Digital Transformation in Retail Industries:

Emergence of Virtual Stores with Mixed Reality

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Preface

Writing this master thesis has been an interesting journey. Sometimes very pleasant, other times less. It is now a piece of my life put on paper which I will store for very long in my memory, together with all the stories happening along its process.

I would like to thank my family and friends for all the support and patience, my professors for a leading hand -and inspiration and my school for this opportunity.

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Abstract

Nowadays the activity of shopping can be viewed as a disturbing topic with reference to the current sustainability movement, appreciation of quality over quantity and environmental issues. On the other hand, commerce in the form of currency, goods or service exchange is a part of modern society, hence it is preventive to continuously discuss its social impact. Retail is a space where several connections and relationships may occur between a brand, customer and product. Therefore the position of retail stores creates a potential ground for affecting social behaviours.

This research deals with the latest disruptions in retail - pandemic implications, widespread use of e-commerce and emergence of mixed reality technology. The accessibility and convenience of e-commerce has increased in its popularity, making it more common for consumers to shop online from the comfort of their homes. It is hard to deny that influence of COVID-19 have accelerated the use of online services, so retailers are analyzing solutions on how to repurpose retail stores to improve all channels of the brand.

One of the alternatives is proposed in this research when introducing a concept of A Mixed Reality Retail Store. Its purpose is to facilitate convenient shopping and deliver a cultural experience to customers with assistance of emerging technology. At the same time keeping it attractive for customers by combining benefits of online and offline commerce. Following this approach, the activity of shopping might encourage consumers to shop consciously with curiosity and responsibility.

Keywords

Retail, commerce, mixed reality technology, customer experience, shopping, interactive design

Abstrakt

V dnešnej dobe je možné považovať nakupovanie za znepokojivú tému vzhľadom na súčasné myslenie za udržateľnosť, preferovanie kvality pred kvantitou a environmentálne problémy. Každopádne obchod jestvuje vo forme výmeny peňazí, tovaru alebo služieb súčasťou modernej spoločnosti, a preto je preventívne diskutovať o jeho sociálnom vplyve. Maloobchod je priestor, kde vzniká vzťah medzi značkou, zákazníkom a produktom. Pozícia maloobchodných predajní preto vytvára potenciálny základ pre ovplyvnenie správania spoločnosti.

Tento výskum sa zaoberá najnovšími zmenami maloobchodu - dôsledkami pandémie, rozšíreným využívaním elektronického obchodu a vznikom technológie virtuálnej reality. Vďaka dostupnosťi a praktickosťi elektronického obchodu sa zvýšila jeho popularita, a preto je pre spotrebiteľov bežnejší nákup online z pohodlia domova. Je ťažké poprieť, že vplyv COVID-19 urýchlil používanie online služieb, takže maloobchodníci analyzujú riešenia, ako zmeniť maloobchodné predajne pre dobro firmy.

V tomto výskume je navrhnutá jedna z alternatív pri zavádzaní konceptu maloobchodného obchodu so zmiešanou realitou. Cieľom je uľahčiť pohodlné nakupovanie a dodať zákazníkom kultúrny zážitok pomocou rozvíjajúcej sa technológie. Zároveň ostať atraktívny pre zákazníkov zkombinovaním výhod online a offline obchodu. Po tomto prístupe by aktivita nakupovania mohla povzbudiť spotrebiteľov k tomu, aby nakupovali vedome so zvedavosťou a zodpovednosťou.

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Introduction

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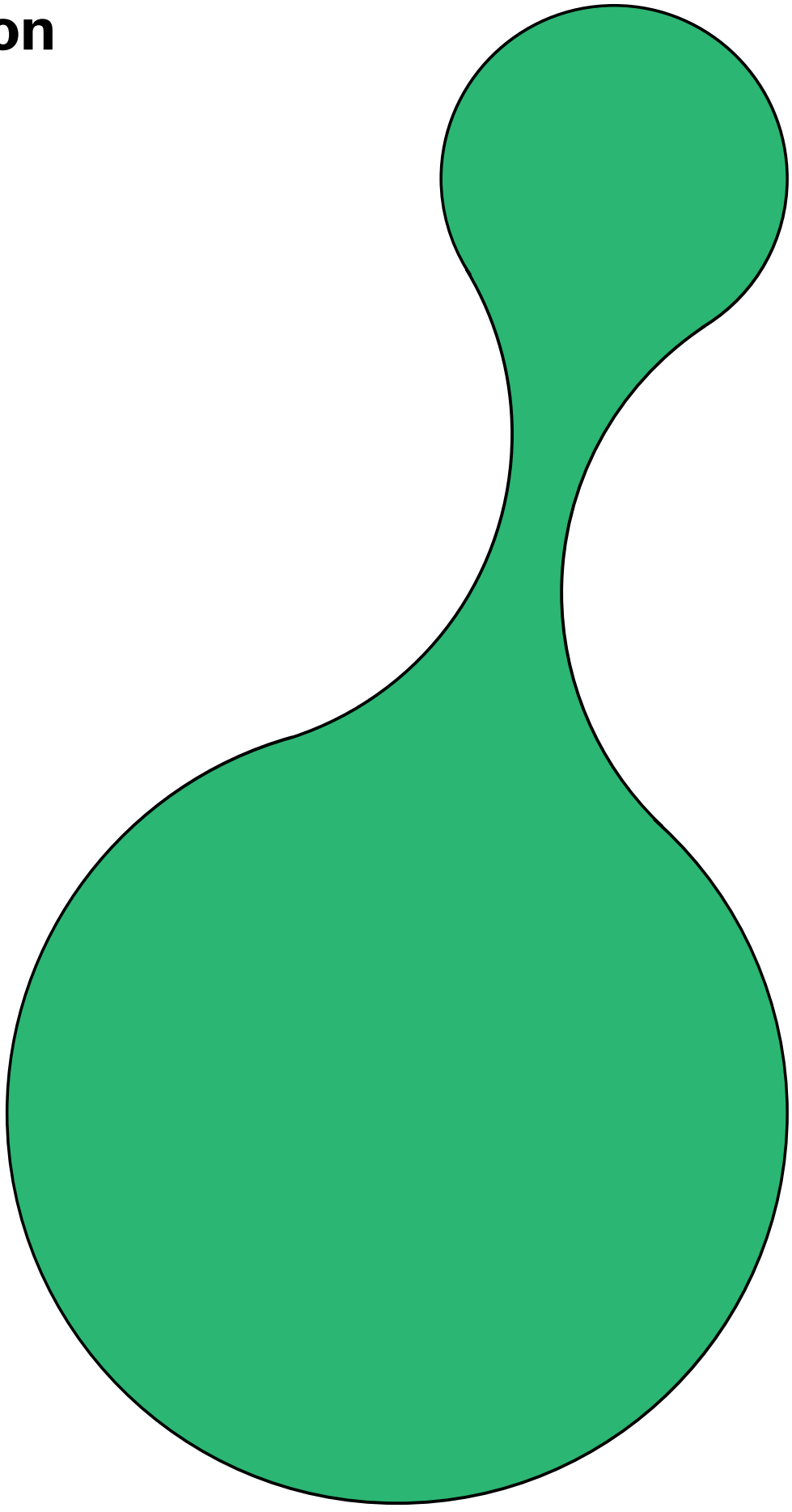

1 Introduction

1.1 Problem Statement

Traditional retail has been going through continuous disruptions over the last couple of decades. The recent COVID-19 pandemic has left a big mark on retailers and we are just going to understand transformations and see what normalities are starting to take shape. Digitalization and urbanization are two sectors with profound economic and social implications shaping the evolution of retail. Due to the growing population, the need for technological innovations emerges to facilitate new demands.

From 1950 until 2015, the population in developing countries increased ten times, from approximately 300 million to 3 billion. [1] Eventually with such rapid urbanization, basic and economic needs have been going through changes in all parts of living such as health, education, food etc. Together with urbanization grows technological change and digitalization. Especially inventions of the Internet and mobile devices have enabled technological transformations across all sectors. The online platforms have extended from a few websites, which are considered as giant e-commerce companies now, such as Amazon or eBay to a huge variety of modified online shopping web pages and apps. When urbanisation decreases the amount of physical space that a person has, digitalization increases movement in the digital space. Internet and widespread 3G, 4G and newly adopted 5G made the technological usage on a mass-scale possible. [2]

"Technology can offer several advantages to address the challenges of urbanization and spatial inequalities. However, technology can also create further divides if the access is constrained. Providing goods and services through digital technology-driven channels is the key focus. The traditional marketplace is fast transforming into a digital mega-market, reaching millions at a time and aiming to provide economic goods and services in a frictionless manner. Retail business has been at that forefront." [1] (Anupam Nanda et al., 2021)

1.2 Relevance and delimitation of the research problem area

The pandemic has changed consumer habits in a way that more of customers are now comfortable with purchasing products online. Even products they never imagined to shop digitally before, and this new type of customer has an impact on retail stores. Predicted future directions of retail are very broad and unidentified and this period may be more critical for retail than any other. The position of traditional retail is questionable and there are many views on its future.

1. Anupam Nanda et al. "How would the COVID-19 pandemic reshape retail real estate and high streets through acceleration of E-commerce and digitalization?" [Online], Journal of Urban Management, 2021

2. Sayyida, S. et al. "The Impact of the Covid-19 Pandemic on Retail Consumer Behavior" [Online], Aptisi Transactions on Management (ATM), 2021

"One of the most important questions right now....what we see in other parts of the world (China) that are ahead of us... is a big move away from flagships because the rent is too high."
(Deborah Weinswig, the CEO and Founder of Coresight Research, 2021)

"It will make it much more likely for retailers to deliver the services that only small stores in small towns could deliver until now, knowing each customer by name, understanding their tastes and making suggestions that are appropriate just for them."
(Lewis of The Robin Report, 2021)

"You might have a few flagship stores in urban areas where they can perform well but they will...transform into destinations for entertainment and experience and shows and events as an attraction to get consumers to come in."
(Robin Lewis, CEO of The Robin Report, 2021)

Collaborations between brands are happening in order to share the cost of rent, to create more effective use of a shop floor and to drive more traffic. The stores face a challenge to become more than just a trading destination. The profession of a store seller and manager will also change, since their task is to attract a customer who knows they can get same products online. The future retail success won't be measured in sales anymore, but experience. Retail stores will need technology as a support to keep the store efficient for retailers and effective for customers. In order to attract customers to come in, they need to lean towards creativity and build new skills that customers won't get anywhere else. [16]

1.3 Objective

The objective is to optimize the relationship between consumers and commerce, finding an opportunity to improve it right in the post-pandemic digital transformation within retail. The thesis analyzes the way our values could be pursued through alternative retail and how its development can adapt to our ethics. It seems like consumers strive towards sustainability, mindful shopping and wasteless consumption, but some factors of reality make it hard for the end-users to follow these beliefs. Decisive factors could be price, time, convenience or effort.

Proposed concept of retail can be one of many alternatives for its future form that hands out a base for meaningful commerce. A type of commerce where we don't shop with a feeling of short-time reward, but we learn, experience and appreciate products. It aims to combine culture and commerce in one place to deliver appropriate good-quality entertainment, give opportunity for retailers to deliver luxury service with convenience, affordability and accessibility, and to create a modern meaning of shopping.

A bigger picture of this transformation is having less individual brick-

16. Richard Kestenbaum, "How Retail Stores Need To Change And Adapt In 2021 And Beyond" [Online], Forbes 2021

and-mortar retail stores in cities, but at the same time offering even more variety of brands with digital technology. Consequently the spaces not used by brick-and-mortar retail stores (usually retail stores are strategically placed in city centers) can be used for public services and community enriching activities. With the emergence of smartglasses, one day we might see cosumers to own a personal pair of mixed reality glasses in a near future, just like they possess a smartphone nowadays. Because of its digital character, products and content can be reached by anybody owning smartglasses and become less exclusive or elitist.

According to TPH Report "The future of luxury fashion" [17], the traditional retail no longer appeals to the new type of customers and the industry is shifting towards more sustainable and ethical products with a great experiential component. The term "new type of customers" represents 61% of the luxury market by 2026, consisting of Millenials and Gen Z.

1.4 Hypothesis

One of the possible future directions for current retail is an alliance with emerging technolgy due to its user=customer outreach, optimization of processes and yet undiscovered digital possibilities. A new form of retails adapted to a post-pandemic type of customer, a sustainable vision of the future, a generation of tech-savvy consumers, a boundaryless system of the Internet and information.

From these factors emerges a concept of A Mixed Reality Store. A store which combines benefits of a physical and virtual shopping. It has a real location, or locations, but the difference between a casual brick-and-mortar store and a mixed reality store is having no physical products on a shop floor. The interior is empty from commercial items and possibly even staff. But when a customer enters wearing smartglasses, a pair of goggles enabling a user to see mixed reality content, a whole other world opens up to them. All objects and other entities have a digital form and customers can interact with items and speak to a virtual agent.

The Internet's quick adaptation and an enormous amount of information that people are able to access nowadays, will potentially lead to more careful customization of received content. Consumers will wish to set their preferences of content they are being exposed to outside of their homes, such as daily news, advertisements, museum exhibitions, posters, movies etc. [12] Due to the nature of digital information, virtual content can be transferred and modified across the world in a satisfyingly high speed, especially with the growing adoption of 5G. The Internet can save user's time and work, create networks and provide a large scope of information to anyone who has access to it. [1]

When imagining a situation when a physical product is represented by an identical virtual object, the user is able to interact with it in a way they

1. Anupam Nanda et al. "How would the COVID-19 pandemic reshape retail real estate and high streets through acceleration of E-commerce and digitalization?" [Online], Journal of Urban Management, 2021

12. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online]. Applied Sciences, 2020

17. Sara Teixeira, "The future of luxury fashion Report 2021" [Online], ThePowerHouse, 2021.

can only do in the virtual world. This situation is familiar for e-commerce when a customer analyzes the product through product photos and videos on a website. The most common layout until today is Amazon's shop interface created 25 years ago to sell books. Companies like IKEA developed a mobile app called "IKEA Place" based on Augmented Reality Technology. It helps customers to imagine furniture pieces in their homes, making sure the colour, size and texture fits their needs. It is also possible to order products directly to their homes from the same mobile app. [18]

Both of previously mentioned actions, browsing on a web and previewing a product through augmented reality app are limited to a 2D screen. But our world is three-dimensional and we are very much used to physically interact with a product we are interested in. We approach it, touch it, maybe spin it around to see the whole form, lift it ,maybe smell it or even taste it. Activity behind 2D screens like laptops and mobile phones lack natural body movement and eyesigth overview. [12] And thats is the reason there might be a bright future for mixed reality technology.

1.5 Research question

Is Mixed Reality technology going to impact retail in the creation of interactive virtual stores?

Secondary: What are they going to look like?

Sub: What are the factors? What are the tools needed?

1.6 Methodology

The research problem deals with a critical situation in the retail industry. Customers change their purchasing practices with online stores, social distancing and closure of brick-and-mortar stores have forced consumers

12. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online]. Applied Sciences, 2020

18. Obsess, "About" [Online], Obsess. [Retrieved 12 July 2021] Available at: https://obsessar.com/about/

to adapt to “order and delivery” consumerism. Retail stores are challenged to come up with ways to attract customers with features that online stores can’t.

This research involves literature review of previously published articles related to the impact of digitalization on retail, current state of mixed reality technology and suggested guidelines on creating a mixed reality system. The articles were searched using keywords in databases such as Springer Link, Mendeley, Google Scholar, Elsevier and Google Search. Reading material is selected based on its connection with creating a mixed reality system. Afterwards the literature is filtered, divided into categories and later put into a logical sequence. Starting with understanding the current state of the retail industry, analyzing the emerging mixed reality technology and then possible implication of the technology into the environment. Afterwards a prototype is developed to test out the hypothesis.

“It’s time to have a serious conversation about retail, and what it will look like in the future. Retail leaders must first understand what customers actually want now and then begin to craft online and in-store experiences that align with consumer expectations and appetite for shopping for categories in both places.” [17]
(Greg Petro, founder of First Insight, 2021)

Design process starts with understanding potential users through a survey. Its results form a customer journey to help imagine customer’s potential steps, needs and wishes. The journey serves as a guideline for sketching an app interface and architectural layout. Since the technology involved is a blend of the real and virtual world, proposals for both physical and digital contents are designed. In this thesis, the prototype is a mixed reality system. The system is given a concrete structure, function and location.

17. Sara Teixeira, "The future of luxury fashion Report 2021" [Online], ThePowerHouse, 2021.

Following illustration shows a methodology for design process:

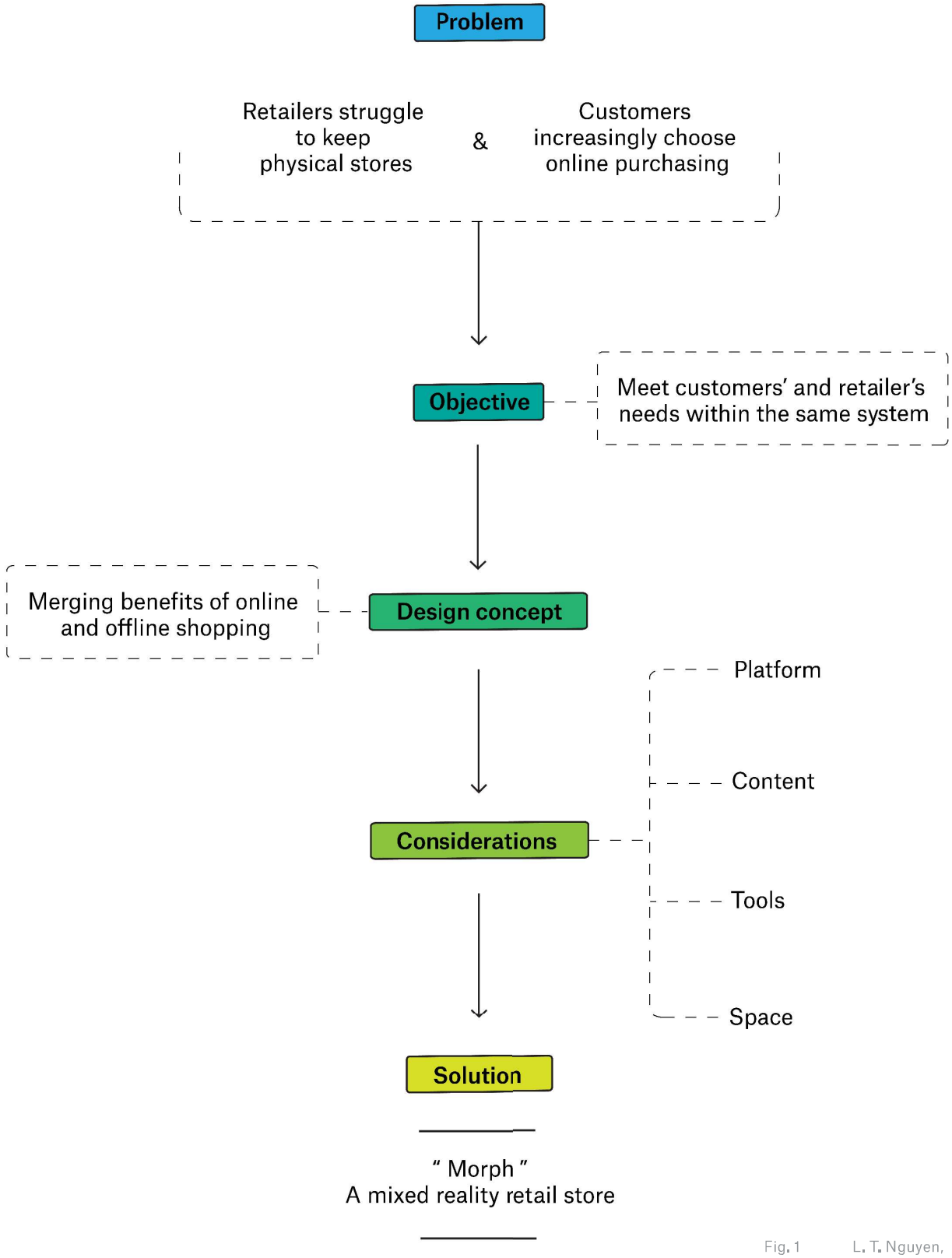

Fig. 1

Fig. 1 L. T. Nguyen, "Methodology for Design Process" [Illustration]. Own source, 2021

Digital disruption in Retail

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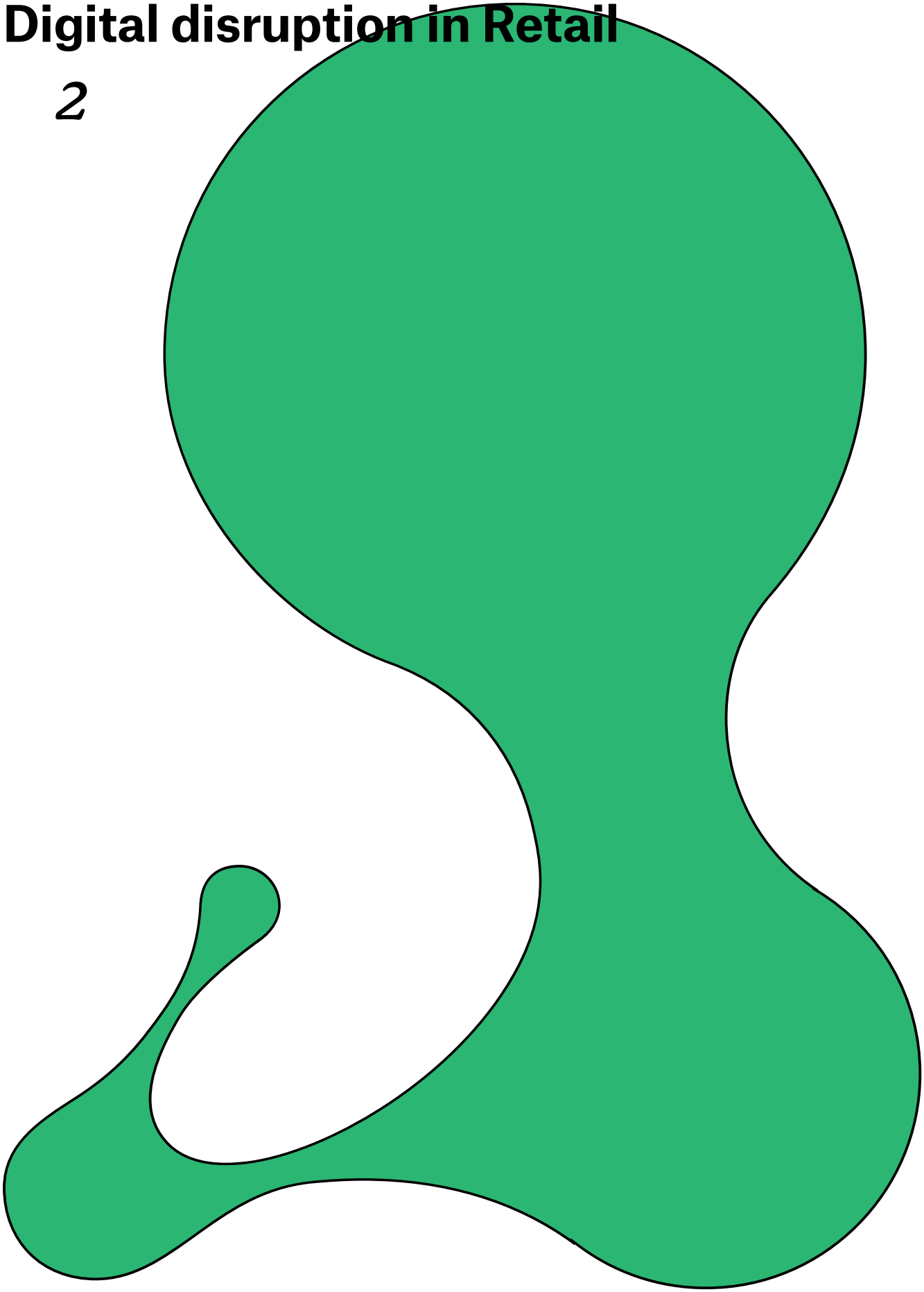

2 Disruptions and digitalization in Retail

2.1 COVID-19 implications, e-commerce and digitalization

2.1.1 The emergence of online platforms and switch to online retail

Retail industry has taken a new form with an online retail platform. Customers have a chance to select from competitive prices and retailers pay lower operating costs.The improvement of contactless payment and distribution systems has brought online platforms from an alternative to the physical store to a mainstay. The relationship between online and brick-and-mortar stores is therefore uncertain whether the online platform is a substitution or a complementary element. (Fornari et al., 2016)

Several studies (Ansari et al., 2008; Mehra et al., 2013) adopt a theory where a consumer would abandon the other channel once they favor one shopping channel. The increasing popularity of online platforms would make customers convert from physical shopping to the digital. Alongside this theory, other studies (Mehra et al., 2013) have highlighted benefits of collaborations between in-store and online shopping. In this synergy, two functions in a customer experience play important roles. These include “showrooming” when a customer visits a physical store, undertakes a research on a product but the purchase happens online. Another function is when an online channel is not capable of delivering in-person interaction and creating an atmosphere to amplify the sensory experience. Therefore combining both channels can increase sales opportunities. While much of these have been forming over the last few decades, the recent COVID-19 pandemic proved to be transformational and its impacts are just about to be experienced. [1]

2.1.2 Pandemic implication

As we might have seen in the past, disasters and crises have huge impacts on consumption behaviour amongst other aspects. During COVID-19 pandemic a visible growth of online shopping and food delivery appeared, sometimes out of necessity. [2]

Online retail platforms can help the retailer to survive and adapt to pandemic circumstances. Health restriction measures have helped some sectors such as retail, food delivery and durable goods, on the contrary sectors such as restaurants, hospitality and entertainment had felt the negative impact. Regarding the property sector within retail, studies (Ailawadi et al., 2014; Elg and Hultman, 2016)

1. Anupam Nanda et al. "How would the COVID-19 pandemic reshape retail real estate and high streets through acceleration of E-commerce and digitalization?" [Online], Journal of Urban Management, 2021

2. Sayyida, S. et al. "The Impact of the Covid-19 Pandemic on Retail Consumer Behavior" [Online], Aptisi Transactions on Management (ATM), 2021

revealed that tenants require flexibility, allowing a shorter rental period in property management, especially after COVID-19.

As retail businesses are trying to recover from left traces of pandemic, they may consider reorientation of business strategies and repositioning their goals together with optimization of physical and digital entities in their business.

2.1.3 Re-identifying the function of physical stores

Retailers shall reconsider the role of physical stores. The key is not to reduce the proportions of retail properties but to identify the function of physical stores. According to research [1], two participants of an interview, retail managers, asserted that an anonymous brand is keeping 20 to 30 stores across the country and a big part of their business is moving online. Physical stores are kept to function as a closet to showcase products. Moreover they will do some sales in-store but it is becoming more and more official to end the sale online. Both participants agreed that the function of physical stores is transforming and with COVID-19 pandemic, retail stores may be soon re-identified based on the needs of retailers. [1]

2.2 The impact of the covid-19 pandemic on retail consumer behavior

Just how the history was stirred up by the recent pandemic, consumer behaviour changes alongside the event. The situation and amount of time spent inside homes made it very attractive to purchase products online. Despite its convenient use, there are other consumer needs affecting the holistic experience which are not found, such seeing and touching the product, feeling its quality and smell.

Digital era brings four types of consumer behaviours. Pure online shopping and pure offline shopping, both using only one channel to carry out the whole process. Pure online shoppers search for products on digital media and make a purchase online, whereas pure offline shoppers are traditional shoppers who carry out the entire process in-store. Webrooming and showrooming are other types of consumer behaviours. In the omnichannel era they are combining online and offline channels. Webroomers search for product information online and afterwards purchase in-store. Showroomers find products in offline stores and make purchase online. Webroomers and Showrooms aim to save money and ensure a quality product. In 2018 reports showed that 52% of total consumers were webroomers and 30% were showroomers.

Online retail sales cover less than 30% of total retail sales, meaning that offline sales still represent the majority of global retail sales. The pandemic did impact retail consumer behaviour but to a small degree, less than 10% of increase. Data analysis [2] showed a change in consumer behaviour

1. Anupam Nanda et al. "How would the COVID-19 pandemic reshape retail real estate and high streets through acceleration of E-commerce and digitalization?" [Online], Journal of Urban Management, 2021

2. Sayyida, S. et al. "The Impact of the Covid-19 Pandemic on Retail Consumer Behavior" [Online], Aptisi Transactions on Management (ATM), 2021

during pandemic, consumers tend to get informed through digital media before making a purchase at physical stores. Their need to touch desired products still remains to be important despite social distancing. [2]

2.3 Current State of Mixed Reality Technology for Digital Retail

Mixed Reality is relatively well-known for its wide usage in various sectors. Industries have been deploying the technology since its first introduction in 1944. The technology has been evolving for a few decades, but there are still some parts to improve and fix. This section will describe current state of MR with a focus on retail industry, specifically digital retail.

The term “digital retail” can be understood as a type of retail which facilitates different digital technologies. Starting from online retail stores, digital retail is now moving towards Omnichannel Retailing which integrates physical and digital stores in different forms.

There are several definitions of Mixed Reality by different authors, for the clarity and universality this section will follow the notion of MR based on Reality-Virtuality Continuum introduced by Milgram et al. (1994) Mixed Reality is anything in between two extremes of the continuum, where real and virtual objects are presented on a single display.

According to Microsoft (2018), perception and Human-Computer Interaction (HCI) are key subjects of MR from a scientific viewpoint. Therefore display technologies have been putting a lot of focus on the quality of interaction between a user and a display or device. Therefore it is necessary to study User Experience, for which it is important to understand Omnichannel Retail, because the base of Omnichannel Retail stands on customer experience. As the subject of this research, the user is the customer. [4]

2.3.1 Display

The authors of “A taxonomy of Mixed Reality Visual Displays” Paul Migram and Fumio Kishino (1994) defined Mixed Reality displays as a subset of VR displays. Further on the division ends up in creating 6 classes of displays. Mobile Augmented Reality has so far become the most popular one, due to its accessibility and ease of use. Apps such as Pokémon Go and IKEA Place helped in spreading the technology worldwide. AR display is defined as class 4 “video see-through” MR displays. Optical see-through head-mounted displays are considered as class 3 MR displays. A representative from this class is Microsoft HoloLens which was claimed to be “ the future of Augmented Reality” in 2016 by Microsoft. HoloLens technological capabilities are HoloLens two-core gestures, voice-based interactions, gaze-controlled UI pointers and artificial intelligence.

4. Jain S., et al. "Current State of Mixed Reality Technology for Digital Retail: A Literature Review." [Online] Springer, Cham, 2019

Despite software and hardware limitations nowadays, HoloLens can be one of devices to profoundly change our relationship with computers and even the environment. Overcoming hardware limitations in the future, users could interact with the environment with more digital information through a pair of eyeglasses representing a computer.

2.3.2 Perception

Mixed Reality content is produced in forms of 3D digital objects blended with real environments in various proportions. Compared to 2D content, 3D digital content is in the early stage of developing visual qualities and general characteristics. Present literature encourages us to look at 3D content beyond just pixel density and resolution. Some researchers propose a model-based perception quality assessment where spatial and temporal features can be benefitted from.

2.3.3 User experience

The way 3D content is perceived through a user becomes crucial in Mixed Reality, hence user experience and quality of the content needs to be determined. The study around user experience includes human-computer interaction through user interfaces, a holistic experience considering environments, psychological factors and quality of the content. [6]

2.3.4 Digital Retail and Mixed Reality

Omnichannel retail as a successor of Multichannel Retail, moves from a system of synergies between online and offline channels towards a system where the concept of channels slowly disappears and focus is put on points of contact. A vision of Omnichannel Retail is collaboration of physical, online and mobile stores as a seamless customer experience. Researchers (Jain S., Werth D., 2019) predict a shift from a product orientation to customer experience orientation in Retail.

Customer experience in Retail can be analyzed as User Experience, since a primary user is a customer. In the Retail industry, User Experience can be affected by Product Experience when psychological effects of customer and product interaction are well thought-through. Customer experience is closely tied to Customer Satisfaction, since satisfaction influences the perception of the content. [4] Researchers (Papagiannidis et al., 2017) suggest that enjoyment and engagement during an immersive experience increases a positive impact on customer satisfaction which influences the intention to purchase the involved product. [6]

The type of customer experience where technology is applied directly in customer-product interaction, highly depends on a

4. Jain S., et al. "Current State of Mixed Reality Technology for Digital Retail: A Literature Review." [Online] Springer, Cham, 2019

6. Papagiannidis, S., et al., "To immerse or not? Experimenting with two virtual retail environments" [Online], Emerald Publishing Limited, 2017

technology acceptance. Researchers (Jain S., Werth D., 2019) reviewed acceptance of AR applications in retail where AR-users have found all necessary information in the store and rated the offer of information better than non-AR-users. Studies on MR applications have also brought a positive conclusion constructed on perceived usefulness, ease of use, personal innovativeness and enjoyment. [4]

2.4 V-commerce in Retail

Few uses can be currently referred to as the term "V-commerce". Some literature relates v-commerce to digitally vertical brands, some understand it as virtual commerce and others refer the terminology to voice commerce. For understanding the topic of virtual commerce clearer, following section will break down previously mentioned meanings of v-commerce. [7]

2.4.1 V-commerce definitions

Vertical commerce

Vertical commerce can be described as merging two or more production stages or distributions, which used to be separated before, under a single ownership (Buzzell, 1983). Brands practicing this type of integration are called Digitally Native Vertical Brands. They are usually born and based on the Internet and put focus on customer experience. E-commerce serves them as a main sales channel, place of interaction with customers and storytelling. Digital brands rely on a loyal customer base and user-generated content to spread the word and promote the brand. Managing several stages under a single ownership in vertical commerce means that these brands skip traditional supply chains or distributions and deliver and follow direct-to-consumer models. The aim is to offer high-quality products with a reduced cost. A down side of a vertical commerce is a question of scaling up the brand.

Virtual commerce

Virtual commerce utilizes through mediums like Augmented Reality (AR), Mixed Reality and Virtual Reality (VR). AR is understood as a technology which provides an enhanced version of the real world by superimposing digital information on top of the real environment, which can be viewed through screens of smartphones or AR smart glasses. MR provides real-time interaction with and between digitally rendered and real-world environments through mixed reality headsets. VR is defined as a fully immersive and responsive 3D computer-generated environment running on advanced input and output devices. Therefore de Regt, Anouk & Barnes, Stuart (2019) define virtual commerce as "electronically mediated commercial transactions that

7. de Regt, Anouk et. al, "V-Commerce in Retail: Nature and Potential Impact" [Online] 6th European Conference, 2019

originate from an alternate reality technological platform and involve either digitally-generated or real-world products and services".

Voice commerce

Development of artificial intelligence, specifically the field of Natural Language Recognition has enabled brands to provide voice activated commerce for self-service transactions and other spoken command actions. Conversation-based commerce grows due to technological progress in the fields of artificial intelligence, machine learning and cloud computing. Besides technological development, consumer acceptance of voice activated technology is necessary to rise as well. Examples of conversational user interfaces are Amazon's Echo or Google Home. Despite its convenience, voice commerce raises questions regarding personal data collected from voice interactions. But as the industry leaders continue to innovate, voice commerce is likely to grow and be adapted in future commerce. [7]

2.4.2 Current implementation of virtual commerce

Augmented and Virtual Reality technologies stand behind a technological and social shift in transitioning from Internet of information to Internet of experiences. And there lies a potential of virtual shopping - to transform shopping experiences and provide almost a real-world alternative. When the virtual user-interface is properly designed, it can support natural shopping behaviour by implementing personalized, immersive and interactive experiences. From the social point of view, the drivers of this technological shift will be younger generations since they are technically savvy, associate themselves with brand's identity and already spend more money on experiential purchases.

