Fast Experimentations with Virtual Technologies Pave the Way for Experience Economy

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Abstract: The ongoing revolution in people's behavior, involving emphasized personal experiences, means that a product plays a decreasing role in competition, and creating an experience is becoming more important. This leads to new kinds of value chains and new kinds of networking, which will create challenges for companies. Cognitive infocomminacations (CogInfoCom) provide fast infocommunications links to extend our cognitive capabilities. Virtual technologies, such as virtual and augmented reality (VR/AR), will increase value creation by combining the strengths of humans and machines. The aim of this paper is to present an approach through which VR/AR with game programming tools can be utilized to boost business and enable new value creation in a world that is developing towards an experience economy. Our design methodology is based on agile innovation principles with fast experimentations that are carried out in co-creation with companies. The practical implementations are considered as multiple case studies. After introducing the current trends in VR/AR, we present our experiences of how these virtual technologies can be applied for CogInfoCom Aided Engineering tasks in various application fields. Despite the increasing popularity of virtual and augmented reality and game technologies, only a small amount of research has examined how they can be utilized professionally in the design processes of small and medium-sized enterprises (SMEs). However, they provide effective tools for increasing user involvement in new product development and marketing. Based on the case studies, we present our experiences of how SMEs can benefit from virtual technologies by increasing their business agility and flexibility, reducing product design risk, shortening product development time, and enabling new business models. VR/AR technology with game programming proved to be effective tools for fast experimentation and co-creation with SMEs.

Keywords: virtual design, virtual reality; augmented reality; experience economy; CogInfoCom aided engineering

1 Introduction

The progress in digital technologies in combination with emerging technologies is changing the way we design, produce, commercialize, and generate value from products and related services [1]. Virtual reality (VR) and augmented reality (AR) are examples of these world-changing technologies, although they are still in the early stages of development. VR immerses users in a virtual world. This immersion effect often provides a real "wow" experience for the user. The 3D Cave Automatic Virtual Environment can also complete the immersion effect. In contrast, AR overlays digital information onto the physical world. The goal of AR is not to completely immerse the user in a virtual environment, but to supplement and enhance reality. These technologies can be seen as part of a larger approach, *Cognitive Infocommunications* (CogInfoCom), which covers numerous fields of human entanglement with information and communication technologies [2, 3, 4, 5].

In CogInfoCom the blending of the natural and artificial cognitive capabilities has brought new directions of research. The CogInfoCom channels can include VR/AR learning environments [6, 7, 8] or even a Sami-speaking robot system [9]. Previously human-computer interaction was mainly based on commands, recent developments in VR/AR and in deep learning has enabled interaction to advance in a more collaborative way [10]. From CogInfoCom aspects interaction and interfacing between the natural and artificial components is disappearing in many cases and it is almost impossible to clearly separate. Through the co-evolution of humans together with information and communication technologies (ICT), the intertwined sets of human with ICT capabilities can be considered conceptually as new cognitive entities [2, 11, 12].

According to a recent Goldman and Sachs report [13], VR and AR have the potential to become the next big computing platforms. Most of the discussion today around VR and AR focuses on consumer-level solutions such as gaming and entertainment. Nevertheless, they also hold great promise in boosting business and in speeding and improving product design. VR/AR technology has evolved, and the prices are becoming much more affordable, which makes them truly usable technologies, even for SMEs. However, most of the reported industrial VR/AR experimentations have been carried out together with big companies [14]. Virtual and game technologies also offer huge potential for SMEs to boost their businesses at an affordable cost level. However, companies working in small-scale manufacturing usually have limited resources for product development and marketing. Therefore, they need help in using co-creation principles [15] in the network consisting of the company, their customers, and a research group. One example of VR collaboration environments designed for testing and training of complex manufacturing systems is Virtual Collaboration Arena (VirCA). This platform is an augmented/virtual collaborative system that enables researchers, developers, and engineers to handle engineering challenges in practical scenarios [6].

