INTRODUCING ADDITIVE MANUFACTURING AND AUGMENTED REALITY IN THE CONCEPTUAL PHASE OF THE DESIGN PROCESS

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ABSTRACT

The conceptual phase is often neglected and rushed by the other departments involved in the design and production process. But the conceptual phase is of great importance for the success of the product on the market. Here, the designer incorporates all the information that he/she has about the new design, generating ideas in order for the output to be a functional and aesthetic product. It is important to make the most of it in order to assure quality result. In order to ensure short conceptual phase that will not reflect on the products' quality we propose introduction of two "new" technologies in the conceptual phase. These "new" technologies that we are proposing to be included in the conceptual phase are Additive Manufacturing (AM) and Augmented Reality (AR). AM is used for creating more realistic prototypes and proof of concepts in a short period of time. While the AR is used for more detail explanation of the products' functionality and usability.

If we apply this approach in the conceptual phase to focus groups meetings, we can be certain that the message that needs to be sent as a designer's intent is received and rightfully understood. In that manner the responses will be on the point and can be used in total, in the redesign phase or the further phases of the design process.

By incorporating new technologies in the conceptual phase, the overall time can be shortened and at the same time, the outcome can be better.

Keywords: conceptual design; additive manufacturing; augmented reality; design process

1. INTRODUCTION

In the early stages of the design process, designers use sketches to communicate their ideas. Drawings and sketches have been widely used by designers as a way to capture and develop their thoughts and ideas about a design problem (Cross, 2008). During the early stages of the design process, when the design problem is still fuzzy and abstract, designers need tools that allow them to analyse, grasp, embody and give expression to thoughts that represent partial and unfinished pieces of the object they are designing (Alcaide-Marzal et al., 2013). Sketches have traditionally been one of these tools especially during the brainstorming phase, when ideas are bursting.

In the next stages of the process the ideas can be reduced and sketches refined, leading to conceptual design and creation of a Computer-Aided Design (CAD) model. CAD software cannot compete with the freedom designers have when sketching. Nevertheless, CAD tools need to be considered in the design workflow when it comes to creativity and freshness (Robertson & Radcliffe, 2009). But sketches and drawings are not enough when an idea needs to be communicated with other sectors, or even the customer. Computer tools efficiently answer a wide range of design problems, related to embodiment desing, detail design, simulation, and manufacturing (Cross, 2008; Prats et al., 2009). The implementation of CAD simplifies things (i.e. streamlines the process), enabling designers to create 3D models and render concept ideas fast. The word “design” in CAD refers more to engineering design, which means that this kind of software is intended specifically for this type of design. That makes CAD rigid and not offering designers the freedom to create what they need.

The introduction of Computer-Aided Industrial Design (CAID) enables designers (industrial designers, in particular) to easily create any shape that they mighet have envisioned. CAID software offers a more liberated approach to design.

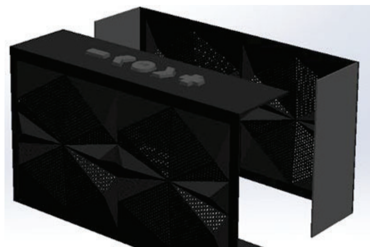
A prototype is an artifact that approximates a feature (or multiple features) of a product, service, or system (Otto & Wood, 2001). Several detailed taxonomies of prototypes have been proposed so far. A typical first taxonomic division is between prototypes that address form and those that address function (Otto & Wood, 2001; Pei et al., 2011). Another common distinction is the fluctuating level of fidelity of prototypes concerning the final model. A distinction is also typically drawn between virtual (simulations, visualizations, or computational approximations of behavior) and physical models. This paper shall elaborate on an expanded index and framework that provides a clearer relationship between the various distinctions (Camburn et al., 2017).