Virtual commerce creates an opportunity for customers to explore different features of the product before purchase. Research by Chesney et al. (2017) indicates that this type of integration has a potential to bridge the trust deficit that might have prevented people from shopping on web-based platforms in the past with future digital retail platforms. Various retailers are already experimenting with virtual commerce and it is expected to spread globally in the near future. Two main alternate reality technologies are mostly used in a retail field so far are Augmented and Virtual Reality. [8]

Augmented Reality implementations

The most commonly known is a try-on technology in clothing or make-up companies. Another sector where AR's features are used is jewellery. Indian company CaratLane introduced the first 3D jewellery try-on app implementing facial recognition and 3D jewellery objects and allow customers to view themselves wearing jewellery on a laptop screen or a smartphone. MAC Cosmetics uses the technology on location in their New

7. de Regt, Anouk et. al, "V-Commerce in Retail: Nature and Potential Impact" [Online] 6th European Conference, 2019

8. Chesney, T., et al., " Information richness and trust in V-commerce: implications for services marketing." [Online], Emerald Publishing Limited, 2017

York retail store through Stationary Virtual Mirrors. Another example is the IKEA Place app which allows customers to place the selected piece of furniture virtually inside their homes. Streetmuseum is a location-based AR app which allows visitors to explore historical information about landmarks in London. So far most of the consumer AR apps work on hand-held devices like smartphones, but the development of AR wearables seems promising, particularly Augmented Reality Smart Glasses. [7]

Virtual Reality implementations

Online commercial giant eBay and the Australian retailer Myer created the first virtual department stores implementing VR as a sales channel. Visitors could preview real-time information, inspect the product (zoom, rotate, move) on smartphones and finalize the purchase through the app. Additionally Sydney residents could sign up for a virtual exhibition. Using VR to build and express brand identity can take up many forms such as storytelling, New Your Times in collaboration with Google created a line of 360 degrees virtual reality films, Chevrolet showcasing features and functionalities through VR product demos, Topshop London Fashion Week live-streaming events and co-creation like NIKEiD Studio.

It is still unclear if VR platforms will replace e-commerce in the full process. V-commerce is great for brand-consumer interaction that can complement current digital and physical channels. Therefore retailers who are following the omnichannel strategy should consider how to implement VR in their overall approach towards customers. The Marketing Science Institute has encouraged future research to look at real-time, integrated and relevant experiences, e.g. contextual differences between online and offline settings, differences between consumer segments, cross-channel effects from v-commerce and traditional commerce. [7]

7. de Regt, Anouk et. al, "V-Commerce in Retail:
Nature and Potential Impact"
[Online] 6th European Conference, 2019

Mixed Reality Technology

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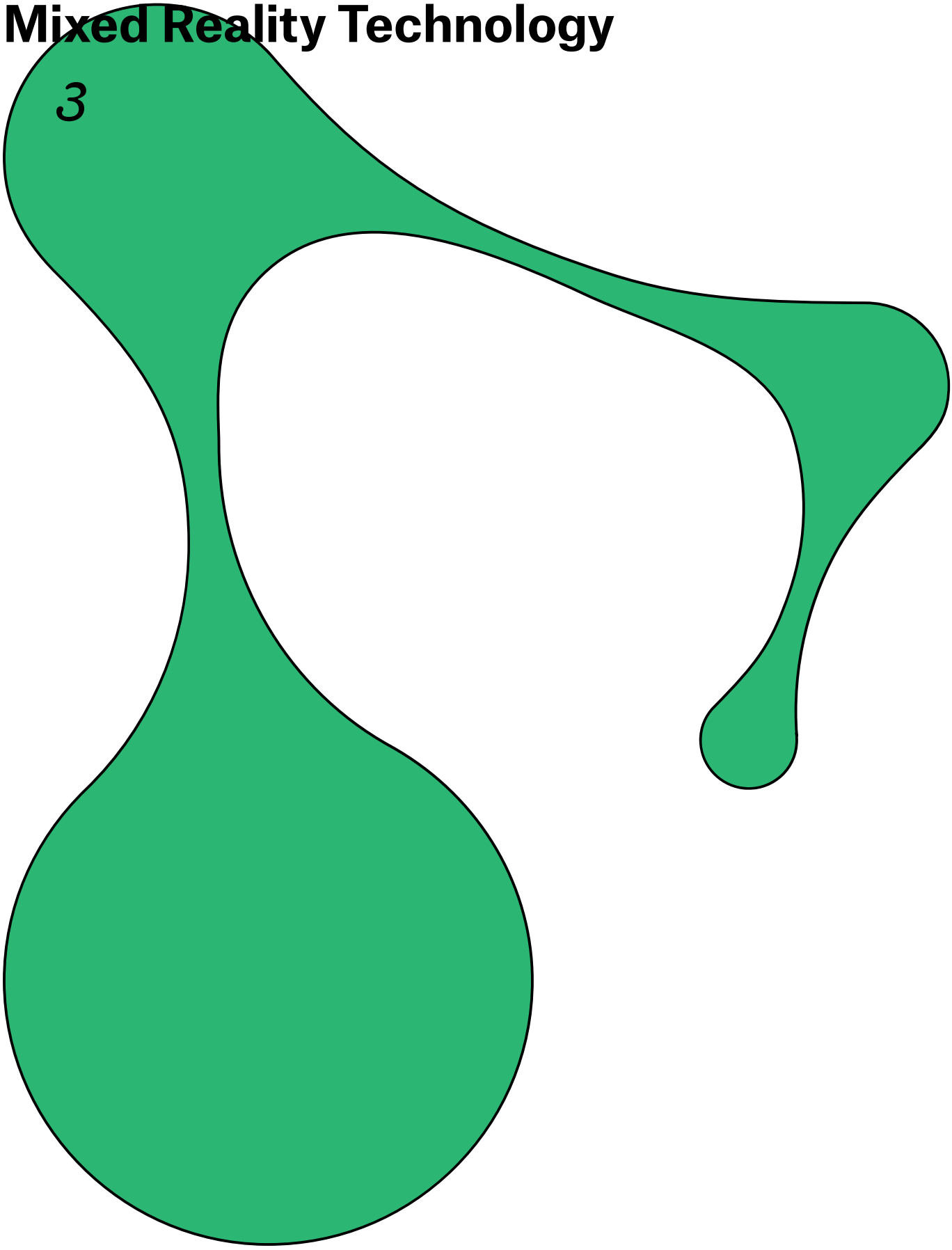


3 Mixed Reality Technology

3.1 Definition(s) of Mixed Reality

Mixed Reality (MR) technology has touched upon many sectors in the past few years and its many possibilities of implication raised the popularity and relevance of this technology. Even though Mixed Reality was already talked about since 1994 there is no universally agreed notion. Many times the understanding of MR is interconnected with Augmented Reality (AR) and Virtual Reality (VR). A widely used definition of MR is a part of Reality–Virtuality Continuum by Milgram & Kishino's (1994), where MR exists as a superset of AR in terms of constituting virtual and real elements within a single display. Following section is working towards a common understanding of the term "Mixed Reality".

As mentioned before, the widely spread understanding of MR is based on Reality-Virtuality Continuum. Yet from the expert interviews and selected literature, researchers realized that it is not a universal notion. Arguably because the continuum is restricted to visual features. Background of Mixed Reality are Computer Graphics indicating that its common notions are drawn to its graphical aspects. Since 1944, when the continuum was first proposed, MR technology evolved together with its technological capabilities, design practices and perceptions from various sectors. Therefore it is valuable to identify different definitions across academia and industry to analyze their differences, relations and limitations. [3]

3.1.1 Milgram et al.'s continuum

Milgram et al. (1994) noticed that at the time the term "Augmented Reality" did not hold a consistent definition even though it was already appearing frequently in literature. Therefore in 1994 they proposed the continuum to better describe meanings of AR, MR and VR and how these realities intersect.

Reality-Virtuality Continuum has two extremes, a fully real environment and a fully virtual environment on the opposite side. Everything in between is considered as MR. Subsets of MR are Augmented Reality, a big portion is real environment augmented with some visual elements, and Augmented Virtuality (AV), partially immersive but still a bigger portion is augmented and a small amount of real environment is added. This continuum is still probably the most popular source when it comes to notions of MR, even though it was created in the 90's. For this reason it is questionable if the definition still applies to current capabilities of MR, because the continuum focuses mainly on visual displays. [3]

3. Speicher et. al., "What is Mixed Reality?" [Online]. ACM CHI Conference on Human Factors in Computing Systems, 2019

3.1.2 Aspects of reality

Commonly known elements of AR are virtual 3D models, which are added to a real environment, and a single display. Although there are also other aspects of MR which are not widely acknowledged and can be simulated in a virtual environment.

Audio

One of the first examples is Audio Aura, where the real environment is augmented with auditory cues instead of digital objects. Another project mixed visual and audio elements resulting in a sound design in MR and VR.

Motion

So far the technology is not capable of augmenting the physical world with motion digitally, but it is an important aspect when it comes to blending virtual and physical realities by manipulating digital objects with movement.

Haptics

Has been looked into as inputs (e.g as tangible user interfaces) and outputs (e.g. devices that enable feeling of virtual objects with hands).

Smell

Is another important element in creating an immersive experience. Examples of projects included authentic smell diffusion (Ramic-Brkic, Belma & Chalmers, Alan, 2010) or smell presentation as augmentation for movies. [6]

3.1.3 Existing notions of Mixed Reality

When researchers (Speicher, D. Hall, Nebeling, 2019) interviewed academia and industry experts, they noted a continuous struggle to define AR and MR. Whereas VR has a clearer distinction in terms of visual and hardware aspects. Seamingly, relevant features for MR required spatial registration and a portion of the real environment. As well as having a user present and being in control is also necessary. Most of them agreed that a single definition of MR would be useful, but at the same time pointed out that in the future we might not use this terminology anymore. When analyzing the collected literature, a clear segregation of papers was not always possible and some of the papers were put under two notions. [3]

Following notions are a combination of experts' (Speicher, D. Hall, Nebeling, 2019) understandings. They point out that the definitions still overlap and are not mutually exclusive.

3. Speicher et. al., "What is Mixed Reality?" [Online]. ACM CHI Conference on Human Factors in Computing Systems, 2019

6. Papagiannidis, S., et al., "To immerse or not? Experimenting with two virtual retail environments" [Online], Emerald Publishing Limited, 2017

Continuum

Taken from Reality-Virtuality Continuum by Milgram et al.'s. Realities (1994) are a spectrum of various combinations of digital and real objects on a single display. The spectrum ranges from a fully virtual and fully real world and a mix in between can represent AR, which is mostly real world with digital objects superimposed, or Augmented Virtuality, which is mostly virtual world in combination with some real objects.

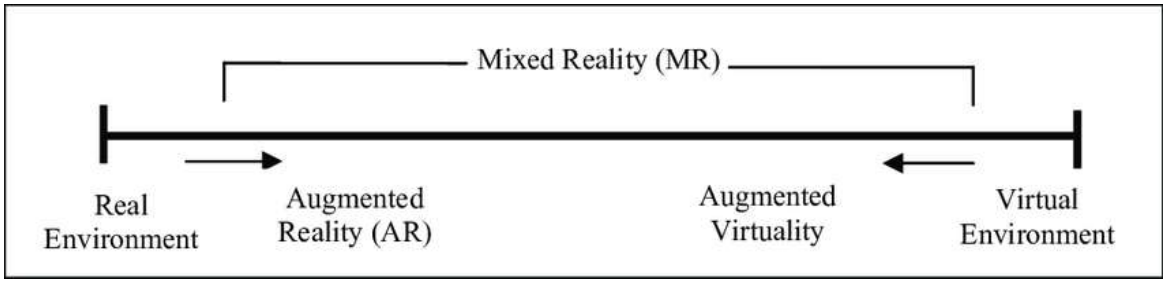


Fig. 2

Synonymum

Another common explanation of MR is a synonymum to AR, where interviewed experts used a notion of AR to describe MR.

Collaboration

In this situation MR is a type of collaboration between AR and VR when two users are most probably physically separated.

Combination

Combination can be unserstood as portions of AR and VR interacting but are not tightly integrated, or as a device which htat can switch between AR and VR when necessary.

Alignment

Perception of MR as an alignment of virtual and digital environments. This notion overlaps with notion of collaboration, but without environments being separated and notion of combination, but environments as not distinctively AR or VR.

Strong AR

MR perceived as a more capable version of AR in terms of environment understanding and interactions. [3]

3. Speicher et. al., "What is Mixed Reality?" [Online]. ACM CHI Conference on Human Factors in Computing Systems, 2019

Fig. 2 Milgram et al., Milgram Reality-Virtuality Continuum (1994) [Printscreen]. In: Speicher et. al., "What is Mixed Reality?" [Online]

3.2 Mixed Reality devices

3.2.1 Types

Head-up Displays

Augmentation is fixed in head up displays (HUD) where information is projected on a transparent screen mounted in front of the user. For instance, this installation allows pilots to look forward and still be informed during critical situations. The projected information is parallelly focused on infinity so pilot's eyes do not need to refocus outside the cockpit. An HUD consists of a projector, a viewing glass and a computer.

Holographic displays

Holographic displays generate 3D virtual scenes that appear with a natural depth of field. Depth perception is important for user's comfort in terms of correct interpretation of what we see in the world. Around 18 depth planes are distinguished for you to understand distance between objects, which are crucial for the brain to understand the surrounding. An advantage of holographic displays is an ability to achieve realistic depth perception, one of many features needed to be satisfied for a comfortable AR mass consumption.

Smart Glasses

Smart glasses are wearable devices that generate AR content on transparent glass within the user's viewpoint. Due to its comfort and practical aspects smart glasses became the more wanted type of augmented reality device. There are categories of smart glasses:

1. Optical see through: the user views reality directly through transparent glasses. Optical see-through glasses work on a base of holographic wave guides and other systems enabling graphical overlay on the real world. Known examples include smart glasses with simple graphical geometry like Google Glass and more complex one like Microsoft Hololens.
2. Video see through: the user views reality through video feeds on a screen. Video see-through glasses have one or two cameras mounted on a device which firstly capture a view and then combine it with computer generated imagery. Examples are traditional mobile AR or HTC Vive VR headset which has an inbuilt camera often used for AR content.

Handheld AR

Handheld AR is a type of video see through. It enabled technology to be truly used on a mass scale, available for anyone that owns a smartphone. [19]

19. Akshay Kore, "Understanding the different types of AR devices" [Online]. UXCollective, 2018

3.2.2 HoloLens

Hololens is one of the most popular devices used in mixed reality applications. Mixed reality simulations are widely used in medicine and aviation for training purposes, because learning with virtual reality can save on operational cost, deliver the same knowledge and potentially increase student's interest. Visualization of learning material allow students to understand the context faster and better comparing to the conventional learning.

Fig. 3

Fig. 3 shows a HoloLens device consisting of a complete holographic computer, capable of running Windows 10 operating system. HoloLens enables the user to see holograms, which they can move, annotate and shape according to their needs or the surrounding environment. This augmentation is possible through reflected virtual objects optically into the real world. The screen has a resolution of 1268 x 720 pixels with a 16: 9 frame per eye. To map the surrounding, 4 cameras are mounted on a device to detect ambient light and sensing the depth. Additionally HoloLens has integrated speakers and 4 microphones. The processing unit has 2 gigabytes (GB) of random access memory, 64 GB of internal storage and supports wireless connectivity WiFi and Bluetooth. Battery life reaches 3 hours of active use. HoloLens are connected to the Internet just as a smartphone or a laptop through a wireless network, but only the network which supports 5-Ghz.

In the academic field, this technology allows access to virtual environments which for some reason can not be accessed in the real world, such as virtual labs, virtual machines, industrial plants. Mixed reality brings in more efficient learning by involving the student directly through interactive high-definition holograms. [9]

9. Islami et. al., "Identification of technology-based mixed reality device" [Online], IOP Publishing Ltd, 2017

Fig. 3 Microsoft, Microsoft Hololens equipment [Printscreen]. Islami et. al., "Identification of technology-based mixed reality device" [Online]

Some of the features that HoloLens provides:

Spatial Sound

It can feel like the sound comes from a point or virtual location in the environment due to clear and real sound effects.

Gaze tracking

Technology which tracks what and where the user is gazing at in order to create or modify 3D illusions.

Gesture input

Allows users to interact with virtual objects through hand commands such as pull up, tap and select.

Voice support

Voice commands are processed through voice recognition. [9]

3.2.3 Vive HTC VR Headset

Vive HTC VR Headset was developed by companies HTC and Valve. The device uses spatial tracking technology allowing a user to move safely in a 3D space and uses two handheld motion-tracking controllers to interact with the digital environment. It allows the user to be fully immersed in a virtual world. This device consists of a head-mounted display system - including a processor, a display and a casing. [10]

Fig. 4

9. Islami et. al., "Identification of technology-based mixed reality device" [Online], IOP Publishing Ltd, 2017

10. HTC Vive. In: Wikipedia [Online]. Wikimedia Foundation, Inc., 2021

Fig.4 HTC, HTC Vive VR Headset [Printscreen]. Islami et. al., "Identification of technology-based mixed reality device" [Online]

Fig.4 shows an example of an HTC Vive VR Headset. Since the device doesn't deal with the external environment, the resolution is higher, the refresh speed is faster and the display is wider, 1080 x 1200 pixel, at a much lower cost. The tracking technology uses an inside and outside principle, where instead of a camera tracking the external environment, in this case two boxes (base stations) send out vertically and horizontally infrared laser sweeps stretching 360 degrees each direction. In order for the HTC Vive VR Headset to connect digital and real environment it must consist of 3 parts - a headset, two base stations and two control components.

In terms of learning, HTC Vive enables students to have a clear overview of the components in the learning process, for instance assembling electric motors . The interactivity leads students towards an experiential learning. [9]

An upgraded version is HTC Vive PRO featuring a higher-resolution display 1440x1600 per eye, attachable headphones, noise filtering microphone and a more balanced lighter equipment weight. [10]

3.3 Ethical Implications of Emerging Mixed Reality Technologies

This section deals with reflections upon emerging technologies AR, MR and VR. Its aim is to understand the relationship between humans and technology, and their impact on each other in order to strive towards a responsible technological development. Following information is a review of an article "Ethical Implications of Emerging Mixed Reality Technologies" by Marcus Carter and Ben Egliston from Socio-Tech Future Labs, published in 2020. [14]

3.3.1 Ethical frameworks for XR

Most of the literature reviewed by the authors of [14] is concerned with ethical issues that XR technology exposes users to. One of the most appreciated perspective comes from Kudina and Verbeek (2019). They mention two responses to the rapid technological change coming from opposite sides of the spectrum. The issue appears when the technology is not widely adopted yet, hence predicting impacts might be too speculative. On the other hand, when the technology is already widely adopted for a long time, it is more difficult to challenge its power and impacts. Therefore they came up with a potential solution which is paying further attention to mediation, especially how an individual envisions development of technologies which are framed by corporations. Kudina and Verbeek's advice is to observe human practices and analyze whether the technology will fit or clash with the existing values.

9. Islami et. al., "Identification of technology-based mixed reality device" [Online], IOP Publishing Ltd, 2017

10. HTC Vive. In: Wikipedia [Online]. Wikimedia Foundation, Inc., 2021

14. Carter M., Egliston B., "Ethical Implications of Emerging Mixed Reality Technologies: The University of Sydney" [Online]. The University of Sydney, 2020

3.3.2 Expectations of privacy in public space

The topic that individuals are perhaps most concerned about is privacy in public spaces since the notions of AR and MR lean towards characters of a surveillance system. Some (Wolf et al. 2018) were questioning the issue of what and who is being surveilled, with a focus on privacy of people and objects in the environment that tend to be around the user of the technology. Wolf et al. (2018) suggest besides questioning privacy of AR and MR in terms of a visual medium, voice and sound present in the environment should be also considered as they are currently overlooked in AR privacy discussions. Other works (Mann, 2013; Denning et al., 2014) envision AR as a platform for "sousveillance". This term indicates a place where everyone can surveil, it challenges a hierarchical top-down surveillance. For instance, this kind of issue appears in AR-based advertisements when biometric and geographical data are exposed.

Another type of discussion revolves around secluding an individual or particular type of information from the public. Kostios (2015) mentions an example where AR users project virtual objects onto private properties. In terms of the content, AR images can be projected as harmful material for the public and can be used for example as a public hate speech.

"What if that blank canvas gets painted with hate speech? What if, perchance, the homes of 'undesirables' are singled out with graffiti that only bad actors can see? What happens when every gathering place for any oppressed community gets invisibly 'tagged'? In short, what happens when bad actors use Facebook's augmented reality to amplify their own capacity to act badly?"
(Pesce, 2017)

Mark AR is an AR-based mobile application which allows users to create and place digital images in a real environment. Developers of this application had to continuously incorporate features to minimize the spread and creation of harmful digital material by requiring personal data such as real names and the need for human moderation.

Regarding public spaces, art galleries are very enthusiastic about implementation of VR technology into their exhibitions. Parker and Saker (2020) speak about art gallery or museum spaces as being spatial and social, characters that galleries and VR experiences have in common. They have interviewed few visitors and got to know that VR creates a feeling of freedom for a user. Additionally the user's view is not accessible for others, so at the end the technology provides autonomy and space which is rare in a crowded museum. At the same time visitors express concerns regarding vulnerability while using the technology which comes from the feeling of being watched by others. One way to look at this situation according to Golding (2019) is to see museums as a place for performance which is now intensified with VR and accept body movements of participants as a part of the museum experience. Even though Parker and Saker (2020)

did not focus on ethics, they do point out that “private” in the context of VR does not align with the expectations of privacy in a real environment.

3.3.3 Accessibility, inclusivity and exclusion

User Interface in Virtual Reality thrives and seems to be more natural and intuitive because it is adapted to our natural body movements and gestures. Although it does not necessarily come reachable to all body types. A survey has been conducted by Wong et al. to discuss what they expect to be necessary additions to VR, based on practices of people with physical and mental disabilities in the context of commercial exclusionary design of VR. Participants have suggested comprehending higher sensitivity of the hardware to avoid physical pain (e.g. when moving a head rapidly), minimisation of feeling of anxiety (e.g. one participant diagnosed with anxiety, also a trans person, when given a male virtual body they felt nausea). Zhao et al. noticed many accessibility issues and proposed bespoke controllers and interfaces (e.g. a “cane” controller for blind people to enjoy the environment with immersive sound). AbleGamers is a disability advocacy group for video games and published an article breaking down few points which developers of VR should consider:

- VR puts a lot of emphasis on body movement and not all users can perform required motions or gestures (e.g. user’s incapability to move their hand rapidly)
- VR might not function properly if user’s body is not positioned in a specific way
- VR contains a wide range of hardware but designing universal and accessible standards for VR is difficult
- VR puts a lot of attention on gaming, therefore it is suggested to develop more VR experiences other than mechanically demanding games
- VR mostly expresses in a visual and gestural form and audio receives less focus
- VR tests are usually applied on able-bodied users, hence including users with disabilities could prevent exclusion in future design of VR

Popular AR mobile application Pokemon Go is developed in a way that it assumes all the users are able-bodied. AbleGamers (2016) mentioned that the core of the game lies on the player's physical movement which means that the game can be unreachable for players with limited mobility. They also proposed using voice-activated controls for blind or poor-vision users.

The world where we can be represented by avatars opens up questions regarding genders and emotions. One of the critical works concerned with this issue is Belamire’s (2016) blog post, where she describes her

experience in a virtual archery game QuiVr. She wrote about sexual harassment taking place in a real-time game. Even though the activity is virtual, it still leaves the same emotional effects. From a survey with users of VR (Outlaw and Duckles, 2018) 49% of female and 36% of male participants experienced some sort of sexual harassment in the virtual environment. Blackwell et al. (2019) suggest to analyze different types of potential virtual harassment for further development of VR applications:

- Verbal harassment (e.g. hate speech passed on through private messages)
- Physical harassment (e.g. unwanted touching or sexual gestures)
- Environmental harassment (e.g. sharing and placing violent content)

3.3.4 Surveillance and platform power

Surveillance is another critical topic found within discussions of emerging Mixed Reality technology, commonly observed in companies producing digital sensors. Special importance is given to accumulation, process and exposure of user's data as a tool for profit or power. Even though VR has not yet become a tool for surveillance capitalism, its potential shouldn't be denied. Bailenson (2018) considers VR as a digital sensor capable of capturing data about the user's body. He mentioned that commercial systems put in practice tracking of the body movement, 90 times per second and high-end technological systems record 18 types of body motions across the head and hands. Which means that being immersed for 20 minutes in a VR environment can produce almost 2 million unique recordings of body language. For instance, Facebook has been operating its VR as a sensor technology by mobilising Oculus data for targeted advertisement. Therefore it is crucial to continuously set regulations and create an ethics committee overseeing future development of VR technology.

The term "platformization of cultural production" mentioned by Nieborg and Poell (2018) is a situation when platform owners try to reach a widespread use of the platform and consequently gain users' dependency upon their platform. Platformization can be directed towards developers as well, not only end-users, through Software Development Kit (SDK) that is used in well-known game engines Unity or Unreal. Other big companies like Google and Microsoft also offer SDK's for integration with Unity and Microsoft is progressively positioning their Windows operating system on a role of a holographic computing platform.

AR mobile applications can be also considered as digital sensors capable of tracking user's spatial and geographical data and can be manipulated by surveillance capitalists to analyze user behaviour and patterns (e.g extracting location data to drive business traffic. Besides the movements and facial features, collecting data of the user's environment needs to be

pointed out too. Processing spatial metadata gives AR and VR companies more detailed information other than just location. Facebook recently came up with a proposal for “live map” which is a user generated mapping technology based on a collection of a vast amount of various data.

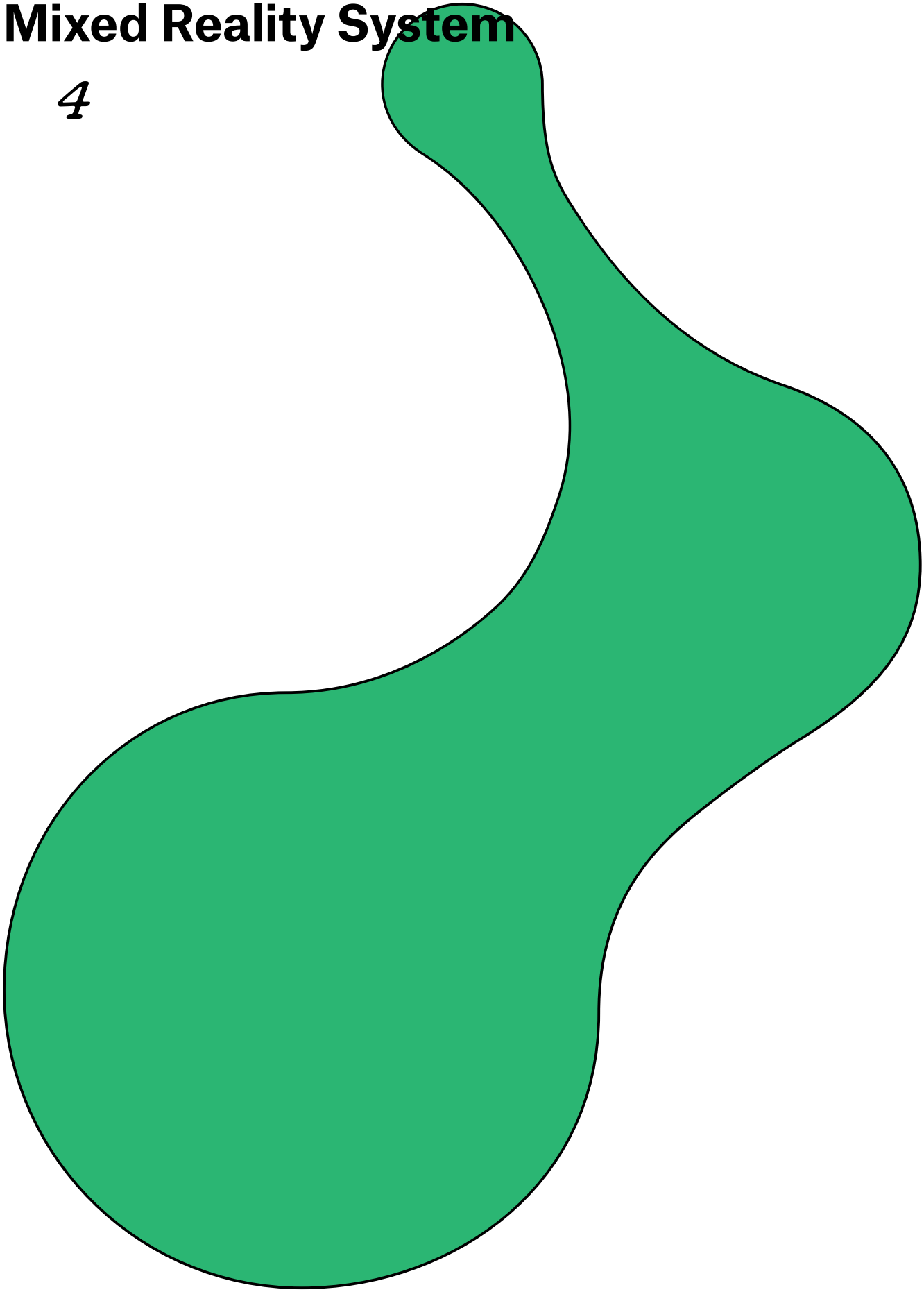
3.3.5 Empathy

Eventually VR can be used in various fields with different kinds of intentions. VR in the film industry is recognized as “an empathy machine”, a term coined by VR filmmaker Chris Milk, because the technology can clearly interpret and mediate a message to the viewer. Milk’s statement (2015) regarding a VR movie “Clouds over Sidra” is that the technology might seem to be just a machine but when a person enters the immersive environment, feelings become real. A viewer is placed into a movie instead of keeping a distance and watching it from a screen. They are surrounded by the same environment as the characters of the movie, therefore the viewer empathises in a deeper way. [14]

14. Carter M., Egliston B., "Ethical Implications of Emerging Mixed Reality Technologies: The University of Sydney" [Online]. The University of Sydney, 2020

Mixed Reality System

4



4. Mixed Reality System

4.1 Framework 1: Characters and Algorithm models

The technological development brought opportunities to create various applications improving our daily life. For example geo-location based pathfinding to orient oneself in a surrounding providing optimal, quick and accurate routes to a selected destination. In the design process of these applications user interaction is a critical part to think of, for instance using appropriate visual strategies to communicate with the user. AR, MR and VR are aiming towards visual interaction with the user. VR creates a fully immersive environment which the user can enter, although the lack of a real environment can relatively be a problem in some cases. Therefore AR solves this solution where the real world is superimposed with digital content. Despite the usefulness of AR, the separation between a real and digital world is still challenging. That is when the MR environment comes to merge two worlds and narrows the gap by creating a window/ interface between. As a result, the execution of practical scenarios between a real-world object and virtual object happens to feel more natural and accessible. [11]

There are 3 elementary features of MR systems:

- Combination of real-world and virtual objects
- Interaction in real-time
- Mapping the environment of real-world and virtual objects to create interactions

4.1.1 Concept of Mixed Reality

Researchers Rokhsaritalemi, Sadeghi-Niaraki, Choi (2020) follow a notion of Mixed Reality by the Reality-Virtuality Continuum (1994) in pursue to propose a general framework for creating a MR application. Following section introduce the overview of their concept of mixed reality and necessary components for MR application. They mention that the main goal of MR is to create a space by merging virtual and real environments where the objects coexist and interact in real-time for user scenarios. Basics of MR space:

MR Characters

Considered MR characters may be immersion, information and interaction. Immersion represents the real-time processing and interpretation of the user's environment. Information means registering virtual objects in time and space. Interaction is accomplished without controllers, instead it

11. Talemi et al., " A Review on Mixed Reality: Current Trends, Challenges and Prospects." [Online]. CC BY, 2020

works on natural communication modes such as gesture, voice and gaze.

MR Benefits

Benefits of MR comparing to AR and VR, based on 3 main characters.

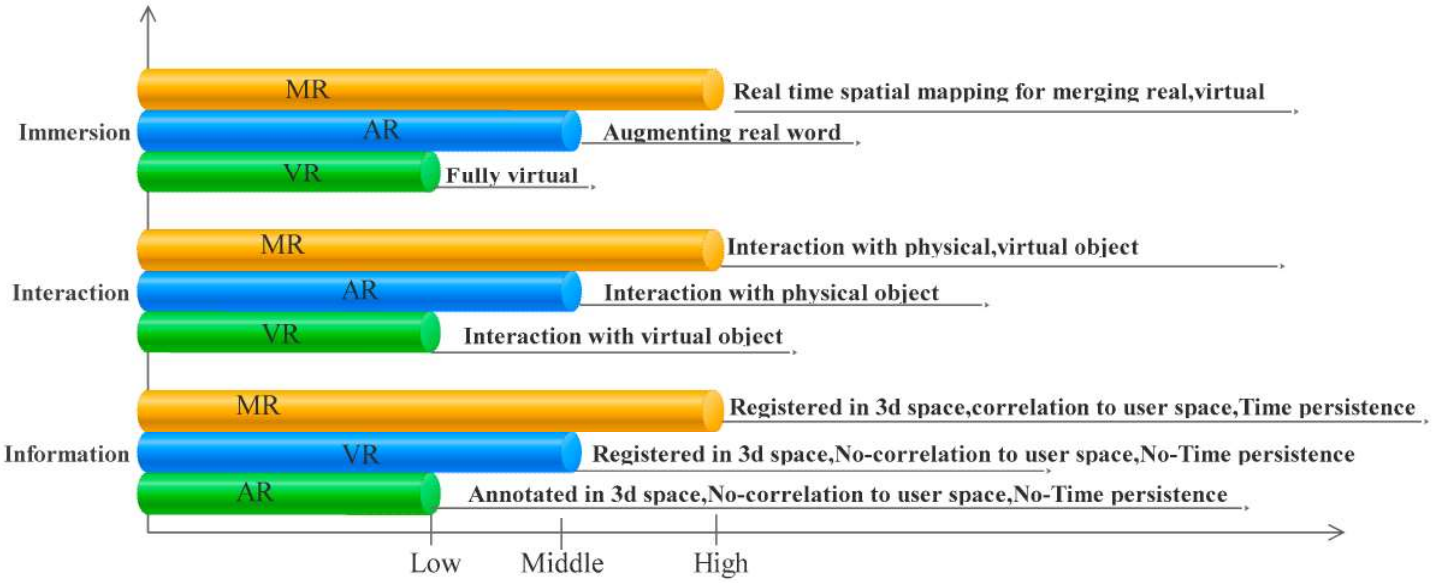


Fig. 5

MR Challenges

Two critical challenges for creating MR environments are display technology and tracking. An MR content should be well understood by users, therefore an appropriate display technology that provides a quality resolution and contrast is needed, as well as methods to track virtual and real objects in a correct time and space in terms of interaction.

MR Technologies

There are 2 technologies to develop an MR space. One of them is optical see-through technology which enables users to see digital objects directly seen on a device, such as transparent glass. Another type is video see-through where digital and physical objects are projected on a Liquid Crystal Display (LCD).

The displays can be divided into 4 types: head-mounted, hand-held, monitor-based and projection-based. When developing or choosing an appropriate display, consideration of comfort (e.g. device weight) and immersion (e.g. the field of view) is important for ease of use.

Fig.5 Talemi et. al. (2020), Benefits of Mixed Reality based on 3 main characters [Illustration]. Talemi et.al. (2020). A Review on Mixed Reality: Current Trends, Challenges and Prospects. Applied Sciences [Online]

MR Steps

In order to create a MR application using see-through technologies (camera), following steps as required. There are described more in depth in algorithm models section.