In recent decades, consumers have been increasingly moving from a focus on price and product functionalities to a valuation of additional product aspects. The esthetic, tactile, and social experience of using and owning a product are increasingly playing a significant role in consumer choice. Creative industries and experience economy are two terms that are often related to this transformation. The term "creative industries" often refers to a wide range of economic activities that are concerned with the generation and commercialization of creativity, ideas, knowledge, and information [16]. Creative industries are defined as those that have their origin in individual creativity, skill and talent, which have a potential for wealth and job creation through the generation and exploitation of intellectual property [17]. Creative industries include advertising, architecture, the arts and antiques market, crafts, design, designer fashion, film, interactive leisure software, music, performing arts, publishing, software, television, and radio. Creative industries have spearheaded a transformation toward creative and experience economies, especially since the advent of digital technology [18, 19]. Our research team also applied many functions that have their origin in creative industries, in the case studies.

The term "experience economy" was introduced twenty years ago by Pine and Gilmore [20], who claimed that our economy has entered a stage of economic development where experience increasingly dominates consumption. This means that a product plays a decreasing role in competition, and creating an experience is becoming increasingly more significant. Since that time, the experience economy has changed many traditional ideas of how consumers evaluate products. The experience economy has been regarded as a principal concept in the experience area studies [21]. Pine and Gilmore [20] spoke about staged experience and categorized it into four fields of experience economy based on two varieties of participation (passive and active participation) and connection (absorption and immersion): entertainment, education, esthetic and escape experience. The hospitality and tourism business is an example of a business area that has shifted its focus from the product or service itself to enhancing tourists' experiences and making them unforgettable. With the advent of digital technology, numerous VR or AR solutions for tourism destinations have progressively provided tourists with more real and immersive virtual environments [21].

This development is now expanding in all business areas. Virtual technologies can pave the way for this transformation in industrial applications. The experience economy has extended from services to all business areas, including the design and manufacturing of products. One example is a major industrial 3D software and PLM software vendor, which lately updated its brand to become a 3DExperience Company [22]. The company provides a 3DExperience platform for its customers and now has dozens of 3DExperience centers around the world. The company states that the platform and centers provide businesses and people with virtual universes for imagining sustainable innovations. Their platform is based on 3D design, analysis, simulation, and intelligence software in a collaborative, interactive environment, which is available both on premises and via the cloud. The company discusses their vision in "The Age of Customer Experience" and explains that their platform leverages 3D software applications to transform the way products are designed, produced, and supported, enabling businesses to create delightful customer experiences. These expressions have much in common with the experience economy content presented by Pine and Gilmore [20]. Many of our case studies with companies have close relations with the experience economy, especially the VR/AR applications implemented for exhibitions and events.

In this paper, we present our experiences of how virtual and augmented reality were applied for CogInfoCom Aided Engineering in various application fields. First we present some current trends in AR and VR in Chapter 2. In Chapter 3, we introduce our methodological choices, including co-creation, multi-case studies, and fast experimentation. In Chapter 4, we present our experiences with regard to how virtual design with 3D scanning, VR/AR, and game programming can be applied in various application fields. In Chapter 5, we discuss our experiments and provide conclusions. Our study has been carried out in a Tekes-financed joint project with Centria UAS and Turku UAS, "Fast Wow Effects Boosting SME Business," and in two international EU projects, "I3: Innovations & Industrial Internet" and "TARGET."

2 Virtual and Augmented Reality Trends

Information technology and digitalization are revolutionizing both products and services. We have entered a whole new global age, and there are countless unrecognized opportunities that will touch every aspect of life. VR and AR with game technologies are important enablers in this development. These technologies are based on digital 3D models, and their utilization has become possible because industrial design has shifted to utilize 3D CAD. These technologies will be part of 3D experience platforms in the future. Increasingly, engineering work is carried out in a digital format; for example, the design and manufacturing of cars, buildings, ships and infrastructure are currently performed using mainly digital information. The digital product process covers the entire product life cycle, from the design stage to after sales and services. One potential area for virtual technology is marketing, which has not yet been widely utilized, to boost SME business. Currently, digitalization has been successfully and effectively implemented mainly by large companies. New technologies, such as 3D scanning, VR/AR technology, and game programming, will allow the use of digital content to boost SME businesses, especially for marketing purposes. Figure 1 shows examples of how our 3D design processes are carried out, starting from 3D laser scanning and followed by 3D visualization, which are leading to VR or AR solutions. The power of VR/AR implementations is that they enhance the human ability to absorb and process the information needed for decision-making. These technologies can provide information in the way that can be intuitively processed by humans. This reduces the cognitive load, especially in situations involving simultaneous or complex tasks.

