

ON THE MAKING OF THINGS: TAKING A RISK WITH 3D PRINTING

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ABSTRACT

In this paper we explore how the tradition of craft can be re-visited to assist a move beyond 3D-printed objects. While CAD, 3D modeling and 3D printing do offer precise tools for the repetitive manufacturing of small objects we argue that the closeness to “the materials at hand” is lost at the current moment. Via a practical design case we illustrate how we have experimented with ways of re-introducing craftsmanship both as an opportunity and as a necessity for moving forward. We combine this explorative/maker approach with an analytical approach, and analyze the process using the viewpoint of David Pye’s (1968) notions of “workmanship of risk” and “workmanship of certainty”.

INTRODUCTION

Historically the practice of making has been equated with the practice of craftsmanship. For centuries makers, designers, artists and craftsmen have worked with their hands using analogue materials, for example: wood, copper, silver and paint, in a form-giving tradition. This tradition is known as the tradition of craft. Throughout this history the reflective practitioner – the craftsman – has used materials at hand to manifest ideas in physical form. They have approached materials dialectically, forming ‘conversations with the materials at hand’ (Schön, 1984). This close connection between the maker and materials at hand has enabled explorations of both form and material properties.

Digital manufacturing seems to have broken, or at least challenged, this close relationship between the maker, the materials at hand, and the object being designed. The development of CAD –Computer Aided Design

enables virtual 3D modeling of physical objects without the restraints of the physical world (including gravity, strength, etc.). The industrial revolution had previously enabled automatic manufacturing of physical objects without careful handcrafting. Digitalization further enabled mass-production, and broke the relation between the maker and the object.

Currently, we see increasing interest in physical computational objects, for example: in the Internet of Things, and in 3D printing as a technique for moving from virtual, 3-D models to physical objects. Yet we also see a return to carefully crafted objects – from models, symbols, representations and abstractions to an increased focus on physical materials and objects. The manufacturing industry now even suggests that 3D-printers might revolutionize manufacturing, as anyone can now become a maker *and* a manufacturer. While this may or may not be true, 3D-printers do offer technical opportunities for novices to print physical objects. As a result, the broken link between maker and material outcome – the 3D-printed object – remains.

In short, information technology enables the manipulation of a representation of the object, but it eliminates the need for hands-on crafting. Technology has become a mediator that introduces a distance between the maker and the material object.

In this paper we discuss the process of casting a pewter reindeer to illustrate how it might be possible to bridge this distance between the maker and the object. This case study is situated in the contemporary realm where craftsmanship, objects and digital technology are brought together. In doing so, this paper illustrates: 1) how a craft-based perspective might afford fruitful advances in current development approaches to 3D-printed objects, and 2) how craft may reintroduce itself as a necessity for pushing this envelope, and thus bridge the distance between the maker and their object “at hand”.

DIGITAL MATERIALS & CRAFT

A key difference between digital and analogue (physical) materials is that digital materials (i.e. “bits”) are manipulated via a virtual representation, whereas analogue materials (like “wood”) are directly experienced through the body and all of the senses when

manipulated. In the digital realm, manipulation is supported via an interface, a button, or a command. Various digital tools and input/output modalities have been invented to enable digital manipulation. Significantly, these tools and modalities also come with a mediating structure between the user/maker and the object being designed.

For instance, instead of using one's bare hands to form a 3D object on a computer the designer must typically use a mouse, mouse pointer or tablet, as well as additional menus, icons, and tools, as mediating structures between the hand and the 3D object being formed. Even when discussing "direct manipulation" the mediating arrangement of icons, metaphors, representations and input/output modalities that the user/maker is directed to when it comes to digital form-making practices remain.

When considered in terms of craftsmanship, the fundamental idea introduced by Donald Schön (1984) that design is "a conversation with the material at hand" is fundamentally challenged when digital technologies stand in the way of direct conversation with materials. In this paper we challenge this separation between the hand and the object being designed by combining digital and physical tools and materials in the process of making. We re-introduce craft as an approach to interlink the practices of digital and analogue form-giving. There are however challenges to this approach as the next section will illustrate, taking as its point of departure David Pye's (1968) distinction between the notions of "workmanship of risk" and "workmanship of certainty".