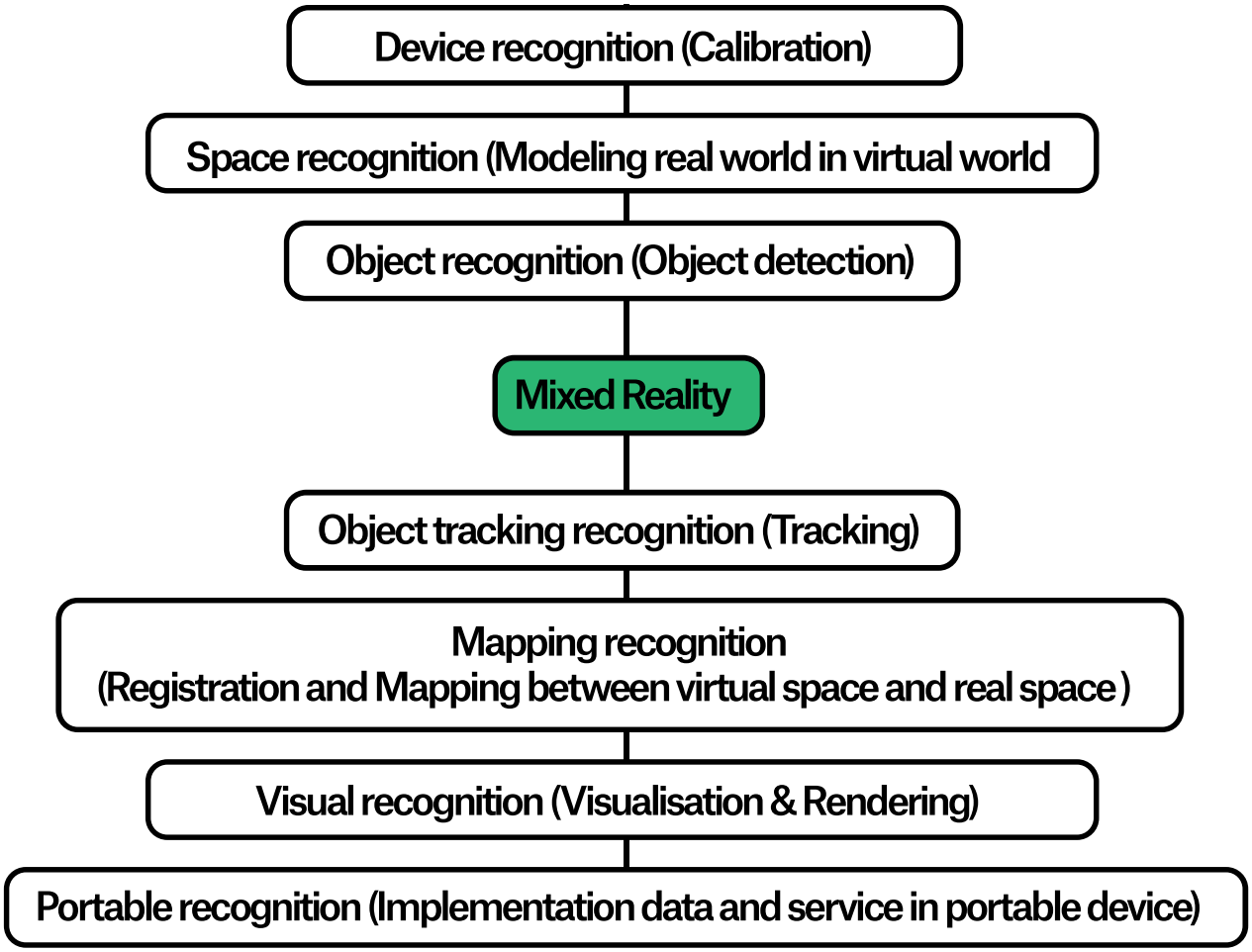


Fig. 6

4.1.2 Algorithm models

The important part of any MR application is an algorithm, because it carries an analytical mathematical model which sets the accuracy of the MR system. Each algorithm model holds a different task, e.g. to calibrate devices for better use and interaction, to identify and track real-world objects, to register virtual objects in real space. Following section will describe algorithm models more in depth.

Fig.6 L. T. Nguyen, Mixed Reality Steps [Illustration]. Talemi et.al. (2020). A Review on Mixed Reality: Current Trends, Challenges and Prospects. Applied Sciences [Online]

Calibration

Calibration models affect devices, such as cameras and optical see-through parts. An example can be found in a head-mounted display worn on the user's head. Calibration solves the problem of instability

between the device and user's hand to provide reasonable interaction with a virtual object. The model is important in the process of scene reconstruction from camera images. Lee, S.C. et al. (2016) introduce implementation of an MR-based needle navigation system for conducting a surgery. The system allows rendering of a needle trajectory and ultrasonic scanning images when using a head-mounted display device.

There are some challenges that need to be addressed to improve current calibration models. For example when using head-mounted displays, incorrect tracking of the user's hands disturbes fusion between the real and virtual hand. This disturbs the stability between the device and user. Further on, the camera calibration needs additional parameters such as lens distortion or environmental effects (e.g. image brightness) to improve model accuracy.

Model of Space and Simulation

MR scenes require space modeling to create the MR environment. It is necessary to model a large space and an object. The process of modeling the room should take into consideration relationships between the space, related objects and user within. The process of a real object simulation, in this case a tissue, needs to think of constraints such as object deformation. Xing, H., proposes a tool-kit for building large-scale MR spaces such as rooms and museums based on Voronoi spatial analysis structure. Scenes are built in the form of a 2D virtual map and 3D space is created using sweeping analysis. Afterwards, arrangement of 3D objects is performed, switching between virtual and real environments. In order to secure the match of virtual and real worlds, the toolkit uses anchor data located in the space. It also uses Voronoi-based structure to edit paths, adjust layers of virtual objects and fast rendering.

When modeling a MR space, there are few challenges needed to be pointed out. For example when creating reconstructions using 3D data and algorithms, it is important to use an appropriate model and model parameters such as size. In simulation models, rendering at higher speed requires optimization computational techniques such as GPU processing.

Object recognition

In order to create a MR scene, it is important to correctly embed virtual objects in a real space for a more persuasive result of blending two worlds. Technically this effect is enabled by identifying and tracking a real object.

In terms of object recognition, an object can be static or dynamic. An example of dynamic object recognition is a human in movement. An image-processing-based approach can be used to detect a human in front of a spectator to insert a virtual object in a real space. Or the other way, a spatial object recognition can be used to display information according to a user's field of view, through a filtering

model based on a user's distance from a display information.

There are still few challenges that need to be mentioned. In image-based approaches based on deep learning, it is important to choose the correct data for training since this data provides useful context, defines the general object and impacts quality of interaction in the MR system. Regarding spatial object recognition, unwanted errors may appear due to other tracking tools such as the global positioning system (GPS).

Object tracking

Object tracking deals with positions of virtual objects in the right place for a seamless interaction. There are 3 types of MR tracking techniques: sensor-based, vision-based and hybrid. Hybrid technique consists of using both sensor-based and vision-based.

Sensor-based tracking methods include GPS, visual markers, acoustical tracking systems. A sensing device is capable of estimating values such as a position of the real object in a scene. The sensor based method requires a scanned digital copy of a real space to place digital objects in the right place.

Vision-based tracking uses computer vision techniques to create images. An example could be an MR application for trying on shoes. The challenge here might be to consider multiple cameras for more accurate tracking and image coverage.

Registration and Mapping

Registration and mapping is about placing a virtual object in the real space. Iterative Closest Point (ICP) algorithm allows overlaying a virtual object in a real space based on the user's current position. This algorithm was used during the inspection of heritage buildings to lower time and cost maintenance tasks. Another proposed type of registration is a markerless registration model for surgeries, to register a virtual medical image on a patient using their facial features. The model generates a 3D model of the patient, detects facial features and recognizes opportunities for transformation and registration. Afterwards through a ray-tracing algorithm the virtual object is placed in a real space.

When using the ICP algorithm for MR applications a device with a good accuracy is required, such as HoloLens. It can be challenging to handle large data during user interaction and registering, therefore a well-designed user interface is needed. Markeless registration needs to be used on a high-resolution device due to complex tasks like WEB-based MR applications.

11. Talemi et al., " A Review on Mixed Reality: Current Trends, Challenges and Prospects." [Online]. CC BY, 2020

Visualization and Rendering

To be able to put a MR content on display, many algorithm

models need to be successfully working, e.g. manipulating light and shadow for more realistic representation of an virtual object, adapting detail of an object according to user's position, dealing with occlusion and invisible objects, managing 3D large data and integrating various display information sources.

Information Transfer for Portable Devices

MR applications in portable devices such as smartphones need to use appropriate models for information transfer when reconstructing scenes from mobile camera images. A given model can introduce a spatial concept for data gathering and interaction for diverse data sources (e.g. sensors and media). [11]

4.2 Framework 2: Multi-media and experience

The following section is a review of an article conducted by George Margetis, Konstantinos C. Apostolakis, Stavroula Ntoa, George Papagiannakis and Constantine Stephanidis published in 2020, called "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums ". [12]

According to the authors, culture strengthens bonds in a society, elevates quality of life, facilitates the past and guides towards an envisioned future. The article puts focus on exhibitions in contemporary museums, looking at the current evolutionary stage of culture. The size of an audience has expanded over time, meaning that a bigger part of the population has access to cultural facilities, and is currently in a phase called "Culture 3.0" which expects individuals to customize their own cultural content they want to be exposed to. Contemporary museums are therefore challenged to follow diverse existing content and shape future cultural experiences.

Since existence of museums in the third century BC, their form has been changing in accordance to sociological, economic and cultural influences. The aspect museums has kept on until now is their orientation towards education. The notion of museums is mainly to share the knowledge with its audience. Contemporary museums have implemented immersive technologies to increase wow-factor, memorable entertainment, provide access to not physically exhibited pieces and give additional information about artifacts.

Culture evolves hand in hand with other disciplines and currently technology seems to be a relevant shaper. Computer graphics, human-computer interaction, computer vision etc. have helped to spread information and helped visitors to better understand the history, presence and visions of the future. According to Culture 3.0, technologies will potentially play a leading role in interactive experiences and turn museums into high-technological cultural heritage spaces.

12. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online]. Applied Sciences, 2020

Museums offer exhibitions of physical artefacts mixed with exhibitions of digital content, where they many times showcase digital content through mixed reality. By employing these technologies they aim to deliver novel experiences with a playful approach. This way the exhibition curators can orchestrate a multi-sensory experience blending the real and virtual worlds, shifting a position of visitors from purely viewers to participants.

Extended reality

Mixed reality in terms of Extended Reality (XR) represents a multi-disciplinary research in the fields of computer vision (e.g. face detection, body tracking, gesture recognition), artificial intelligence (e.g. conversational systems, natural language processing and generating), computer graphics (e.g. realistic 3D modelling, animation and rendering) and natural interaction. MR has a tendency to revolutionize cultural experiences regarding interpretation, interaction and visualization. In these terms, MR aims to extend 5 basic human senses, sight, touch and hearing, as well as smell and taste.

XR technologies allow people to “travel” to a different place away from their physical location, review history and explore imaginary spaces. Humanitarian agencies have been working on AR/VR/MR from a perspective of empathy-inducing features of these technologies, because they can effectively educate, explain and raise awareness about certain issues. Even evoke a response or an action from a viewer. A physically exposed artifact can be augmented with additional digital information viewed on a smartphone, it can be graphically altered or can be exclusively visible only through VR.

As XR technologies gradually improve by time in level of immersion and realism, they have the ability to transfer and form consumed information. In order for the experience to function properly 3 technological challenges need to be sorted out.

- Diminish reality - to hide and substitute some parts of the real world
- True mediated reality - to superimpose realistic virtual characters
- Natural multimodal interaction - interaction with virtual agents in a natural way

Diminished Reality

As an etymological term “diminish” means to become gradually less. In terms of MR, diminished reality represents a digital substitution of real parts of the environment. Diminished reality has a slightly different approach towards augmentation since it substitutes parts of the real world rather than superimpose them, but is still considered as a subdomain of MR. The term was coined by Steve Mann, an inventor in the field of AR, and represents a reality where parts of

the real world can be removed. Until today, several approaches of diminished reality have appeared and they can be roughly divided into 2 categories: the first one requires registered photos and prepared structured information, and the second one works during real-time processing without pre-processing the target environment.

True Mediated Reality

The notion of “true mediated reality” is introduced by the authors of this research paper. They describe a highly believable digital environment consisting of realistic virtual characters, pointing out features like photo-realistic reconstruction of 3D models, real-time rendering and animation, realism and interactivity of digital objects.

To reach high-level realism and believability two aspects must play along - geometry and illumination. Additionally high demand in realistic interaction emerges through real-time animation of deformable digital objects to achieve realistic representation. Therefore, a critical technological challenge is to deliver realistic, high-fidelity and high refresh rate rendering of deformable virtual characters.

Regarding humanoid 3D models, so called virtual agents, it is not only important to realistically render the agents but few other aspects to imitate human behaviour must be considered such as movement, affection, verbal and non-verbal communication, face expressions, body posture and gaze direction. To enhance representation of virtual agents with natural behaviour, the algorithm model should include perception capabilities that will allow agents to access information about the state of the user and other agents, to understand real and virtual surroundings, attention capabilities to recognize focus and interest and decision making. An alternative direction how realistic humanoid 3D models could go is an integrated low-cost system for photo-realistic 3D representations. Due to commodity cameras and depth sensors, technologies are able to extract a life-like human “an avatar” employing a 3D mesh geometry and collected data.

Natural Multimodal Interaction

Natural interaction within virtual environments has a tendency to increase the feeling of immersion, optimize user experience and enhance the enjoyment. That is due to the fact that users are able to interact with virtual characters as they would with physical artefacts through movements, gestures, expressions and manipulation with the object. To interact with virtual agents in a most natural way, modalities like gestures, head and body movement, touch as well as speech and gaze. They are already achievable in mixed reality environments, but future implications should work towards infusing multiple modalities into an already

complex system for natural interaction with virtual agents. Taking into consideration museum exhibitions, visitors would like to interact with the real environment and with each other, then the algorithm model needs to consider how to navigate virtual agents and object behaviour in a real-life crowd. Natural speech interaction is another way to improve natural interaction. Including natural speech in embodied agents is still rare, but the popularity of adding personal chat services into user interfaces in applications, shows a potential in usefulness of dialogue-based systems.

4.2.1 A Conceptual Architecture for Unifying XR Experiences for Realistic Virtual Museums

This article proposes a conceptual model for XR experiences implemented in museums and a case study showing the conceptual model in practice.

The conceptual model contains:

- Elements directly affecting user interaction - responsible for delivering the XR experience
- Components manipulating processes unseen by users - responsible for interpreting user interactions

Fig.7 shows a conceptual model consisting of essential components:

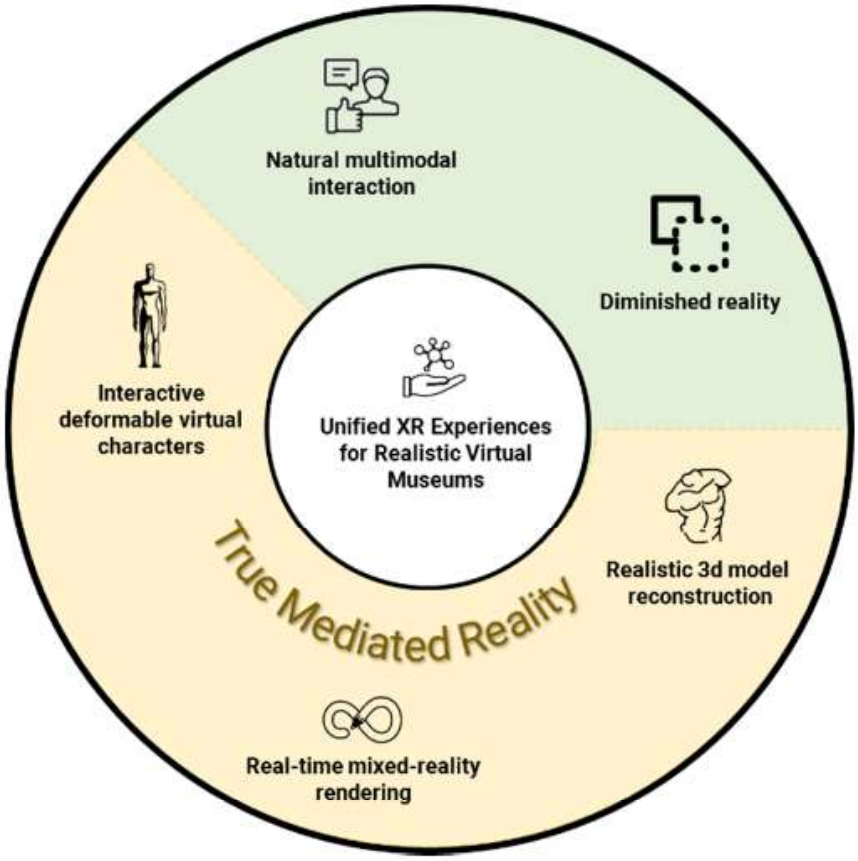


Fig. 7

Fig.7 Margetis et. al. (2020), Unified XR for realistic virtual museum [Illustration]. Margetis et.al. (2020). X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums. Applied Sciences [Online]

Diminished reality component takes care of removing physical elements in real-time, most likely being substituted with their virtual version. For this technique to function properly, scene registration and localization processes need to identify user's and object's positions. This is an ongoing procedure since in real-time processing the location of the user and view of the object changes constantly.

True mediated reality delivers a high quality experience through reconstruction of realistic 3D models, real-time rendering and animation. The virtual objects are placed in a virtual environment in order to substitute physical artefacts. The virtual representations should not only replicate their physical version but also try to deliver an original form in case of damaged artefacts.

Natural interaction with other users and virtual agents is what unifies the whole experience. Natural language processing handles received user's commands (gestures and natural language) and at the same time emotion detection detects user's emotions for further adaptation of the system. All the identified information affects the decisions done by virtual agents, after interpreting user's gestures, speech, emotions and other impacts such as number of users who actively interact with the virtual exhibition and who is passively following the exhibition.

4.2.2 Case study: XR Natural History Museum

Based on a previous research [12], following the conceptual architecture for delivering XR experience, authors of th article created an example of an interactive XR exhibition dedicated to Pleistocene Cretan fauna. The exhibition aims to showcase living, animated and life-sized reconstructions of the fauna living on Crete 800,000 years ago. The intention is to create a uniform XR experience that combines various mediums (augmented, virtual and mixed reality), using each of their potential appropriately and enable visitors to interact with the museum physically and digitally while being immersed in the same room with other visitors.

XR Systems and Applications

The authors introduce 2 interactive systems which can co-exist in the same physical space to support the museum exhibition.

First of them is a virtual reality, a fully immersive experience, in a small museum room where fossils and reconstructed skeletons are shown as digital excavation sites. The user can walk around and explore the scene and view information in forms of texts, images, audios or videos borrowed from a museum's archive. Visitors can also switch to other virtual scenes which will completely change their virtual environment and will bring them to the reconstructed past. They

12. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online]. Applied Sciences, 2020

can view each animal animated in its own habitat, giving visitors clearer description of the animal's look, movements and life. They can control “time travel” on a timeline which appears on a User Interface and therefore explore various periods of Pleistocene Cretan fauna.

The second applied interactive system is mixed reality where a physical room is curated to accommodate the mixed reality scene. The installations, in this case physical animals made out of plaster, are diminished in visitor’s view. As the real version fades away, a life-like animated virtual reconstruction of the animal appears and is capable of roaming around the room and the user. Techniques of natural interaction can be applied to enhance realism so the animal is capable of reacting to the user's attempt to touch it, while understanding a surface and mapping the space to avoid collisions with other animals, visitors or museum’s furniture.

Mapping to the Proposed Conceptual Model

Following illustrations represent previously mentioned applications and systems which are the components of the conceptual framework for XR experiences. They intend to guide the development of the system, interpret the relationship between technologies to derive a concrete structure of algorithm model. Consequently to identify which elements are made for interaction and which ones are made as fixed structures for true mediated reality.

Fig. 8 shows co-existence of two interactive medias on the same physical space. Both supporting Pleistocene Crete exhibition.

Fig.8 Margetis et. al. (2020), Conceptual diagram of the Pleistocene Crete Interactive XR exhibition [Visualization]. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online].

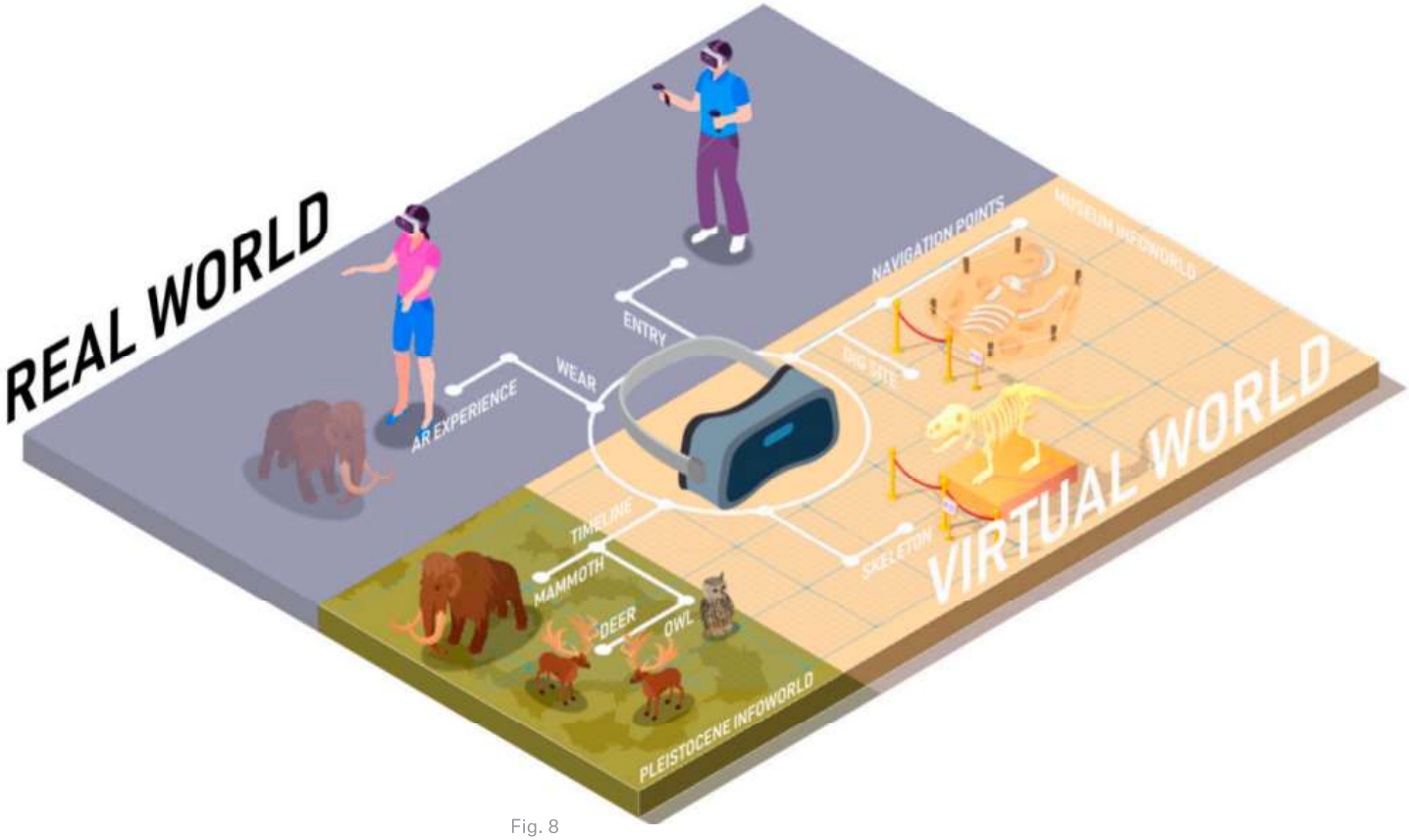


Fig. 8

Fig. 9 is an example of a mixed reality content. Users walk around the room and explore audio-visual material of the exhibition. They can switch to preview different animals in various habitats and time.

Fig. 10 shows the environemnt allowing users to travel back in time in several peridods, as well as explore movements and conditions animals got to live in.

Fig. 9

Fig. 10

Fig. 11 explains system architecture of the Pleistocene Crete exhibition. Green components responsible for delivering XR experience and yellow components manage True Mediated Reality elements of the experience.

According to the mapping created by the authors of [12] , the exhibition system architecture and their conceptual model combined, allow all the necessary elements and IT components to create a unified XR environment. The system functionalities can be recognized as parallel-running services which allows the system to be easily broken down into separate components, therefore simplifies the system development and integration.

12. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online]. Applied Sciences, 2020

Fig.9 Margetis et. al. (2020), Museum Environment [Printscreen]. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online].

Fig.10 Margetis et. al. (2020), Pleistocene environment [Printscreen]. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online].

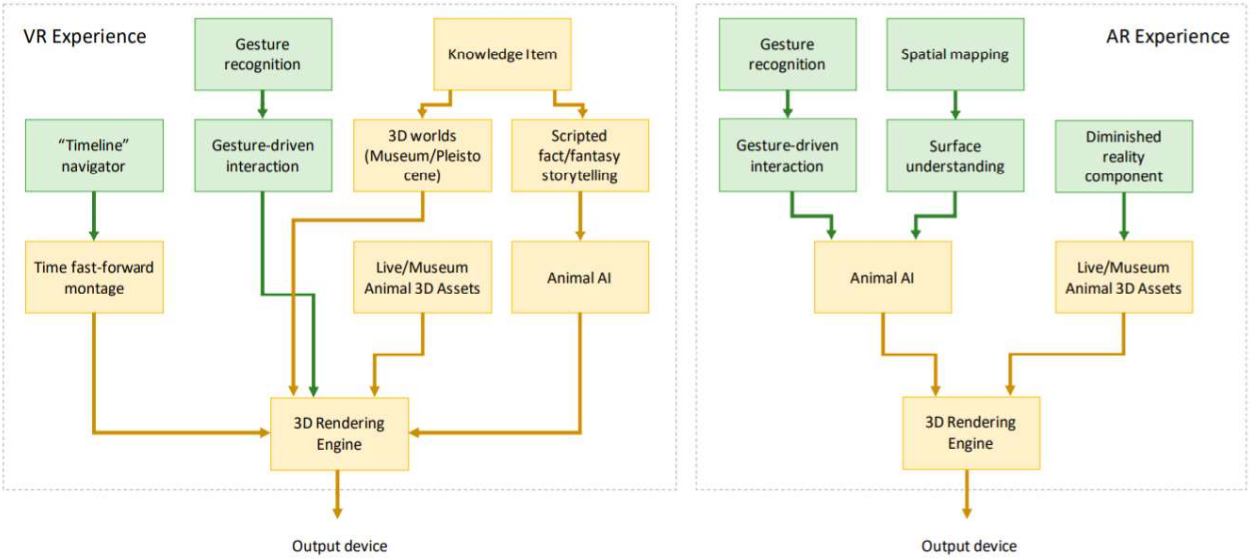


Fig. 11

Operational Setup and Evaluation Framework

Proposed framework can be applied to various exhibitions in cultural institutions similar to the nature of the one described. To produce a XR content, exhibition curators and technology experts should collaborate for the outcome to be highly believable.

The concept is intended as an additional part for exhibitions taking part in museums where an appropriate space is needed to utilize XR experiences. An area for an interactive activity should be planned out to minimize risks and injuries, at the same time to offer a demonstrator enough space to freely move around and enjoy the realism of the experience. Museums are encouraged to employ one expert to demonstrate, guide and be present at each experience to handle unexpected issues and give out personal tutoring. An XR experience should have a duration to guarantee each visitor in a crowd has time to try the application and to avoid motion sickness, especially in case of first-timers. For future development, feedback from visitors should be gathered based on criteria such as usability and engagement.

Contemporary museums have been changing its form, expanding their content, offering not only historical but also art exhibitions, displaying scientific and technology artefacts. After time visitors are becoming more tech savvy, yet technology should not be utilized as an end product in a context of exhibition, but used to elevate the experience, enhance understanding and knowledge. Looking at the potential of XR, the authors are proposing a unified XR experience in realistic virtual museums. They encourage future research to work towards diminished reality, true mediated reality and natural multimodal interaction.

12. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online]. Applied Sciences, 2020

13. Dou H., Tanaka J., "A Mixed-Reality Shop System Using Spatial Recognition to Provide Responsive Store Layout" [Online]. Springer, Cham, 2020

Fig.11 Margetis et. al. (2020), System architecture for XR Exhibition [Printscreen]. Margetis et al. "X-Reality Museums: Unifying the Virtual and Real World Towards Realistic Virtual Museums" [Online].

Technology development should be interested in fading parts of the real environment as it naturally works with human senses, virtual characters should not only look realistic but also to act according to human natural behaviour. Regarding devices used to perceive virtual environments, users should be almost not aware of wearing them for high comfort and immersion. Lastly, interaction should be multimodal just as humans naturally interact. If all these technological challenges advance, museums can expect a revolution in exhibits, leading not only towards entertainment but to elevated quality of learning and understanding. [12]

4.3 Framework 3: Shop design and Responsive Layout

Following section is a review of a research paper “A Mixed-Reality Shop System Using Spatial Recognition to Provide Responsive Store Layout” by Hao Dou and Jiro Tanaka in 2020. [13] The study proposes a concept of MR Shop system which is capable of spatial recognition, blending virtual elements with the real environment, and providing interaction. Due to recent development of MR technology, it is now possible to start a mixed reality experience and map an environment purely with just a head-mounted device. To support the realism in the mixed environment researchers additionally deal with store layout, music, decoration and a virtual assistant.

Current online shop system, mainly web-based online shops, lacks common in-store features and product information related to the customer's environment. And because of missing in-store features it can be more challenging or limiting to express the brand characteristics.

This research [13] proposes a conceptual system for a MR shop which potentially can be a future shopping system. The system consists of 3 parts:

- spatial recognition
- responsive store layout and
- store interaction

Firstly, the selected physical space is scanned through depth cameras and a spatial algorithm model helps to understand the surfaces. Afterwards the algorithm is given layout, formed by scanned surfaces and prefered layout of shop items, in order to create an interactive MR store layout. After the design of a shop is built, interaction between a user and virtual objects is handled, in terms of gestures to manipulate a product or voice commands to communicate with a virtual agent (Fig. 12).

13. Dou H., Tanaka J., "A Mixed-Reality Shop System Using Spatial Recognition to Provide Responsive Store Layout" [Online]. Springer, Cham, 2020

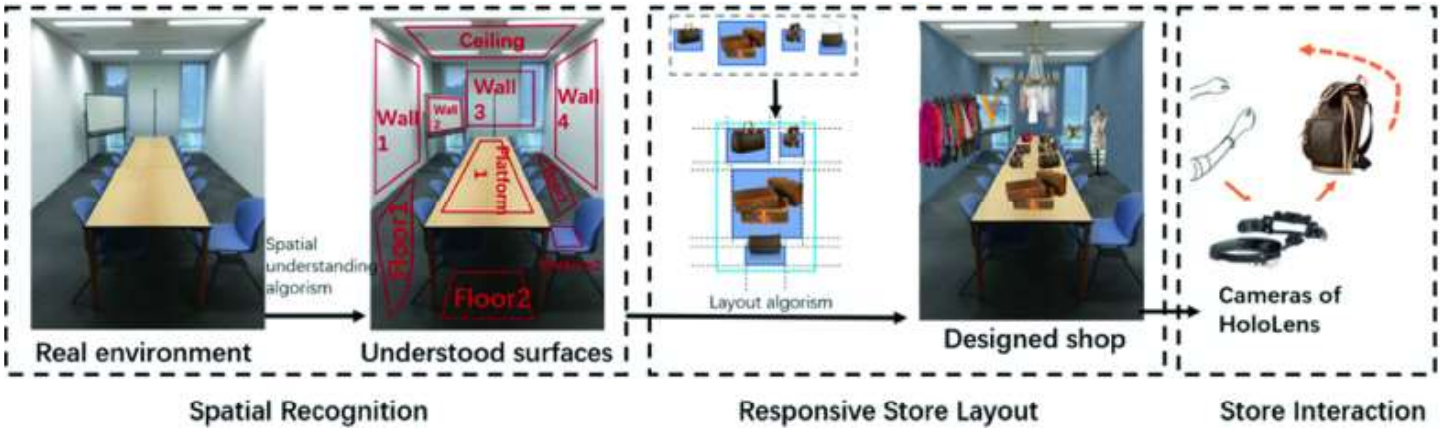


Fig. 12

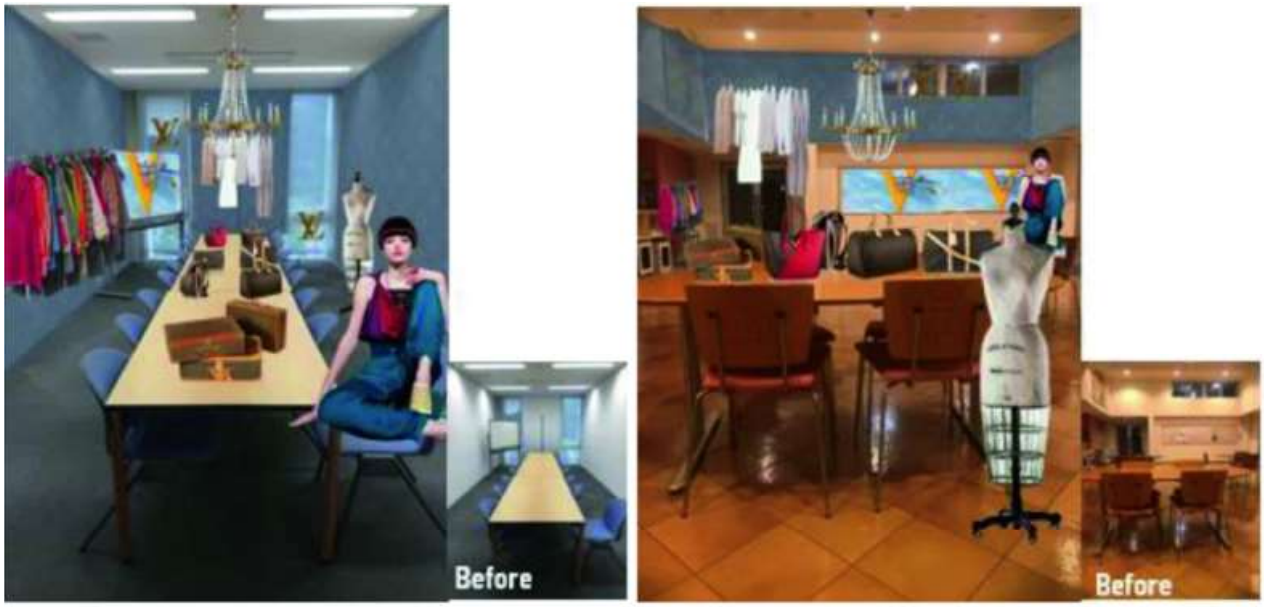
Fig.12 Dou H., Tanaka J., The process of generating a mixed reality shop. [Printscreen]. Dou H., Tanaka J., "A Mixed-Reality Shop System Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Due to an instant interchangeable character of the digital world, one physical room can become many virtual stores. Since the spatial algorithm already understands the physical surfaces, virtual characters also gain their own categories, such as being objects placed on a table, hanging on a wall or from a ceiling (Fig. 13).