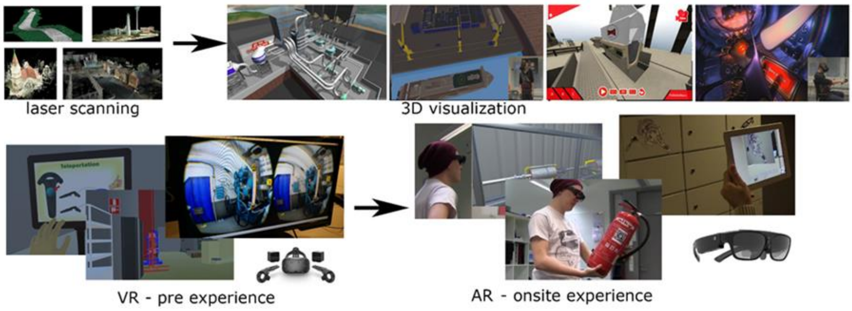

Figure 1
Examples of the 3D design process leading to VR or AR solutions

Why should we invest in VR and AR technologies? Around 85% of VR and AR growth will come from non-gaming sources. AR-based smart glasses have been identified as a vital technology in the smart factories of the future [23]. Goldman Sachs estimates that knowledge transfer is the biggest business area for VR and AR technologies [13]. Facebook has spent $2 billion on Oculus VR. Meanwhile, Samsung and Oculus have launched VR headsets together. Google has introduced AR glasses called Google Glass. In addition, Google DIY has invested $542 million into Magic Leap Augmented Reality. Microsoft is developing a headset for the Xbox console. Apple is also working on its own virtual reality goggles, and Apple's head-mounted display patent was awarded in April 2014. In addition, Sony has also developed a VR headset for PlayStation 4 [24].

VR and AR technology was considered science fiction for many years. Currently, most of the discussion around VR/AR technology centers on consumer-level solutions such as gaming and entertainment. Recent developments with inexpensive and powerful VR headsets and AR solutions have expanded their use from entertainment and into many professional fields, such as, healthcare, tourism, marketing and even industrial applications. The International Data Corporation (IDC) study in 2016 predicted that in the next five years VR/AR technology will be utilized in other fields including education, logistics, and manufacturing [25]. This IDC study also forecasted changes in VR/AR equipment, including screenless viewers, standalone head-mounted displays (HMDs) having the necessary computer power integrated into the display, and HMDs connected to a smartphone, PC, or console. A recent Goldman and Sachs report [13] estimated that VR/AR revenues will total at least $80 billion by 2025, and this figure could rise as high as $182 billion. IDC Research has an even more positive forecast for

VR/AR technologies [25]: worldwide revenues for AR and VR are expected to reach $162 billion in 2020 (from $5.2 billion in 2016).

Technology is evolving very fast, especially in VR/AR. Therefore, the IEEE P2048 Working Group is currently developing 12 standards for VR/AR technology together with participants from over 200 companies and institutions all over the world [26]. Evolving technology and increasingly affordable prices make VR/AR a truly usable technology. According to a PricewaterhouseCoopers (PwC) technology forecast [27], there are five ways businesses could benefit from VR technologies: shortened time to market, reduced product design risk, increased business agility and flexibility, transformed talent development and training, and newly enabled business models. Baya [27] stated that recent developments in virtual and augmented reality continue to reshape the production and business models of all creative industries. Advances in technologies such as the Internet of Things (IoT), 5G, and cloud computing are enabling more efficient use of VR/AR technologies in industrial applications. Interaction with the customer is becoming increasingly important in marketing.

VR can be defined as the use of technology to create the illusion of presence in an environment that is not really there [28]. This illusion can be generated in various ways. One of the most common uses is mobile VR, which has developed rapidly from the 20th to 21st Centuries. Whereas, Mattel's View-Master utilized films, nowadays consumer mobile devices operate with Google Cardboard or Samsung Gear VR-type low-cost headsets. These headsets combined with sensors in mobile devices create a powerful tool for creating immersive user experiences. For example, various amusement parks now feature roller coasters where VR content combined with the consumer's physical location and movements increase the user experience. VR content can also be displayed with more sophisticated VR glasses, which have better resolution and sensor technologies to track and trace the consumer's head movements. These improvements decrease motion sickness, which is still one of the main challenges in VR technologies [29, 30].

