Appraisal of Augmented Reality Technologies for Supporting Industrial Design Practices

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Abstract. Having become widespread and easily accessible with the rapid advancements in technology, augmented reality (AR) offers potential uses for industrial designers, especially for design students. Some design stages, during which traditional tools and methods are used, may not fully communicate the total experience that a product offers. AR can provide a digital layer in which designers can present information and make their presentations more interactive. With this aim in mind, design practice fieldwork with three progressive studies was conducted. The results show that AR can be utilized mainly in presentation and prototyping stages of a design process, to show details such as audiovisual feedback and digital interfaces. With further developments, AR has potential use for several other design activities.

Keywords: Augmented reality · Industrial design education · Design process · Design activities

1 Introduction

To respond to a design brief, professional industrial designers and design students carry out various activities including briefings, field and user research, concept generation, prototyping, user testing, materials and manufacturing selection, and presentations. In representing their ideas, designers use tools and methods such as hand sketches, digital 2D sketches, 3D computer models and physical mock ups. However, the tools and methods traditionally used by industrial designers are not always enough to convey the full spectrum of user-interaction offered through a new product design.

Augmented Reality (AR)a visualization tool that combines digitally created data with the real environment, is a technology that has become relatively easy to access in recent years. Considering that industrial design is a field characteristically open to technological advancements, it can be argued that now is a good time to sample how AR could be utilized within a design workflow. A variety of AR technologies have been developed recently, ranging from room size projections to apps running on smart devices. The literature review carried out in support of this paper revealed that potential uses of AR for industrial design, especially with education, have not been explored adequately.

The aim of this paper is to present the possibilities of AR technology for supporting industrial design practices and to make propositions on how AR can bring

R. Shumaker and S. Lackey (Eds.): VAMR 2015, LNCS 9179, pp. 513–523, 2015.
DOI: 10.1007/978-3-319-21067-4_52

enhancements at different design stages. First, the product development process is explained through design activities and their deliverables. Secondly, the literature review covers commercial and academic uses of AR, alongside related technologies and uses of AR in current design practices. Lastly, fieldwork was carried out to understand whether AR technologies can be reasonably beneficial to industrial designers, and to reach a recommendation on use of AR systems for industrial design education. The scope of this paper is not to cover the whole range of the AR technology, but rather to explore at what stages of design and in which activities AR can be utilized with its current state; and to make predictions on future developments, so as to better fit technological solutions to designers.

2 Overview of Augmented Reality Technologies with Their Relevance to Industrial Design

2.1 The Product Development Process

In a typical design project developed in studio-based industrial design education, the goal is to develop a product from the ‘ground-up’. The final year Graduation Projects course handouts offered at the Department of Industrial Design of Middle East Technical University (with student projects winning RedDot, iF Concept awards, and rated by Domus Magazine as one of Europe’s top-rated design schools), Turkey in the years between 2012 and 2014 were examined with the premise that the graduation project calendars developed in collaboration with companies are a good representative of new product development process. In Table 1, the design activities and deliverables expected from students are matched with the medium of presentation.

Table 1. Deliverables expected from design students and the medium of presentation

Design activities and deliverables	Medium of presentation
• Project statement	
• Analysis of similar products	• Text
• User group research	• 2D images
• Problem definition map	• Diagrams, charts
• Initial idea workshops	• Sketches
• Prototypes	• 3D mock ups
• Presentation boards	• CAD renderings, drawings