Fig. 13

Fig.13 Dou H., Tanaka J., Different MR shop in the same environment.[Printscreen]. Dou H., Tanaka J., "A Mixed-Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

If a user is in a different physical layout, the system would automatically scan the scene and adapt the same virtual elements accordingly (Fig. 14).



(a) The seminar room (b) Another real environment

Fig. 14

The system is intended to be used by shop designers. A virtual element only needs to be designed once and then it will be automatically placed according to the given layout. Even though the virtual product looks the same, customers' experiences can differentiate because they are in their own chosen physical environment.

Fig.14 Dou H., Tanaka J., The same The same MR shop in the different environment. Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

4.3.1 Mixed-Reality Shop System

3 main functions are necessary to generate a MR shop:

- Spatial recognition
- Responsive store layout
- Store interaction

1. Spatial recognition

Spatial detection

The first step is to detect surfaces of the physical space which is done using depth cameras in a Mixed Reality Toolkit (MRKT). The data collected determines position, size, horizontal and vertical (Fig. 15).

Fig. 15 Dou H., Tanaka J., The process of spatial detection. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

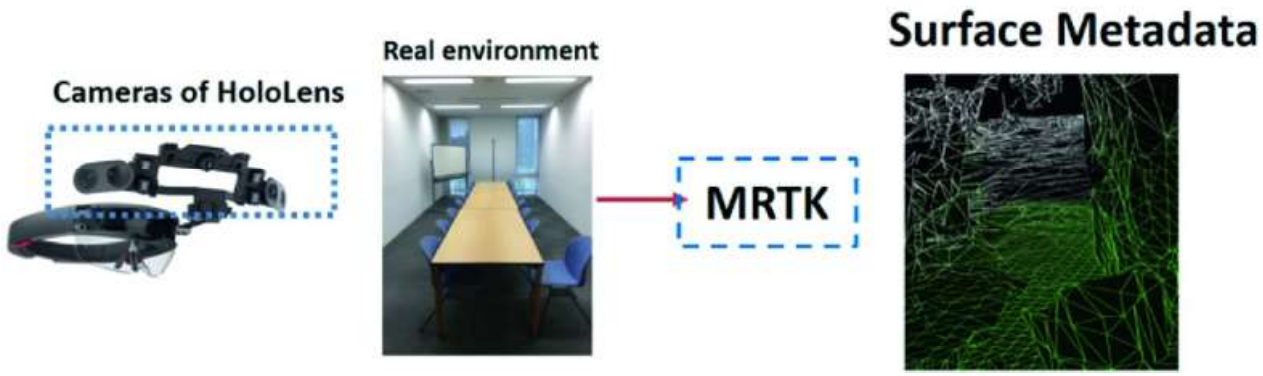


Fig. 15

After detecting surfaces of the physical space, Spatial Metadata Processing has a function to understand each of the detected planes (Fig. 16). Authors propose an algorithm model to understand surfaces, firstly eliminating surfaces which are smaller than the smallest item in the store and then categorize by judging collected metadata. Planes have different functions just like they do in a real store. For instance, lighting usually hangs from a ceiling, walls accommodate advertisements or clothing racks and tables are used for displaying smaller products.

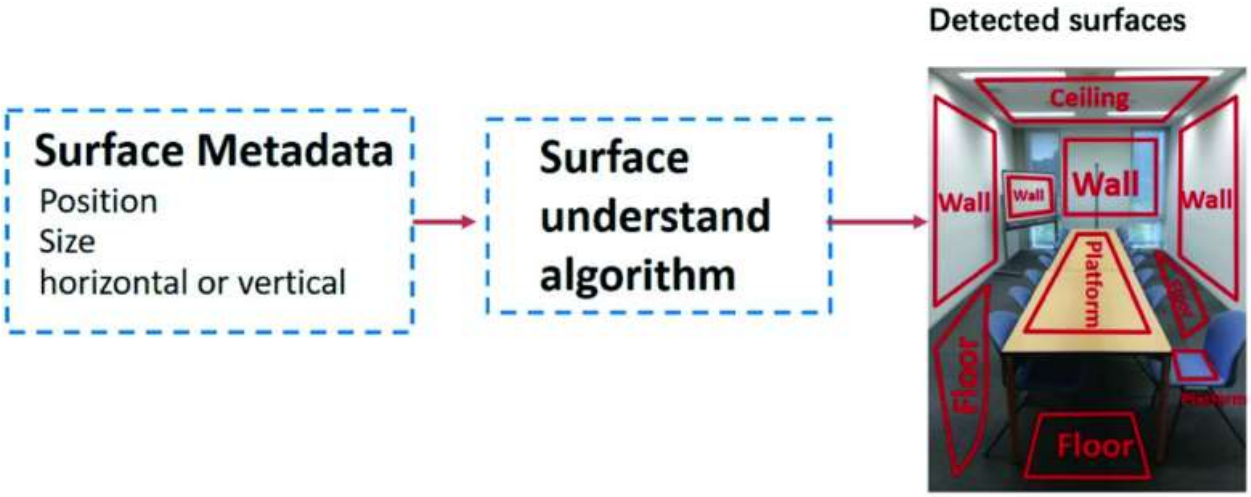


Fig. 16

Spatial understanding algorithm is useful for managing metadata into specific surfaces that can be understood by shop designers. Based on surfaces and virtual elements, a layout mechanism can be developed for product placement.

Fig. 16 Dou H., Tanaka J., The process of surface understanding. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

2. Responsive Store Layout

Once the surfaces are understood, the model can continue on generating the layout of the store. The authors propose a few shop layouts based on placement characteristics of both physical and virtual elements.

Independent Layout Mechanism

This algorithm does not give associations to virtual products, in other words categorization of products.

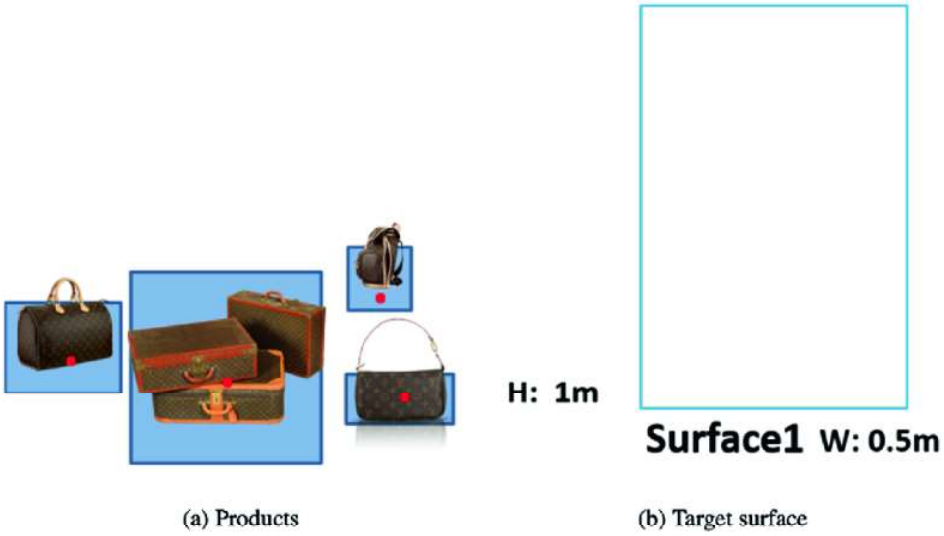


Fig. 17

Independent Layout Mechanism takes 4 steps to follow:

1. Order of sequence - organize the items into an ordered sequence, starting from an item which will be chosen first when traversing (Fig.18).

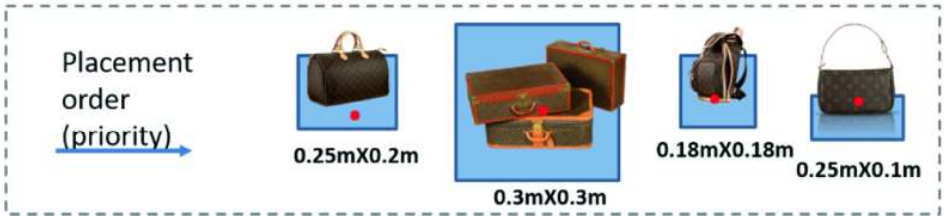


Fig. 18

2. Direction - choose the direction of the traversal of the selected surface. In the given example, the direction of traversal is along the rown, from top to bottom of the surface. Information in the first and second steps determine characters in a display configured by a shop designer. Afterwards, a layout can be designed, keeping in mind to place high-priority products first (Fig. 19).

Fig. 17 Dou H., Tanaka J., Products and target surface. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Fig.18 Dou H., Tanaka J., Arrange the shop items into an ordered sequence. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

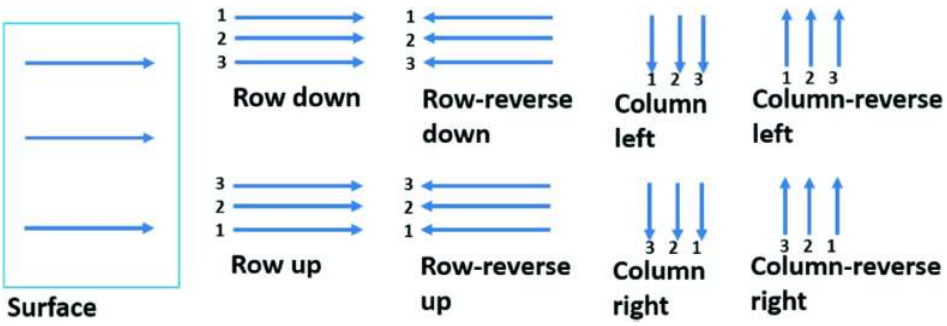


Fig. 19

3. Product placement - previously designed algorithm traverses the surface in the chosen direction (from left to right) and from the first line (top to bottom). Place products based on their priority until there is no space left. Afterwards, move to the next line (Fig. 20).

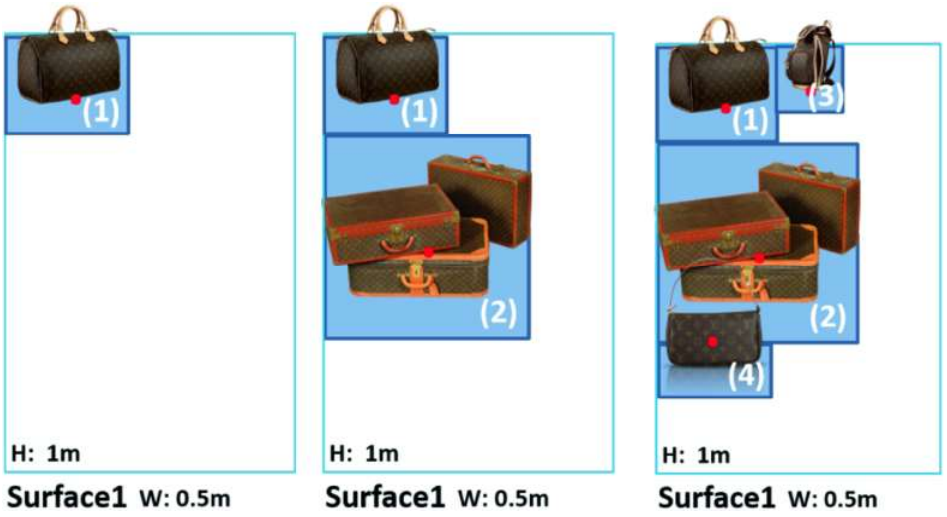


Fig. 20

4. Product spacing - shop designers are encouraged to create the same spacing between products, in rows and columns (Fig. 21).

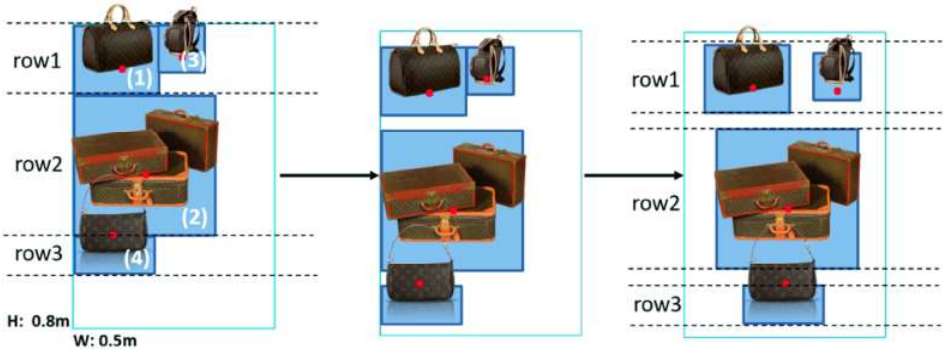


Fig. 21

Fig.19 Dou H., Tanaka J., The direction of traversal. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Fig.20 Dou H., Tanaka J., The layout sequence of the independen layout algorithm. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Fig. 21 Dou H., Tanaka J., Make the same spacing between rows and columns. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Since the area of physical surfaces and digital display is limited, researchers designed floating indicators to visibly show that hidden items are available to be viewed as well. They integrated a voice command “show other items” to display hidden products. When the user gazes at the indicator and says the command, the item which is not displayed shows up and the indicator changes its status. By repeating the command, the user can return to its first display set (Fig. 22).

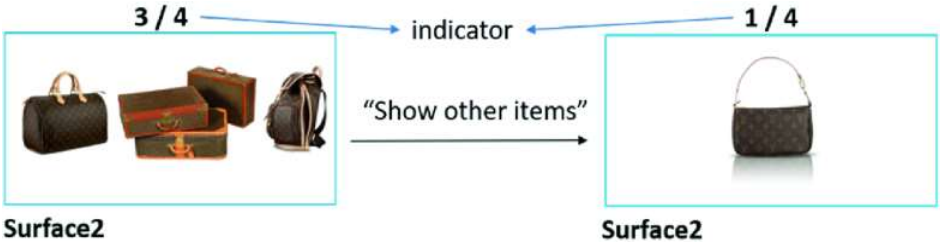


Fig. 22

Group Layout Mechanism

Unlike independant layout mechanism, group layout mechanism gives products associations like in common shops (e.g. bags group, shoes group, tops group). This mechanism provides another feature which is placing multiple groups on one surface. The placement of multiple groups can create its own structure, but since physical environments and surfaces differ from each other, the area of each group is not fixed (Fig. 23).

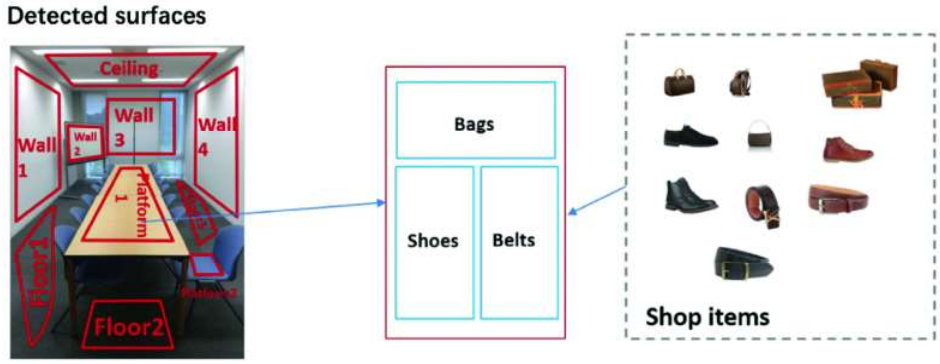


Fig. 23

Fig.22 Dou H., Tanaka J., Products indicators. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Fig.23 Dou H., Tanaka J., Group layout example. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

To solve the problem of undefined group areas, researchers came up with a “flex size” concept (Fig. 24). Flex size is represented by a percentage smaller than 100% of the physical surface. It is a proportion of a structure and its size varies from real measurements of the surface (Fig. 25).

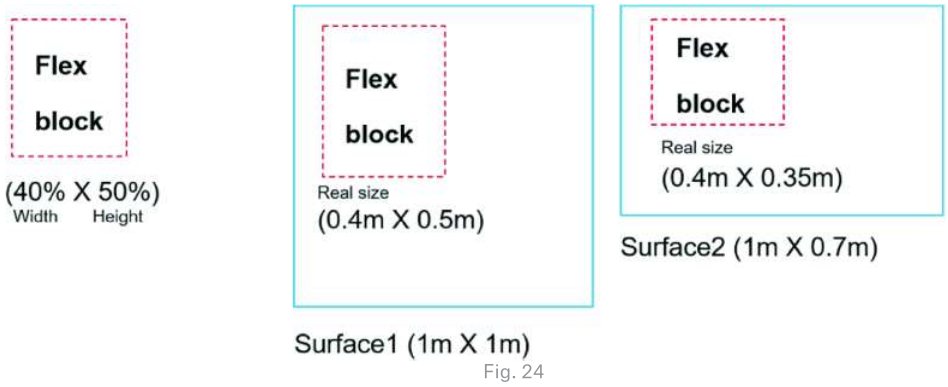


Fig. 24

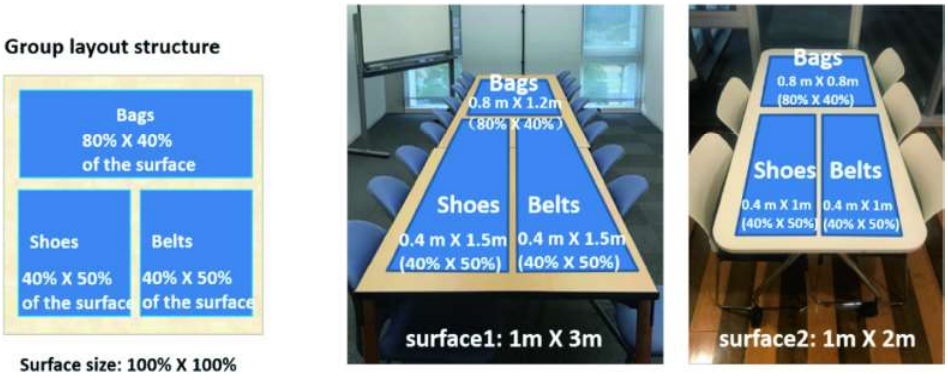


Fig. 25

Even though the concept of flex size is adjustable for different surfaces, not all of them are suitable. For example, real measurements of the surface3 result in an appropriate group area for placing items due to its short width (Fig. 26).

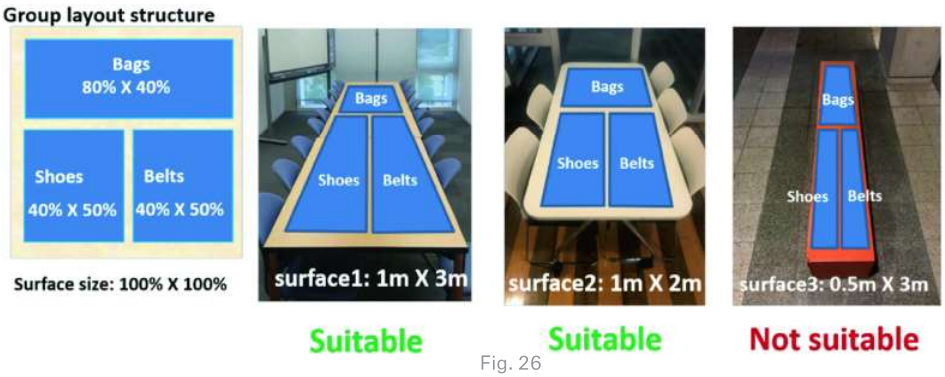


Fig. 26

To avoid product placement on unsuitable surfaces, the system allows shop designers to specify multiple sets of structures and specify their size range. The system generates a layout depending on the area of a surface. For example, displaying the same 3 groups of products, in a size range of surface1, the system generates structure1 and in a size range of surface2, the system generates structure2. If a size range of a surface is not specified, the system will assign 100% x 100% to each group, meaning it doesn't have a structure (Fig. 27).

Fig.24 Dou H., Tanaka J., The flex size and the real size [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Fig.25 Dou H., Tanaka J., Same layout structure in different surfaces. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Fig.26 Dou H., Tanaka J., A fixed structure may not be suitable for all the surfaces. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

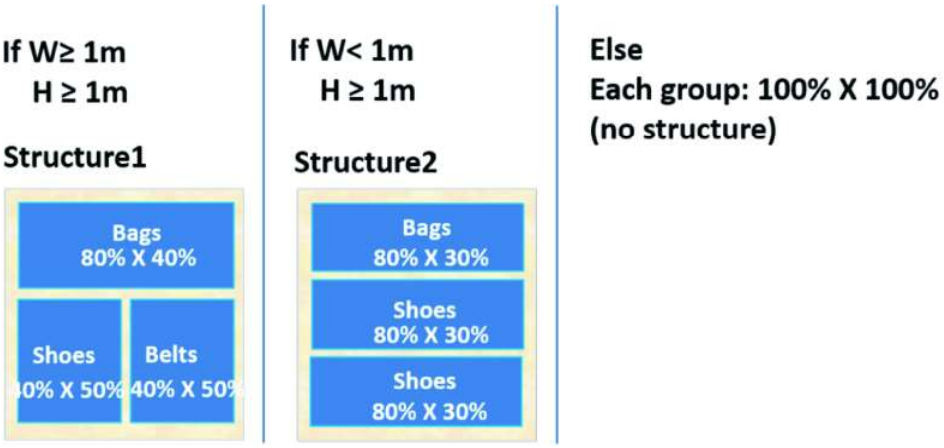


Fig. 27

If the range is not specified, the algorithm gives each group 100% with no structure. That way the layout can suitable for any environmet (Fig. 28).

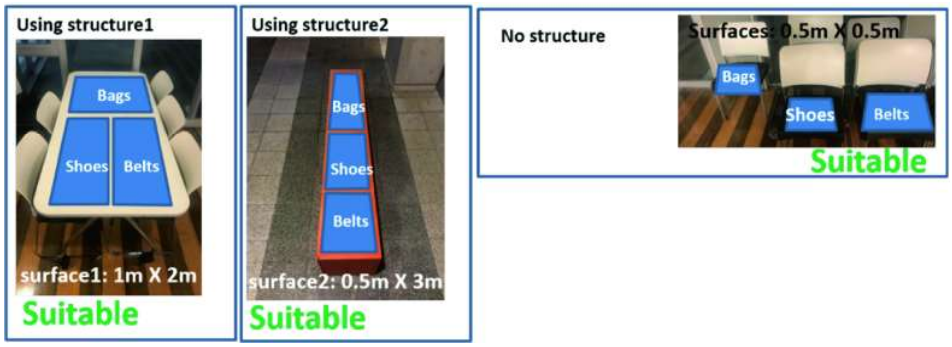


Fig. 28

Summary of the layout mechanism:

1. Arrange virtual products based on a target surface. The system traverses from a ceiling to a floor, in each surface type from largest to smallest surface (Fig. 29).

Fig. 29

Fig.27 Dou H., Tanaka J., Multiple sets of structures. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Fig.28 Dou H., Tanaka J., Different layout structures in different surfaces. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

Fig.29 Dou H., Tanaka J., Arrange shop items groups into an ordered sequence. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

2. Define desired sets of structures with a percentage size and a traversal direction of each product group (Fig. 30).

Fig. 30

3. View the target surface in the real environment and select an appropriate structure based on a real surface area. Calculate the real measurements of each group.

4. Utilize an independent layout mechanism to generate the layout of each group. Generate the MR shop for interaction.

3. Spatial sound

Studies have shown that a consumer's experience is very much affected by sound feedback. Sounds and music are also a part of brand identity and can represent different interactions. The system allows store designers to implement 2 ways of music interactions. First one is a global mode where users can hear the same sound anywhere in the virtual store. The second one is a space sound which is a certain type of sound connected to a specific element for offering more interaction possibilities.

4. Virtual Store Employee

A store employee is a critical element in regards to differentiation between a virtual and physical store. When the user is already attracted by a look of a product, for the further details about the product they tend to reach out for a store employee. A type of personal service often impacts user's trust and their relationship with the brand. In the system of a MR shop, users communicate with virtual employees through voice commands. There are 3 types of voice commands to start different actions:

- "I want to visit the Prada shop."
- "Introduce this product."
- "What's the price of this product? I'll take it."

Fig.30 Dou H., Tanaka J., Describe multiple sets of layout structures. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

5. Virtual Product Manipulation

Users can manipulate (move or rotate) virtual objects with two hands. Cameras of HoloLens are used as a reference to detect hand gestures and a mixed-reality toolkit handles gesture operations (Fig. 31).

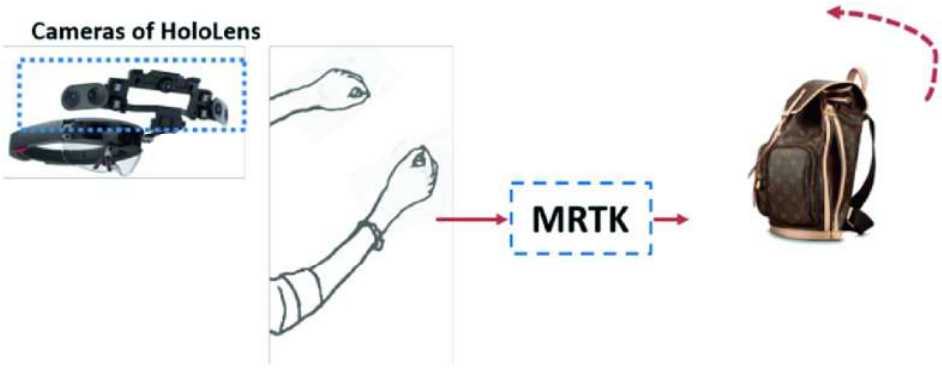


Fig. 31

4.3.1 Implementation

Hardware

Necessary equipments to build the system:

- Depth sensors - detect and recognize physical space
- Microphones and speakers - process voice commands and provide feedback
- Head-mounted display - enables the view of MR shop
- Computer - a server to store the shop elements

The device used as a reference was Microsoft HoloLens. It was found appropriate because it caters a see-through head-mounted display, built in depth cameras, microphones and speakers. It delivers 3D holograms which are pinned to the physical space where the user is located. Voice commands are translated into text through a dictation system and the system performs an operation based on the keywords.

Researchers used a laptop as a reference to store shop elements and designed layouts. The head-mounted display and the laptop are in the same network environment to reach a high speed connection.

Other technical elements:

- Mixed-Reality Toolkit (MRKT) - handles environment data analysis and gestures input functionality
- Microsoft speech-to-text API - interprets voice commands into text
- Microsoft text analytics API - takes out

Fig.31 Dou H., Tanaka J., Two-hand manipulation gesture. [Printscreen] Dou H., Tanaka J., Reality ShopSystem Using Spatial Recognition to Provide Responsive Store Layout" [Online]

keywords from an interpreted text

Graphical User Interface

Store designers are provided with a web-based user interface. Shop elements are uploaded and assigned attributes such as size and placement preferences. Users' voice commands will generate the store elements into a mixed reality environment.

Voice Commands

In order to deliver as much natural interaction as possible, the system includes a function of voice input. Through voice recognition techniques, it extracts the keywords and responds in real-time.

Two-hand manipulation

The server stores shop elements and a prefered design layout by a store designer. Each shop element has its representation in 3D. Users can estimate the size of a virtual product by looking at the bounding box around it and if a two-hand manipulation script is added into the system, they can drag, move and rotate the virtual object.

Evaluation

Participants - Researchers created a prototype and invited 10 participants to try on their MR shop and give feedback. 2 of them were females and 8 of them were males in the age between 22 and 25 years old. They all had basic computer skills and some of them had experience with a head-mounted display.

Method

All participants receive an introduction and guidelines on how to use the device. Further on they were asked to visit the virtual Prada shop and flower shop, and get to know the products they were interested in.

Result

Participants were afterwards asked 7 questions regarding usability and impression. Participants answered on a Likert scale from 1 to 5. (5 is most true)

1.Usability of the system

Q: The system is easy to use.

A: 4.5

2.Usability of a store employee (voice interaction)

Q: The interaction with a virtual store employee is useful or interesting.

A: 4.8

3.Usability of gesture interaction

Q: The gestures interaction is useful or interesting.

A: 4.2

4. Experience of searching for a product

Q: I can easily find products of interest in the mixed-reality shop.

A: 4

5. Experience of understanding the product

Q: I can easily understand the details of the products in the mixed-reality shop.

A: 4

6.Experience with brand characteristics

Q: I can feel the brand characteristics in the mixed-reality shop.

A: 4.5

7.Experience with the overall shopping experience

Q: The system can provide a good shopping experience.

A: 4.6

Participants rated the MR shop system higher than the mobile shopping system. Especially when it comes to understanding information and features of a product. Mobile shopping system is limited to 2D images, text and videos, while the MR shopping system offers manipulation with a virtual object of each product for a fully visual display.

Conclusion

Researchers developed an algorithm with a spatial understanding that translates complex environment metadata into detected surfaces. Additionally they designed a layout mechanism to generate a virtual store layout.

After conducting a user study, they have received positive feedback. The proposed mixed-reality shop might be one of the directions of the future shopping system.

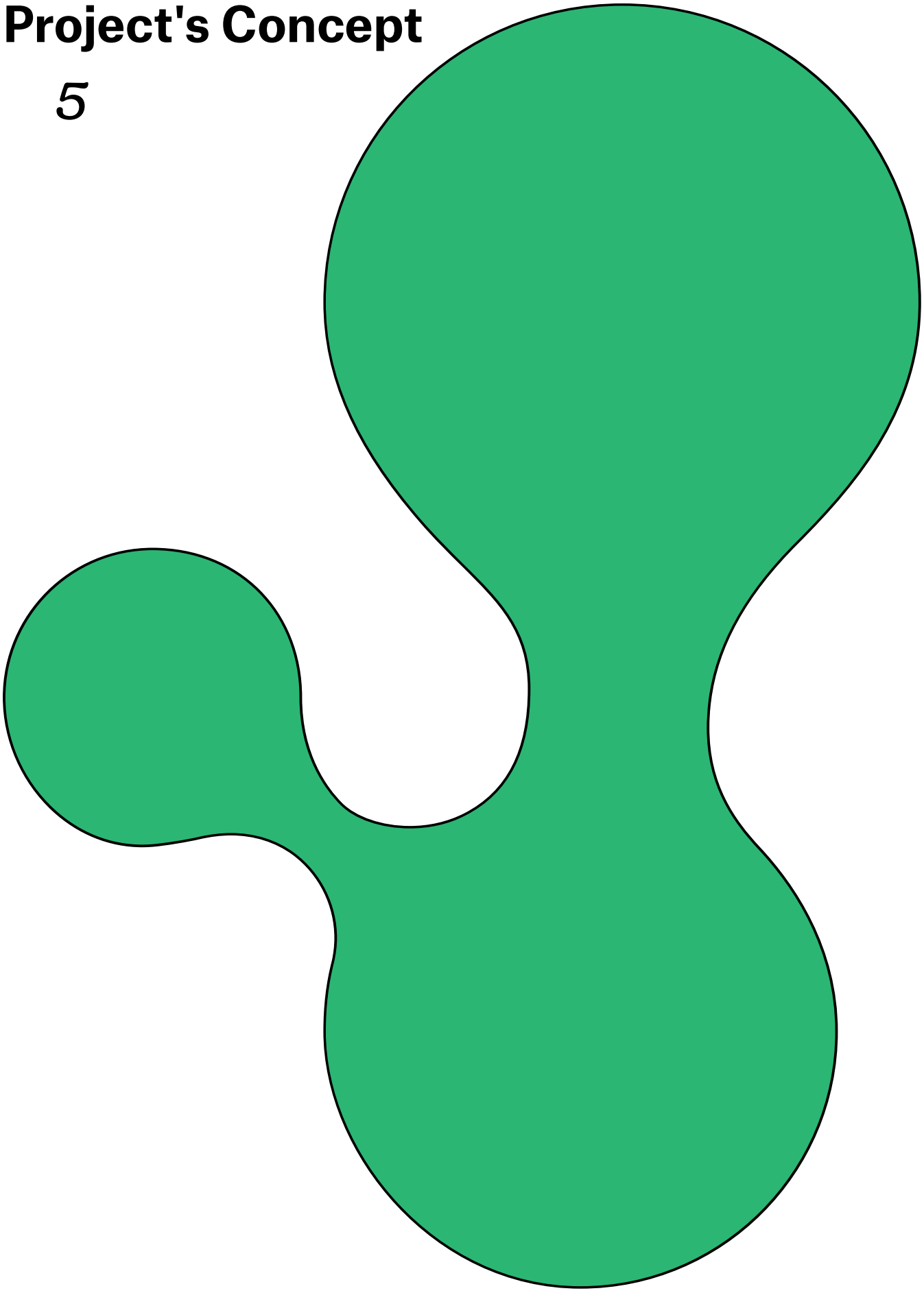
Future work and limitations

Even though researchers proposed a mixed-reality shop prototype, the web-based interface is still 2D. However the idea of a mixed-reality store is being immersed and displayed in 3D. [13]

13. Dou H., Tanaka J., "A Mixed-Reality Shop System Using Spatial Recognition to Provide Responsive Store Layout" [Online]. Springer, Cham, 2020

Project's Concept

5



5. Project's Concept

5.1 Study cases

5.1.1 Study case 1: E-obuwie store

Eobuwie is a polish footwear retailer recognized for innovative solutions in their stores. The concept is based on 'eobuwie.pl' e-commerce blended into a physical store making it an easy-to-shop self-service destination. Customers have an opportunity to shop according to their own preferences while having access to almost the entire brand's stock. The concept of new footwear retailing combines convenience of online shopping with the fast fulfillment of brick-and-mortar stores.

Eobuwie stores have no physical products for sale displayed on a shop floor. Instead customers browse through products on digital screens, making the purchasing experience smooth and very much alike to their own online shopping process.

The store layout consists of a clear path from an arrival zone to a stockroom and a warm comfortable launch in the middle of the store (Fig. 32). Eventually it is planned out for both customers seeking quick transactions (search, order and purchase) and customers who prefer a slower pace (browse, try-on). [20]

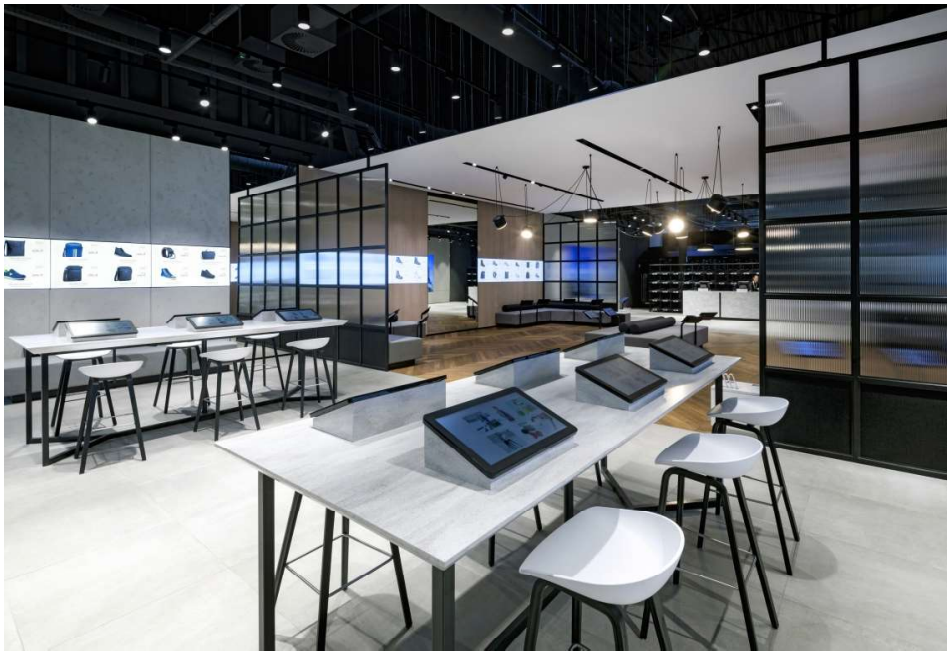


Fig. 32

20. "Eobuwie.pl brings digital fluidity to physical retail" [Online]. Ixtenso Magazine, 2018

Fig.32 Dalziel & Pow, E-obuwie interior [Photo]. Eobuwie.pl brings digital fluidity to physical retail [Online]. Ixtenso Magazine (2018

A system of racking facilitates a seamless transportation of shoe boxes in the stockroom. Over 100 000 of shoe boxes of different brands and products are housed in behind the cash desks (Fig. 33).