AR can be defined as a set of technologies that superimposes digital data and images onto the physical world. At its core, AR transforms volumes of data and analytics into images or animations that are overlaid on the real world [31]. Today, most AR applications are delivered through mobile devices, but the delivery will increasingly shift to hands-free wearables such as head-mounted displays or smart glasses. While VR can be used when real-world objects are not available or unreachable, AR can only be used on-site. Sophisticated VR glasses are already widely available in the consumer market, but AR glasses are generally prototypes or early phase products. The lack of affordable, lightweight, high-performance smart glasses has been the main barrier to the widespread adoption of AR. On the other hand, some AR technologies such as Daqri's Smart Helmet are already so robust that developers are able to outline the future of the both consumer and professional markets [32, 33].

AR creates business value in two ways. It is becoming part of products themselves, and it is improving performance in the overall value chain, including product development, manufacturing, marketing, after-sales services, and numerous other areas. There are several examples of successful implementations of AR in industry. Boeing showed that AR improved productivity in wiring harness assembly by 25% [34]. General Electric has reported that combining voice commands with AR increased productivity 34% when workers were performing complex wiring processes in wind turbines [35]. Xerox reported that the rate at which technical problems are resolved without any on-site help increased 76% due to the use of AR [36]. Moreover, AR becomes even more effective when it is integrated with VR, artificial intelligence or robotics. AR’s core capabilities are visualizing, instructing, and interacting [31]. VR integration can add simulation as a fourth capability. This can be very helpful in many situations, for example, for training purposes in hazardous environments.

3 Fast Experimentation and Co-Creation

Our working method was based on fast experimentation, which applies many of the principles of agile innovation [37]. Agile methods have emerged and revolutionized information technology in recent decades. Today, agile methodologies are spreading across a broad range of industries and functions [38]. For us, agile innovation is a team sport in collaboration with companies, implemented on a daily basis, as presented by Morris et al. [37]. Examples of the principles that we have applied include delighting the customer through rapid delivery of a minimal key feature set and delivering value continuously to address progressively deeper, tacit customer needs.

Our iterative fast experimentation cycle is presented in Figure 2 [39]. The cycle has a close connection to CDIO, which is an educational framework stressing engineering fundamentals set in the context of conceiving, designing, implementing, and operating real-world systems and products [40]. The iterative innovation process starts with open innovation and continues clockwise from conception to design, implementation and operation. Fast experimenting is an essential part of our model, providing the speed needed for the innovation process in fast-developing markets. Experimenting includes both technological and business experimenting. The results of the innovation process are innovative quality products and services. In technology experiments, versatile competences are necessary, including know-how on VR/AR design and user interfaces, which can vary from mobile devices to 3D CAVEs. Advanced 3D scanning, point cloud handling, 3D modeling, and game programming are technologies that can also be utilized in the fast experimentation cycle. In particular, we have found that game technologies provide effective tools usable in fast experimenting, not only for entertainment purposes but also for industrial applications.

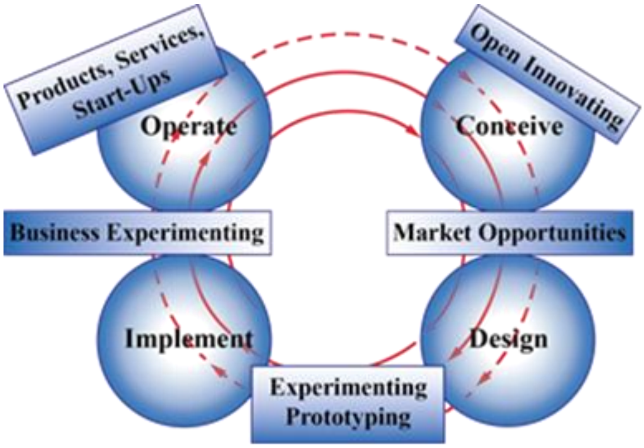

Figure 2
Our iterative fast experimentation cycle

For us, co-creation refers to collaboration with customers for the purpose of innovation. This has become a foundational premise of service-dominant logic [41]. The difference between co-creation and customization lies in the degree of involvement of the customer. The customer plays a less active role in customization than in co-creation. In the co-creation process, the customer or business partner is an active collaborator right from the beginning of the innovation process. Virtual and game technologies provide valuable tools for use in this process. The challenge for businesses is that in the co-creation process the market orientation should be proactive, which requires identifying and satisfying the latent needs of customers [15].