A project statement that sets the criteria for a potential design contribution and defines the problem statement is presented to students in the first step. The user group, the context of use, and the essential requirements for the product are described, followed by user group research that illuminates the characteristics of a potential user. Project-specific research is carried out to gather information about similar products concerning function, usability, aesthetics, usage context, interactions, cost, and material. A problem definition map that underlines the keywords in the project statement that set criteria for design is developed. The first concepts begin to take shape in initial idea workshops, where students are expected to be adventurous and innovative while meeting the needs of the user. To present in the preliminary screening, students keep revising and developing their concepts to a point where they select two preferred and strong design proposals, for which they prepare mock ups and presentation boards. The presentation boards have visualization and details regarding the target group, mood-boards, storyboards that explain usage steps, CAD product renderings, exploded views of product parts, interface ideas, technical drawings, section views, and so on. These details are continually refined up until the final presentation. The presentation boards for the final screening are very specific. Apart from the previously mentioned details, details such as user-product interaction, interfaces, anthropometric assessment, selection of materials and manufacturing processes, mechanisms, and assembly are required to be visualized.

This process and the deliverables from educational design projects are arguably similar to the workflow of an industrial designer working in a professional setting. The physical tools and digital methods used by designers and design students vary in affectivity, and the possible positive outcomes from bringing AR into the design process should be investigated.

2.2 Augmented Reality Technologies

AR is a method to embed computer generated data into real environments with the goal of enhancing human perception [1]. In other words, it is a combination of virtual objects and physical objects that exist at the same time in the same environment [2]. As explained in the mixed reality continuum coined by Milgram et al. [3], AR falls between a spectrum of real environment, which is the physical world that humans live in, and virtual environment, a space that is comprised solely of digitally created elements. AR, therefore, is a combination of real and virtual; interactive in real-time; and, can be observed and/or experienced in three dimensions [4].

AR systems comprise a combination of hardware and software components. The hardware components can include a computer or a mobile device, a monitor or a projector, a camera, tracking components, a network system, and a marker. The software components can include an application or a program that runs locally, web services, and a content server.

AR has been in development since the 1960 s, however, recent developments have made the technology accessible and on demand in commercial and research fields. Examples of AR can be seen in sectors such as advertising, architecture and construction, museums and tourism, medical, mechanics and repair, social networking, entertainment, military, and navigation. As for research, institutions including MIT Media Lab, New Zealand HCI Lab, Georgia Technical University, automotive industry leaders such as BMW, GM, Land Rover, and hardware developers such as Google, Oculus Rift, and Microsoft have developed a number of noteworthy AR applications.

The AR apps that are relevant to industrial design activities are rather limited. The Botta Design mobile app, where users are allowed to ‘try on’ different types of watches is an example of visualizing user-product interaction. Another example is IKEA’s printed paper catalogue, enhanced with the 3D models of the products to show the assembly steps and to visualize the products in their intended usage environment.

Research on the usage of AR in industrial design activities focuses on visualization of products, simulation of usage and ergonomic analysis [5], virtual design environments, hybrid/augmented prototyping, assembly in industrial design [6] and collaboration across design disciplines [7, 8]. The bulk of the findings about using AR in industrial design activities have been focused on augmented prototyping, and virtual design environments.

In augmented prototyping, AR has been considered as a valuable tool for bridging the gap of low quality mock-ups that lack detail. Verlinden et al. has coined the term of augmented prototyping to describe the process of enhancing physical prototypes with virtual details [9]. Some experimental tools for achieving this goal are a system for prototyping interactive handheld products [10], a tool for projecting materials, textures and colors onto surfaces of 3D mock ups [11], a system that combines rapid prototyping with AR based manipulation of shapes, colors, textures and user interfaces [12].

Another utilization of AR into design processes is as a tangible tool for dimensional form-giving, which has been argued to result in more usable and interactive design processes [6]. Likewise, experimental tools such as a system for visualizing and interacting with virtual design objects for reviewing [13], a display concept that uses AR along with haptic feedback for surface creation [14], a concept of using digital tape for freeform virtual geometry design [15], a freeform modeling tool as a virtual 3D workbench [16], a virtual reality environment for creating concept shapes [17], systems for creation of 3D shapes for product design [18] have been developed.