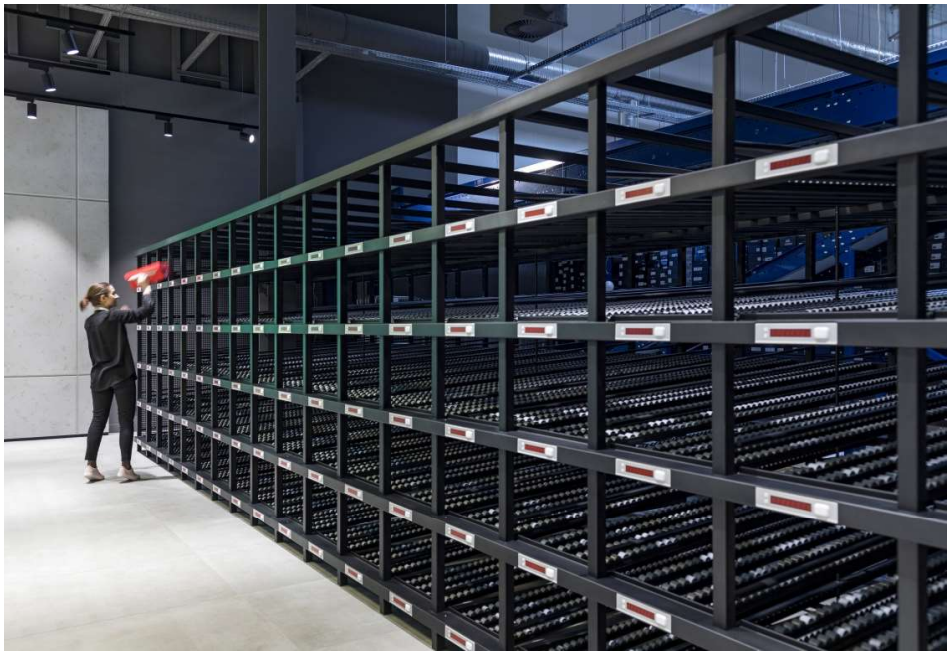


Fig. 33

Fig.33 Dalziel & Pow, E-obuwie racking system [Photo]. Eobuwie.pl brings digital fluidity to physical retail [Online]. Ixtenso Magazine (2018

5.1.2 Study case 2: Gentle Monster store

Gentle Monster is a South Korean eyewear brand with a string of stores across East Asia, United States, United Kingdom and other countries. It is known for challenging the customers and elevating the retail game with its provocative interior design. In February 2021, the brand opened its new flagship store HAUS 0 10 10 10 1, also called “HOUSE Dosan” because of its location in the neighbourhood Dosan. Breaking down the name, “01” represents a future forward direction in quantum mechanics, which is the brand’s characteristic feature, and “HAUS” from German indicates that the store houses several affiliated brands.

HAUS Dosan is situated in a five-storey concrete building, fully redeveloped by an in-house design team in order to meet the expectations of the brands’ vision called Unopened:Future. Visitors find themselves surrounded by collaborative installations between the brand and various artists. From retail, visitors can browse through eyewear from Gentle monster, cosmetic products from TAMBURINS and imaginative desserts from NUDAKE.

Fig. 34

21. "GENTLE MONSTER opens experimental retail space HAUS DOSAN in seoul." [Online]. Designboom, 2021

Fig.34 GENTLE MONSTER, HAUS DOSAN Exhibition [Photo]. GENTLE MONSTER opens experimental retail space HAUS DOSAN in seoul [Online]. Designboom (2021)

The space itself has a purpose to host retail, exhibitions and experimentations. When entering, visitors are facing a massive structure, an art installation created in collaboration with artist Frederik Heyman (Fig. 34).

Second floor is a showcase of the brand's optical eyewear, accompanied by media installations. Third floor is made for sunglasses with a theme combining past and future. Here a walking robot is exhibited (Fig. 35), made in Gentle Monster's own robot lab as another element of their experimental philosophy. [21]

Fig. 35

Fig.35 GENTLE MONSTER, HAUS DOSAN Interior [Photo]. GENTLE MONSTER opens experimental retail space HAUS DOSAN in seoul [Online]. Designboom (2021)

5.1.3 Study case 3: Balenciaga The Fall 21

A fashion house Balenciaga introduced The Fall 21 Collection on a VR runway accessible to only selected guests who received a headset sent out to them. Later on, this collection was opened to the public in the form of a video game called “Afterworld: The Age of Tomorrow” resembling a world and clothing in the near future. Balenciaga tries to set an example in repurposing clothing, normalizing wearing clothes for decades, even forever, and accepting the outcomes of material aging.

The game Afterworld imagines the worldin the year 2031 and each player starts out by choosing their avatar. They appear in a virtual Balenciaga store with a similar layout and set design to a common physical retail store. By exiting the store, players find themselves on a busy street of a fictitious metropolitan city and later lead to a rave in a forest. Throughout the game other avatars wear garments from The Fall 21 collection. A player needs to overcome a few tasks to win a game and the surprise lies on a very top of the mountain above the city. [23]

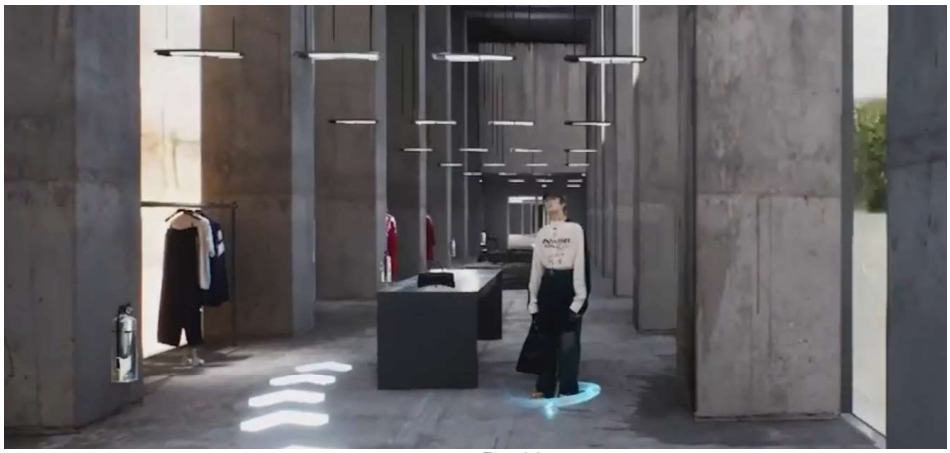


Fig. 36

Fig. 37

23. "Collection note" [Online]. Balenciaga, 2021

Fig.36 Balenciaga, Afterworld game [Printscreen]. Collection note [Online]. Balenciaga (2021)

Fig.37 Balenciaga, Afterworld characters [Printscreen]. Collection note [Online]. Balenciaga (2021)

5.1.4 Study case 4: LOEWE Exhibition

LOEWE Foundation - Craft Prize is the fourth edition of exhibitions honouring contemporary craftsmanship hosted by LOEWE, a spanish luxury fashion house. Due to social distancing and other restrictions influenced by COVID-19 in 2021, they have adapted its form to existing limitations.

The brand decided to host a virtual exhibition which is accessible through their website. It will present works of 30 finalists of the prize. Viewers “walk through” The Great Hall of the remodelled Musée des Arts Décoratifs in Paris, where the exhibition would have taken place. All the final works are viewed as high-definition 3D models allowing visitors to explore the museum from anywhere in the world. [24]

Fig. 38

Fig. 39

24. Loewe Craft Prize 2021 [Online]. Loewe, 2021

Fig.38 LOEWE, LOEWE Virtual exhibition [Printscreen]. Loewe Craft Prize 2021 [Online], Loewe (2021).

Fig.39 LOEWE, Artwork of a finalist [Printscreen]. Loewe Craft Prize 2021 [Online], Loewe (2021).

5.2 Project's Context

The retail industry has been going through several disruptions in the last few decades. Especially the recent event of pandemic resulting in closures of retail stores for a significant period of time. Besides the fall of popularity in physical stores, people were convinced to adapt to online shopping even though they did not have experience with it before. Experts encourage retailers to redefine the concept of physical stores and combine benefits of having online and in-store sales channels. [1]

The goal of this project is to test out a concept born from merging benefits of digital and physical retail. The combination of two worlds results in A Mixed Reality Retail System. Variants within the mixed reality world can be numerous and dependable on a ratio of physical and virtual objects. For the intention of presenting a specific example, the proposed retail store has a physical location, structure and inventory, but utilizes product displays, media and staff like in an online store. Its design process is based on previously collected data from selected retail stores and their non-traditional way of merchandising, system of Omnichannel Retail and current state of Mixed Reality Technology.

5.2.1 Project's location, stakeholders and users

Location

The location chosen as a reference, is a Danish city - Copenhagen. Being the capital city of the country, its population is approximately 600 000 people. I have been living here for 6 years and recently started to notice that the center of Copenhagen is less and less busy, mostly used by passing tourists, and package spots in the neighbourhood are becoming busier with longer queues. From my personal experience, as a local I rarely visit the city center because it is overtaken by shops and mostly of brands which I am not interested in. This outcome makes me feel a little bit disappointed since the city center is strategically the best location to meet for citizens. [25]

Therefore this concept presents a network of shopping options throughout the city. Characteristics of an MRS is to be accessible and convenient for the users. The bigger picture is to have several MRS spreaded in the city as a net. Its physical and geographical convenience lies in being reachable within 2 km, which is approximately a walk within 20 mins and a bike ride within 6 minutes (Fig. 40). [26]

26. Time Trap (film). In: Wikipedia [Online].Wikimedia Foundation, Inc., 2021

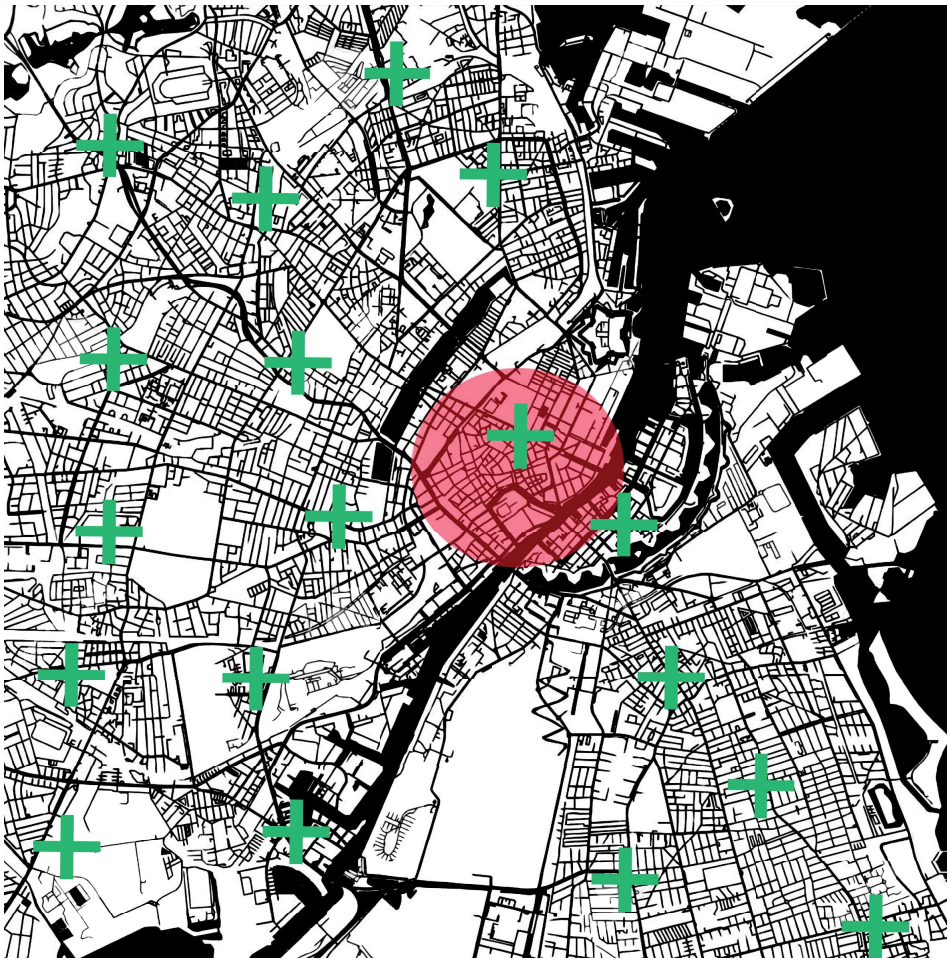


Fig. 40

Fig. 40 is a map of Copenhage. It graphically describes the idea of placing MR stores in neighbourhoods 2 km distant from a user. Green crosses represent MR stores and red zone shows 2 km radius.

Stakeholders

PUUF is a furniture design studio in Copenhagen, Denmark. Its focus is circularity, sustainability, functionality and play. Recently they have launched a line of furniture which is available for consumers to buy from their website. The studio doesn't include a showroom, but it houses a warehouse where the furniture is being produced. Because it is located 12km away from the city center and the area is mostly industrial, it becomes quite challenging and time consuming for potential customers to pay a visit.

Fig.40 L. T. Nguyen, Placement of MR stores [Illustration]. Own source, 2021

Fig. 41

Fig. 42

Fig.41 PUUF, Recycled plastic components [Photo]. Available at: www.instagram.com/puuf.studio/

Fig.42 PUUF, Recycled plastic sheet [Photo]. Available at: www.instagram.com/puuf.studio/

COMPONE is a fashion studio based in Bratislava, Slovakia. Its focus is reusability, circularity and authenticity. Garments are designed in a Compone app by customers and produced by a machine. The production consists of used clothing pieces which are stitched together digitally and mechanically. The studio doesn't own a showroom since the pieces are 3D virtual elements and clothes are produced after a customer purchases them.

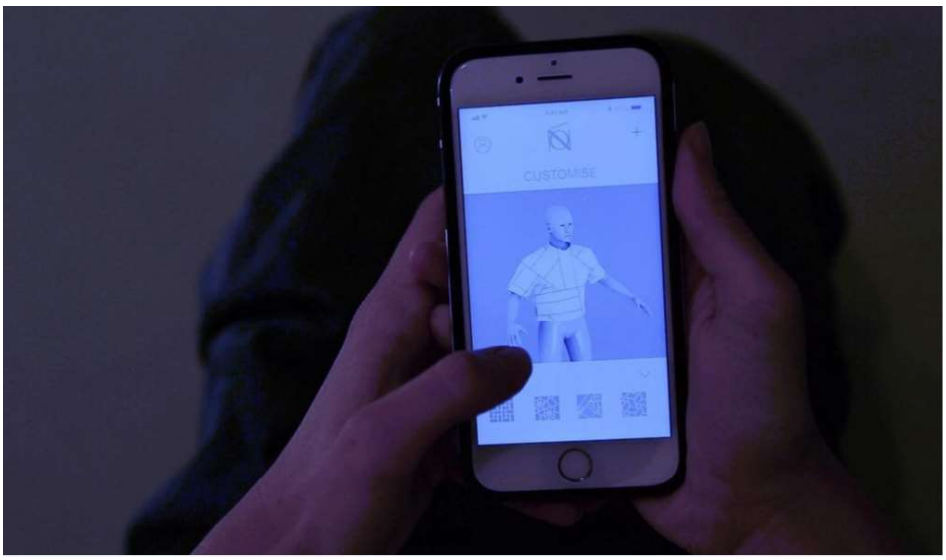


Fig. 43

Fig. 44

Fig.43 Compone, App interface [Printscreen]. Compone, Available at: https://www.instagram.com/compone_studio/

Fig.44 Compone, 3D clothing [Printscreen]. Compone, Available at: https://www.instagram.com/compone_studio/

Users

Copenhagen citizens - From my personal observation throughout the years living in Copenhagen, I believe that people are tech-savvy and constantly work towards a better future. In this case the better future is sustainable solutions, rethinking traditional ways of living and utilizing technology for a comfortable everyday life. This project aims more specifically on Millenials and Gen Z due to their basic technological skills. Additionally according to "The Future of Luxury Fashion" report [17], 61% of a luxury market in 2026 will be consumers from these two generations.

5.2.2 Project's design concept

A concept of a **mixed reality retail store Morph**: a brick-and-mortar store, situated in your neighborhood as frequently as needed. It fulfills the requirement of being the store "just behind the corner", where you can try on products, not spend too much of your time, receive help and enjoy the experiential component. MRS has a hidden fulfillment center which means that you can pick up physical products right away from the store if available.

The store serves as a house for various brands which are sharing the same values and customer target group. The showroom can introduce one or few brands, and can switch between brands within seconds due to its digital character. For this compatibility to happen, there needs to be an organized layout for registered products and direct guidelines for brands to upload their products on the same digital platform. Each customer is free to view a product display of their choice and have a personalized selection.

Key elements to consider for design:

1. Mixed Reality device - for this proposal to carry on, it is assumed that in the future people will possess a mixed reality device as they currently do possess smartphones.
2. 3D digital objects - retailers provide scans or digital models of their products.
3. Digital platform - a platform enabling mixed reality objects to be displayed, viewed and interacted with.
4. Physical space - easily accessible for potential customers, physical interior design and layout should be complementing mixed reality design and layout.

Fig. 43 explains a mixed reality store. Each segment provides a materialistic or emotional input into the collaborative system.

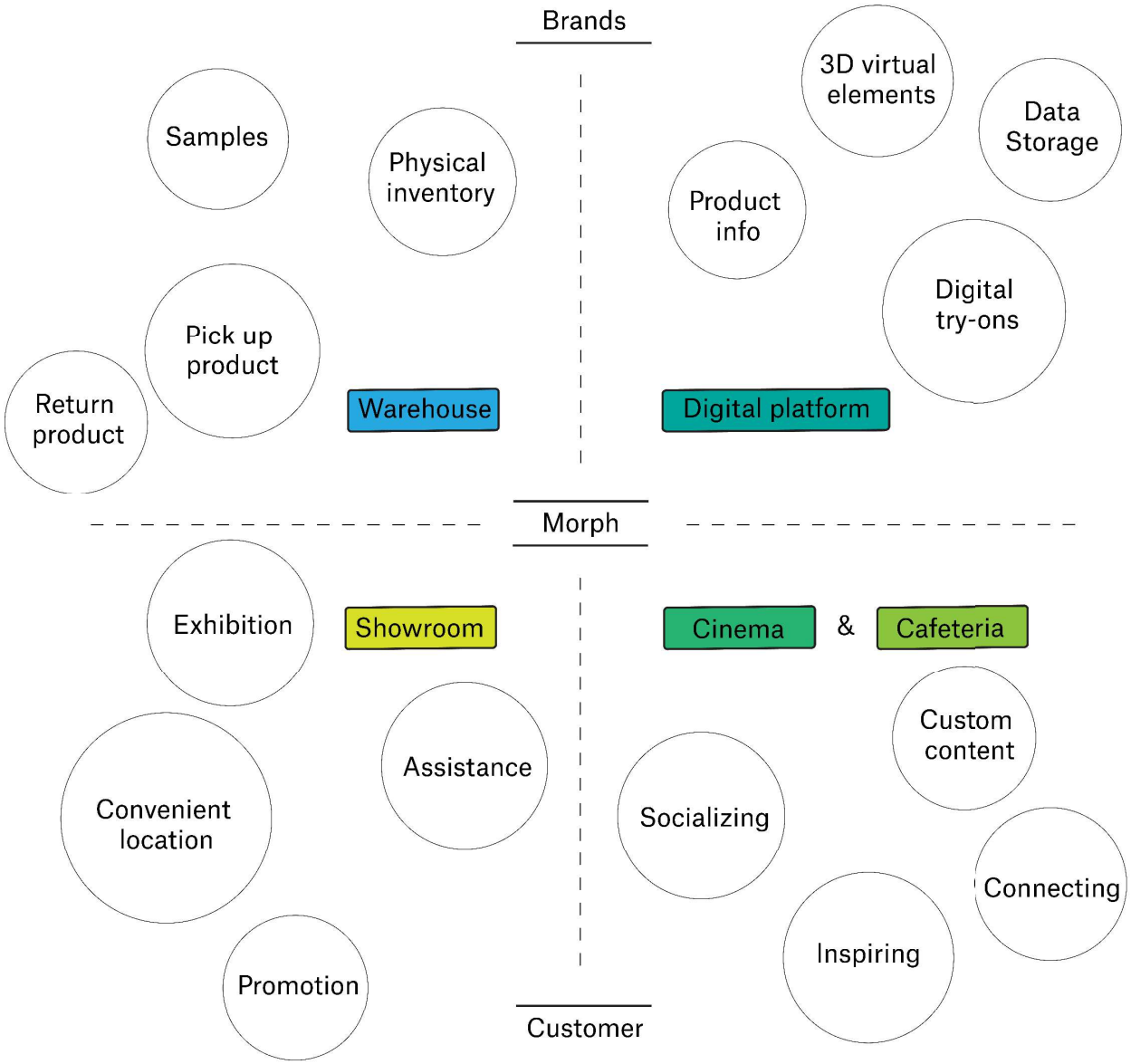
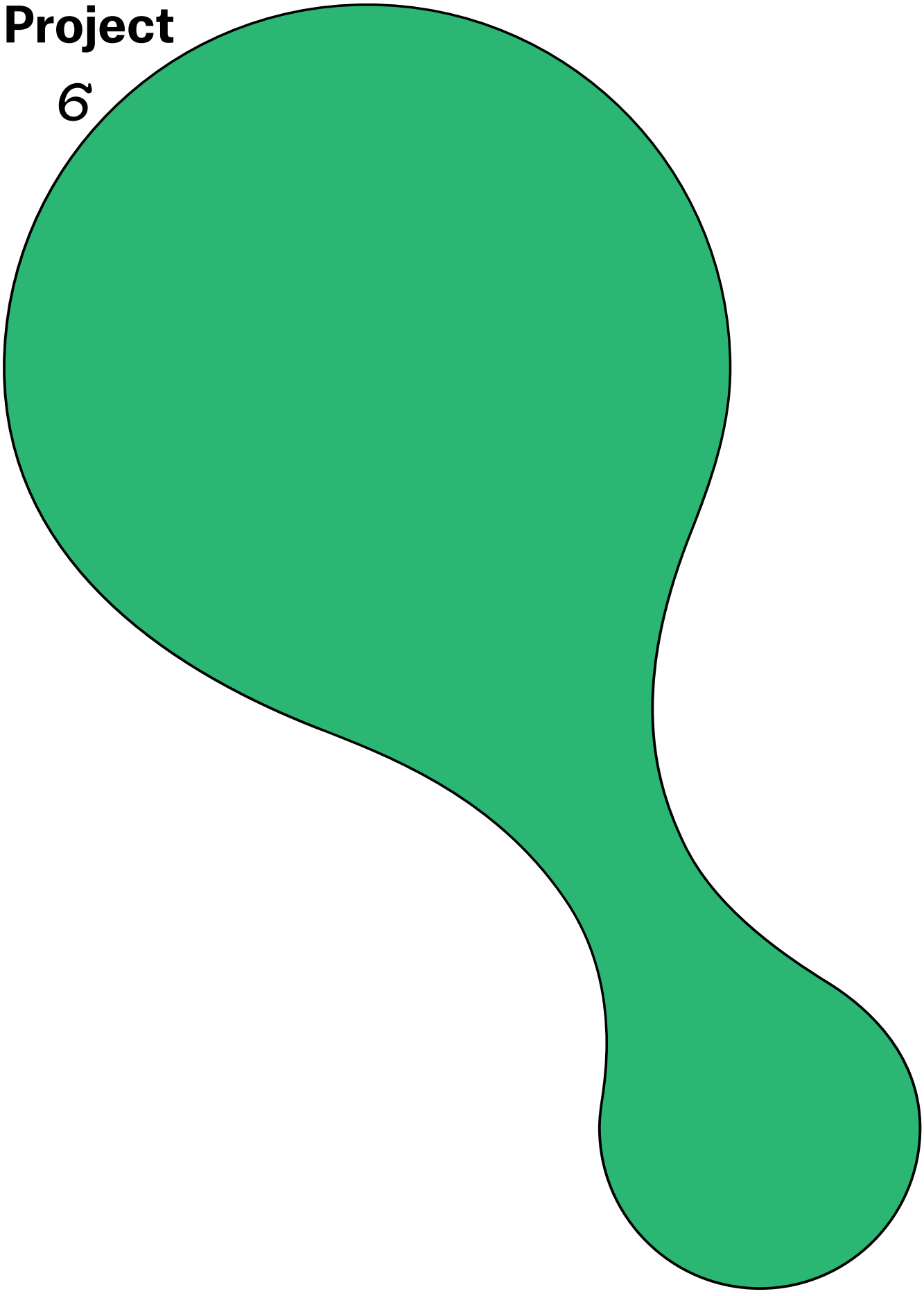


Fig.43 L. T. Nguyen, Design concept [Illustration]. Own source, 2021

Fig. 43

Project 6



6. Project Design

6.1 Design process

In order to design a mixed reality system, one must consider factors of both physical and virtual world. The design proposal will include elements related to study specialization - contemporary design. Considering the time and work available, several elements of the MR system willl be sketched out rather than submitted in detailed. Concepts for user experience, user interface, architectural layout and interior design will be drawn out and finally put together as a prototype.

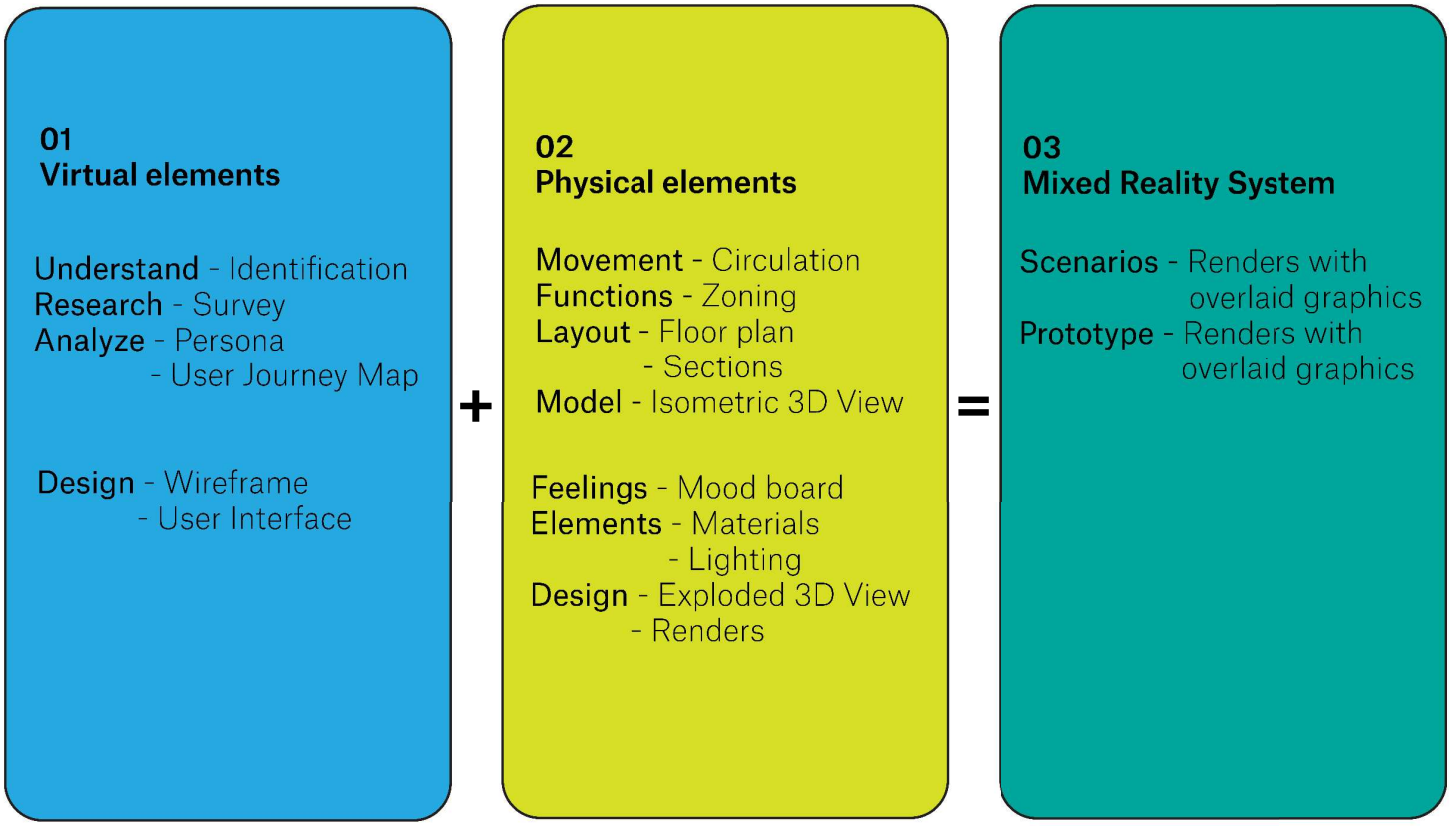


Fig. 44

Fig.44 L. T. Nguyen, Design process [Illustration]. Own source, 2021

6.2 Virtual elements

6.2.1 Understand - Identification

Let's start the process with understanding and identifying user's problems in order to work towards a solution, then understanding the brand's goals and missions to see how they align with problems that users are facing.

Fig. 45

Fig.45 L. T. Nguyen, Understanding users [Illustration]. Own source, 2021

6.2.2 Research - Survey

Challenge the assumptions and base the research on questioning potential users. I have interviewed 9 people who potentially might be the future customers. 5 of the participants are female and 4 are male. Most of them are Gen Z and the rest are millenials. They are students and working post-graduates, between age 14 - 27. I have created 12 questions, aiming to understand the current reality of users, problems they are facing and in what future they would like to live in regarding commerce, consumption and retail. Afterwards I have collected most common answers.

Example: Clothing (9) - 9 participants answered “Clothing”.

1. Within the past 12 months I have been looking for and buying these types of retail products... (excl. everyday consumer products such as groceries)

Clothing (9), electronics (5), furniture (2), cosmetics (2)

2. I usually visit e-commerce websites when I search for following products...

Clothing (6), electronics (5), furniture (2)

3. My mostly visited e-commerce website is ... and I use it because...

A: Amazon - huge variety of products, low price

Zalando - convenient (free delivery and returns)

ASOS - simple website, easy navigation

IKEA - easily accessible, nice designs and affordable

4. I would usually visit a physical store when I search for following products...

Clothing (7), furniture (2), electronics (2)

5. My mostly visited store is ... and I go there because...

Second hand shops - unique pieces, sustainable

ZARA - big selection of clothes for a low price

H&M - sales

Celine - for the luxury feeling and design

6. I find the activity of shopping ...(e.g. inspiring, frustrating, enjoyable, meditative)

Enjoyable for a short amount of time (30-60 minutes), not so often and in small quantities becasue I have a feeling of treating myself, interesting and relaxing. But more often frustrating, overwhelming and annoying when I can’t find the desired product andspend too much time in a store or browsing a website.

7. Top problems I find regarding online shopping are ...

Not being able to see the real size, material and quality. (5)

Delivery and return issues (3)

Overload of choice (3)

Data protection issues (2)

No assistance

8. This is how I cope with the problems I find during online shopping...

Vist the brand's physical store. (4)

I make sure their return policy is appropriate. (2)

I check reviews and do a research about the company.

I ask my friends for opinions.

Only visit certain websites and don't save my bank/ personal details.

9. Top problems regarding shopping at physical stores are ...

Time consuming, adjusting to opening hours, commuting (4)

Lacking clear overview of available goods. (3)

Limited selection. (2)

Messy stores. (2)

Trying on clothes and carrying it.

Pressure of buying an item because of browsing or trying on.

Higher prices, no personalized sales.

10. This is how I cope with the problems I find during shopping at physical stores...

Planning ahead on what products to buy. (4)

I ask the shop assistant. (2)

I leave. (2)

I order it online instead, either at their website or other with a lower price. (2)

11. I think that current state of commerce and attitude towards consumption should ... (Describe your vision on future way of shopping.)

I support online shopping but there should be a way to introduce features that physical shopping brings to customers.

People should stop buying fast fashion or similar products, focus more on quality and sustainability.

Would be useful to have a demo in VR before purchasing a product.
Shift people's mindset on valuing products they already own.

Use app to view products in my own space, or to use an avatar representing myself to see if clothes will fit my measurements

Consumption should be deemed as an experience as opposed to a day to day mindless event. Become more conscious so that only real needs are fulfilled through consumption.

I don't know.

12. I'm interested in changing/ not changing the current state of commerce because...(Express your opinion, concerns & objectives.)

Environmentally friendly consumption and sustainability is not where it is supposed to be - Greenwashing.

People should be more aware about their purchase and the reasons behind its cost - tranparency.

I expected recycling and returns to the same brand I bought the products from to be more common by now.

Photos are tricky and brands will try to create best pictures of their products. Therefore it would be useful to have a way to preview product's real condition. It would be useful to have a way to preview product's real condition.

Even people around me who understand there is a huge waste and overconsuming problem, they still buy fast fashion brands and meaningless products.

Slower pace of consumption could help slow down society and have a positive ripple effect in 1.) physical-mental wellbeing, 2.) the climate 3.) the economy(?)

Summary of the survey:

Where people are today?	Obstacles that stop them	Where they want to be
Customers mostly shop clothing, then electronics, furniture and cosmetics. They visit mass scale e-commerce websites for convenience, segmentation, good policies and lower price. They visit physical stores for quality check, size fitting, atmosphere and easy accessibilty if it's nearby. They find shopping enjoyable, rewarding and realxing when it lasts a short amount of time, desired products are available and easy to reach. They find it frustrating, overwhelming and annoying when a user can't find the desired product, spends too much time in a store or browsing a website.	Not being able to see the real size, material and quality. (5) Time consuming, adjusting to opening hours, commuting (4) Delivery and return issues (3) Overload of choice (3) Clear overview of available goods. (3) Limited selection. (2) Messy stores. (2) Data protection issues (2) Trying on clothes and carrying it. Pressure of buying an item because of browsing or trying on. Higher prices, no personalized sales. No assistance	Combination of benefits that digital and physical stores offer. Consumption should be deemed as an experience and become more conscious. Genuinely focus on quality, sustainability and environment. Slower pace of consumption. Implement technology to cut on wrong purchases and avoid misinterpretation. Valuing products users already own.

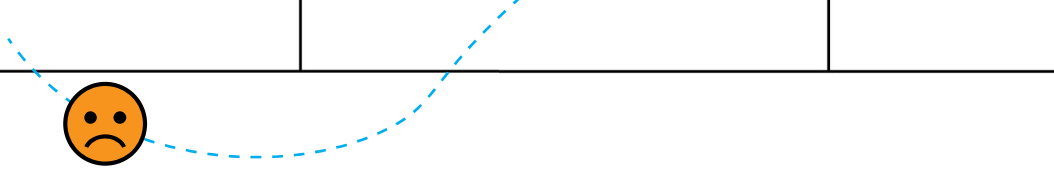


Fig. 46

Fig.45 L. T. Nguyen, Survey summary [Illustration]. Own source, 2021

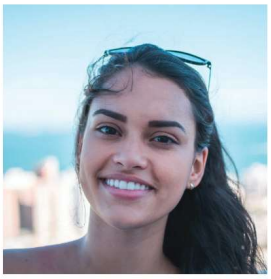
6.2.3 Analyze - Persona & User Journey Map

After understanding the situation from the perspective of a customer, research results are translated into a fictive persona, Alice Liang, represententing interviewees.

