aspect of a third industrial revolution. This means that it not only will influence the way we make things, but that it will also have an economical, social and cultural impact. One of these impacts is the emergence of virtual communities of 'makers' or virtual guilds; global open-source software and networks, which are an important driver behind knowledge dissemination and expansion (Bonanni and Parkes, 2010).

2.2 Characteristics of Additive Manufacturing

The characteristics mentioned in this paragraph are inspired by the principles of additive manufacturing as described by Lipson and Kurman (n.d., pp. 20-24) but categorised and annotated according to our own insights. To characterise additive manufacturing it is best to distinguish hardware related aspects from software related ones.

2.2.1 Hardware related

In terms of hardware the most important characteristics are:

- Additive manufacturing is a layered additive process: a great number of section cuts is stacked to create the 3D product. This allows for the creation of complex (e.g. interlinked or hollow) shapes, which hardly can be realised by means of conventional subtractive technologies. It diminishes the need for assembly as things can be printed all in once and little (often expensive) waste by-product.
- Additive manufacturing is non-specific. Most conventional production technologies need specific tooling for each product (e.g. a certain mould for injection moulding or a special chisel when

milling). One and the same AM-machine can print all sort of shapes and products without having to adopt the hardware in between. This results in zero setup time, no additional tooling costs per product and no extra costs for complex shapes. It actually has become possible to parallel produce one-of-a-kind pieces. Lipson and Kurman (n.d. pp. 22) claim that additive manufacturing is zero skill manufacturing. This is true as far as it concerns the hardware aspects. We disagree on this point when it comes to software related aspects and the finishing of printed jewellery, as will be argued respectively below and in paragraph 4.2.

- Hardware related limitations are found in the resolutions that can be achieved, the type of materials that can be printed and the size of the building platform. All three aspects are constantly stretched by technical progress and in the end only limited by the laws of physics.

2.2.2 Software related

A popular image of AM in mainstream media is that “by pushing the button the machine prints a chair, a cup, an opener, whatever you want” (own translation of Nieuwkerk (2011)). It is easily neglected that AM-hardware needs a digital file to function. Creating such a file requires software, but the digital nature of this input reaches further than solely software-related aspects:

- Creation of digital input. With the development of computing power, CAD-software has developed from 2D drawing into 3D solid modelling, from which stereolithography-files can be created. This file format can be sliced into printable layers. Traditionally CAD-software was developed for the professional market and required quite some modelling experience. Over the last years less extensive yet more intuitive programs like *Sketch up* and *Blender* have opened up 3D modelling to a broader audience. Even this software is hard to handle for people with none or little modelling experience (Versteeg, 2011).

  Dealing with software does not require the same manual skills as traditional craftsmanship, but it does ask for extensive practice to acquire a feeling on how to compose the drawing of a complex product. This goes beyond knowing where to find a certain software-function.

  An alternative way to create a digital file is by making a 3D scan of a physical object, either an existing product or a design exploration in, for example, clay. This technology is relatively new and usually asks for post processing using modelling software. Within *our study collection* we find the Bear Earrings, which are based on CT-scans of an actual Bear skull. Outside *our study collection* we find Portrait me, a cameo based on structured light 3D-scanning (Figure 2).

Figure 2 From left to right: ‘Portrait me’ by Vivian Meller and Laura Alvarado (2013). Scanning in progress (left) and printed result (middle), Bear Earrings (3DPrintedSkull) based on CT-scans.

- Easy manipulation of digital files. Once one masters the software, files can easily be altered and saved as a copy to create multiple variations. This characteristic is further strengthened by the fact that programs like *Rhino* and *Grasshopper* have become parametric and thus allow for generative design. This means that an algorithm defines the relations between a set of parameters. By altering one parameter the output (in this case: the software model) changes.
- Easy sharing and multiplication of digital files. The non-physical nature of digital files allows for easy distribution over email and Internet. As a result of this it becomes possible to de-centralise production. On the other hand it raises ethical and philosophical questions. Amongst others Warnier, et al. (2014, pp. 24-28) plead for a redefinition of copyrights. In line with Benjamin (1939), who concluded that with the rise of mechanical reproduction techniques, the aura of works of art got lost, one can wonder how digital reproduction techniques influence the perceived value and uniqueness of a design. This is particularly interesting in the context of jewellery as it traditionally derives part of its meaning from its (perceived) unique existence. (Unger, 2010, pp. 161-163)

2.3 Printing technologies

Commonly AM-technologies are categorised in two groups (Lipson and Kurman, n.d. and Warnier, et al., 2014): binding processes and deposition processes.