One way to present the methodical choices of our study is by using the research onion, an illustrative presentation by Saunders et al. [42]. The research onion (Figure 3) presents relations between some research philosophies, approaches, choices, strategies, time horizons, techniques, and procedures. In our study, the methodical choices were mixed methods; on the strategy level, we combined action research and case study principles in the form of multi-case studies [43]. It is well known that case studies are especially useful for exploring topics in which there is a relative lack of strong theory [15, 43]. In such circumstances, case studies are often able to provide descriptions in previously under-investigated areas.

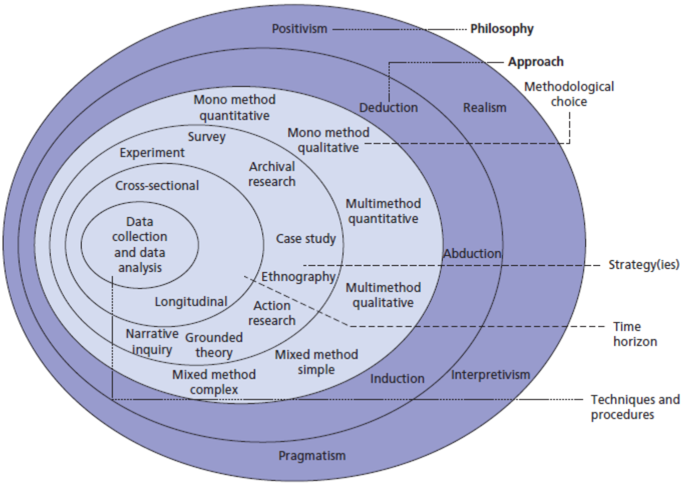

Figure 3

The research onion by Saunders et al. [42]

4 Case Studies Utilizing Virtual Technologies

We carried out case studies in our projects with multidisciplinary methods based on agile and fast experimentations [39, 44, 45]. We found that game programming software (e.g., Unity and Blender) and versatile digital environments (smart phones, tablets, VR/AR headsets, desktops and 3D CAVEs) functioned seamlessly for fast experimentations. The chosen programming approach provided an economical and fast way to transform the results from one platform to another utilizing alternative methods (see Figure 4, left). Examples of the equipment (HTC Vive virtual glasses and 3D CAVE in Centria) used in our experimentations are also shown in Figure 4 (right).

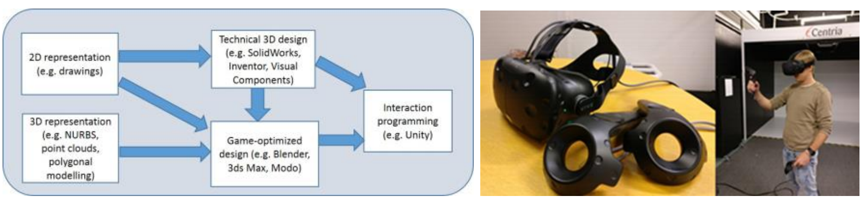

Figure 4

Alternative ways of using virtual and game technologies (left) and examples of equipment (right)

Our experimentations were directed in various areas. Figure 5 presents examples of the automation equipment and work cell design, which were carried out in co-creation with SMEs. Virtual design of automation equipment was applied both with technical 3D CAD software and game programming. The key idea was to effectively re-use the original 3D design when moving from one platform to another. In the robotized door manufacturing, work cell virtual design and simulation were used from the beginning in the layout design and continued into off-line programming. A virtual model with updated sensor information were later utilized for remote monitoring and maintenance operations. In some cases, 3D CAVE, mobile user interfaces, and VR/AR environments were also utilized in the design process. Virtual design and simulation software along with both 3D CAVE and virtual glasses were used in the design of linear servo technology-based wood processing equipment (Figure 5, right). Our earlier studies have also shown how complicated CAD drawings can be utilized in the development of an industrial training game. The result, IndustrySim demonstration [46], contains a massive amount of CAD drawings of a coal-fired power plant.