WORKMANSHIP OF RISK AND CERTAINTY

We currently experience increased availability of 3D printers, CAD and other digital design and manufacturing tools (see for instance Lipson and Kurman, 2013). At the consumer level, this situation may seem to speak in favor of non-craft making. Although we have described above how digital and physical materials are of quite different character, they share the common denominator of being subject to craft. The traditional notion of craft implies a skillful application of manual dexterity to impose a certain form to material. Although this definition may prompt thoughts of pottery, cabinet making or other traditional crafts, we suggest that crafting with digital materials are kindred, not only in spirit but also in the set of skills and aesthetic sensibilities required to work with a computer to create something of functional and/or aesthetic value.

This view resonates with Risatti's (2007) notion of craftsmanship as being concerned with "skilled activities" in bringing craft objects into being. Similarly, Sennett (2008), suggests that craftsmanship is "an enduring, basic human impulse, the desire to do a job well for its own sake". Interestingly, Risatti and Sennett are not concerned with notions of tools, techniques or materials in their understanding of craft and craftsmanship.

While we contend that working with digital and physical materials are quite different activities we have found that Pye's (1968) notions of *workmanship of risk* and *workmanship of certainty* are apt at capturing some of these differences, while also pointing at similarities of digital and physical materiality in the context of craft.

According to Pye what sets craft apart from other modes of manufacturing, is the idea that the acts of design and making (in craft) cannot be fully isolated from each other. Although a potter's plan for what they are about to make may be carefully articulated in detail, what happens at the potter's wheel will inevitably involve a deviation from the plan. Indeed, it may be argued that this is what makes craft what it is: each produced item may originate from the same plan, but each item is at the mercy of what happens during the actual making. This is what Pye refers to as the workmanship of risk. As a crafter, one can never fully control the outcome of one's making. Put differently, *the process of making is also a process of design; a process of giving form*.

Further on, Pye's notion of *workmanship of certainty* is a mode of manufacturing where the "making" should introduce as few deviations from the blueprint as possible. Here, the ideal is that different objects made from the same specification should be identical. Design and manufacturing in this scenario are ideally isolated activities. Whereas elements of surprise are an inherent (and welcomed) part of workmanship of risk, elements of surprise are shunned in workmanship of certainty.

Is it plausible to say that crafting with digital materials is inherently a workmanship of certainty with perfect right angles, absolutely straight lines and mathematically correct surfaces? We suggest that it is not. However, digital materials allows for certain forgiveness, as an action can always be undone in a way that is undoable when working with physical materials. Perhaps more important, crafting in the digital domain allows for tooling techniques that speak in the direction of workmanship of certainty. For instance, in 2D and 3D drawing and modeling programs, the workspace can typically be configured to allow for snapping to grids and other objects. Objects can thereby be perfectly aligned and adjusted in relation to one and other.

The point is that it is largely a matter of decision on the part of the maker to what extent they make use of this potential for control and automation when making in the digital. In contrast, in the case of physical materials, this decision is not as easily made. The cost involves choosing a way of making that depends on relatively accessible tools or advanced manufacturing machinery. However, the recent accessibility of low-cost 3D printing technology and fab labs, partly changes this.

THE MAKING OF THE PEWTER REINDEER

In this section, we present the steps involved in the making of a keepsake in the form of a reindeer. We decided to make this reindeer as it is part of the logo for our university (see fig 2). The project was initiated in

response to an impending visit to our newly inaugurated Human Computer Interaction Laboratory by The Royal Swedish Academy of Engineering Sciences and the king of Sweden.

Our goal for this visit was to make a small object that we could give to the visitors as a gift that was both reminiscent of Umeå university and its northern geographical location, and the result of a mixed making approach that embodies traditional craft and materials, as well as digital materials.