2.3.1 Binding processes

Technologies in this group first spread a whole layer of material and then solidify the contours of the object to be printed. The printed object is totally embedded in not-solidified material, which also services as support for free-hanging elements. This means that, except for the liquid-based SLA-technology, no addition support structure is needed.

- Stereolithography (SLA) or Digital Light Processing (DLP) is based on liquid photopolymer that solidifies when exposed to light. After a layer is solidified the building platform lowers a little bit in order for the next layer of liquid to be solidified. The photopolymer can be mixed with different materials (e.g. wax and ceramics), to achieve different material properties. SLA allows for a high level of detail.
- Selective Laser Sintering (SLS) is based on layers of powder that is melted together by means of a laser. SLS technology can be used for a wide range of materials reaching from plastics to metals. Depending of the used material SLS is also called Direct Metal Laser Sintering (DMLS), Selective Laser Melting (SLM) and Direct Manufacturing (DM).
- Inktjet Powder Printing (3DP) prints layers of powder on a layer of glue. Objects produced by means of 3DP technology aren’t as strong as SLS produced ones, but can be strengthened through post processing (e.g. sintering in case of glass or ceramics and infusing with resin in case of plastic). In contrast to other techniques 3DP allows for full color objects.
- Laminated Object Manufacturing (LOM) builds objects from full layers of sheets (for example paper or metal) cutting the proper contour in each layer. LOM isn’t used so much.

2.3.2 Deposition processes

Deposition technologies build objects by extruding liquified material that fixates on the previous layer. As the object stands free in space, free hanging parts need a seperate support structure.

- Fused Deposition Modelling (FDM) extrudes thermoplastic material. The layers are relatively thick, but FDM produced products have good mechanical qualities. Most current home-printers use FDM-technology.
- Paste Extrusion is related to FDM, but uses moderately heated materials (like chocolat) or materials that dry by air (e.g. clay or cement).

- Polyjet printers (also called Multi Jet Modelling or Material Jetting) print photopolymer contours and then solidify it by means of UV-light. As each layer can have a different colour and can be another material, a large variety of colours and material properties can be achieved.
- Laser Engineered Net Shaping (LENS) blows powdered titanium or steel into a laser beam that instantly melts onto the object being printed. Through the use of multiple nozzles the composition of an alloy can vary within one product.

3. Identifying characteristics of *Our study collection*

In this paragraph we aim to get a general understanding of how *Our study collection* of printed jewellery is composed.

3.1 The creators

In figure 3 *Our study collection* is categorised to the educational background of the creators. It needs to be mentioned that the separation between jewellery art-, craft- and design-schools is somewhat ambiguous, as each institution has its own ratio of all three elements. Therefore the division should be interpreted as schools with an emphasis on respectively conceptual quality, traditional manual production and jewellery design (aesthetics, industrial production and market).

Most creators do not have an educational background in jewellery. Architecture and (Industrial) Design dominate the non-jewellery backgrounds. This might be explained by the fact that those educations are familiar with CAD-software. In paragraph 4.2 we'll analyse how non-jewellery education adds new meaning to jewellery.