Fig.47 Girl, Source: www. pexels.com

Fig.45 L. T. Nguyen, Persona [Illustration]. Own source,2021

Fig. 47



ALICE LIANG

Age: 24
Occupation: Business analyst
Status: Single
Location: Copenhagen, Denmark
Tier: The primary end user
Archetype: The planner

"The world would be boring without creativity."

BIO

Alice is a life enthusiast with an alalytical mind.
She is hungry to know the world, people and places.
Her job gives her financial stability and ability to plan ahead which part of the world she will visit next.
She enjoys social and cultural events, and she is very conscious about her time and decisions.
She finds fascination in arts, design and performance but has never gone deeper into these fields.

BEHAVIOUR

She is responsible and not afraid of hard work.
Uses Instagram for inspirations in travels, fashion, interior design, food and make-up.
Follows magazines for latest updates in business, technology, world news and self-develpment.

GOALS

Save time on meaningless tasks.
Contribute to the well-being of our planet.
Be inspired and inspire people.

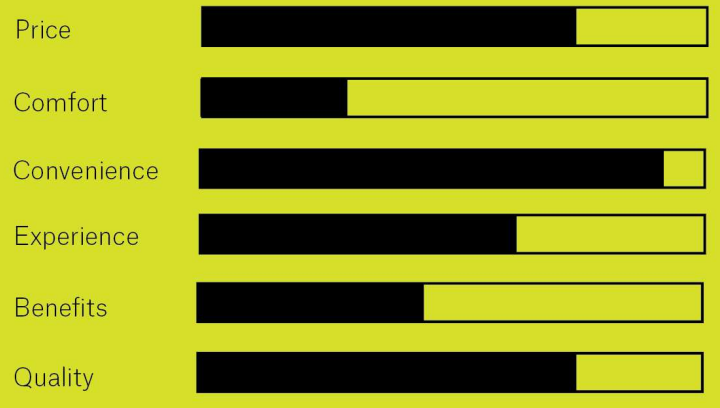
PAINPOINTS

She finds current state of consumption to be meaningless and toxic but many times she falls into the hole of mindless shopping herself.

She would like not to create as much waste as possible and appreciate things she posses.

She hopes to utilize technology not only for the sake of trends but for sustainability.

MOTIVATIONS



PERSONALITY

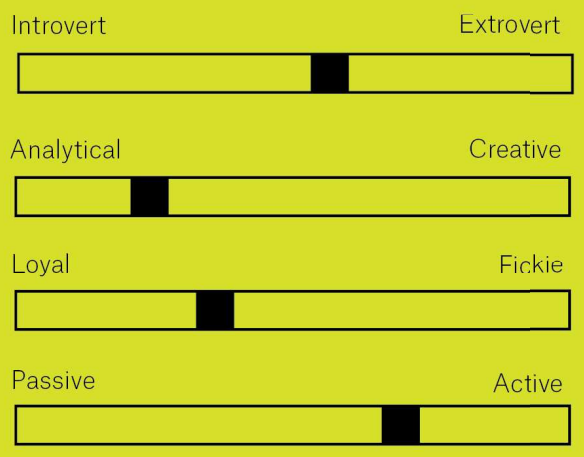


Fig. 48

User Journey map is sketched out to help with imagining potential scenerios, e.g. the moment when a customer gets to know about Morph, the way they get convinced to visit the store and the moment they decide to purchase a product.

It is necessary to understand customer's goals and afterwards design a system where these goals can be reached. The two main goals which are being focused on are "having ability to find desired products" and "have a menaingful experience. These features are additionally chosen to differentiate the store on a marketplace and to be used for marketing campaigns.

Fig.45 L. T. Nguyen, Customer Journey [Illustration]. Own source,2021

	ACTIONS	TOUCH POINTS	EMO TIONS	THOUGHTS	OPPOR TUNITIES
DISCOVER	Word of mouth Informed by a neighborhood council Social media E-mails Online advertisment	Baner ad	😐	*"Hm interesting. A mixed reality shop just opened around the corner and I can go there anytime."*	
LEARN	Enter MR Shop Register/ Log in Start demo	Landing page Registration form Interactive video	☹	*"This technology is still novel to me. I am not sure what do they expect me to do."*	Build an effective, easy to understand and remember demo. Encourage users on benefiting from virtual assistants.
USE	Without virtual assistant With virtual assistant Personalize product/ brand segmentation Search for the desired product Product preview Product try-on Customize Explore information about product's origin, production, features, usage and cost Walk through a persona-lized exhibition created by in-house brands Select prefered time spent in MR shop Preview your journey	Navigation links E-commerce site Category page Product page Search bar Product captions Product alteration	🙂 😐 ☹ 🙂	*"Great, I can get an assistant to guide me through the whole process."* *"I have been wanting to replace my old coffee table for some time, but didn't had energy or time to do a proper research."* *"Many options, not making it easy for me to decide. From the first impression they all look great."* *"Let's check some insights and see which company fits my values the most."*	Build clear navigation links and category pages. Offer ability to quickly compare and help users to deeply analyze products.
DECIDE	Select for purchase or archive Save information about its usage for long-lasting good condition. Watch a performance or documentary provided by in-house brands Start your journey	Account page Documentary	😀	*"The video about the design drivers and production of this chair helped me better understand its value."*	
GOALS	Have an ability to find desired products Make a conscious buying decision Have a meaningful experience Shop within a convenient time and place	Payment page Feedback form	🙂	*"I will save it in my archive to see if it fits to my apartment and then purchase it from home."*	Send out reminders and customer experience survey in foms of text or voice message

Fig. 49

6.2.4 Design - User Interface

As the case is involved around mixed reality technology, user interface is connected and influenced by the real environment. Digital 2D elements are superimposed on user's display, functioning as buttons and links on a trasitional website. The difference is their manipulation with both hands, using natural movements and voice commands instead of manipulation with a mouse. Products and other digital elements can be viewed in 3D.

Following section presents a wireframe of both digital and physical scenes based on steps from a user journey map.

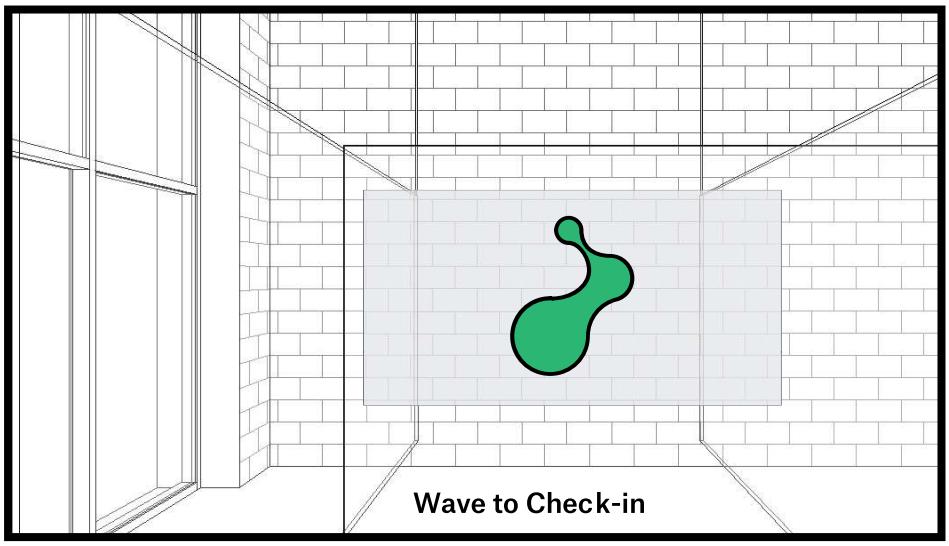


Fig. 90

START

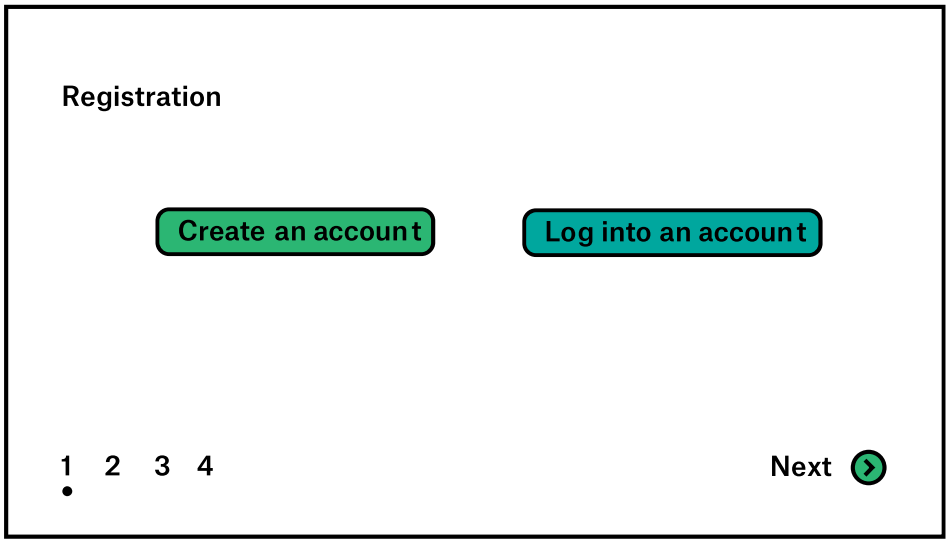


Fig. 91

2D View of a graphic interface visible through a head-mounted dislay.

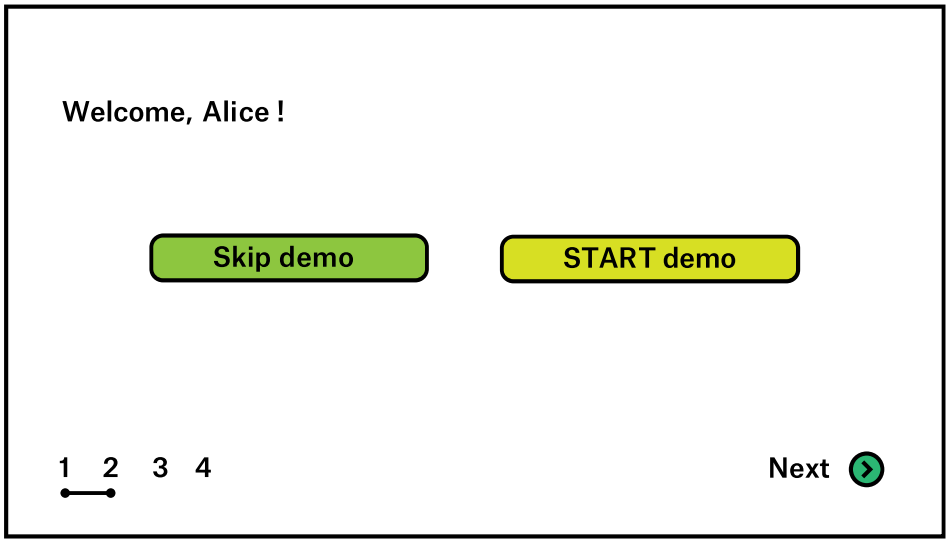


Fig. 92

Fig.90 L. T. Nguyen, User Interface - Check-in [Illustration]. Own source,2021

Fig.91 L. T. Nguyen, User Interface - Register [Illustration]. Own source,2021

Fig.92 L. T. Nguyen, User Interface - Demo [Illustration]. Own source,2021

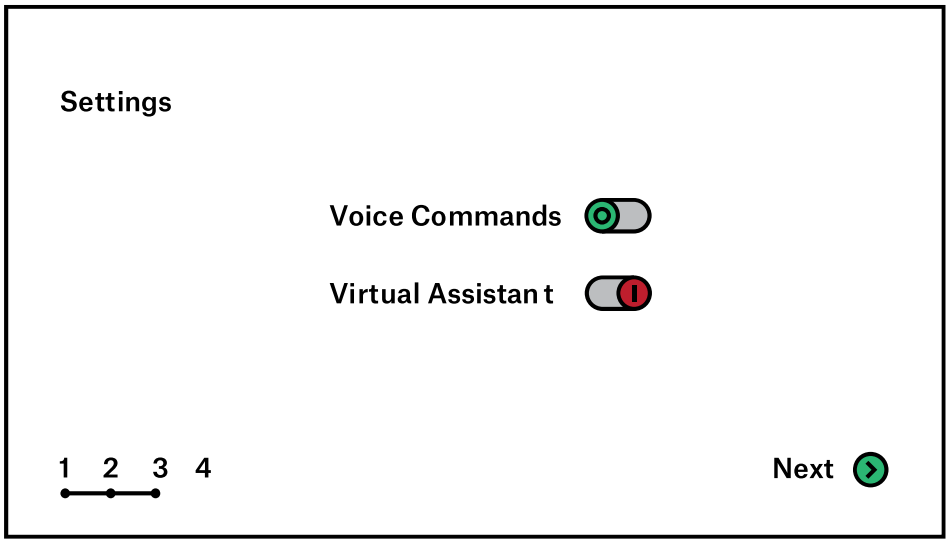


Fig. 93

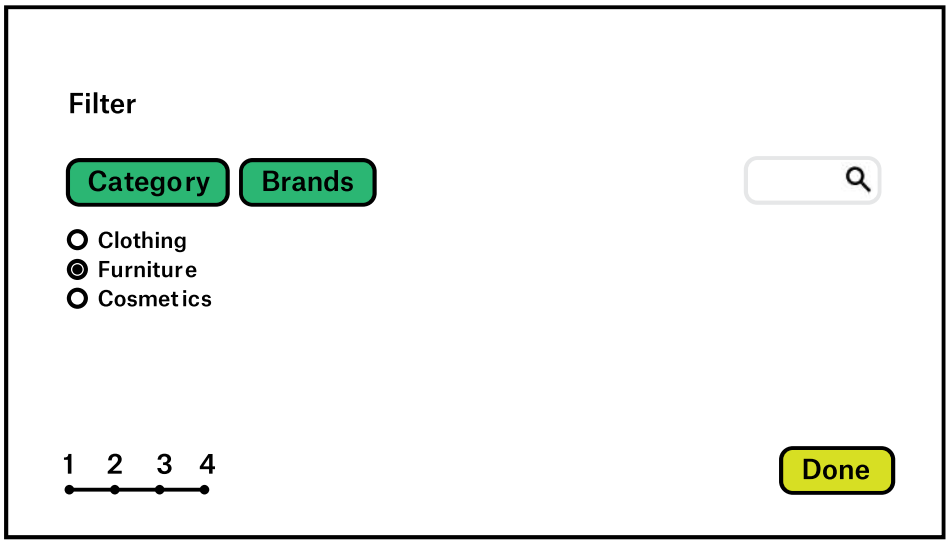


Fig. 94

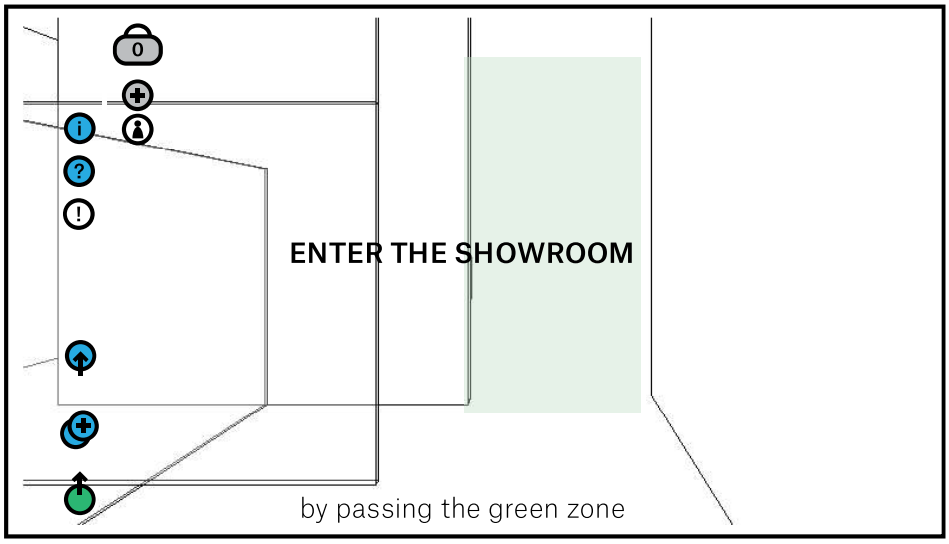


Fig. 95

Fig.93 L. T. Nguyen, User Interface - Voice command [Illustration]. Own source,2021

Fig.93 L. T. Nguyen, User Interface - Personalization [Illustration]. Own source,2021

Fig.95 L. T. Nguyen, User Interface - Enter showroom [Illustration]. Own source,2021

3D View of the real environment withan overlaid graphic interface.

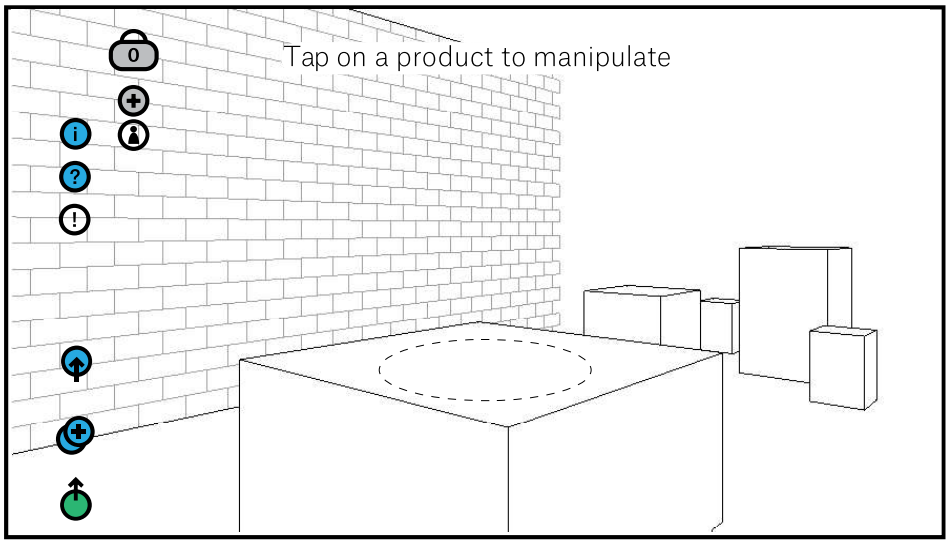


Fig. 96

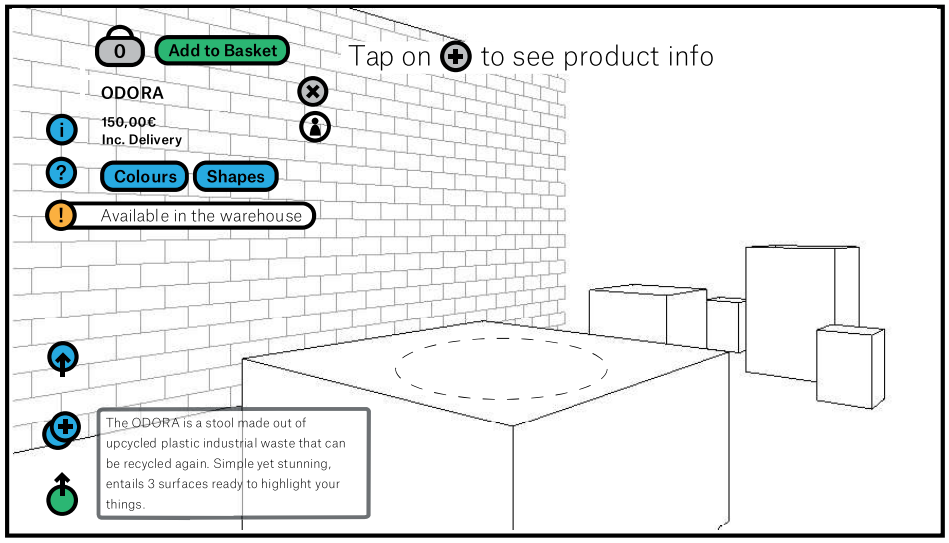


Fig. 97

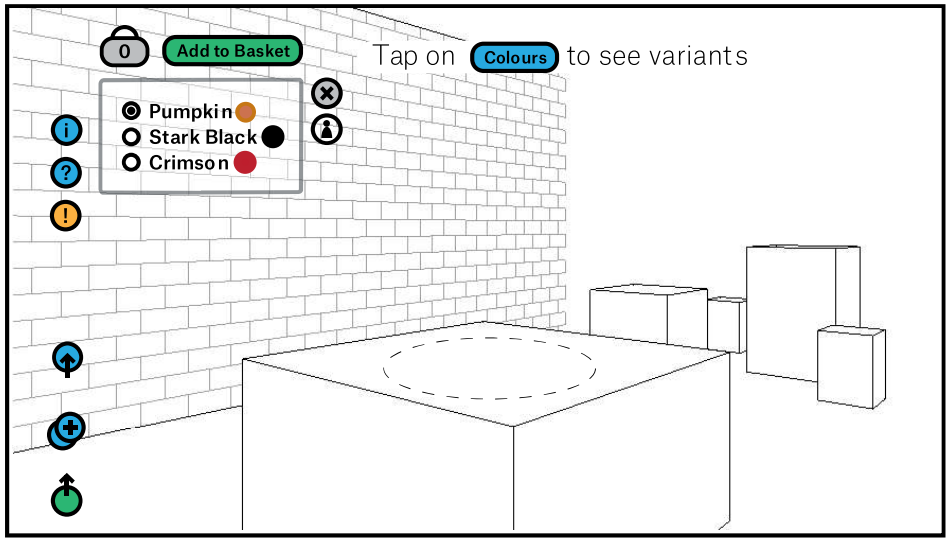


Fig. 98

Fig.96 L. T. Nguyen, User Interface - Product manipulation [Illustration]. Own source,2021

Fig.97 L. T. Nguyen, User Interface - Product info [Illustration]. Own source,2021

Fig.98 L. T. Nguyen, User Interface - Product colours [Illustration]. Own source,2021

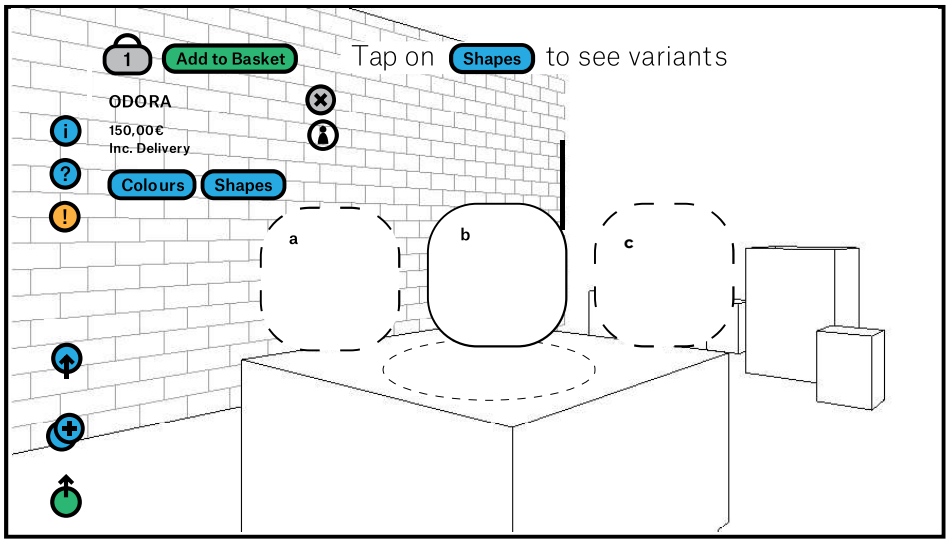


Fig. 99

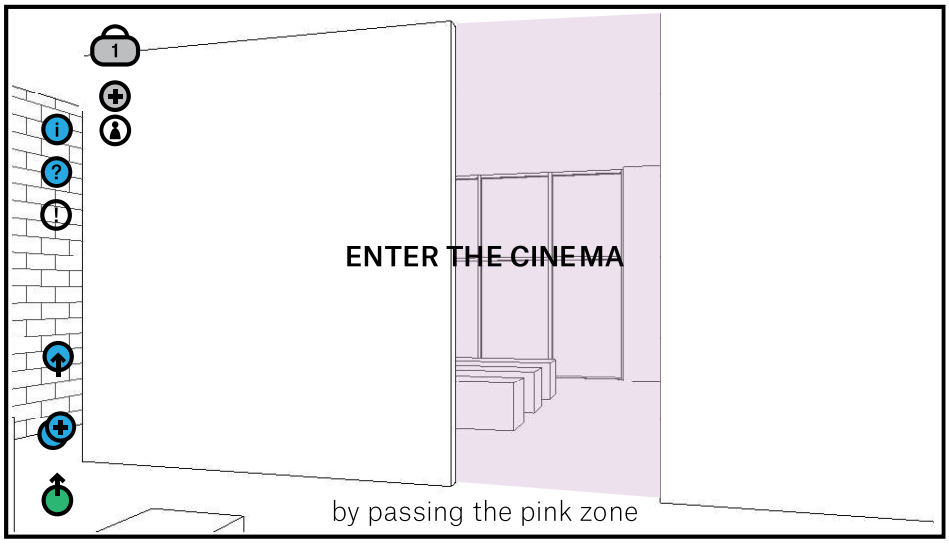


Fig. 100

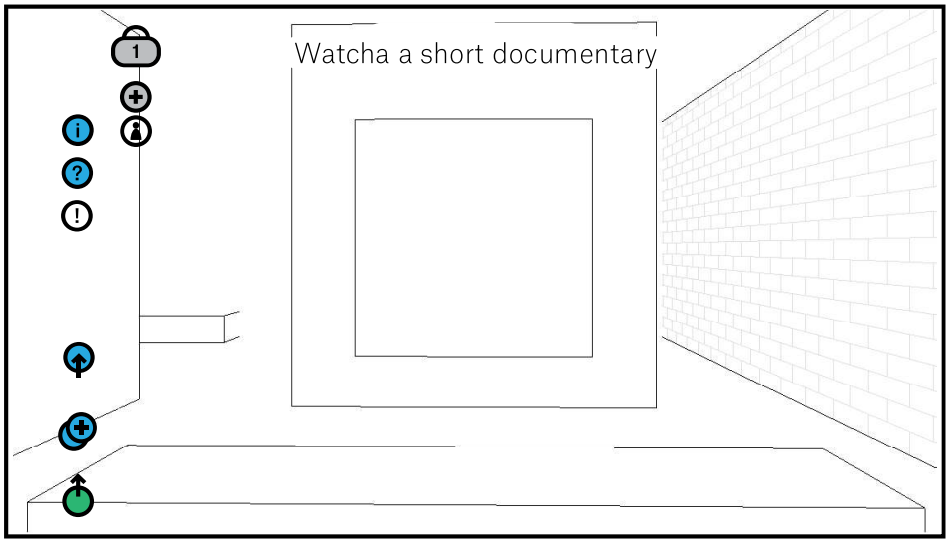


Fig. 101

Fig.99 L. T. Nguyen, User Interface - Product shapes [Illustration]. Own source,2021

Fig.100 L. T. Nguyen, User Interface - Enter cinema [Illustration]. Own source,2021

Fig.101 L. T. Nguyen, User Interface Watch documentary [Illustration].

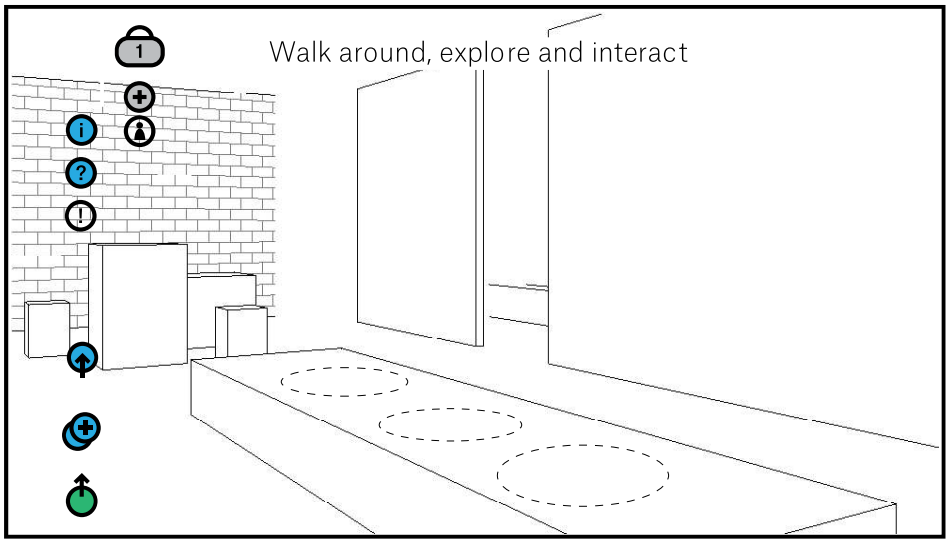


Fig. 102

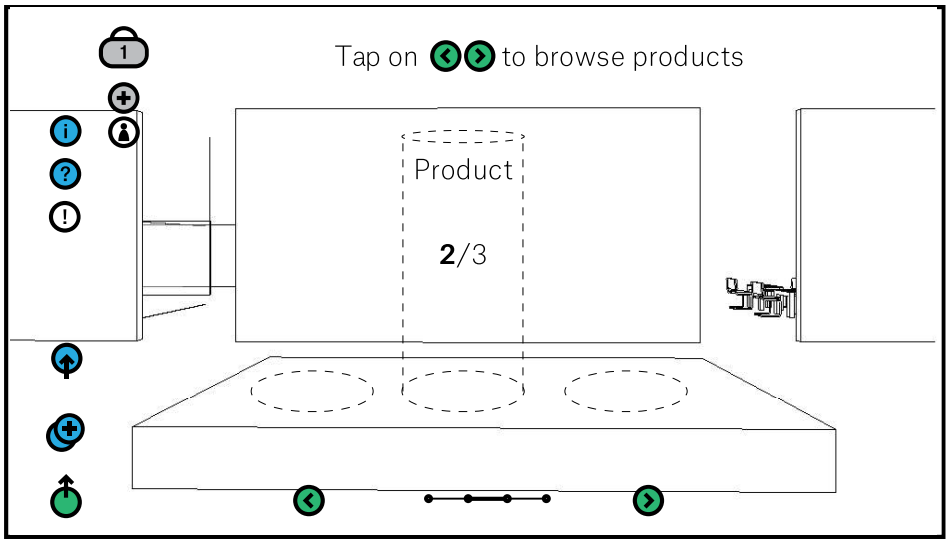


Fig. 103

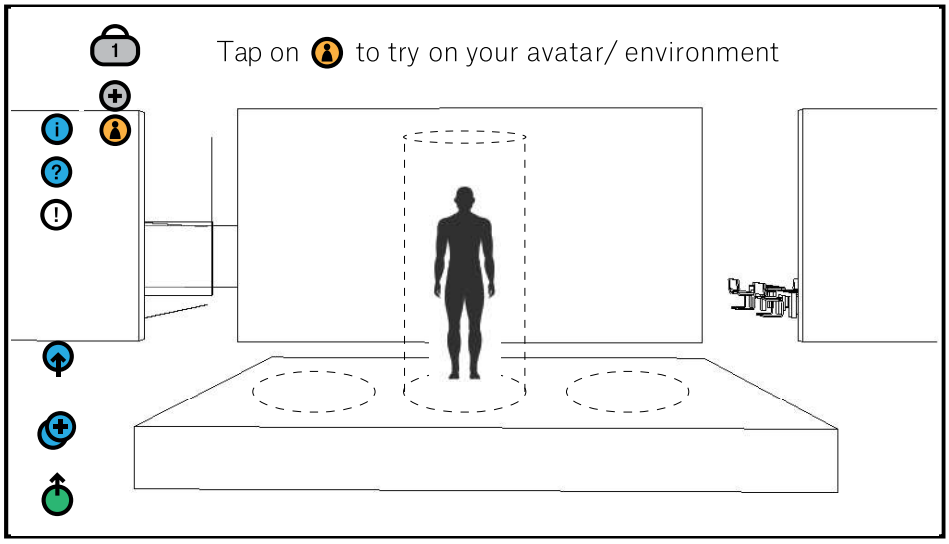


Fig. 104

Fig.102 L. T. Nguyen, User Interface - Explore showroom [Illustration]. Own source,2021

Fig.103 L. T. Nguyen, User Interface - Browse products [Illustration]. Own source,2021

Fig.104 L. T. Nguyen, User Interface - Try on avatar [Illustration]. Own source,2021

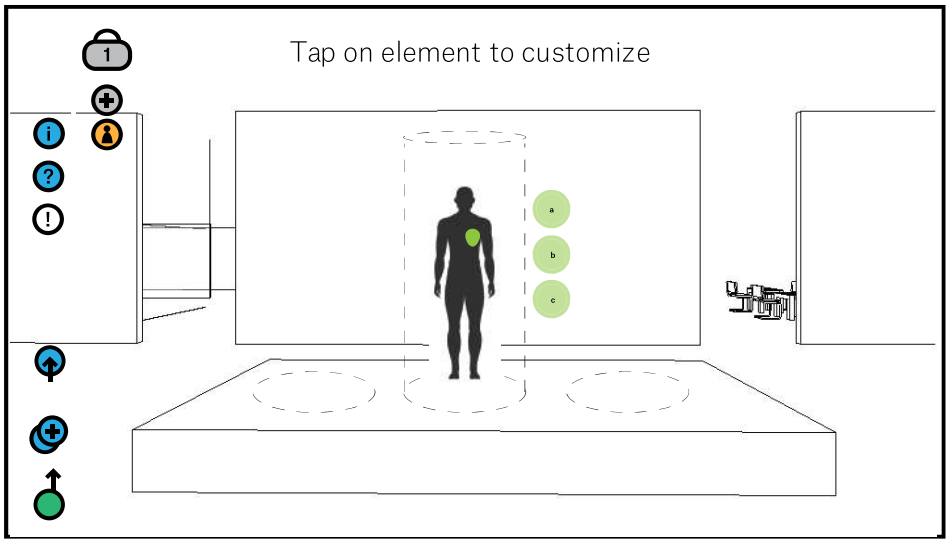


Fig. 105

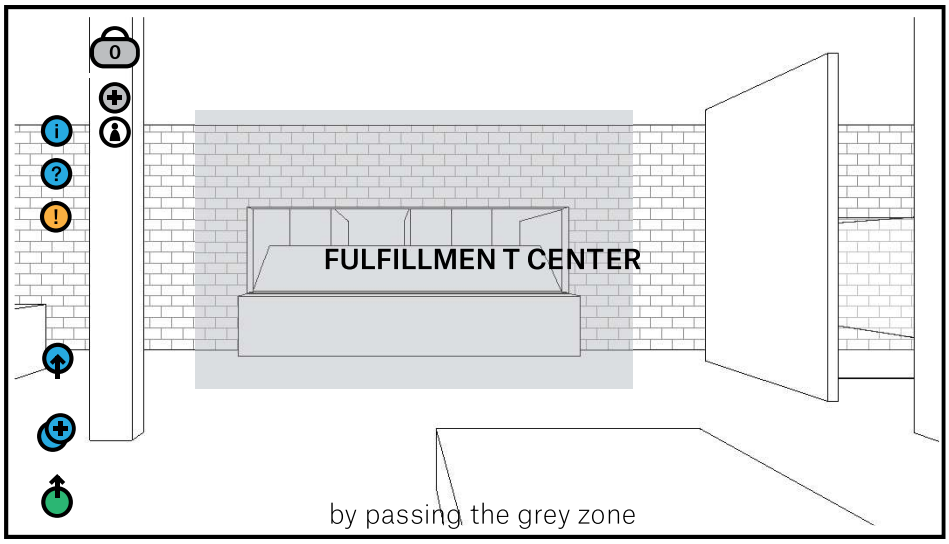


Fig. 106

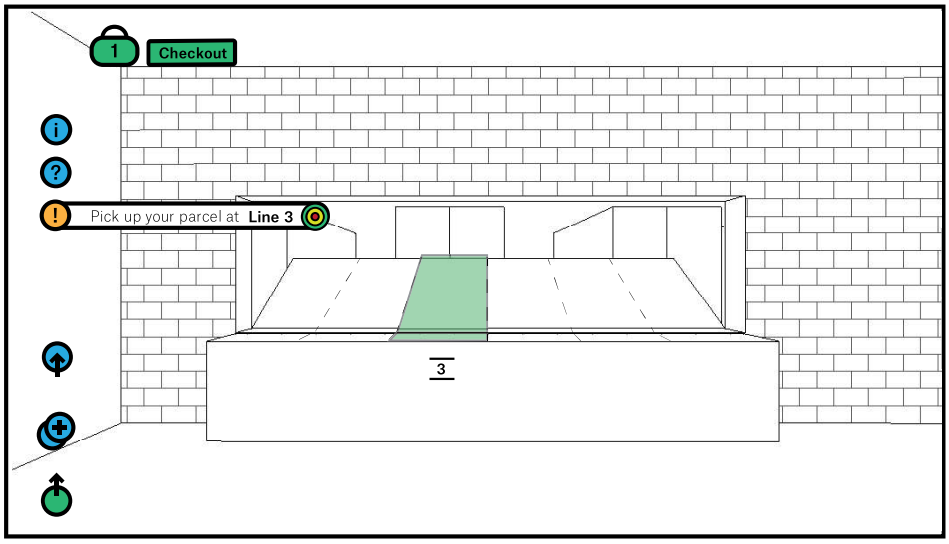


Fig. 107

Fig.105 L. T. Nguyen, User Interface - Customize product [Illustration]. Own source,2021