The detailed making we describe here will be analyzed in terms of materiality and risk in the following section.



Figure 1: Pewter reindeers casted in a silicone mold.

STARTING POINT: A 2D LOGOTYPE

Once we settled on the idea of making a pewter reindeer, we started out with an existing logotype for Umeå University:

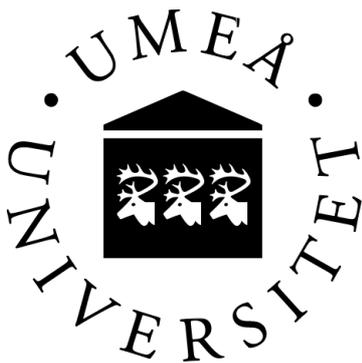


Figure 2: The logo for Umeå university.

Although we at first considered making a pewter casting of the whole logotype, we realized that given the time frame and available resources, it would be too big a project to carry out successfully. Instead, we opted to edit the logo in such a way that only one of the three reindeer heads remained.

At this stage, our ambition was to make as little changes as possible to the original reindeer design as possible. In

the end, we had to make slight simplifications to the shape with some reduced level of detail.

EXTRUSION FROM 2D TO 3D

The next step in the making process was to make a 3D model that, after being 3D printed, would serve as an intermediary mold to hold the silicone for the final mold.

The resulting 2D vector graphics from the previous step was exported from Adobe Illustrator and imported into Autodesk Maya. As shown in figure 3, a cylinder closed at one end was combined with an extruded version of the 2D reindeer shape.

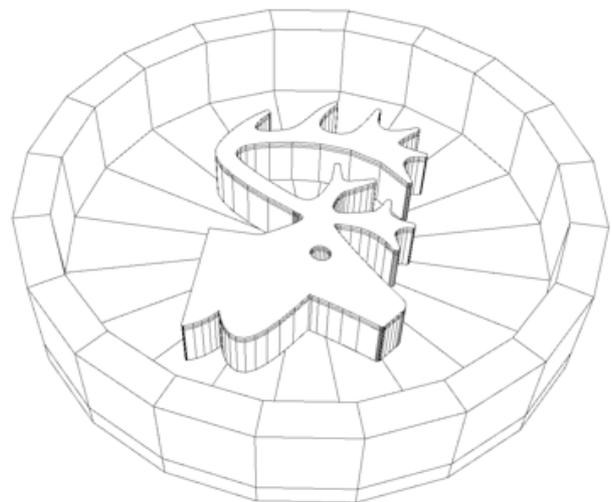


Figure 3: 3D model of intermediary mold.

As simple as it may seem, this step proved to be less than trivial. The 2D shape included details that caused problems to get a working 3D extrusion. To address the problem, the 2D shape had to be edited and simplified and imported into Maya again a number of times before we arrived at a 3D shape that was adequate for 3D printing, but still true to the original shape.

3D PRINTING OF THE MOLD

The 3D model of the intermediary mold was printed on a MakerBot Replicator 2, a consumer-level 3D printer. The material used for the print was a blue PLA plastic (see figure 4). The printing as such did not pose any particular problems. By using a configuration set to medium quality, we struck a reasonable balance between print quality and time for printing.

MAKING OF THE FINAL MOLD

Once the intermediary mold was printed, a two-component silicone design to withstand heat was mixed and poured into the intermediary mold. A release agent (Vaseline) was applied as a thin coating on the inside of the mold to ease the release of the cured silicone from the mold.



Figure 4: 3D printed intermediary mold (left) and final silicone mold (right).

After approximately 24 hours, the silicone had fully cured and could easily be separated from the intermediary mold. The resulting mold appeared to be a perfect (negative) casting of the 3D printed object, although it was apparent that the silicone mold has some air pockets that we, at the time, did not know if they would cause any problems.

PEWTER CASTING

In order to make the pewter casting, we used a simple steel crucible with small pewter ingots and heated it with an electric heat plate. Once liquefied, the molten pewter was poured into the silicone mold and was set to rest until it was possible to handle.