3 Fieldwork for Evaluating AR for Industrial Design

3.1 Planning of the Fieldwork

The fieldwork consisted of three interconnected studies. Study 1, which aimed at creating awareness of AR among industrial designers and was conducted with seven industrial designers, started with a survey about the tools and methods that designers use. The second part of this study consisted of a presentation that showed examples from a wide range of AR applications to participants. The presentation stage was followed by an interview that asked participants to reflect on one or more of their past design projects, to come up with ideas about how AR could have supplemented their design process. Study 2, which aimed at exploring the potential of mobile AR applications in a design project, was conducted with eight graduate level design students in a course project. In the first part of the study, they were shown a presentation about AR and a demonstration of the application Metaio, for the iPad, which were selected because they have free versions and provide the most functionality among content creation AR applications. Then the participants were asked to make use of this application to add interactive content to their final presentation boards of the concept alarm clock design project that they carried out. Later on, they were asked to complete a survey evaluating this application about how they thought it enhanced their presentation, their likes and dislikes of the process. In Study 3, the researcher undertakes an exercise to show the potentials of where AR can contribute in design projects. She uses her already completed projects as examples to reflect on potential contribution of a wide range of AR applications from mobile apps to room-size projections, as well as making suggestions for the future.

3.2 Results and Analysis of the Fieldwork

Study 1. Study 1 started with a preliminary study to find out the following: the activities that industrial design students carry out; the deliverables expected at the end of each of these activities; and, evaluation of physical materials and digital tools used in design projects. The participants were asked to recall their undergraduate design projects to list the stages and/or activities in a design project. The design activities were, with some variations between each participant: project briefing, literature and field research (including a user group review), initial idea generation, sketching and model making/prototyping, user testing, technical drawings, renderings of 3D models and final presentation. During these activities, the participants were expected to present deliverables such as field research results, sketches, usage scenarios, moodboards, interview results, mock ups, CAD drawings and renderings, interface details, manufacturing schemes with material selection, and videos. As mentioned in Sect. 2, these deliverables are produced using a variety of physical and digital tools and methods. When asked to evaluate these physical materials and digital tools, the participants firstly commented that they were not able to represent *interactive* details of the products. These details, such as audiovisual feedback or digital interface content, are not displayed adequately in 2D presentation boards or physical mock ups. The second problem that participants reported to encounter was scaling problems of CAD applications. Because there is no way of realistically visualizing the interaction between the digital 3D model of the product, and the user and the environment, the participants had to create physical models as a parallel process, to determine product size and proportion.

In the second step of Study 1, the participants attended a presentation about AR technology that informed them about usage areas, to inspire them towards fulfilling the third (and last) step of the study: brainstorming about how AR could have been useful if it were to have been adopted during a past design project.

The main design activity that participants thought AR could enhance is *presentations*. The participants mentioned that in stages that they are expected to present details such as sound, light, digital interfaces, user-product and product-environment interaction etc., a 2D presentation board is not sufficient. Being able to use AR to present these details would make their presentations substantially more informative.

Another activity that could benefit from AR enhancement is *scenario building*. While drafting the steps of interaction between the user and the product, traditional methods for visualization are not enough to portray the full range of usage steps, especially for products with digital interfaces.

The participants also thought that AR could be useful for *prototyping* stages of design. Often, product mock-ups are a secondary requirement expected of design students, with time pressures experienced to prepare a realistic physical model that represents details such as textures, materials, colors, and so on. AR could be a convenient and effective way of enhancing a simple physical model, through layering of this additional visual information.

Other activities that AR was found to carry potential are *user tests and usage instructions* (by visualizing the product to testers and showing them how the product is meant to be operated), *conducting research* (by scanning existing products to gather information or creating a material library by taking pictures of textures to later project on physical models), *getting feedback* from instructors (by visualizing a wider range of detail in the development of a project), and possibly for *idea generation* exercises.