Fig.106 L. T. Nguyen, User Interface - Enter Fulfillment centre [Illustration]. Own source,2021

Fig.107 L. T. Nguyen, User Interface - Pick up parcel [Illustration]. Own source,2021

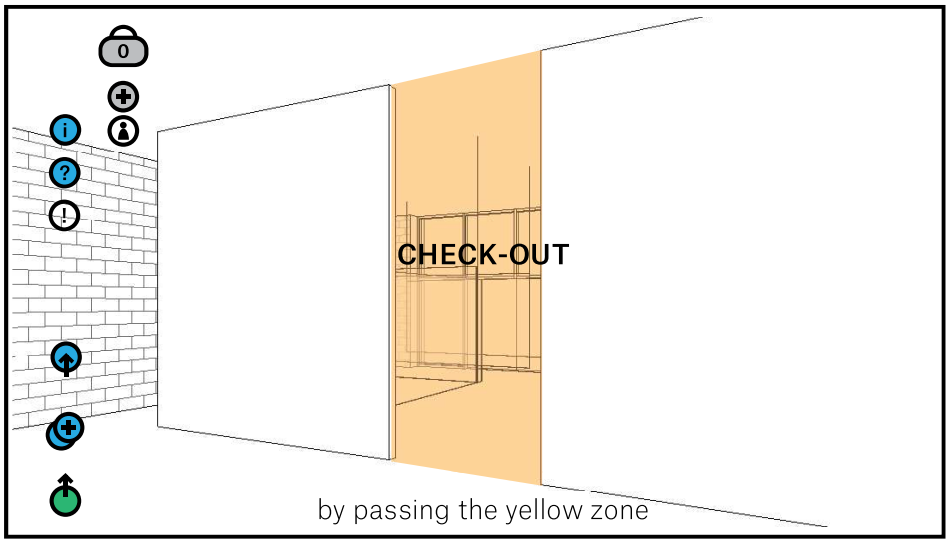


Fig. 108

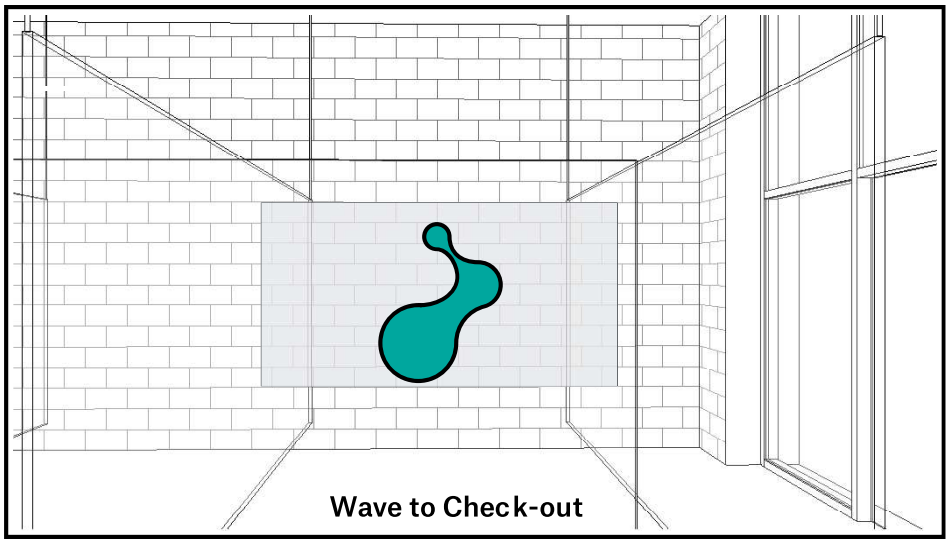


Fig. 109

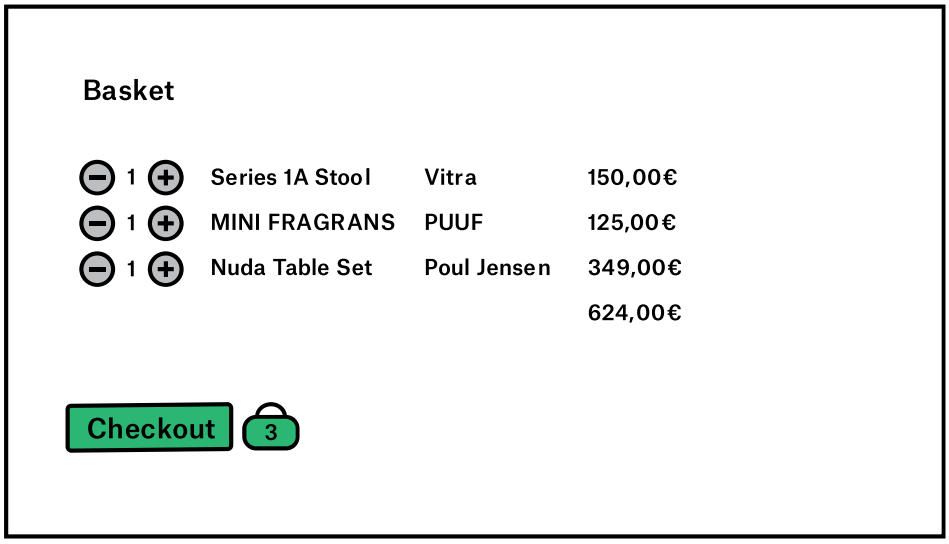


Fig. 110

Fig.108 L. T. Nguyen, User Interface - Enter check out [Illustration]. Own source,2021

Fig.109 L. T. Nguyen, User Interface - Check out [Illustration]. Own source,2021

Fig.110 L. T. Nguyen, User Interface - Basket [Illustration]. Own source,2021

2D View of a graphic interface visible through a head-mounted dislay.

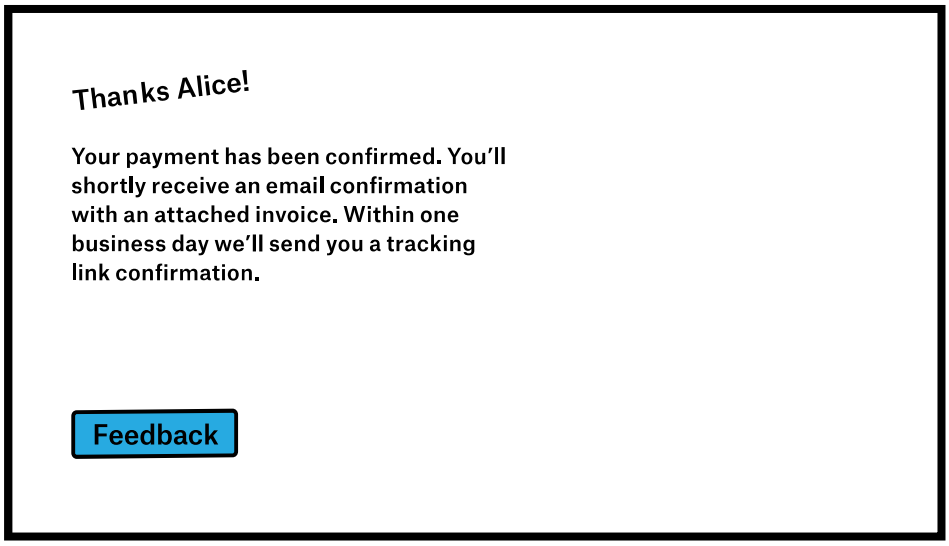


Fig. 111

THE END

Fig.111 L. T. Nguyen, User Interface - Confirmation email [Illustration]. Own source,2021

6.3 Physical element

6.3.1 Movement - Circulation

Fulfillment center

Fast lane

Experience

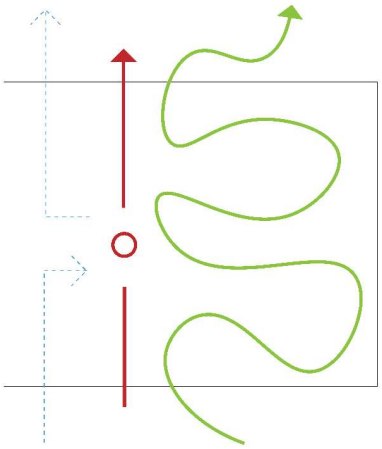


Fig. 50

6.3.1 Function - Zoning

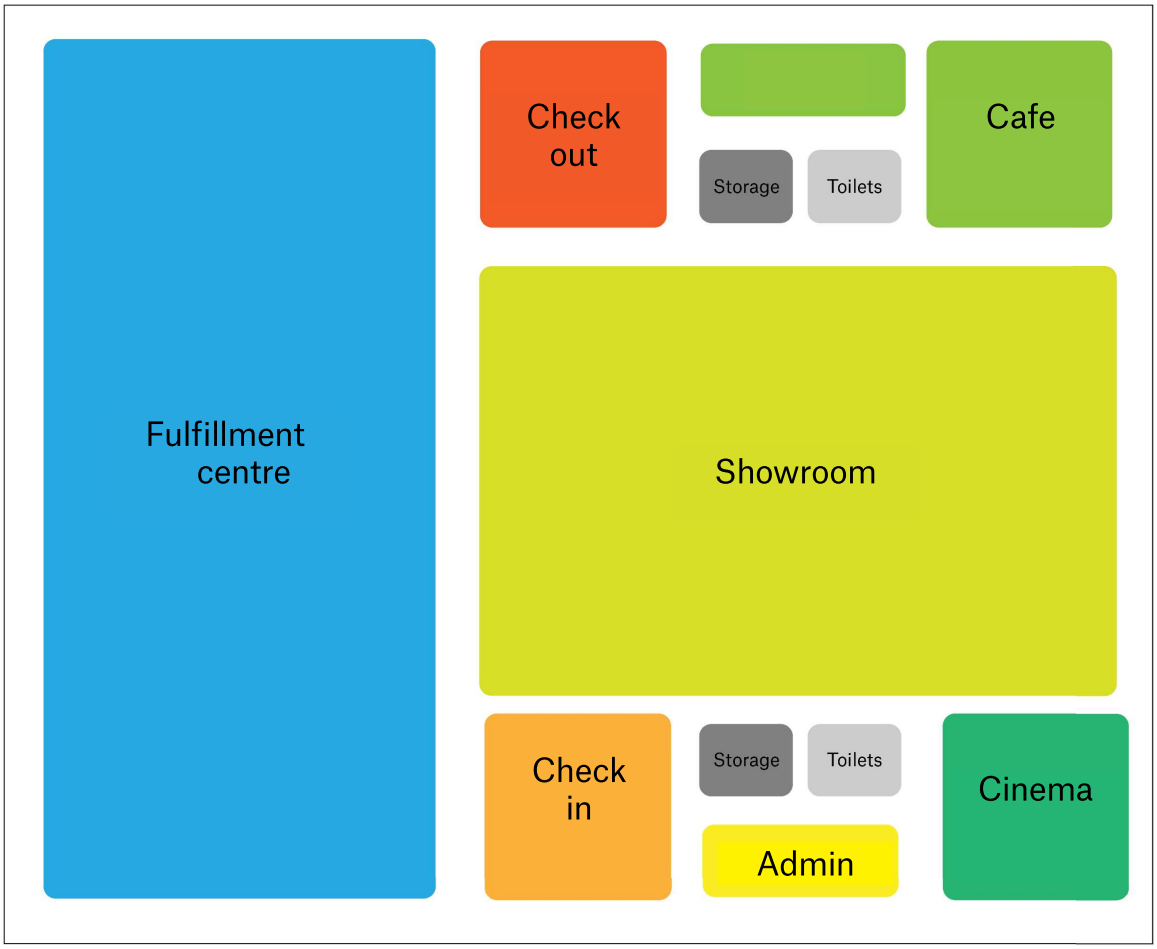


Fig. 51

Fig.50 L. T. Nguyen, Circulation plan [Illustration]. Own source,2021

Fig.50 L. T. Nguyen, Zoning plan [Illustration]. Own source,2021

6.3.3 Layout - Floor plans, Sections & 3D View

Floor plan
Ground floor

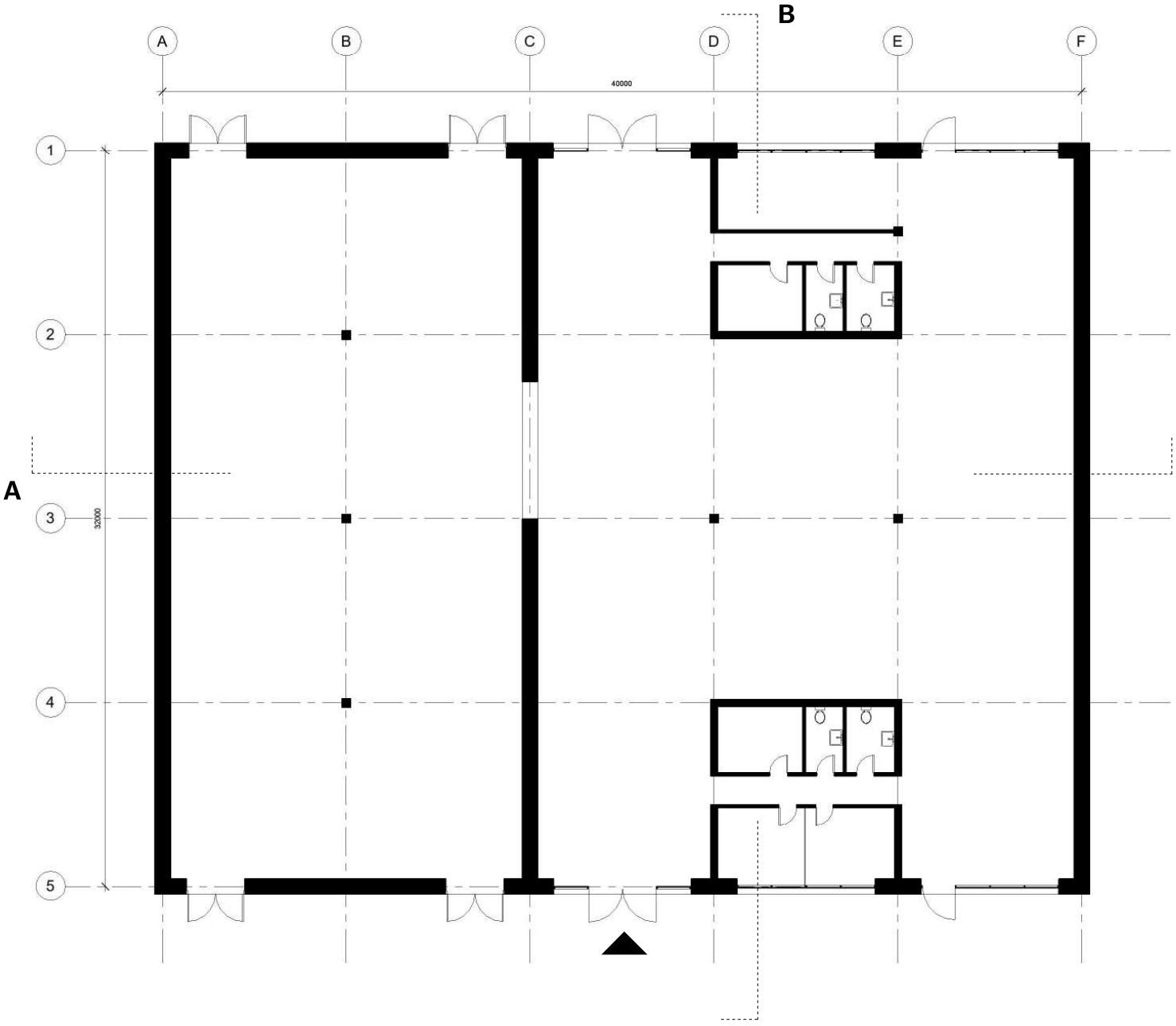


Fig. 52

Fig.52 L. T. Nguyen, Ground floor [Illustration]. Own source,2021

6.3.3 Layout - Floor plans & Sections

Section A

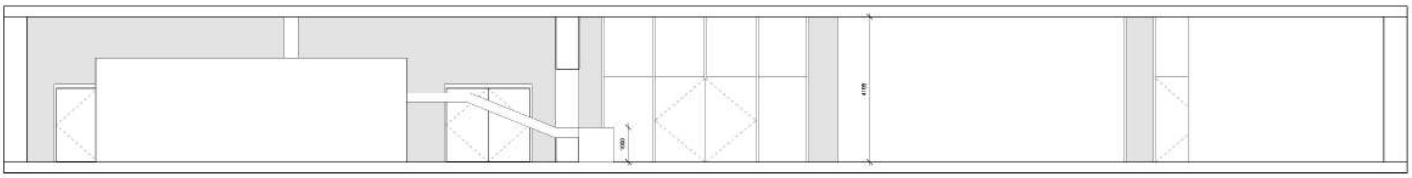


Fig. 53

Section B

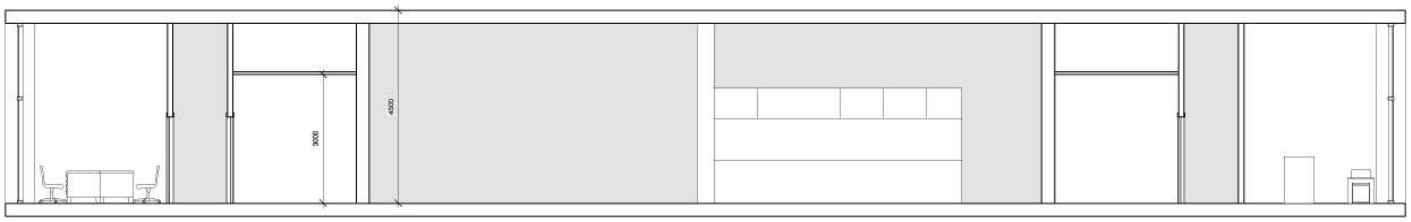


Fig. 54

3D View

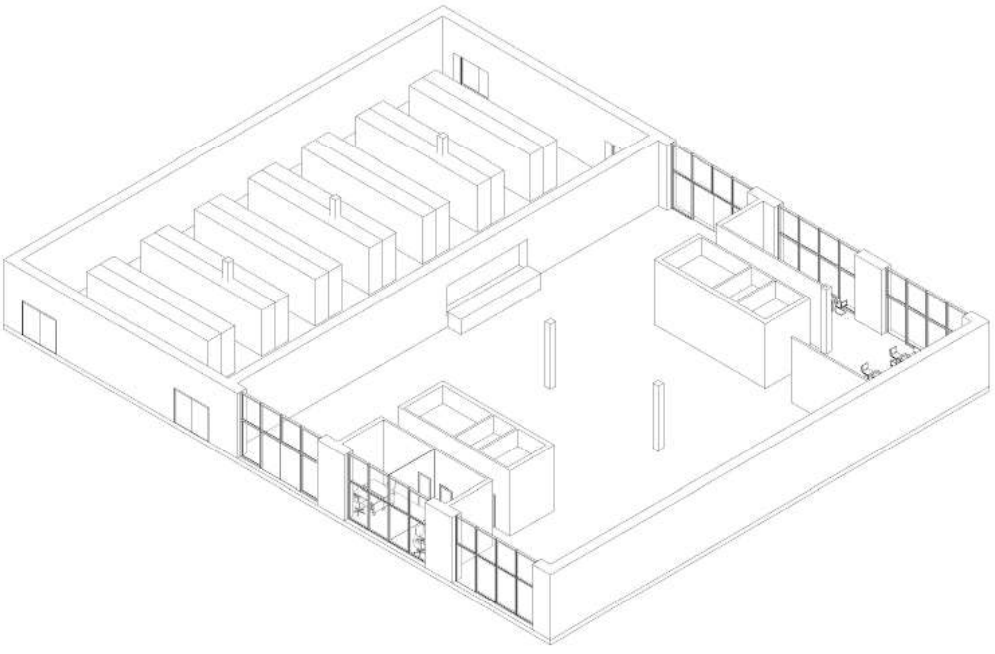


Fig. 55

Fig.53 L. T. Nguyen, Section A [Illustration]. Own source,2021

Fig.54 L. T. Nguyen, Section B [Illustration]. Own source,2021

Fig.55 L. T. Nguyen, 3D View [Illustration]. Own source,2021

6.3.4 Feelings - Mood board

This section imagines a visual direction for interior components of the mixed reality store. The inspiration come from a sci-fi movie "Time Trap" where a group of students is trapped in a cave, experiencing series of strange events related to time and space distortion. A place where the possibility of communication between dimensions is real. [26]

" A futuristic cave"

Elements to consider: Curved walls, Organic shape, Wall openings, Modest lighting, White colour palette, Metallic accessories.

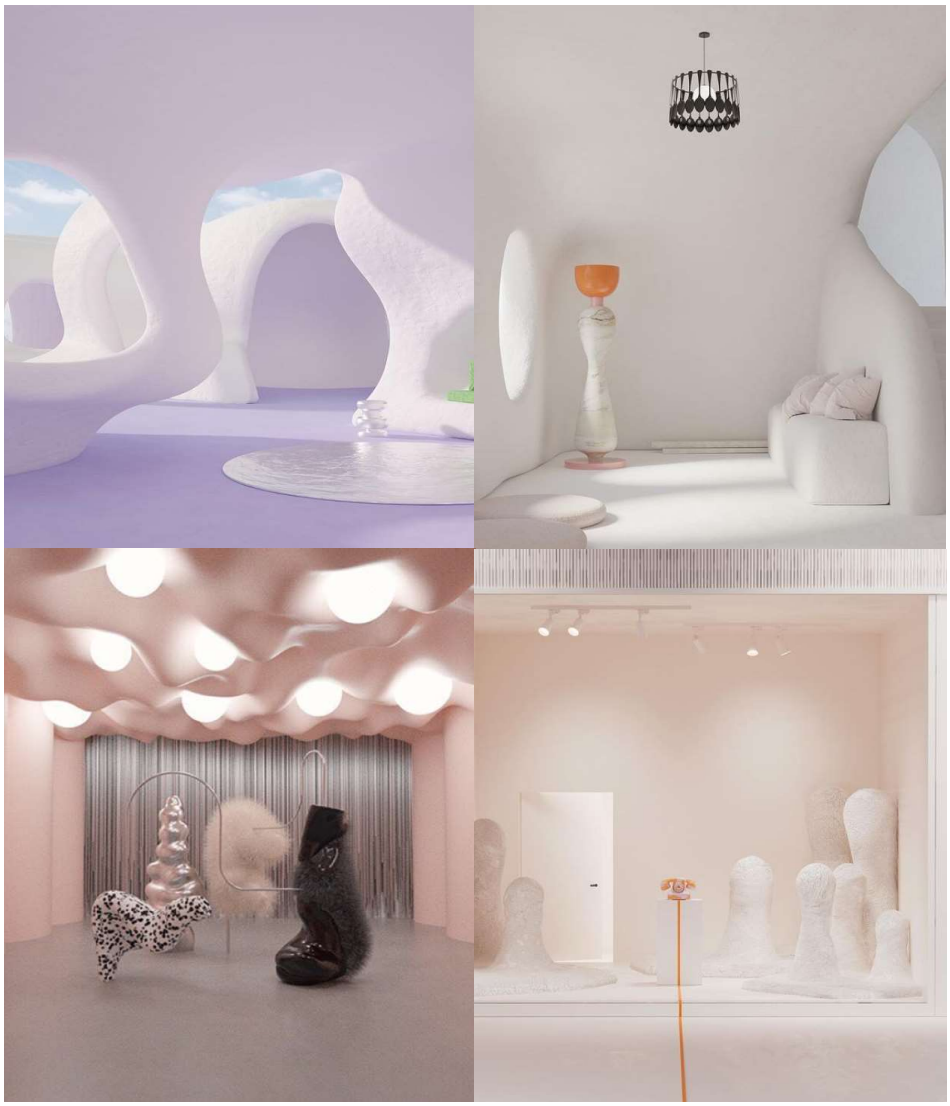


Fig. 56

26. Time Trap (film) [Online]. Wikimedia foundation 2021. Available at: https://en.wikipedia.org/wiki/Time_Trap_(film)

Fig.56 Reisinger Andres Interior renders [Printscreen] Source: https://www.instagram.com/reisingerandres/

6.3.5 Elements - Materials & Lighting

3D printed Bioplastic division walls

The proposed material to divide interior into various rooms is recyclable bioplastic. Due to 3D printing technique it can be custom-made, built in desired shapes and lightweight.

The inpiration comes from The European House built by DUS Architects. It is a bioplastic temporary structure, consisting of printed elements which can be removed, shredded and repreinted after use.

These features make it possible for design to be temporary and sustainable at the same time. It can be a useful and save waste, considering that prefereneces of retailers and customers might change throughout the time.

Fig. 57

Fig. 58

Fig. 59

Fig.57 DUS, Shredded recycled plastic [Photo]. DUS Architects, https://houseofdus.com/

Fig.58 DUS, Recycled plastic components [Photo]. DUS Architects, https://houseofdus.com/

Fig.59 DUS, Temporary structure [Photo]. DUS Architects, https://houseofdus.com/

Lighting fixtures

Lighting fixtures are meant to be indistinct, modest and blending with the interior. Proposed materials for lights are milky glass, clear glass, metal and white plastic. For visibility and safety, the light should be strong enough to enlighten the whole shop floor The light colour should be neutral, considering it to be combined with overlaid grpahic content.

Wall lighting

- Wall pendants Example (Fig.60): Astrolighting

Floor lighting

- Globe light Example (Fig. 62): Slide studio

Ceiling lighting

- Recessed spot light Example (Fig. 63): DeltaLight
- Illuminated stretch ceiling Example (Fig. 61): Spanlite

Fig. 60

Fig. 61

Fig. 62

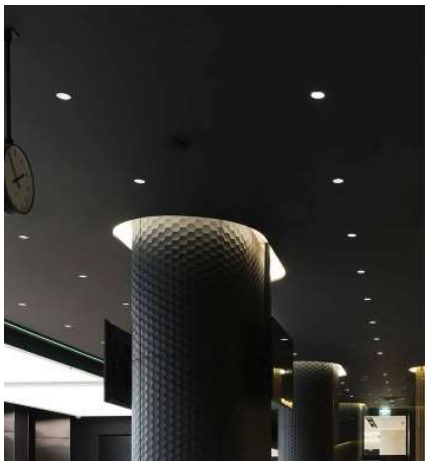


Fig. 63

Fig.60 Wall pendant. Source: https://www.astrolighting.com/products/7994

Fig.61 Illuminated stretch ceiling. Source: https://spanlite.com/stretch-fabric-ceiling/

Fig.62 Globe light. Source: https://slidedesign.it/en/prodotto/globo/

Fig.63 Recessed light. Source: https://www.deltalight.com/en/products/light/imax

Furniture

Furniture serves as a complimentery part of a store. Its function is either to give customers place to rest, to visually emphasize a spot for product display and to humanize the space through touch with comfor table materials.

Recycled plastic furniture

- product displays
- pick up return bar
- seating and tables

Metallic elements

- check-in check-out bars
- accessories

White creamy textile

- upholstery
- rugs
- curtains

Fig. 64

Fig. 65

Fig. 68

Fig. 67

Fig.64 White textile furniture. Source: https://theivyhouse.co.nz/products/armadillo-malawi

Fig.65 Plastic product display 1 Source: https://smile-plastics.com/inspiration/

Fig.68 Plastic product display 2 Source: https://smile-plastics.com/inspiration/

Fig.67 Metal newspaper holder. Source: https:https://moodings.com/products/curva-magasin-holder-stal

6.3.6 Design - Plan & Exploded 3D View

Recycled plastic interior walls are printed to divide the space into showrooms. Its temporary structure can be dissasembled and replaced with a new structure according to needs of the retail store.

3D Printed Interior walls

Fig. 69

Fig.69 L. T. Nguyen, Plan of 3D Printed interior walls [Illustration]. Own source,2021

Isometric 3D View

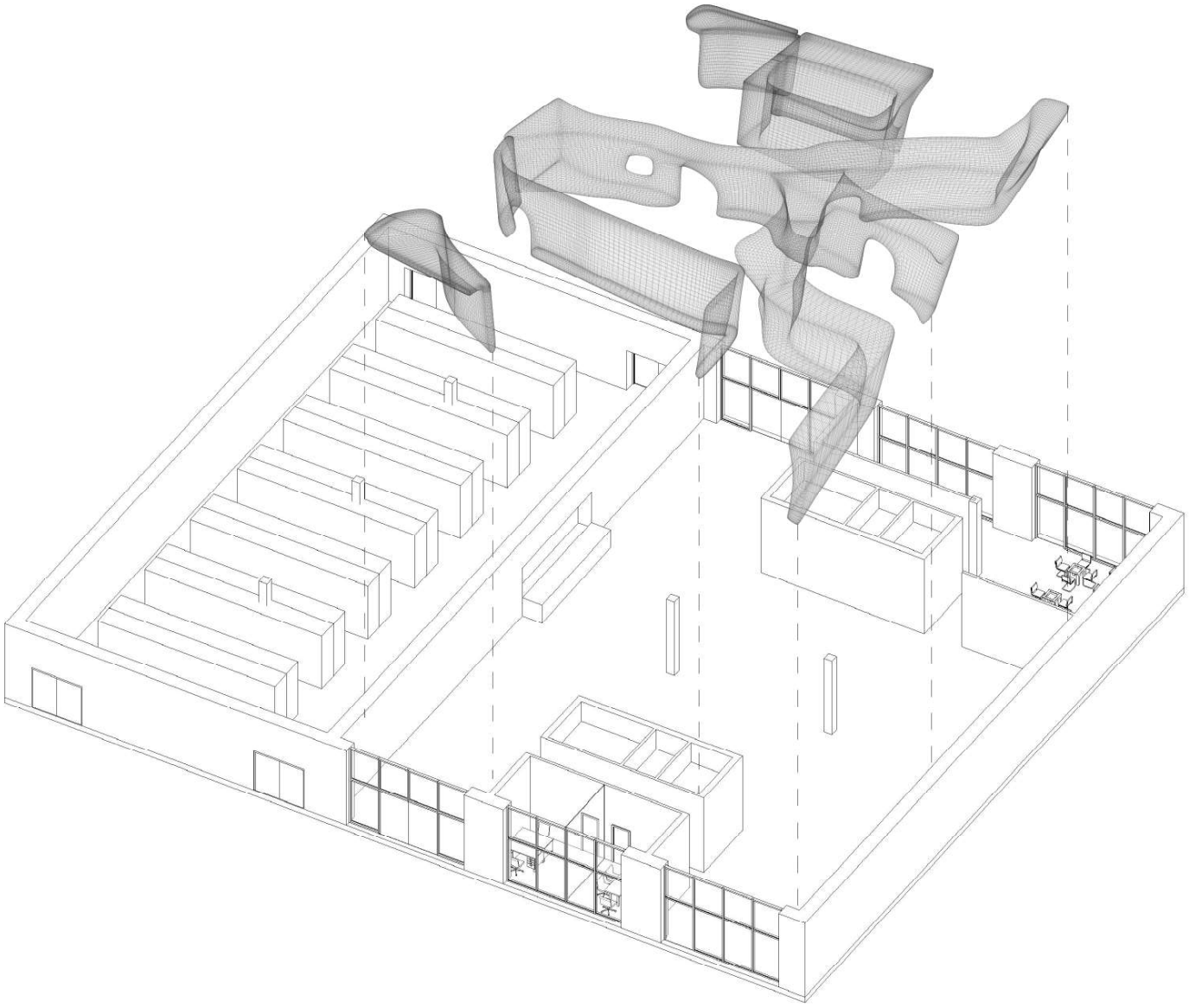


Fig. 70

Fig.70 L. T. Nguyen,Isometric View of 3D Printed interior walls [Illustration]. Own source,2021

6.4 Mixed Reality System

6.4.1 Scenarios - Renders without interactivity

Following scenerarios show user's view without interactivity with products. Once customers register in the store, they are able to see 2D and 3D superimposed digital content.