Figure 5: Final mold poured with pewter.

As apparent in figure 5, the pouring posed some difficulties. In order to make the pewter fill all finer details of the mold, the pouring had to be done quite fast with the risk of overfilling the mold. If too little pewter was poured, some of the finer details of the mold was left unfilled. Thus, a fair degree of trial-and-error and re-melting of pewter characterized the pouring. In the end, fifteen reindeers were made.

REINDEER FINISHING

Given the fact that the silicone casting of the 3D printed object was next to perfect, it not only captured the general shape of the reindeer, but also the typical signature of 3D printed objects in the form of strands

and layers. To the left in figure 6, it is apparent how the 3D printed look also was transferred to the pewter casting. We decided to keep some of the reindeers as they came out of the mold, whereas others were subject to a quite heavy sanding and polishing that largely removed the 3D printed aesthetics (see figure 6).



Figure 6: Reindeers with different finishing.

MAKING AS CONFIGURATION OF RISK AND MATERIALITY

The description of the practical steps in the project above is intentionally kept as straightforward as possible and free from any specific conceptualization.

In this section, we take a step away from the practicalities and interpret what we have done using the previously discussed notions of risk and materiality. The goal is to demonstrate how a maker process can be conceptualized, but also designed, as a chain of steps where each step can be said to be of a certain configuration of workmanship and materiality.

2D AND 3D MODELLING

The initial step where we started with a ready-made 2D logotype, our intention was to stay as true as possible to the original reindeer shape. As it turned out the 2D shape could not be used exactly as it were. We had to make some changes to the shape in order to be able to extrude it into a 3D model. However, our work at this stage was driven by the goal to change as little as possible. Put differently, at this stage we did not want to introduce any form aspects due to chance, tooling or elements of surprise.

In terms of Pye's distinction of workmanship of risk and workmanship of certainty, our work at this stage can best be described as following the ideal of workmanship of certainty. Hence we made use of what help there were in the used programs for snapping, curve simplification, etc., in order to not deviate from the original 2D design more than necessary.

In terms of materiality, this stage was certainly concerned with a digital material in the form of vector shapes and 3D volumes.

Graphically and conceptually, the 2D editing as well as the 3D modeling based on the 2D shapes be described through the model in fig 7. Used in this way, the model

can be used to articulate some characteristics of a distinct step or stage in an overall making process.

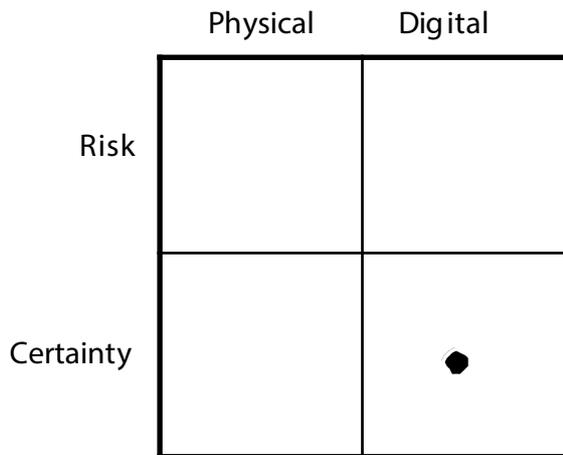


Figure 7: Modeling of digital material as workmanship of certainty.

3D PRINTING

The step where the 3D model of the intermediary mold was printed into a physical, functional object, is by and large a step best described as being concerned with a physical material.

Perhaps not as obvious, is the question to what extent this is a matter of workmanship of risk or workmanship of certainty? On the face of it, it may seem apparent that what one might wish for, is a perfect physical replica of the virtual object. However, the print is far from perfect. It called for redesign of the original 2d shapes to print adequately. Above all, it is far from a smooth and perfect as its virtual, digital counterpart. It comes out, not smooth to the touch, but rather textured and marked by the very mechanisms and principles of 3D printing.