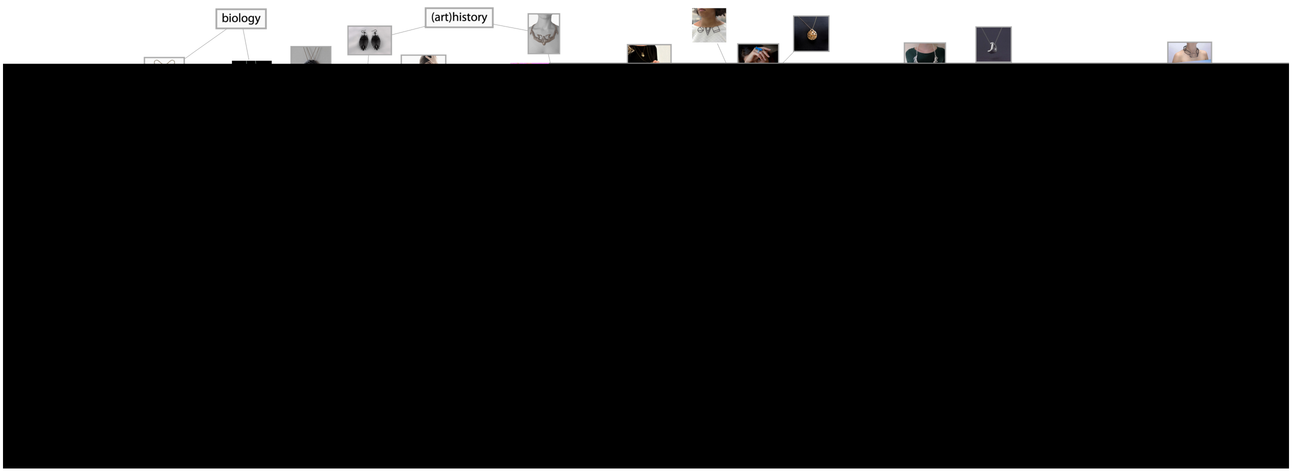

Figure 3: Our study collection categorised based on the educational background of the creators.

Traditionally goldsmiths work individually. Figure 4 shows that the creators without a background in jewellery education, introduce working in duo's and studios to the field of jewellery.

Figure 4: *Our Study Collection* categorised based on the way creators work

3.2 Used technologies and materials

When we categorise *Our study Collection* based on the used printing technologies and materials we find that SLS-technology is dominant for the production of both metal and plastic pieces. Figure 5 is only about the printing, it doesn't show if and what finishing the designs got after printing. In the paragraphs 4.1.3, 4.2 and 4.3.1 we'll pay attention to the impact of post-printing treatment.

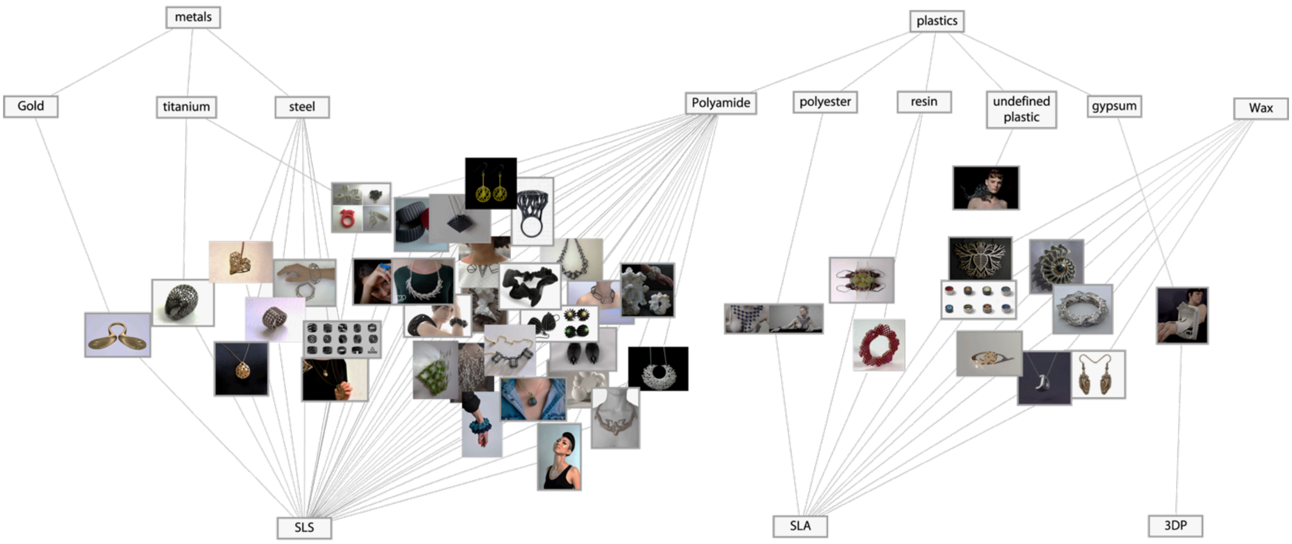

Figure 5: *Our Study Collection* categorised based on used technologies and materials

4. Reflection

In this paragraph we formulate tendencies, opportunities and threats that we see for jewellery in relation to additive manufacturing. We base this analysis on existing views on jewellery (Besten, den, 2012 and Unger, 2010), the characteristics of additive manufacturing (paragraph 2.2) and factual observations on *Our study collection* (paragraph 3). When possible we sketch future perspectives. We use examples from in- and outside *Our study collection* to illustrate our insights. Each jewel holds a large number of attributes and meanings. When we argue that a jewel has limited added value concerning a specific attribute, this should not be seen as a disqualification of the piece as a whole. In other words: we do not aim to judge the individual pieces.