Figure 5
Examples of virtual design applications carried out in co-creation with SMEs

We have been working for several years with various methods of cognitive infocommunication with robots and cobots (collaborative robots). This includes lead though programming, virtual design-based off-line programming (OLP), automatic CAD-based or vision-based programming, and gesture- or voice recognition-based control. We also recently demonstrated that VR glasses can be utilized in robot programming (Figure 6). In the virtual environment, the operator can take an immersive step inside the robot work cell and, for example, check that the welding tracks are correct. In addition, the robot track points could be saved for creating a robot program. We tested VR glasses with two commercial software programs that included this possibility. The immersive robot programming environment is a totally different programming platform than the traditional operator panel, but after some training it can be very illustrative and is well suited for educational and training purposes.

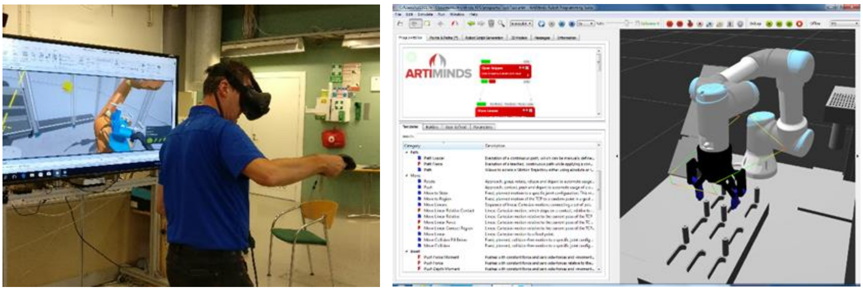

Figure 6
Experiments in immersive and virtual model based robot programming

Interactive product presentations with game technology can provide ways to get important feedback for user interface design. Therefore, we implemented VR-based applications for interactive product presentations for marketing, events, and fairs. This is particularly important for products that are too large to present in the fairs, such as large hangar or industrial doors or premium class boats (Figure 7). The collaborating companies presented these applications in many international fairs in 2017. In these cases, the original technical 3D design data was effectively re-used when moving from one presentation platform to another (3D CAVEs, VR/AR devices, smart phones, PCs or tablets). Because SMEs do not typically have virtual environments themselves, collaboration and co-creation with research groups is important. With game programming tools, interactive features could be added with fairly moderate efforts to the technical 3D design. These interactive features are especially necessary in commissioning tasks or when providing training in safety, maintenance, or assembly operations. This is very cost-effective if the commissioning, assembly, or service process is physically distant far away, which is often the case with hangar doors or premium class boats.

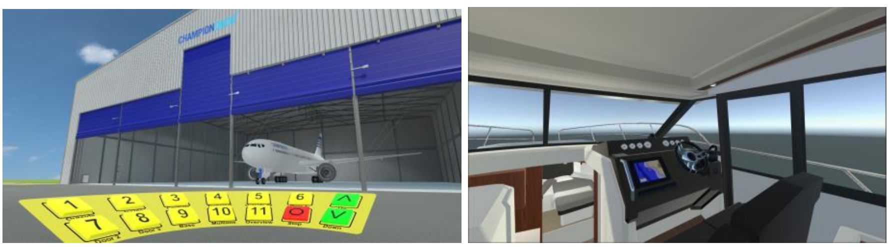

Figure 7
Interactive product presentations for marketing were created for different platforms

Interactive guides were also created with game programming for parts of the production processes. Figure 8 (left) shows an example of one stage of a production process in the metal industry. In the application, the operator can interactively choose different views and animations. Figure 8 (right) demonstrates the product principle of a patented piece of gluing equipment with changing views and zooming.