This could be thought of as a failed workmanship of certainty; a degrading of quality in the transformation from digital to physical. However, we like to think of this as an example of workmanship of risk, where the typical signatures of 3D printing can be compared to the signatures of traditional hand tools. Much like the crafted wooden bowl carries its unique signature from chisels and other tools used to make it, the 3D printer imposes form that can be hailed, not shunned.

Articulated by means of the model, the 3D printing stage of the making of the reindeers is thus a stage with a physical material approached from the ideal of workmanship of risk:

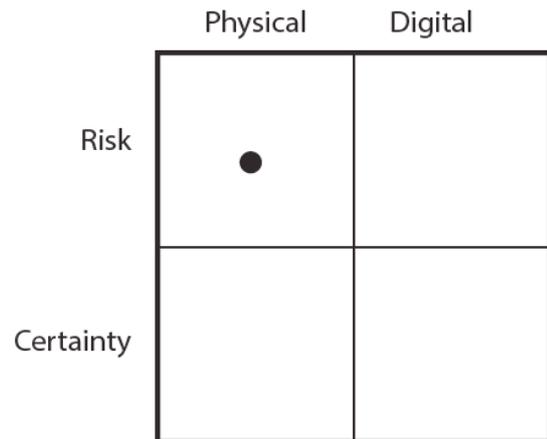


Figure 8: 3D printing of physical material as workmanship of risk.

SILICONE MOLDING

The part of the process where the silicone was poured into the 3D printed intermediary mold is also concerned with physical materiality. Unlike the 3D printing, we think of this step to be a matter of workmanship of certainty. The silicone mold came out very true to the original design. However, as mentioned before, there were some air pockets in the mold, but they did not affect the shape, but were rather located inside of the silicone and at its backside.

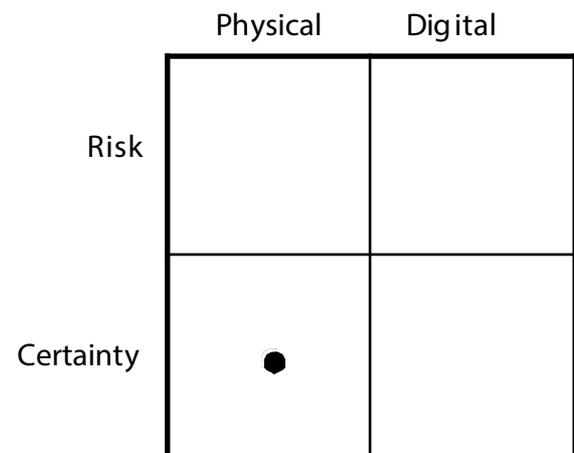


Figure 9: Making of silicone mold as workmanship of certainty.

PEWTER CASTING

The next step in the process is the actual casting of the pewter. Our initial outset was that the pewter reindeers should be quite true to the initial logotype design and this can be understood as having workmanship of certainty as our implicit ideal.

In practice, this turned out to be a step that was all but about certainty. First, the pouring proved to be quite challenging. As mentioned, both the speed of pouring and amount of molten pewter were variables that were difficult to control. Some reindeers came out thicker than others; some came out without pewter in the more detailed areas. Also, although the silicone used was designed to withstand high temperatures it deteriorated with time. The removal of the casted reindeers required

some bending of the mold, which seems to have altered it to some extent. Also, when we made the first few reindeers, the air pockets did not seem to have an influence, but if the mold was not allowed to cool down between casts, especially one air pocket expanded and made a noticeable imprint on the reindeer.

The issues with the pouring that we experienced could most likely be addressed by means of using a two-part mold, instead of the open mold design. A two-part mold would have a sprue (inlet for molten metal) that would act as a funnel for the molten pewter. The risk of over pouring would be eliminated, as the effect would only be a matter of snipping off the excess pewter in the sprue.

In the end, we had about fifteen reindeers that were *unique* in different ways. Although workmanship of certainty may have been our initial ideal for this stage, it is probably better described a being characterized by a workmanship of risk. In hindsight, this is a serendipitous turn, because the uniqueness of each reindeer was really something that we appreciated and made them, in our mind, more objects of craft, rather than objects of manufacturing.

