VIRTUAL TOOLS FOR PRODUCT DEVELOPMENT

Methods in early product development

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1 Introduction

Several new virtual tools have emerged for today's product development. The reasons and motives are extensive: globalization has molded the world, and teams have become more cross-regional; technology and computational methods have dramatically improved, enabling the use of tools such as augmented reality or digital twins; and finally, the line between work and home has become more indistinct, where work-from-home has become near standard option in many companies and industries. That said, the tools have expanded from computer aided development technologies (CAD) to methods in earlier and later phases of the product development. For instance, Zhang et al. 2004, argued that initial drivers for virtual product development were the potential to improve quality, cost and value effects, as well as the timeliness within the process of actual product development.

We took a more holistic perspective on the virtual tools in product development and divided the work in three general phases: customers and their integration in the very early phases via digital means, concept development (while staying away from standard CAD methods) by utilizing state-of-the-art technology such as Augmented Reality and Digital Twins, as well as addressing the virtual teams and its implications to product development as a whole.

2 Virtual Customer Integration

Studies shows that customer participation in the ideation and launch stages improves new product financial performance directly as well as indirectly through acceleration of time to market, whereas involving customers in the development phase delays time to market and in turn deteriorates new product financial performance. (Woojung Chang & Steven A. Taylor 2016)

Successful virtual customer integration requires

1. Determination of customer profile,
2. community identification,
3. virtual interaction design, and
4. user access and participation for the virtual dialogue with customers (Füller et al., 2006)

2.1 Case AUDI, development of infotainment systems

The project was focused on the development of infotainment systems. Two main objectives were stated at Audi Infotainment:

a. Deliver information about customer expectations, preferences and upcoming trends in the infotainment world quickly, cheaply and interactively and
b. give insights concerning customer acceptance, perceptions and input quality of web-based customer integration in new product development in general.

The Virtual Lab as a web-based interaction platform (Fig. 1) was used to meet both of these goals.

Fig. 1 The Virtual Lab as a web-based interaction platform

The community-based innovation method consisted of 4 above mentioned virtual customer integration steps

1. Determination of customer profile: Highly innovative insiders, early adopters, heavy users in the low-end segment The Virtual Lab included different development tasks emphasizing different attributes of online customers simultaneously.
2. Community identification: The Audi homepage was used as the online setting where all various customer types mentioned in the previous step should be found. Lead users as well as normal buyers could be identified at the homepage centered around the Audi brand. Additionally, the Audi Newsletter was used for the identification of potential participants. Also, sites like www.autobild.de, www.autospiegel.com etc. turned out to be meeting places for interested consumers.
3. Virtual interaction design: To set up an interaction process with customers, their particular characteristics as well as motivations need to be considered for the design. No single best solution for the design of virtual interaction exists as it depends on the

specific context. Several design parameters may be varied in order to align the virtual interaction with the objectives of customers and producers. The exclusive information provided on infotainment systems, the presentation of upcoming entirely new designs as well as multimedia experience formed the value proposition offered to participants. No monetary incentives were offered as intrinsic motivation turned out to be the key driver.

4. User access and participation: Once the virtual interaction platform was programmed and tested, customers were accessed and contacted. E-mails, banners, pop-up windows, or short articles can be used to get in touch with the customers encountered in the Internet and inform them about their roles in the innovation project.

Results: Overall, 1662 customers participated in the Virtual Lab. The participants expressed 219 service ideas, gave 261 comments on the console, and contributed 728 visions on future cars. From a customer perspective, the interaction was perceived to be very attractive. A total of 1365 participants or 78.2% wanted to take part in future virtual development projects not restricted to infotainment systems.

3 Emergent Tools in Virtual Concept Development

This chapter cover two larger state of the art technologies in virtual product development: Augmented Reality and Digital Twins. The AR-tools are beginning to cover product development phases quite exhaustively, yet here the earlier phases are emphasized. That said, the later phases of concept creation and testing will be addressed with virtual product models, Digital Twins.

3.1 Augmented Reality in Virtual Product Development

Creativity has been studied for a long time, and one of the essential findings is that too straightforward and constrained methods restrict the creative process (Benami & Jin. 2002). For this reason, in early concept development, visualization of the ideas is mainly done by drawing by hand, since it is really fast, intuitive and unconstrained. It is also noted that drawing done by hand are susceptible to ambiguity or a loss of information relating to dimensions and space. People could interpret hand drawings in various ways. (Tovey & Street. 1997).