4.1 Aesthetics

In relation to aesthetics we distinguish between structure, shape and non-visual aspects.

4.1.1 Structure

When looking at *Our study collection* we see that almost half of it has an open structure. This form language isn't specific for printed jewellery, yet can be found in many 3D printed products (figure 6) and originates from the production process. The more open a structure, the less material and machine-time is needed, which results in a cheaper object.

In relation to these futuristic shapes Knott (2013) writes "They are made to look like the technology from which they are made, and they rely on the fact that 3D printing is big news." This implies that when 3D printing becomes mainstream, this form language will loose its attractiveness. On the other hand, production-costs will always be important (especially in lower segments of the market). One could explain the use of AM to create these structures by the fact they are very hard – if not impossible – to make with other production methods. In that case we argue for more refinement: e.g. truly using the third dimensions or drawing inspiration from the refinement of filigrain.

Figure 6: Open structure (left to right): Pentagon Pendant (Onur Mustak Cobanli), Camion Collection (Goncalo Campos), Stereodiamond Necklace (Géral Dejean), shoes from strvct-collection (Continuum), Crania Anatomica Filigre (Joshua Harker)

A second structure related aspect is the possiblity to print interlinked shapes and avoid assembly. Some of the designs from *Our study collection* make use of this (figure 7). There is room for further exploration of esspecially the dynamic qualities that can be reached through the use of interlinked shapes (also see paragraph 4.4.1 Relation to the human body).

Figure 7 Use of interlinked shapes. Left to Right: Gemetrica Collection (Summer Powell), Reeds Necklace (Marmalade Park), Jointed Jewels (Alissia Melka-Teichroew)

4.1.2 Shape

We often see complex repetitive and organic forms in printed products (figure 8). Warnier, et al. (2014, pp. 40-41) have attributed this to the human fascination with complex geometries that can be found in nature. For ages it has been difficult and time intensive to reproduce this type of shapes. Modelling software with copy-paste and scale functions and parametric abilities has changed this. Within this type of shapes we found a special category, the so called *fractals*. A fractal is a natural phenomenon of shapes built from repeating similar shapes at different scales which can be described mathematically (see for example the Mandelbulb bracelet in figure 8).

Nature inspired shapes have been a returning pattern in jewellery design for a long time. We don't expect the ease of 3D printing to change this appreciation.

Figure 8: left to right, organic shapes: Kinesis (Daniel Widrig), Voltage (Iris van Herpen), Kimberly Ovitz (Prosoma Necklace), Mandelbulb (Mandelwerk)

4.1.3 Non-visual aspects

The visual is only one part of the sensorial experience of jewellery: its weight, texture and adaptation to our body-temperature are important as well. AM-technology allows for the creation of shapes that previously were difficult to create from certain materials. For example: based on its shape we traditionally would expect the necklace of Kimberly Ovitz in figure 8 to be forged in metal. The fact that it is printed in plastic results in an unexpected volume-weight ratio. It could be interesting to explore the related perceived value, as traditionally weight is objectively (in case of precious metals) and subjectively positive related to value.

Traditionally jewellery has a high level of finishing that results in specific tactile qualities. Right from the machine printed pieces always show traces of the layered production process, that often not match the surface qualities that we are used to. On this point also see paragraph 4.3.1 *Hybrid production*.

4.2 The creators revisited

Sofar we have been writing about *the creators* of printed jewellery, as we perceived that to be the most neutral term. When taking a closer look at the printed pieces we see different emphasises, from which different creator-profiles can be deducted:

- The *Goldsmith* takes a craftsman-approach, which is reflected in the attention for material qualities, manual contribution and the level of finishing and detailing. We often see a hybrid production process applied, as we'll describe in paragraph 4.3.1.

Figure 9: example of *The Goldsmith*-profile, Covert Jewels (Cinnamon Lee)

- The *Maker* (a member of the Maker Community) explores additive manufacturing and exploits its advantages. His designs carry the traces of the production process as described in paragraph 4.1 (figure 10). Inspiration often comes from nature, which is quite literally portrait.