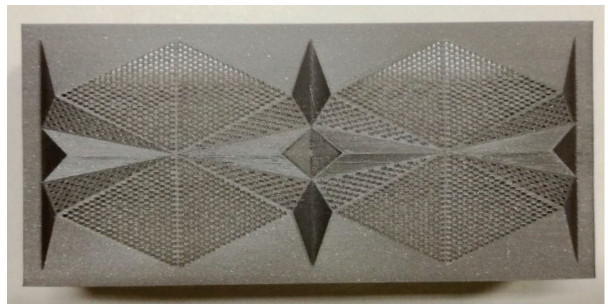
In different stages of the design and production processes, different prototypes are made to fulfill specific purposes. Camburn et al (2017) identify 10 different purposes of the prototypes: refinement, communication, exploration, active learning, timing, ideation, fixation, feedback, usability, and fidelity. Every one of these tasks is vital to the final output and the success of the product. Depending on the product, a different type of protytope is made. However, in most cases, not every one of these tasks needs to be fulfilled. But one thing has to be taken into consideration every signle time and that is timing. Both empirical and industrial studies highlight that early prototyping is critical to innovation (Jang & Schunn, 2012), specifically during the first 30% of a design project (Elsen et al., 2012), it is especially crucial to test the challenging systems (Otto & Wood, 2001). In fact, late prototyping is correlated with unsuccessful efforts (Jang & Schunn, 2012). The precise selection of when to engage prototyping should be considered strategically (Otto&Wood, 2001). This decision may depend on complexity. It is important to note that committing a larger amount of time to prototyping does not correlate to greater success (Yang 2005). Positioning efforts early on in the overall timeline is particularly critical.

As a result of the reviewed literature we are not trying to implement “new” technologies into the creative process. Our reaseach and practice locate the problem in comunication between the designers and other departments, as well as the users (customers). Research in design supports prototypes as essential to explore and enhance design usability (Barbieri et al., 2013). Prototypes enable observation of real-time interaction between users as well as between users and the design (Kurvinen, Koskinen & Battarbee 2008). Prototypes are also valuable for communicating concepts within the design team. This is why we propose the implementation of the so-called new technologies for communication purposes to better transfer information and properly gather feedback.

1.1. Additive manufacturing in conceptual design

Additive manufacturing (AM) is a group of processes used to build models by adding layers. This approach emerged in the late 1980s and early 1990s, noting constant increase in its development ever since. AM enables direct manufacturing from a design model. These technologies reduce the effort and cost to produce complex geometries. They enable mass customization and adaptive systems creation. Empirical research has extracted several best practices from such databases for leveraging AM in prototyping, including the following heuristic guidelines: reuse features to reduce effort, employ cellular structures to increase strength and reduce mass, embed functional features in mesostructure, and employ part segmentation to increase the effective print size (Camburn et al., 2017). Figure 1 below shows an example of an appearance prototype made for a survey conducted at the Faculty of Mechanical Engineering in Skopje (Djokikj, 2020). The two models have uncanny resemblance (Figure 1-a) and the fabrication time is just two hours, no need for any tooling or any additional preparation.





a) b)

Figure. 1: Example of use of AM in the conceptual design (Djokikj, 2020)
a) CAD model; b) Prototype fabricated with AM

The involvement of additive manufacturing in the early stages of the design process is proposed by many authors. Evans (Evans, 2002) proposes CAID/RP methodology to streamline the New Product Development (NPD) process. The use of CAID and RP in the early stages of the design process shortens the time needed to develop an idea to a finished part. When it comes to the commercial need to reduce NPD timescales and to acknowledge the extensive lead times required for the production of appearance models, potential problems need to be identified.

The use of AM in the conceptual design phase is exceptionally beneficial if these technologies are used for the manufacturing of the final part. Since the model can be designed appropriately for manufacturing at the first attempt using the design rules for AM.

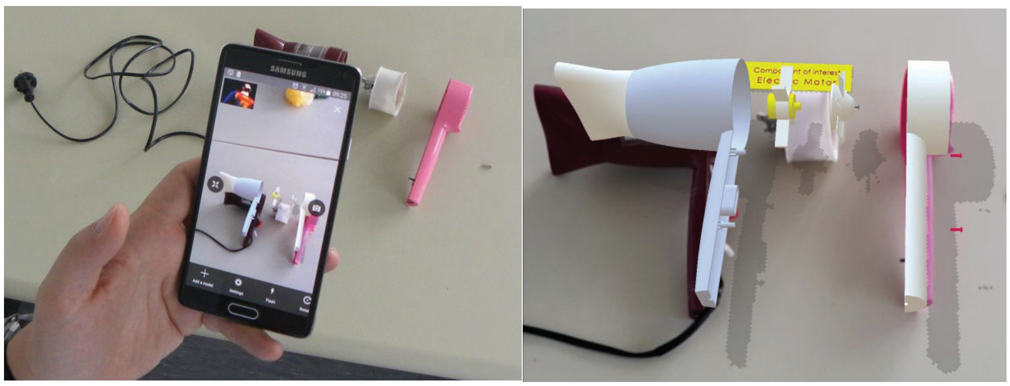
Nevertheless, the use of AM in the conceptual design phase is also beneficial for the design process itself as well as the whole production process, even when the final part is being manufactured elsewhere. As stated above, the first reason for this is streamlining both the design and production processes by having functional prototypes in the early stages of the design process. The second reason is the possibility to thoroughly examine the prototype to eliminate errors in the final part. The third and maybe the most important reason for the success of the product is to communicate the idea with the customer.