3.1.1 Visualizing concepts using augmented reality

Augmented reality can provide new methods for visualizing concepts in concept development phase. Concepts can be visualized in AR environment in detail at very early stages in the concept phase. In example in figure 2, AR software is used to present a concept using AR software in mobile phone.

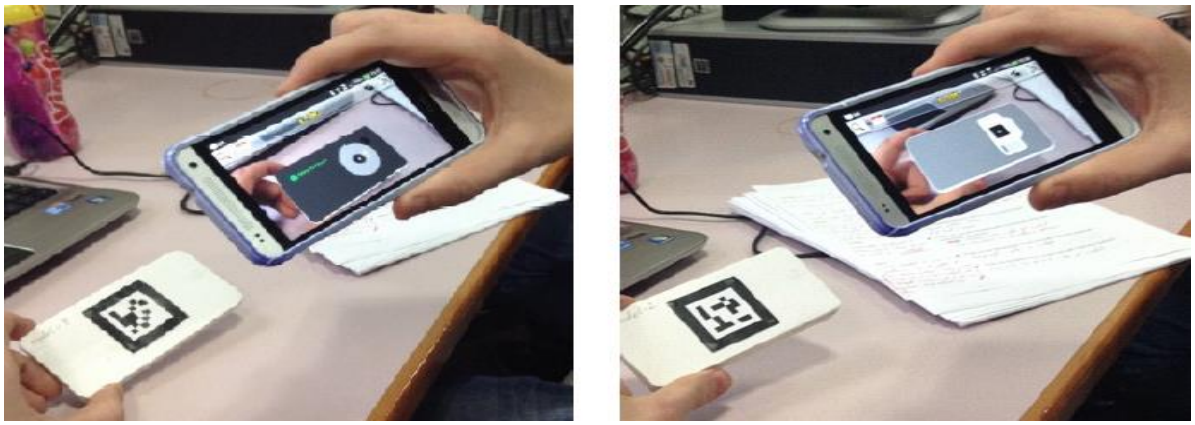

Fig. 2 Interpreting concepts of a mobile phone using mobile AR application (Mair, Robinson & Storr, 2014)

These kind of AR implementations can help product developers communicate ideas and concepts to stakeholders. Virtual concepts are easy to share, and they can also be shown to stakeholders at any time or any place. Also, AR can help to get quick feedback on concepts when prototypes are not available in example if in a lack of time or money.

Visual concepts and ideas are easier to present to stakeholders. AR visualization could remove some of the ambiguity which can be present when interpreting drawings, since viewing concepts in AR is more instinctive and it has the "feeling" of a real product. Viewing a concept in AR can help recognize its size, scale and dimensions because the concept can be seen and compared to real world objects. Also, stakeholders could possibly communicate their needs and ideas more clearly when the concept is more concrete and easier to visualize and interpret. (Mair, Robinson & Storr, 2014).

3.1.2 Creating new concepts using augmented reality

Augmented reality could also provide alternative possibilities for ideation and creation of new concepts. Drawing in 3D-environment is currently being developed and first prototypes of 3D drawing boards have already been made (Reipschläger & Dachselt, 2019). 3D-drawing could operate as unconstrained and lightweight CAD. Usage of heavy 3D-modeling software is not common in early concept creation because they are often is heavy to use, and they require precise constraints and details for the design.

Creating concepts straight to 3D with AR could provide creative stimulus to designers. The designers could instantly gain visual feedback from the design and potentially a rough virtual prototype could be made straight from the idea of the concept. In figures 3 & 4 a prototype of 3D-drawing board is presented.