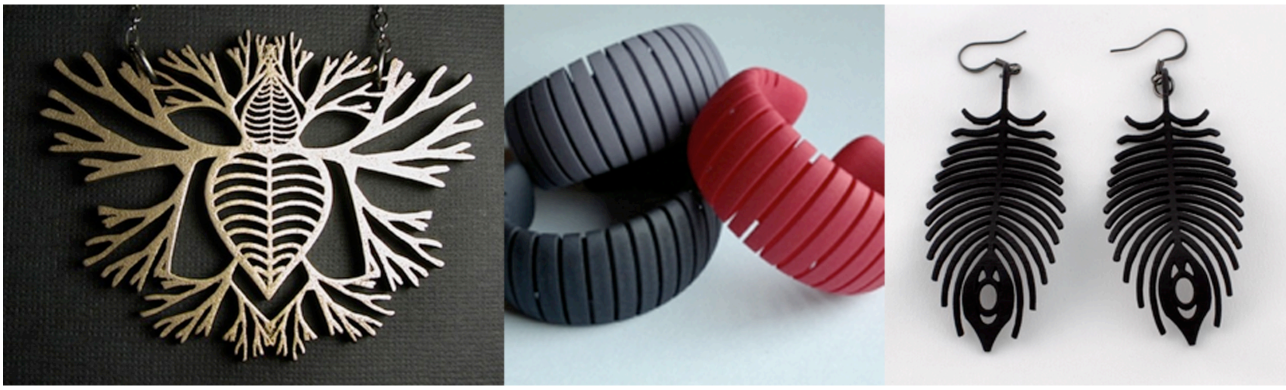

Figure 10: examples of *The Maker*-profile, from left to right: Branching Heart Necklace (Jamie Spinello), Snake Bracelet (Dario Scapitta), Peacock Feather Earrings (MODBot)

- The *Jewellery Designer* is driven by meaning and conceptual value. Some of the designs refer to the rich tradition of jewellery (figure 11).

Figure 11: examples of *The Designer*-profile with anonymous traditional predecessor, from left to right: JD-monogram (Patrick Durgin-Bruce), Memento collection (Francesca Smith)

Each of these profiles has their own value. In our opinion *the Goldsmith* and *Jewellery Designer* directly innovate the field of jewellery design, whereas the work of *Makers* often misses a certain 'jewelleryness' (Besten, den, 2014). This term might be best summarized as 'the complex and subtle construct of meaning, form, wearability and materiality' (inspired by Besten, den, 2012 pp. 17-32 and Unger, 2010 pp. 11-16).

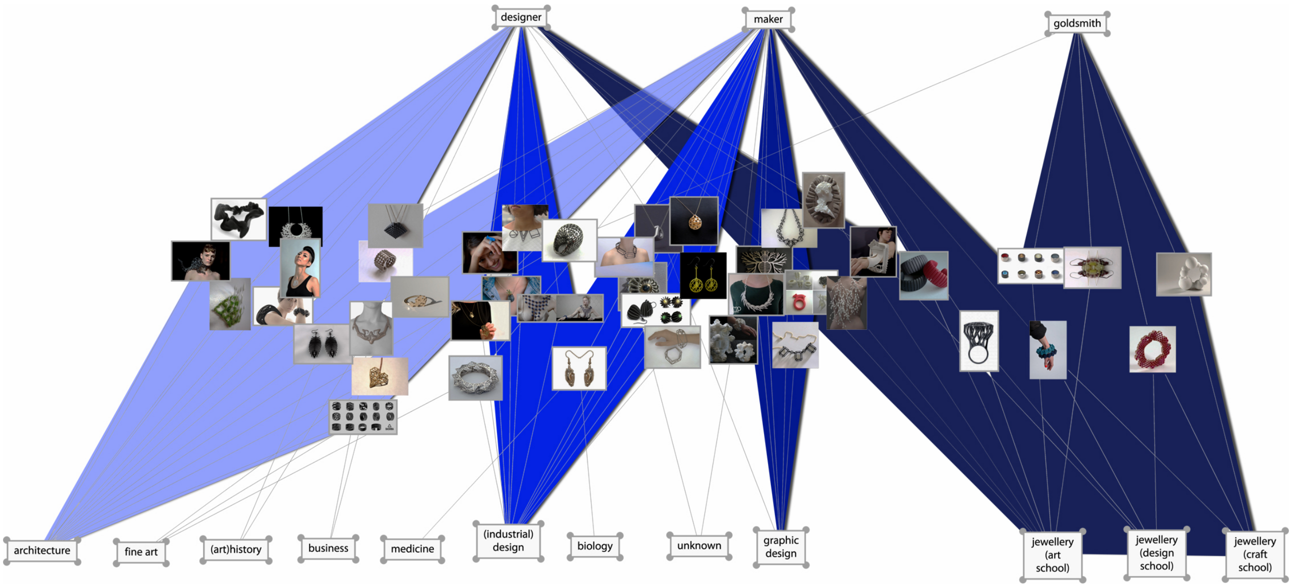

Figure 12: visual overview of the relation between dominant education backgrounds and creator-profiles within *Our Study Collection*

Within *Our Study Collection* we identified 18 *Designers*, 22 *Makers* and 5 *Goldsmiths* (figure 12). It is interesting to see that we could only find direct relations between the *Goldsmith*-profile and jewellery education and between the *Maker*-profile and an educational background in Graphic Design. As described in paragraph 3.1, cooperation starts to emerge; it would be interesting to explore were combining the skills of *the goldsmith, the maker* and *the jewellery designer* could lead to.