1.2. Augmented reality in conceptual design

Augmented reality facilitates capturing the voice of the customer and the user experience in a uniquely quantitative fashion (Carulli et al., 2013). An augmented reality prototype might, for example, integrate eye-tracking for detailed use assessment (Bordegoni et al. 2009). It is also both cost and time effective (Ferrise et al., 2012). Augmented reality facilitates the potential to engage more senses in the user-interaction environment at an earlier stage (sight, sound, touch, and so on.) (Barbieri et al., 2013). A unique benefit is the ability to independently manipulate each sensory feedback (Ferrise et al., 2012). A controlled study found an augmented reality prototype to provide equivalent usability data from participants as a physical prototype (Bruno et al. 2010). These technologies may also enable live modification of a virtual (Ng et al., 2015) or physical model (Anderl et al., 2007).

In our previous reserch (Rizov et al., 2019) we have come across similar findings as those in the literature we reviewed. In particular, we found that implementing AR in the process engages the user, making them more involved into and interested for the product, which is a board game in this particular case. A different study demontrates (Mircheski and Rizov, 2017) the implementation of AR in a nondestructive disassembly process. The use of AR proved to be effective and easy to comperhend by users (Figure 2).

It has been noted that several authors suggest the implementation of AR in the design process. Mair et al. (2014) suggest an approach to assist the identification of suitable areas of application of AR within the product design process. This approach utilizes an established methodology for product design development that allows each stage in the design process to be identified and considered in a logical and structured manner. These authors imply that with the proposed approach, AR is suitable for use in any stage of the design process as opposed to other well-known techniques, like drawings, basic computer-aided design, virtual reality, or rapid prototyping techniques and suchlike, to produce physical models. Ng et al. (2015) has an interesting approach for the implementation of functional 3D models into an AR environment. This approach has been developed mainly for design reasoning and evaluation, to ensure that the design is both functionally and geometrically consistent. Designers create conceptual designs by first defining how the product can be used, in the form of a Product Use Model, followed by creating basic 3D models using their bare hands in an Augmented Reality CAD Environment (ARCADE). The functional behavior of a product can be simulated as a prototype in ARCADE to demonstrate the use of the product and detect potential usability issues.



a) b)

Figure. 2: Example of use of AR for nondistructive dissasembly (Mircheski and Rizov, 2017)
a) Presentation of the process; b) AR animation showing on-screen

2. THE MODEL

The models proposed in this paper support a standard design process with added value. As it can be seen on Figure 3, the beginning is a standard design process, and the prototyping stage includes AM and AR. AM is used for both the appearance and functional prototypes. In the early stages of the design, many different models are fabricated in order to find the most appropriate one. Different models are also created for both the appearance and the functional prototypes. With the functional prototypes, specific elements of product functionality are being tested. The functional prototype does not match the look of the final product even close. This is why functional prototypes are mainly used by a closed group of professionals within the field. The appearance models are evaluated by professionals within the field or the company, but the users (customers) are also included. These models are judged based on appeal and feel (i.e. ergonomics). Everyone can have a say and the feedback goes back to the designers doing the inital sketches or the 3D models.

The implementation of AR in the conceptual design process is mainly needed for the functional prototypes, but also for the interaction models. This does not mean that AR cannot be used for the appearance prototypes. Moreover, there are cases where the use of AR in appearance prototypes is necessery. For example, if the product is equipped with new or still unknown technology, creating an AR prototype is the logical solution. If funding for the prototyping phase is limited, the use of AR is also the smart solution.