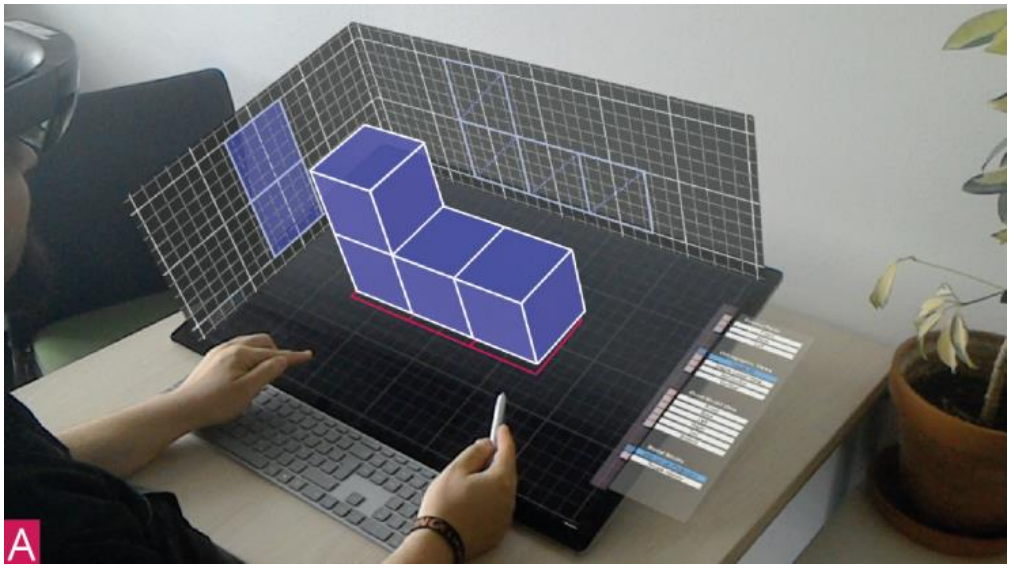

Fig. 3. Prototype of a 3D-drawing board (Reipschläger & Dachselt, 2019).

Fig. 4. Drawn object is visualized after modeling (Reipschläger & Dachselt, 2019).

However, 3D-drawing in augmented reality is still restricted by the limitations of the technology, but it will most likely become a powerful tool powerful tool for early concept creation in the near future. Some limitations include small field of view when using AR glasses and high requirements for memory and processing power for the devices.

3.1.3 AR applications for concept development today

Visualization of rough concepts in AR environment is viable with today's technology and it can provide significant benefits for concept presentation and demonstration. AR can create an instinctive feeling and look for the product, demonstrate concept size and scale in relation to real world and it could possibly replace early prototyping at certain situations.

3D-drawing in AR environment is still a new technology. Augmented reality tools and its applications are currently being rapidly developed. It is highly probable that 3D-drawing will become almost as intuitive as hand drawing in the future and applying it to concept creation is most likely going to allow fast, highly visual, and unconstrained concept developing processes.

3.2 Digital Twins in virtual concept development and testing

Virtual product models, popularized as Digital Twin, are sophisticatedly computed replicas of the real world. They are built with network of models which all have a level of interconnectivity (Miller et al. 2018). The most complex models are enriched with the combination of sophisticated model-based engineering, digi-physical production systems, as well as production and operation data. For instance, a digital factory environment could be built to simulate machine concepts' initial performance or fit in that specific environment. Thus, Schleich et al. 2017 suggest that Digital Twins enable to bridge the gap between design and manufacturing, resulting in increased product development performance and decreased the time to market. Furthermore, Digital Twins enable more effective prediction of product and process development. Moreover, as they eliminate the need to create physical prototypes, the Digital Twins not only reduce time, but resources required to build and test tangible concepts.

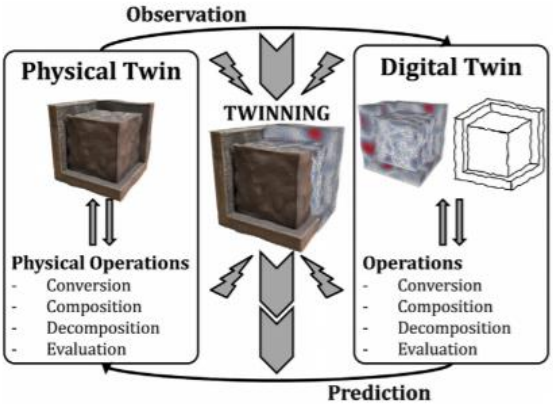

Fig. 5. Twinning, advanced method of different operations on to existing product and digital twin, aiming for prediction models as well as data for later improvements (Scleich et al. 2017).

Finally, the capability to assess consequences of products and process decisions in a virtual world has significant edge over traditional means. The vision for a Digital Twin is an entangled relation between a virtual model and a physical product. Finally, an actual physical product can be “twinned” with a virtual model (Fig. 5), for ongoing data collection, pairing, and simulations, to aid in further product and servicing development processes (Schleich et al. 2017).

4 Virtual teams

Advances in information technology (IT) has provided possibilities for new organizational forms in product development. One such organizational form is virtual teams. Virtual teams utilize IT (e-mail, phone, software) to enable information sharing, communication, teamworking and filesharing remotely. Implementing this system could improve companies’ operational flexibility especially now during the COVID-19 pandemic.

New product development has been recognized as an important factor in small and medium enterprises (SMEs) survival and growth. Virtual production development teams have been shown to help SMEs increase their efficiency and competitiveness. One reason for this is the ability to choose employees without geographical restrictions, which means that the employer has more freedom in the recruitment process since there are more candidates to choose from. Some other advantages associated with virtual teams are reducing design time, reduced relocation time/ cost, and better team outcomes in terms of quality, productivity and efficiency. Employees that work in virtual teams also feel more satisfied, since it gives them more flexibility in balancing work and personal life. A properly implemented virtual team can also increase the knowledge base of the company and as a result reduce the time to market (Ale Ebrahim, 2015).