Study 2. Study 2 was carried out through the conduct of a design project entitled ‘Bedside Alarm Clock’ in METU Department of Industrial during the 2013–14 Fall semester on the postgraduate course ‘Design for Interaction’. The study aimed to create a hands-on experience of AR during the design process. In the first step of the study, the participants attended a presentation about AR and a demonstration of the AR app *Metaio*. With this information and a tutorial that they had been provided with, the participants were asked to add interactive AR content to the presentation boards of their bedside alarm clock project – the results of which formed the second step of the study. In the third and final step, the participants presented their finalized design concepts with the added AR content in their presentation boards and mock-ups.

The participants enhanced their presentation boards and mock-ups with sound files, video files and 3D model files. As can be seen in Table 2, all of the participants added the sound of their alarm clock in their presentation boards, either embedded in a video that showed interaction details during usage, or separately to show what sound the alarm clock would make when activated. For the videos, which were superimposed on presentation boards and mock-ups (Fig. 1), six of the participants showed the alarm lights and the movements of the products, whereas three of the participants showed the interaction steps of operation. One of the participants chose to show the alarm light glowing (Fig. 1), and another participant decided to present the interaction steps of the digital interface in the form of a video augmented to the surfaces of the physical mock-up (Fig. 2). One participant took it a step further by augmenting the mock-up of the project with a 3D model that showed the true texture of the material of the product (Fig. 3).

Table 2. AR content added to the presentations of participants

AR content	Purpose	Number of participants integrated (out of 8)	Medium of presentation
Sound	alarm	8	2D presentation board
Video	alarm lights and the alarm-clock’s movement	6	
	interaction steps	3	
	alarm lights	1	3D mock-up
	interaction steps	1	
3D Model	product form, material texture, graphics	1	

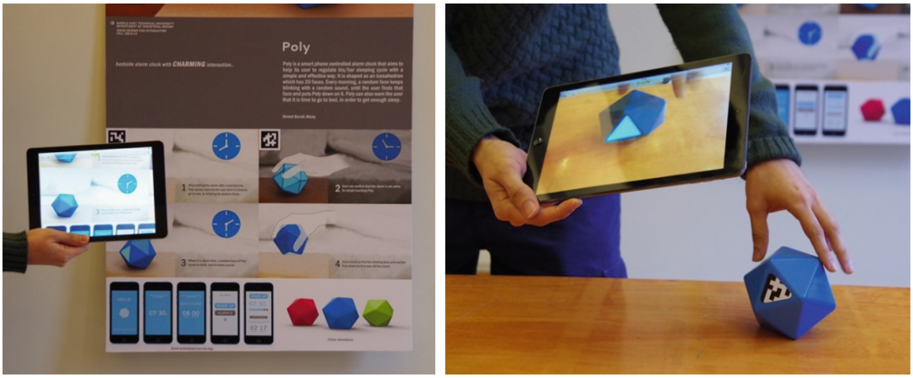

Fig. 1. A participant scans the markers on a presentation board (left) and then the mock-up (right) to show the augmented animation of glowing alarm lights.

Fig. 2. A participant shows interaction details on a video on the mock-up (left), and the in-app screenshot (right).

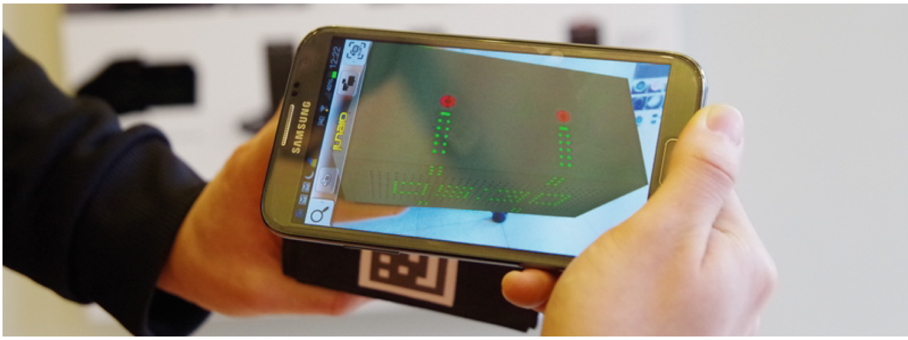

Fig. 3. A participant scans the marker on the mock-up to show texture and animation of blinking lights.