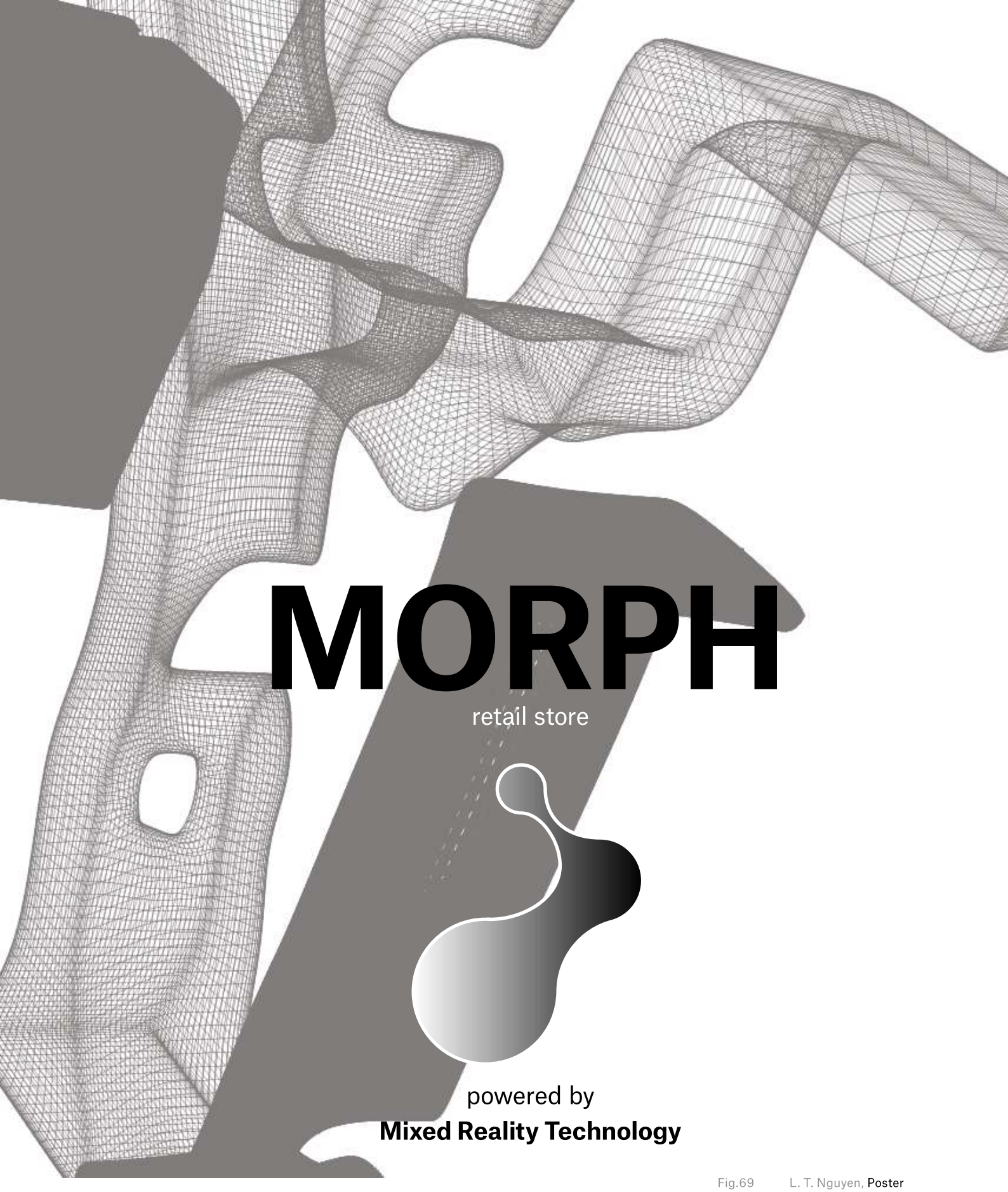


Fig. 71

Fig.69 L. T. Nguyen, Poster [Illustration]. Own source,2021

Entrance

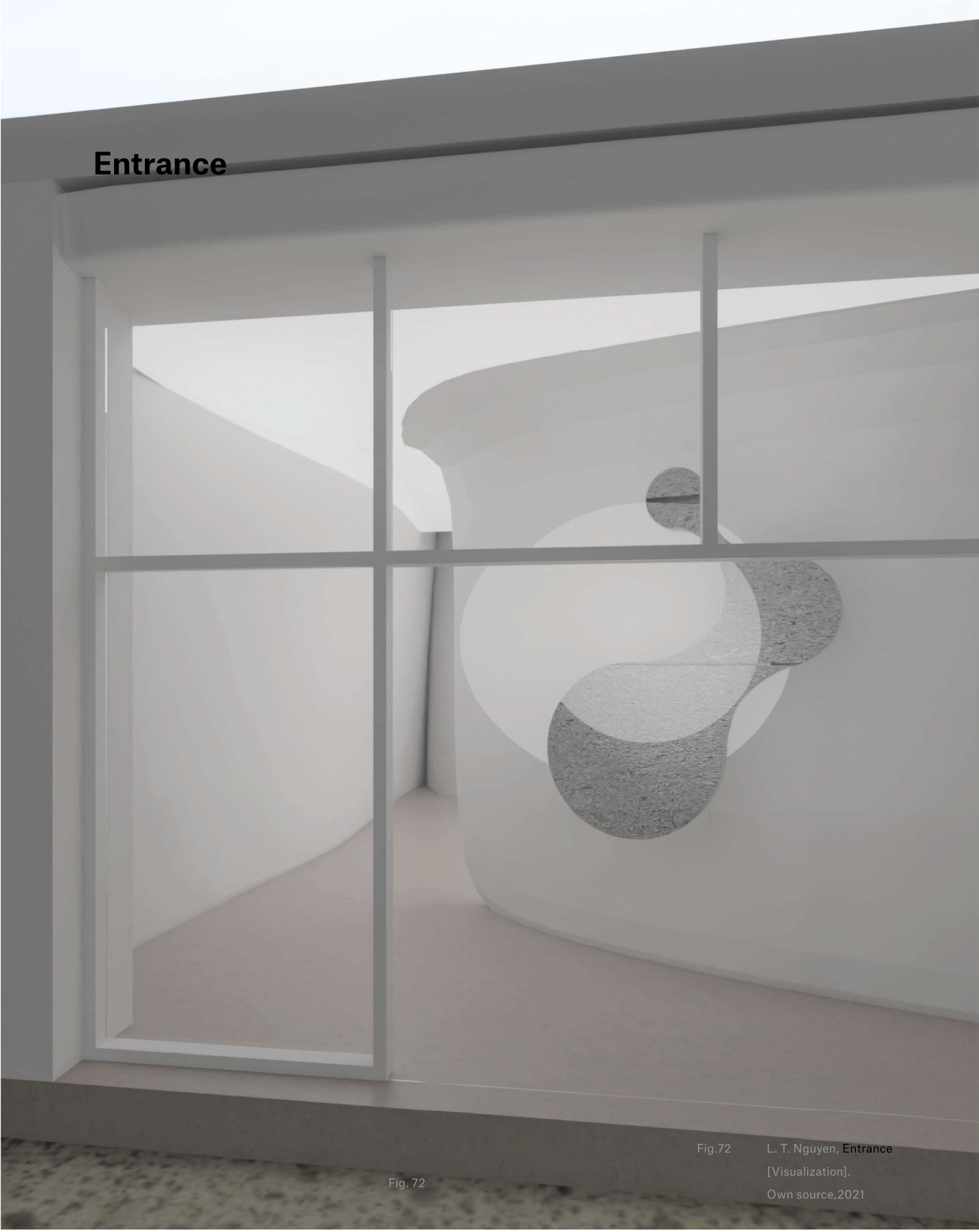


Fig. 72

Fig.72 L. T. Nguyen, Entrance [Visualization]. Own source,2021

Check-in counter

Fig. 73

Fig.73 L. T. Nguyen, Check-in counter [Visualization]. Own source,2021

Registration

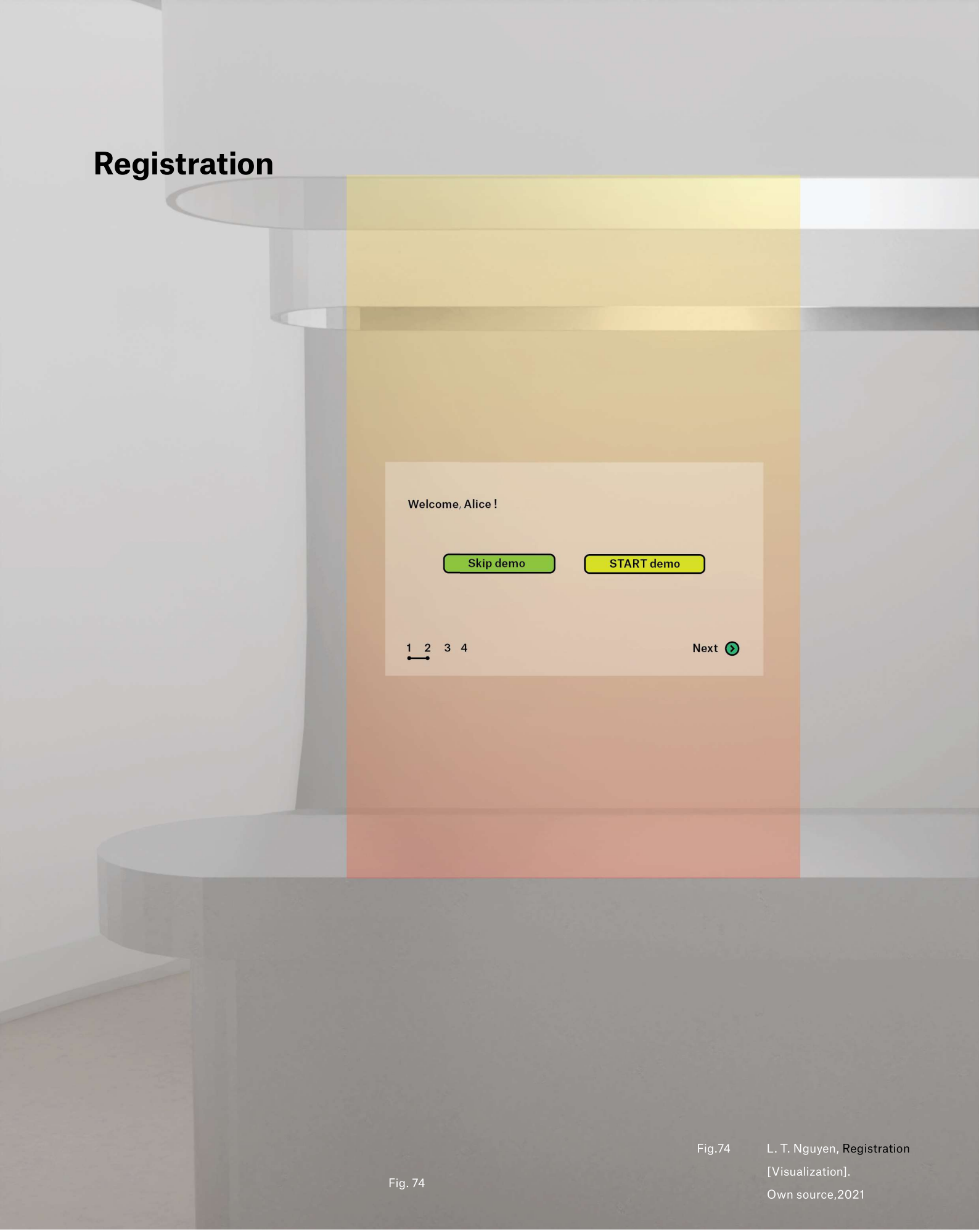


Fig. 74

Fig.74 L. T. Nguyen, Registration [Visualization]. Own source,2021

Fig.75 L. T. Nguyen, Showroom 1 [Visualization]. Own source,2021
Reference:
Stools: PUUF (www.puuf.dk)
Bookshelves:
PUUF (www.puuf.dk)

Fig. 75

Cinema

Fig. 76

Fig.76 L. T. Nguyen, Cinema [Visualization]. Own source,2021

Showroom 02

Fig. 76

Fig.76 L. T. Nguyen, Showroom 2 [Visualization]. Own source,2021
Reference:
Stools: PUUF (www.puuf.dk)

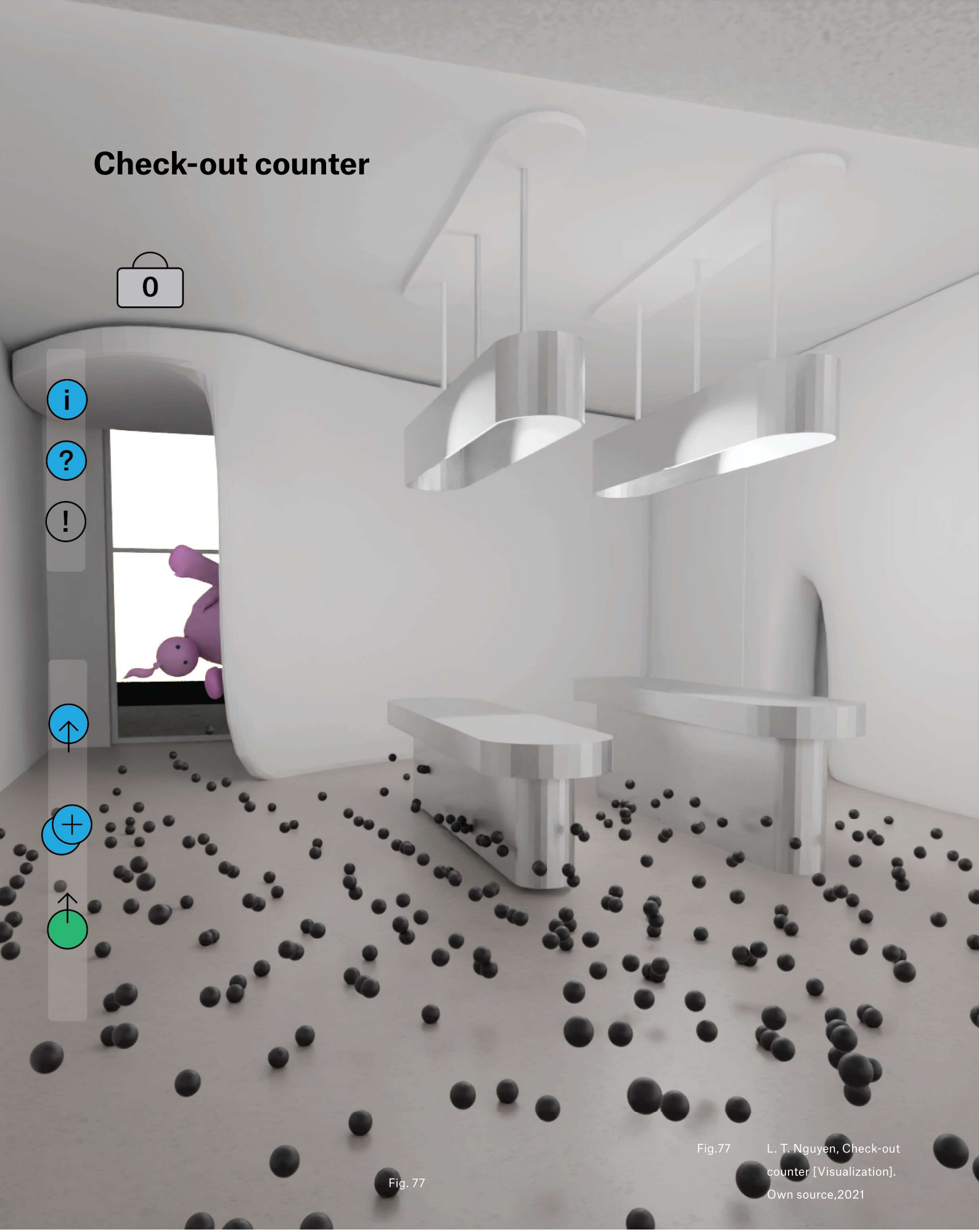


Fig. 77

Fig.77 L. T. Nguyen, Check-out counter [Visualization]. Own source,2021

6.4.2 Scenarios - Renders with interactivity

Subsequently come scenarios of user and product interactions. Customers can operate products with two hands, browse through selections, view variants and try on their avatars. The activities include exploring medias in different forms such as text, image, video and 3D objects.

Two versions of mixed reality scenarios are presented: the first version with PUUF furniture elements and second the version with COMPONE clothing elements. This variation aims to show how flexibly the digital interface and content can change the interior.

Showroom 01 - Real environment

Fig. 81

Fig.81 L. T. Nguyen, Compone Showroom 1 [Visualization]. Own source,2021

Fig. 82

Fig.81 L. T. Nguyen, Compone Showroom 2 [Visualization]. Own source,2021

Fig. 82

Fig.82 L. T. Nguyen, Compone Showroom 3 [Visualization]. Own source,2021

Showroom 02 - Real environment

Fig. 78

Fig.78 L. T. Nguyen, PUUF Showroom 1 [Visualization]. Own source,2021

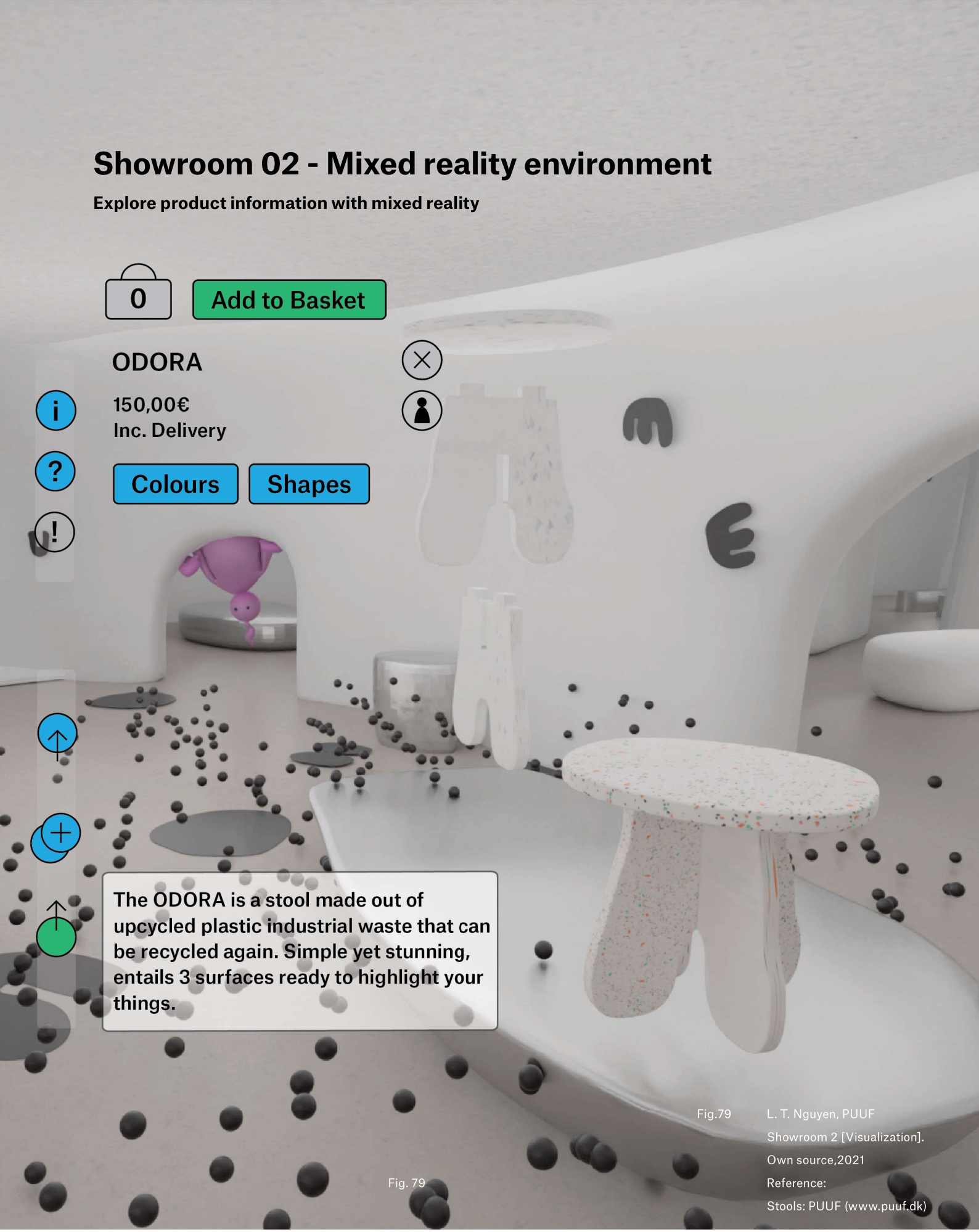


Fig. 79

Fig.79 L. T. Nguyen, PUUF Showroom 2 [Visualization]. Own source,2021
Reference:
Stools: PUUF (www.puuf.dk)

Fig. 80

Fig.80 L. T. Nguyen, PUUF Showroom 3 [Visualization]. Own source,2021
Reference:
Stools: PUUF (www.puuf.dk)

6.4.3 Prototype - Interactive application

The final design part includes printscreens of an interactive prototype created in Unity. Two scenes are presented, an interactiveand and an observation scene. When interacting with the selected product, the background is shaded to bring attention only to the selected item. (Fig. 112) shows a usert interface when inspecting a product. Viewers can manipulate with the 3D object and access product information. (Fig. 113) presents a colour changing functionality. Once the viewer closes the product information interface, they appear in an observation mode and can clearly see both real and virtual environmet. Virtual objects are animated and serve as another way to deliver product information. For instance in (Fig.114), viewers can understand the product assembly easier when it's shown in 3D and in real size. Digital world can offer unique effects and adition to strengthen brand identity and entertain customers (Fig.115). Due to lack of equipment, the prototype exists only in a digital form. The architecture is meant to be understood as a real environment, in this case white components such as walls, ceiiling, floor and product display.

Fig.112 L. T. Nguyen, Protype - Product inspection [Illustration]. Own source,2021

Fig.113 L. T. Nguyen, Protype - Change colours [Illustration]. Own source,2021

Fig.114 L. T. Nguyen, Protype - Product assembly [Illustration]. Own source,2021

Fig.115 L. T. Nguyen, Protype - Effects [Illustration]. Own source,2021

Interactive scene

Fig. 112

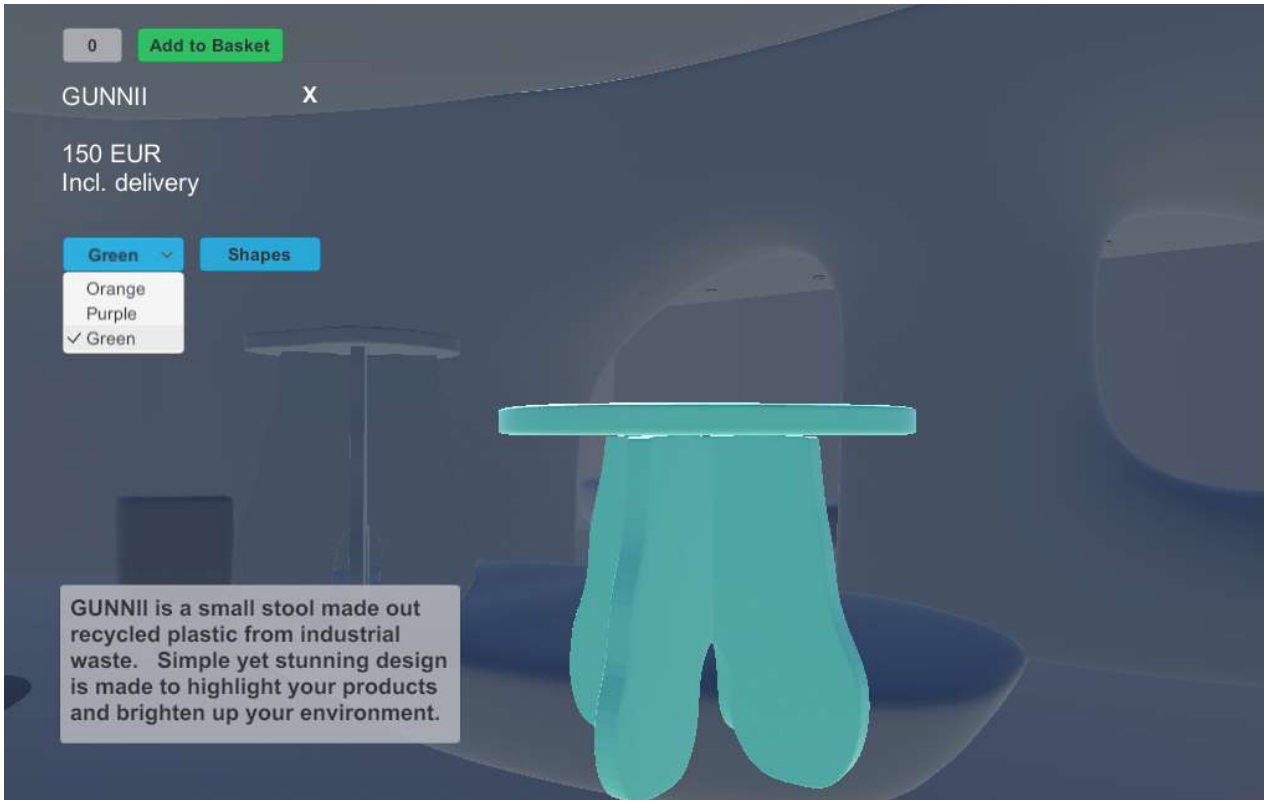


Fig. 113

Observation scene

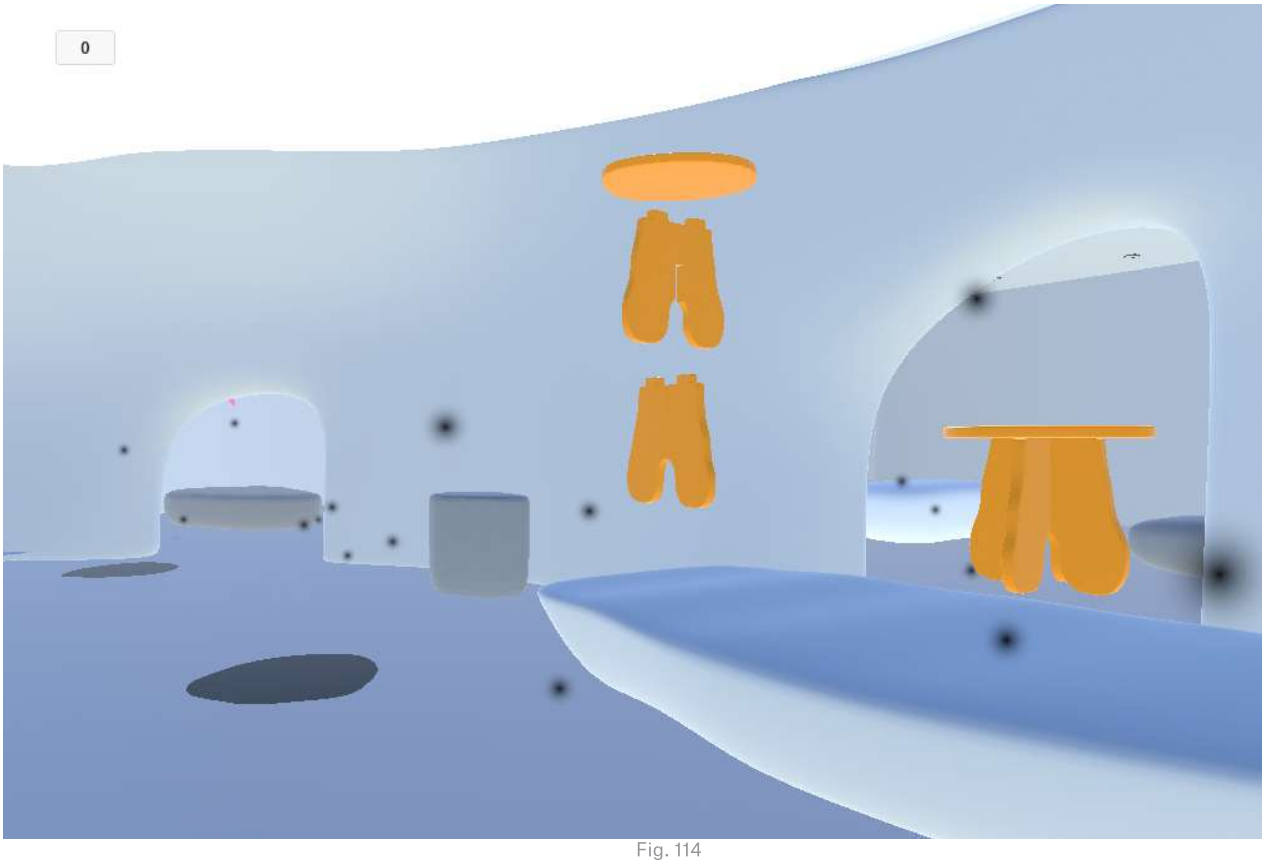


Fig. 114

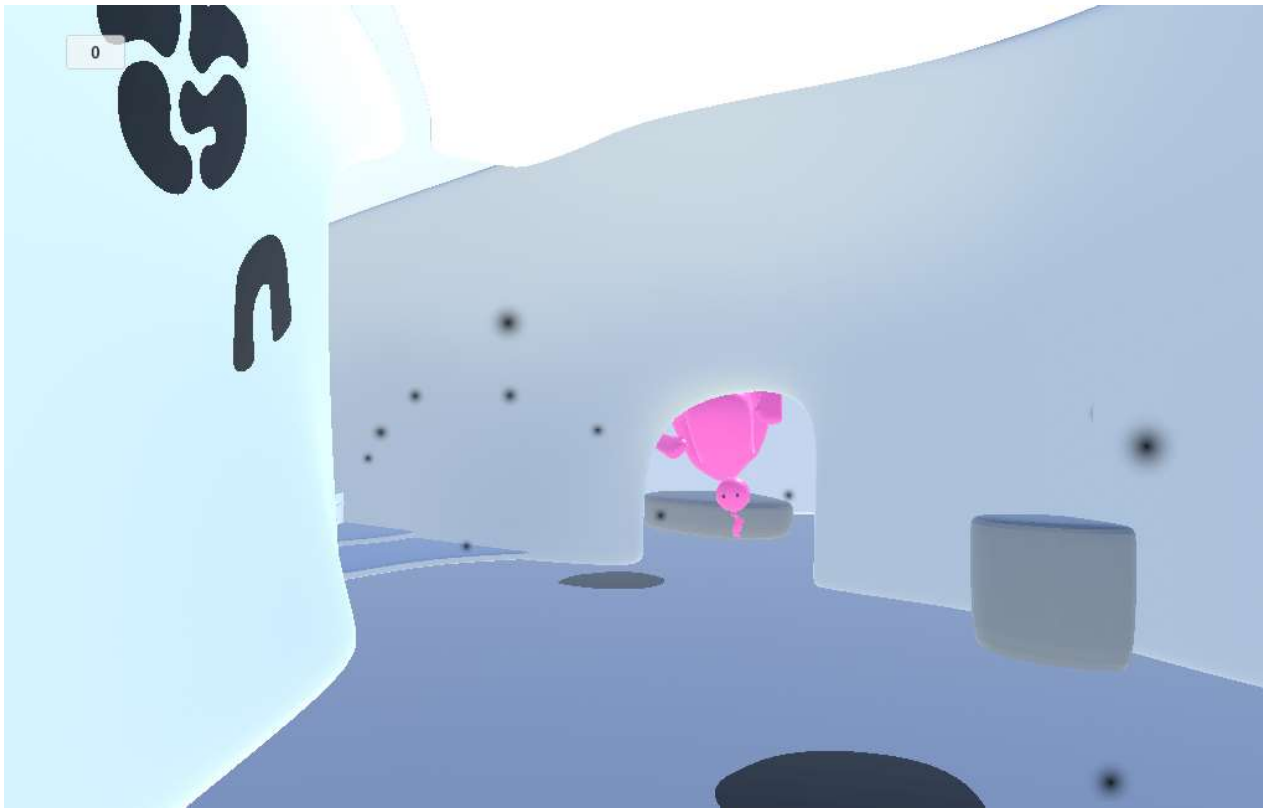
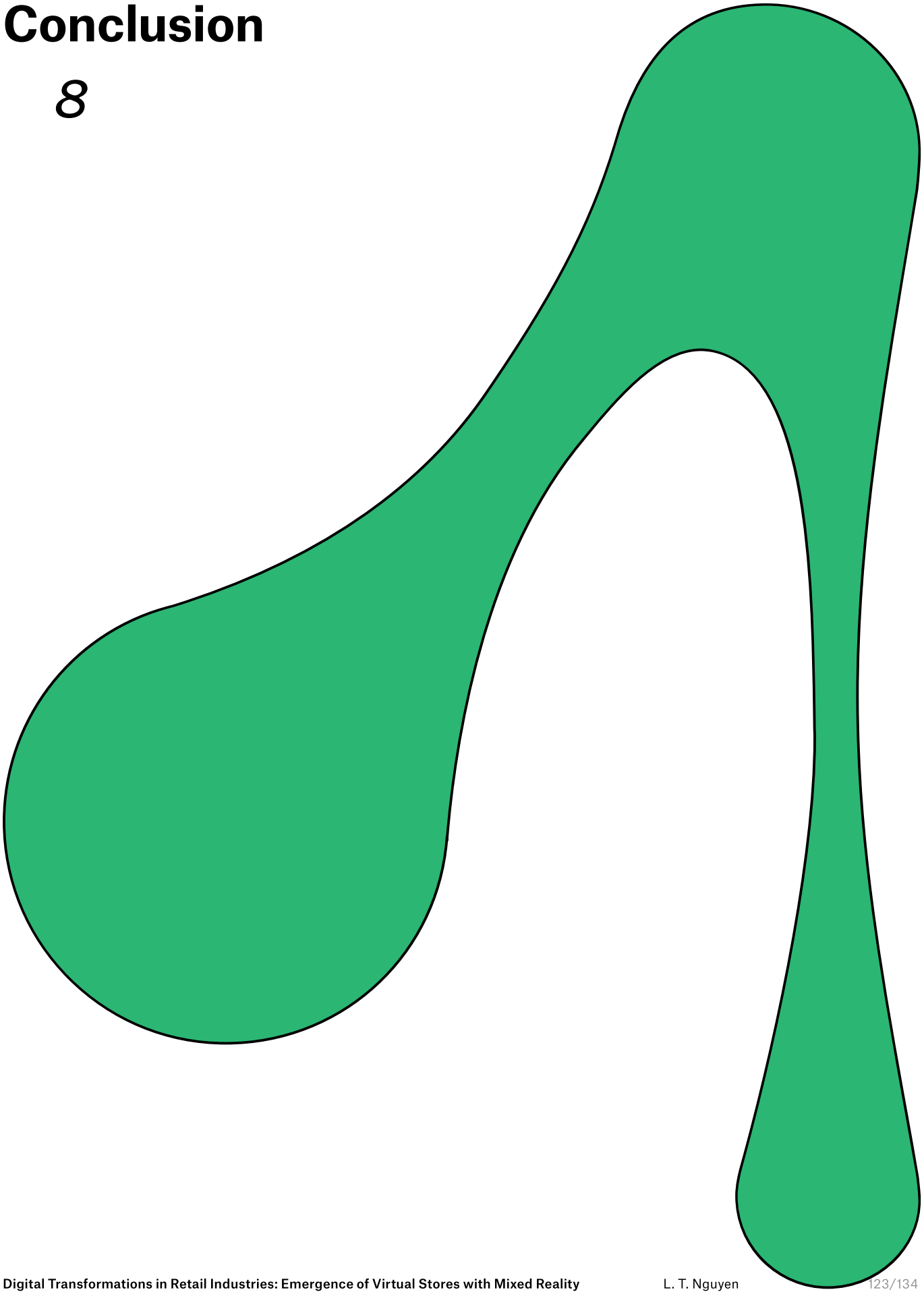


Fig. 115

Conclusion

8



In order to carry out the master thesis about implication of mixed reality technology into retail, research about any possible factors had to be carried out. A search for information about current situation, customer eperience, development of MR technology, possible implications of technology on specific users, the act of shopping, relationship between retailers, customers and brands, effects on urban life and human behaviour.

In this thesis I have introduced bits of each fields to give readers an idea of current situation in the retail world. Afterwards a design is proposed to offer one of directions future retail could go. Augmented and Virtual Reality are already being known and used within brands, mostly for commercial purposes. That is due to technology novelty and we are in the stage of playing around and testing its potential.

The proposed design fulfills the objective of this research on a social, cultural and technological level. It's hard to assume that this system would fit every customer, because people's wishes and expectations may vary, and our needs change throughout the time. From a social level, the purpose of creating a physical store is to bring people out of small screens and create opportunity for interaction outsie. The space offers common rooms, services functioning with real employees, areas for human interaction such as a cafe. Its cultural feature can be perceived as an addition, but in the future it might change the perspective we have on shopping. A future form of shopping can be a combination of inspiration, education and trading. This apporach aims to create a conscious type of consumerism and lower on toxicity of mindless shopping. The technological aspect of this project brings together benefits we seek from online and offine shopping. It creates a platform for brands to directly communicate with their customers and the other way around. Tne concept of housing several brands under a retail store is to utilize a platform for all members for an easy use and access. The management, privacy, security and survaillance will be taken care of to avoid exploitation of information.

All the topics this master thesis has dealt with could be analyzed in more depth for future researches. The concept of a mixed reality store can be used in a different context, e.g. galleries for digital art, entertainment centers for students or a shared space for events. For any sourt of service where physical and digital elements take place, this could be an improved system for a traditional way of living.

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