Nevertheless, AR in the conceptual phase is mainly used for interaction models. These models are essentially intended for the users, so they can exploit full functionality of the product without the part being finished. Interaction of the users with the product is of high importance, since it can give feedback to the designer about the behavioral characteristic. This kind of feedback reveals users' hidden emotions which are directly linked to the satisfactory feel of the product. Usually, this kind of experiment can be made during the last stages of the design process and prior to production. But with the implementation of AR, users can interact with the product while it is still in development.

Additionaly, AR can be implemented to demonstrate product functionality. This is again intended for the users (customers), who can have the appearance model in their hands and trigger different functionalities which can be demonstrated on-screen (mobile phone, laptop, or PC monitor).

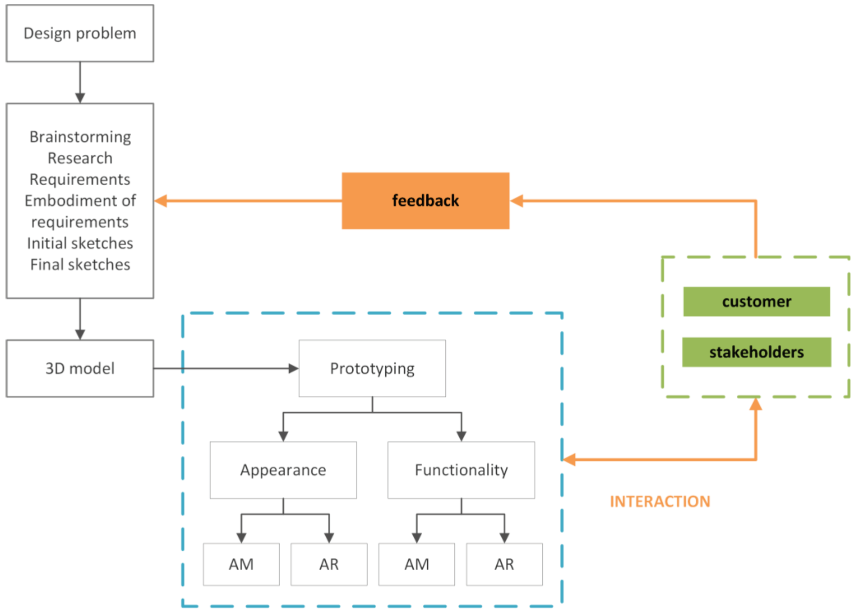


Figure. 3. The proposed model of implementation of AM and AR in the design process

4. RESULTS AND DISCUSSION

Implementation of AM and AR can speed up the design process and shorten the time to market. Having appearance and functional prototypes so early in the design process means that any design flaws can be identified and removed early in the process. Having all the potential glitches eliminated in the early stages of the process can prove to be quite effective, as any delay in the production process is equal to losing valuabale resurces such as time and money.

As explained in the last paragraph, the model that we are proposing with this paper leaves room for the design team to choose the appropriate prototype as well as the appropriate technology, depending on the product and the whole presentation plan. We are not suggesting that both technologies should be applied to any case. We simply want to demonstrate that the use of these technologies (i.e. AM and AR) is highly possible and also necessary in the conceptual phase of the design process. That is why in our flexible model, it is the design team and all the stakeholders who can decide on the appropriate strategy: what king of a prototype is needed and wether AM, AR, or both, will be used.

We believe that the use of both AM and AR is extremly beneficial because it enables communication between all those involved in the design proces: designers, customers, stakeholders, and other members in the process.

5. CONCLUSION

This paper analyses the opportunity of using two "new" technologies in the conceptual design phase. These "new" technologies to be included in the conceptual phase are Additive Manufacturing (AM) and Augmented Reality (AR). Research has shown that using AM for creating more realistic prototypes and proof of concepts also shortens the time needed to complete the process. At the same time, AR is used for a more detailed explanation of product functionality and usability. The model presented above evidently speeds up the design process, but more importantly, it provides valuble feedback to the designers from both peers and customers. Having all these tools in play in the early stages of the design process can prove to be very beneficial. It is up to the designers and the whole team to choose which one they will take into consideration.

For further research, this model has to be applied to current products, in order to evaluate the functionality of a particular design and production process of the model.

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