Thus, this stage of the making process can be depicted in the same way as for the 3D printing stage:

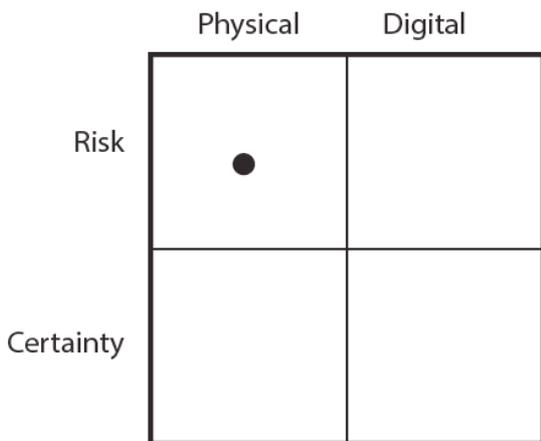


Figure 10: Pewter casting as workmanship of certainty.

FINISHING

The pewter reindeers came out of the mold looking dull from oxidation and sometimes with pewter strands bridging details of the reindeer that were not supposed to be connected. We used a tin snip and sanding in different ways to address these issues.

In order to explore different final looks, some reindeers were heavily sanded to rid the design from the typical imprints of the 3D printing stage, whereas most of them were only polished with a piece of cloth and polishing paste. This treatment did not have the same affects on all pieces, probably due to the fact that they came out of the mold with different surface qualities.

To sand the reindeers as heavily as we did for some of them, produced what we take to be a rather stylish look,

but it lacked the idiosyncrasies of 3D printing. The heavy sanding may indeed be thought of as a way to mitigate or compensate for the form giving aspects of the “risky” 3D printing.

In terms of our model, this stage is also a matter of workmanship of risk (even if not to the same extent) with a physical material.

DISCUSSION

The previous section described a practical making process in terms of steps that could be described as a configuration of materiality and risk. In the example, the making process constitutes a chain, where each link is characterized as a matter of being concerned with physical or digital material and to what extent it is subject to the influence of chance, serendipity or other aspects of deviations from a plan or blueprint.

We propose that these chainlike structures may serve the purpose to not only describe making processes after the fact, but also as a means of designing making processes. In doing so, we hope to be able to give a conceptual foundation for making as craft even if the making involves digital materials and manufacturing machinery such as 3D printers, that, at face value, suggests a non-craft approach to making.

Although, the notion of craft traditionally may imply physical hand tools, skillfully applied to a raw (physical) material, we propose that what makes a making process a process of craft is the extent to which it involves Pye’s (1968) workmanship of risk. By articulating already carried out making processes and making yet to come, as chains of different materiality and risk, we get a vocabulary that helps in being explicit about the process and highlight the characteristics of the different steps.

CONCLUSION

In this paper we have explored how the tradition of craft can be re-visited as to move beyond 3D-printed objects. With a point of departure in how technologies including CAD, 3D modeling and 3D printing demonstrate how such technologies offer precise tools for the repetitive manufacturing of small objects we have in this paper argued that the closeness to “the materials at hand” is lost at the current moment. Via a practical design case we have illustrated how we have experimented with ways of the re-introducing craftsmanship both as an opportunity and as a necessity for moving forward – beyond repetitive form-making as enabled by modern technology. In this paper we have done so by combining an explorative/maker approach with an analytical approach. With this as our methodological ground we have been able to also theorize and analyze our maker/design approach from the viewpoint of David Pye’s (1968) distinction between the notions of “workmanship of risk” and “workmanship of certainty”. By introducing this analytical framework we have demonstrated not only how craft is re-introduced in this

context, but also how each stage of the design process can be described, characterized, and ultimately understood. We take these to be key issues for moving design practice in general forward.

As a final remark, in a time where digital materials and 3D printers are commonplace, there is indeed a heyday for craft rather than the end of it.

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