The participants had very positive reactions to the *Metaio* software package, commenting that they were able to show details of their projects that they would not have been able to show if they did not have access to the technology. The participants described the presentation enhanced with AR to be informing, surprising, interesting, and fun. Suggestions for improvement in using AR for presenting industrial design projects were: using an app specialized for industrial design purposes, and being able to interact with the AR content.

Study 3. Study 3 was carried out by the first author, to personally reflect – having had the benefit of exposure to Studies 1 and 2 – on the general potential uses of AR in industrial design activities. It included two parts: (i) exploring existing AR solutions for industrial design, and (ii) imagining and predicting future AR solutions for industrial designers.

For the first part of study 3, the author used mobile AR apps to enhance two past design projects, the first being an espresso-based coffee machine completed as part of the postgraduate course ‘Design for Interaction’ offered in the 2012–2013 Fall semester at METU Department of Industrial Design. Using the *Metaio* app, the author enhanced the presentation board of the project by adding a video showing the blinking lights of the product, a video of the hand gestures that activate the milk steamer, and the sound the steamer makes upon operation. In addition, *Augment* software was used to show the product in its intended usage environment. With these enhancements, seen in Fig. 4, the author was able to show audiovisual feedback of the product, and present the product in its intended usage environment without having to spare the significant effort to build a physical or interactive electronic prototype.

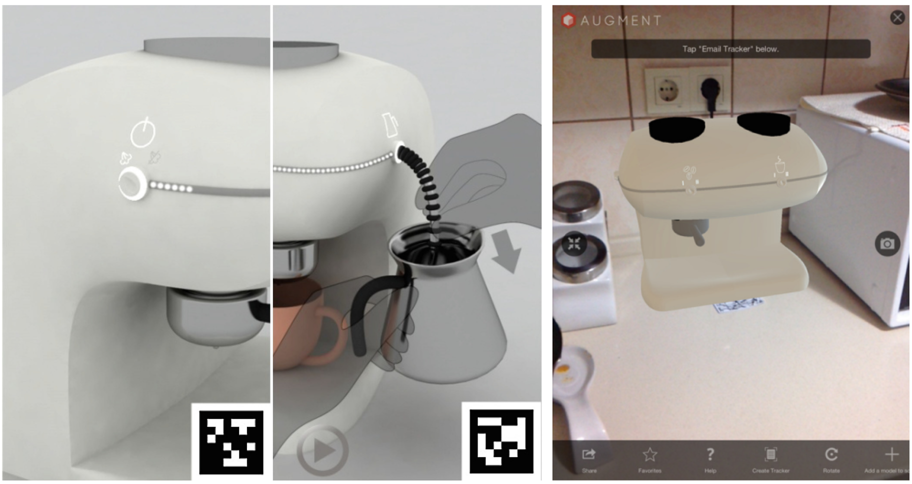

Fig. 4. AR content to enhance the design presentation of an espresso-based coffee machine

Another past design project that the author enhanced with AR is a ‘wake up light’, completed as a requirement of the postgraduate course ‘Usability and User Experience Assessment in Design’ during the author’s student exchange to Delft University of

Technology. This product aims to wake people in a relaxed, natural environment by mimicking natural sunrise and sounds from nature. For AR enhancement, the plain, white physical prototype of the project was used as a canvas for the projection mapping AR app Dynamapper (by Reotek). With Dynamapper, the glowing warm light of the product and the digital interface was projected onto the surface of the physical model, as shown in Fig. 5. This way, a realistic representation of the final design concept could be experienced in the intended use environment, without the need to create any working electronics inside the model.