4.3 Creating

4.3.1 Hybrid production

We see great potential in hybrid solutions, where digital production technology doesn't take over existing practice, but merges in and therewith renews it. An often seen example is printing a wax model that is then cast in precious metal (see figure 9). Figure 13 shows some more examples: printed parts that are assembled using crafty techniques (Brech), printed moulds to create brooches in a wide variety of shapes and materials inspired by mass produced buttons (Noon Passama) and printed pieces that gain character from the dying process (Dorry Hsu).

Figure 13: From left to right: Multiname ring (Brech), Extra Button (Noon Passama), The Aesthetic of Fears (Dorry Hsu)

Does hybrid production imply that additive manufacturing is 'just' a new tool, as is often suggested in an attempt to deepen the discussion around the value of 3D printing (for example Knott (2013))? To answer this question we need to understand the relation between tool and craftsman. Sennett (2008, pp. 194) describes how craftsmen grow an intimate relation with their tools. Over time they learn how to use a tool and adapt it to their needs. Especially the first FDM-printers for private-use allow for similar behaviour. Within the maker community numerous examples of 'the machine' can be found[2]. The fact that industrial parties printed all jewels of *Our study collection*, is blocking the growth of such a craftsman-tool-relation between the creators and the 3D printer.

Outside *Our study collection* the work of Peggy Bannenberg is the best example we could find of using the 3D printer as a tool. She experimented with changing material while printing to achieve colour ramps. Moreover she added gemstones during the process (figure 14). It seems that there is room for exploration on this point.

Figure 14: Dia-bol-rings (Peggy Bannenberg)

4.4 The wearer

When discussing jewellery the relation – both physical and emotional – with the person who wears it can't be neglected.

4.4.1 Relation to the human body

Jewellery is – often for a long time – worn close to our body. Digital technology has the potential to deepen the intimate relation between jewel and body. For example by adding dynamic qualities. The opportunity of 3D printing to print interlinked shapes, makes it realitively easy to create complex joints that enable pieces of jewellery to follow the movements of the human boy. See for example the Jointed Jewels by Alissia Melka Teichroew (figure 7).

4.4.2 Unique versus personal

The opportunity of additive manufacturing to mass produce one-of-a-kind pieces (paragraph 2.2.1) needs to be further specified into unique, customised and personalised.

- *Uniqueness* has to do with the number of pieces made. It is interesting to see how Ted Noten consciously plays with this concept in the 'Miss Piggy'-rings (an exponent of his 2006 project 'Haunted by 36 women') (figure 15).

[2] For example: The Endless Chair by Dirk van der Kooij, who transformed an old production robot into a 3D printer

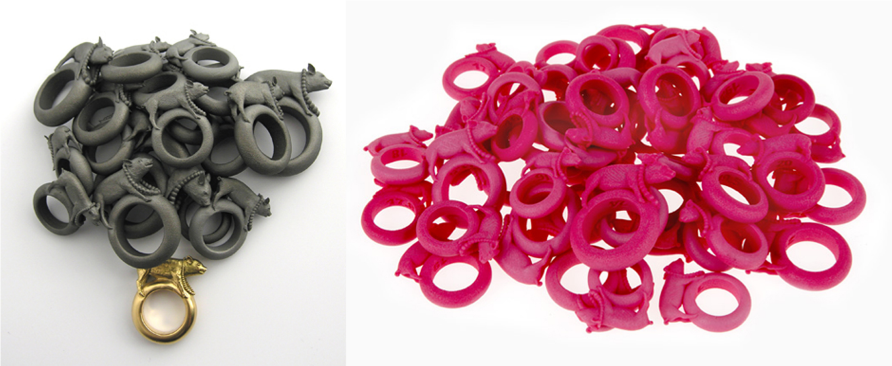

Figure 15: Miss Piggy (Ted Noten), 18K gold 2 prints, 25 titanium ones and an infinite number of plastic ones

- *Customization* is the process of adapting a given concept to the wishes of a customer by offering choices. The larger the number of choices offered, the more the outcome will be perceived as unique, while it in fact it is no more than a variation. The Kinematics-series by Jessica Rosenkrantz and Jesse Louis-Rosenberg for example can be customized by online manipulation of the model (figure 16). The perceived uniqueness comes from *the act* of manipulating and from *visual differentiation* achieved by manipulating the given variables. However, it is questionable whether the one outcome is essentially different from the other.