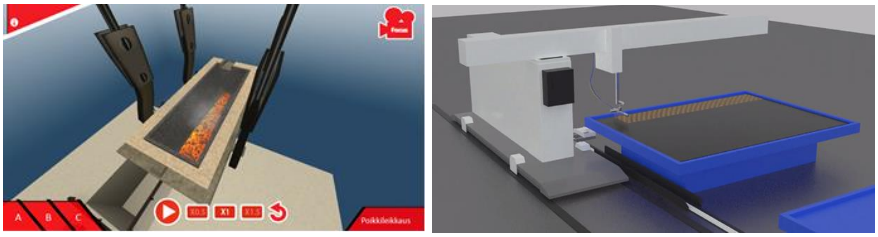

Figure 8
Interactive marketing presentations of production process

Interior design of houses is an area where the experience economy has growing importance in the market. We created a virtual model of a holiday house and an interior design tool for educational purposes (Figure 9). Both the quick modeling and the interactive interior design application were created using game programming software. The result was successfully implemented in two different 3D CAVE environments and in a virtual glass solution. In this application, the user can move freely in the house, and he or she is able to change the colors and textures of the surfaces. The interactive application also includes a kitchen in the holiday house, in which the user may change the furniture models (e.g., door colors and models of the kitchen cabinets) in the same way they can change the colors and textures of the surfaces. The immersive environment can be utilized both for the kitchen design and in marketing. The same idea of changing the colors and textures of the surfaces was later included in the product presentation of the premium class boat shown earlier in Figure 7.

Figure 9
Virtual model of a holiday house and interior design tool application based on game programming

One application area where we have applied virtual and game technologies is healthcare solutions [39], where we have tested rehabilitation games and a speech and language therapy game developed by the Turku Game Lab (Figure 10). The skiing rehabilitation game was tested both on our laboratory with a service robot and on our collaborating SME's premises. The Sanalanka therapy game for young children was tested by speech therapy groups. The virtual and game technology received very positive feedback in both applications. The user group in the rehabilitation tests was mainly elderly people, while in the speech therapy tests the users were children.

Figure 10
Virtual and game technology were also applied in the healthcare field

As we have shown, virtual and game technologies can be seen as business-boosting enablers, especially for SMEs. Our approach has not been to focus on entertainment but rather on the immersion in or enhancement of reality. However, entertainment can also be one of the enablers. We have developed exhibition games that combine traditional game cards and AR [39, 44]. Visitors are attracted to play mini games and collect game cards from exhibition booths. These cards can be used to customize a visitor's avatar. After visiting all the booths, the visitors are able to receive awards. Figure 11 shows a fair game designed for the exhibition center, containing 28 game cards and seven mini games. Every booth has a poster that will be triggered in the game.

In Figure 12, another fair game is presented. This 2.5D game has been designed for a local book fair. This game concept is more cost effective and easier to scale for other purposes. Visitors are asked to scan postcards found in the exhibition booths and open virtual doors. Each door leads the visitors to a mini game. This game has the same reward mechanism as the first game.

Figure11
A 3D fair game concept combining traditional game cards and AR

Figure 12

A 2.5D fair game utilizing traditional postcards and AR

Conclusions

VR and AR are good examples of technologies that combine the strengths of humans and machines. They are also typical, in other areas of Cognitive Infocommunications, which cover numerous fields of human cooperation with information and communication technologies. These technologies will be even more important in the future because our economy has entered a stage of economic development where experience increasingly dominates consumption. In this paper, we presented our fast experimentation and co-creation-based approach to use VR and AR to boost SME business. The application areas included virtual design, training, maintenance, and assembly operations. We also introduced some interactive product presentations for marketing, events, and fairs utilizing virtual and game technologies. Further, we presented examples of how these technologies can be utilized in education, training, and rehabilitation. Based on our experience, virtual and game technologies are effective tools for fast experimentation and co-creation with SMEs. The exploratory nature of the research means that our promising findings are still tentative and need to be confirmed later with larger-scale studies. Our collaborating SMEs have found the case implementations very beneficial, and some of them have already invested in the latest virtual technologies. However, in the future these single-case implementations will not be sufficient to ensure successful businesses. We fully agree with the opinion of Porter and Heppelmann, that every organization needs a strategy for VR and AR [31]. Even SMEs must have a strategy for using these technologies as an added value service in their product life cycle management, including design, sales, production and maintenance. In particular, SMEs should prioritize co-creation with research groups, in this area.

Acknowledgement

The authors would like to thank everyone who participated in the development of the case studies, especially Mr. Ari Lehtimäki and Mr. Anttoni Porri are greatly acknowledged. This work was carried out within the projects mainly supported by the Finnish Funding Agency for Technology and Innovation (Tekes), EU Interreg Nord program and EU Northern Periphery and Arctic 2014–2020 Programme which also are acknowledged.

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