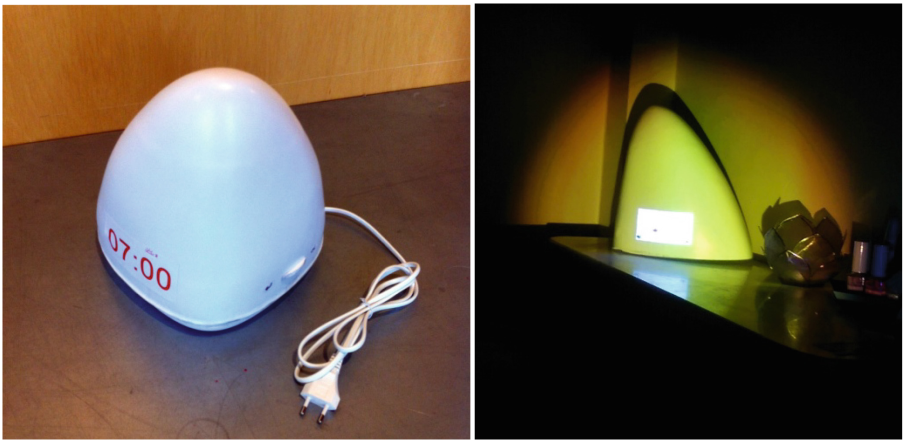

Fig. 5. Physical mock-up of the ‘wake up’ light project, augmented with *Dynamapper* to show the intended interface and light glow.

Table 3. Potential areas of benefit from AR, based on design activities and design stages

	The Design Process	Project briefing	Research	Initial idea generation	Interim presentation	Development of design concepts	User testing	Final presentation
Currently available (S2, S3)	Presentation				✓	✓	✓	✓
	Physical mock up creation				✓	✓	✓	✓
Suggestions for future use (S1, S3, L)	Scenario building activities					✓		
	User tests and usage instructions						✓	
	Project research		✓					
	Material considerations					✓		
	Mechanical and structural considerations						✓	
	Display and feedback interfaces					✓	✓	✓
	Real-time virtual interaction			✓	✓	✓		
	Product surface creation			✓	✓	✓		
	3D visualization of 2D drawings			✓	✓	✓	✓	✓

S1: Study1 S2: Study 2 S3: Study 3 L: Literature review

The second part of Study 3 focused on imagining and predicting future AR solutions for industrial design purposes, to improve suitability and technology adoption. Firstly, additional interactivity in AR solutions would bring great benefits to existing hardware and software combinations. Being able to interact with the AR content in real time would enable designers to create and modify their own content in a virtual environment. Examples of virtual design environments have been the focus of recent research, but easily accessible solutions are yet to be released. Secondly, an AR solution that is developed just for designers would be very fruitful to enhance the design process. It has been shown through this paper that AR could be useful for several design activities. Table 3 summarizes the potential of AR to fit to different design activities, based on the current availability of relevant solutions.

4 Conclusions

The work presented in this paper shows that amongst currently-available AR technologies, some can offer promising support for industrial designers and industrial design students, mainly through augmenting presentation activities. Product design details such as audiovisual feedback, interaction details and digital interfaces can be readily and effectively shown with AR.

The second most fruitful use of AR within industrial design processes is in physical mock-up creation, where the technology can be used to enhance the mock up creation/prototyping process by superimposing material, texture and interaction details onto a plain (e.g. white, undetailed surfaces) physical model. Additionally, future developments will enable a number of design activities to be carried out with the addition of AR, to make the design process richer and more interactive. The fieldwork for this present study was carried out in an educational setting; however, it is known that the design activities where AR brings benefits in education are essentially the same activities mirrored in professional design practice. Thus, both design students and design professionals can benefit from adoption of AR for future design projects. For further research, keeping in mind the results of the fieldwork, a mobile app specialized in AR for industrial designers, can be developed.

Acknowledgements. The authors would like to thank all the participants of the fieldwork.

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