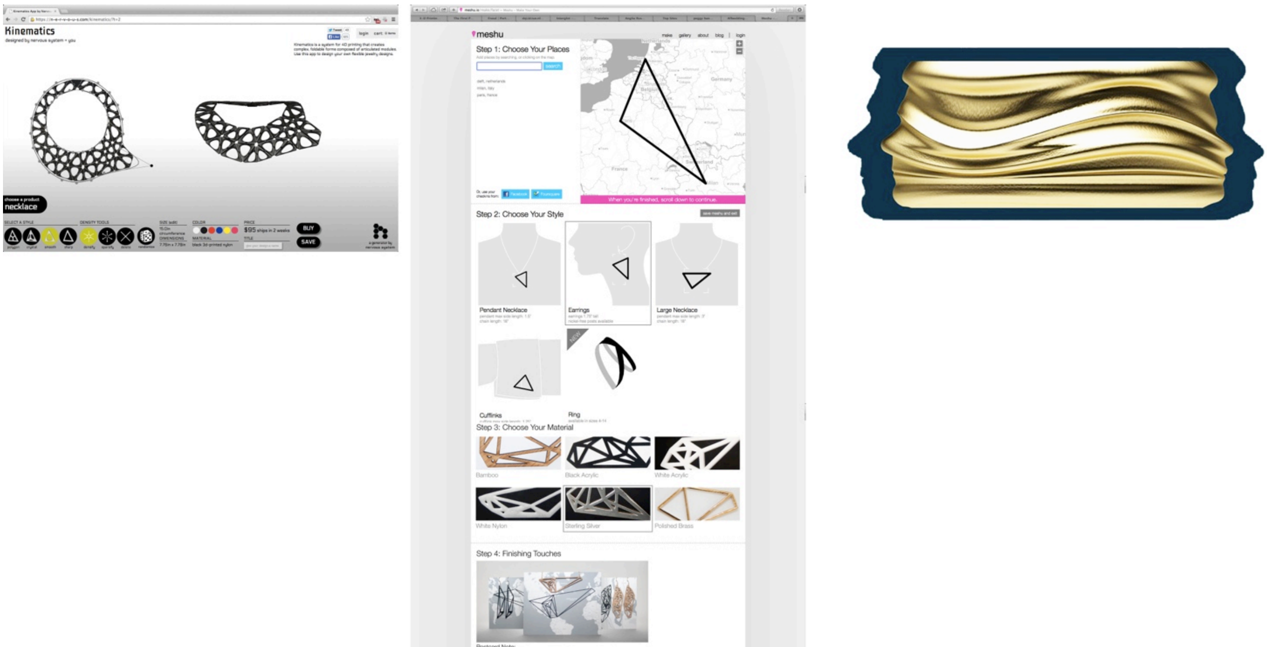

Figure 16: left to right: printscreen from https://n-e-r-v-o-u-s.com/kinematics/?t=2 [accessed 22-6-2014], printscreen from http://meshu.io/make/facet [accessed 22-6-2014], Face-to-face (Cardillac)

- *Personalisation* is customization based on user specific input. The (perceived) uniqueness then comes from the *act of manipulation*, the *visual differentiation* and *meaning of the input*. For example: Meshu by Sha Hwang and Rachel Binx creates an abstract shape based on the spatial organisation of geographical places that are significant to the customer (figure 16). The ultimate form of personalisation is taking biometric information as input. We already saw 'Portrait me' (figure 2). Another example is Face-to-Face by Cardillac, which is based on two human profiles that fluently merge into each other (figure 16).

From the examples above it is clear that customization and personalisation offer interesting opportunities to create unique and emotionally charged pieces. At the same time we need to be aware that the concept of personalisation in jewellery isn't innovative at all: goldsmiths working on commission have been doing it for ages. Whereas computer interfaces for (mass)customization like *Nike iD* minimize the distance between multinationals and their customers, they enlarge the distance between jewellery creators and their customers by taking out the human contact.