If companies wish to implement virtual teams, it is also important to be aware of some of the challenges of implementing and maintaining a virtual team. One of them is the lack of nonverbal cues, such as body language, nodding, facial expressions and voice intonation. Some of these problems can be addressed by using audio and video technologies such as zoom or Microsoft teams. This type of communication reminds more of a face-to-face interaction than e-mail or messaging. However, there are some benefits with e-mails and messaging because the participants can then avoid interruptions and have more time to think about their response. Another disadvantage is that some employees can feel isolated and experience loneliness

because camaraderie and relationships are harder to establish without shared meals or informal conversations. The lack of face-to-face situations also make it harder to coordinate work, which means that effective planning, leadership, and communication are even more important in a virtual team. Cultural differences can also prove challenging in global virtual teams, because of language, cultural context, and norms (Dufrene, 2016).

From a product development point of view virtual teams can create diverse teams with multiple perspectives. This diversity can bring more novel and comprehensive ideas. However, explaining ideas and concepts can be difficult because of the limitations that comes with not having face-to-face communication. (Yu, 2015) From an early product development point of view we think that virtual teams can be applied, but the challenges would increase when physical products or prototypes have to be made.

5 Discussion

As demonstrated in the Audi case, virtual tools enable achieving large-scale involvement of customers to derive insights effectively and efficiently on further improvements, but also to identify customer deterrents for the potential product. The key implications for early product development was especially in scaling through continents, which has become more of the today's standard in globalized business environment. That said, not only were Audi able to participate customers potentially from different regions, they enabled many customer insights on a very specific product, part of a larger ecosystem. In physical world such magnitudes would be near impossible to achieve, especially for an accessory product. On a different note, customer focus groups, small number of customers participated in in intensive early ideation, are also very viable option for similar application, especially if the key customers are geographically dispersed. Moreover, one could argue that one of the key reasons customer focus groups do not realize, is the lack of motivation to invest resources from the customer side. With more efficient processes and removal of commuting, virtual approach could influence customers' decision to join the ideation in the first place.

Speaking of customer integration in early phases of product development, such initiatives could be scaled internally within multinational corporations. Both instances require similar skill sets as the establishment of virtual teams. First, the baseline in technological tools and platforms must be established. Secondly, the coordination and communication must be well planned and

executed. This allows to achieve clear understanding of the purpose and objectives, as well as to engage in fruitful discussions.

When transitioning from the ideation, validation and selection, to the actual product development, today's advances in product modelling technologies follow to an extent the same drivers as they have a decade ago, only the computational advances allow better use of simulations, analyses, and visualizations. That said, one of the advantages of virtual tools in product development is building and simulating large and complex products without investing any physical resources, and thus making the validation of even more refined, but virtual, concepts easier and more affordable. In addition, visualization and simulation enables product developers to detect early on latent problems, as well as performance related issues (Schleich et al. 2017). This could save potential reconfiguration costs later in the process. Moreover, the virtual nature of such constructs allows the transferability for demonstration purposes. Whether it is for pitching internal business cases or use for customer negotiations. Therefore, the product developers' tool kits are increasingly expanding, requiring the basic know-how of these technologies, but especially understanding strengths and applicability of such technologies in different scenarios.

While the understanding and establishment of cross-functional (or continental) virtual tools may require more initial planning and establishment in terms of accessory technology and platform acquisitions, it could be argued that such measures will eventually pay out. As Elbrahim (2015) agreed, the increased precision, efficiency, and transparency, improve the overall quality and timeliness of the whole process, to all stakeholders.

To conclude, emerging virtual tools in product development not only improve quality, efficiency, and time to market, but increasingly aid in the creativity aspects, as well as in transparency and collaboration throughout the process - which are arguably important, as increasing number of businesses globalize and continuous innovating requires more and more advanced efforts. These tools, from the very early phases of product development, include virtual customer collaboration platforms in ideation and feedback, AR tools aiding in ideating and visualizing 3D early concepts, as well as Digital Twins in creating more defined systems for testing and simulation. The different product development aspects of collaboration, ideation, concept generation and validation, as well as prototyping to testing, all remain today fundamentally the same. Meanwhile the means to achieve results by more efficient and effective ways requires learning new tools and embracing the arsenal's potential as a whole.

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