5. Conclusion

This paper aimed to get an understanding of the added value of additive manufacturing for the creation of jewellery. In order to achieve this goal we tried to see beyond the hype and identify tendencies, opportunities and threats. We found that:

- The opportunities of additive manufacturing are strongly connected to its digital nature and related technologies like 3D scanning and the Internet (paragraph 2.2.2).
- Additive manufacturing broadens the opportunities in terms of complex shapes, dynamic constructions and radical personalisation. At this moment in time the implementation seems often immature and strongly technology driven, instead of jewellery-driven (paragraph 4.1).
- Additive manufacturing broadens the community of creators. Multidisciplinary cooperation between craftsmen (*the goldsmith*), designers (*the jewellery designer*) and software engineers (*the maker*) seems promising. At the same time a lack of understanding of the complex and subtle construct of meaning, form and materiality that jewellery is, could weaken the field (paragraph 4.2).
- We see great potential in hybrid solutions, where digital production technology doesn't take over existing practice, but merges in and therewith renews it (paragraph 4.3.1).
- Jewellery creators tend to outsource the printing, this threatens the intimate relation between creator, tool and material (paragraph 4.3.1).

References

BENJAMIN, W., 1939. *Het kunstwerk in het tijdperk van zijn technische reproduceerbaarheid.* Translated from German by H. Hoeks, 2008. 3rd edition. Amsterdam: Uitgeverij Boom

BESTEN DEN, L., 2012. *On jewellery: a compendium of international contemporary art jewellery.* Stuttgart: Arnoldsche

BESTEN DEN, L., 1-4-2014. *The golden standard of Schmuckashau*. Retrieved from http://www.artjewelryforum.org/articles/the-golden-standard-of-schmuckashau [accessed 3-9-2014]

BONANNI, L., PARKES, A., 2010, Virtual Guilds: Collective Intelligence and the Future of Craft. *The Journal of Modern Craft,* 3(2), pp. 179-190

CAPPELLIERI, A., DEL CURTO, B. and TENUTA, L., 2014. *Around the future: new materials and new technologies for jewellery.* 1st edition. Venice: Marsilio Editori

KNOTT, S., 2013. *3-D Printing: Hot air? Are consumers in a more powerful position because manufacture has been added to their toolbox?* [online] available at http://www.artjewelryforum.org/articles/3-d-printing-hot-air [accessed 22-6-2014]

LIPSON, H. and KURMAN, M., n.d. *Frabricated: the new world of 3D printing. The promise and peril of a machine that can make (almost) anything.* Wiley

MENDELS, P., 2013. *From Collection to Reflection: On designing Freed, a tool for free and flexible organization of designers' digital work.* Ph. D. University of Technology Eindhoven. Available at http://dqi.id.tue.nl/freed/From_Collection_to_Reflection__Philip_Mendels.pdf [accessed 20-6-2014]

NIEUWKERK VAN, M., 2011. *De wereld draait door* [tv program] 25-2-2011. Available at http://dewerelddraaitdoor.vara.nl/media/69543 [accessed 22-6-2014]

OBAMA, B., 2013. *State of the Union.* Available at http://www.whitehouse.gov/the-press-office/2013/02/12/remarks-president-state-union-address [accessed 21-6-2014]

RIFKIN, J., 2011. *The third industrial revolution: how lateral power is transforming energy, the economy and the world.* [e-book] New York: Palgrave Macmillan

SENNETT, R., 2008. *The Craftsman.* London: Penguin Books

UNGER-DE BOER, M., 2010. *Sieraad in context: een multidisciplinair kader voor de beschouwing van het sieraad.* Ph. D. Leiden University. Available at https://openaccess.leidenuniv.nl/bitstream/handle/1887/15121/Sieraad%20in%20context.pdf?sequence=4

VERSTEEG, M.F., BESTEN, E.L. DEN, 1-9-2014, *Study-collection 3D printed jewellery*. Available at: http://www.brech.nl/wp-content/uploads/2014/09/Study-Collection-3D-Printed-Jewellery.pdf

VERSTEEG, M.F., VOUTE, J., ANEMA, H., 2011. *Personalised printed value: R&D-plan voor de ontwikkeling van het TNO SBIR concept.* [internal business study commissioned by TNO (Dutch Organisation for Applied Technological Research)]

WARNIER, C., VERBRUGGEN, D., EHMANN, S. and KLANTEN, B. eds., 2014, *Printing things: Visions and Essentials for 3D Printing.* Berlin: Gestalten