Contents

Acronyms

AR	Augmented Reality
CAVE	Cave Automatic Virtual Environment
HMD	Head-mounted Display
VR	Virtual Reality

Papers

- https://www.frontiersin.org/articles/10.3389/frobt.2016.00074/full

- Prof Mel Slater's theory https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2781884/

- How to build an embodiment lab: achieving body representation illusions in virtual reality, https://www.frontiersin.org/articles/10.3389/frobt.2014.00009/full

Definition

"The user is effectively immersed in a responsive virtual world." (Fred Brooks, 1999)

Augmented Reality (AR) and Virtual Reality (VR) are about delivering the sense of presence, of being somewhere else without actually being there.

Properties

- The user has dynamic control of their viewpoint.

Properties that make VR more immersive than other types of media:

1. **3D Stereovision**
2. **User dynamic control of viewpoint**
    - The experience is more real than the 3d cinema (enhanced user experience).
        - In a 3D cinema, you can have hundreds of viewers looking at one big display. But in VR, the display is updated according to the exact viewpoint of one specific user through a built-in head-tracking device integrated in the head-mounted display (HMD).
3. **Surrounding experience**
    - Enhanced visual perception: The field of view is covered entirely by the VR screen, and thus the user feels more immersed than e.g. in a 3d cinema.

VR Devices (VR Display Systems)

e.g. VR Headsets like Oculus Rift (it is a HMD head-mounted device):

Oculus Rift 1: Photo by [Lux Interaction](#) on [Unsplash](#)

CAVE - Cave Automatic Virtual Environment

- **You are in a room,** the computer software updates the images in the wall of the room. You still wear some glasses, but you feel less sick with nausea.
- Designed to be used by a <u>single user</u>, but more users can enter the same room:
    - Multiple users can be in the CAVE together but they will not have the same experience: The person wearing the tracker would have the best experience. Your own experience will depend on how far you are from this person who wears the tracker.
    - There are 3 walls back-projected -> so that users do not cast a shadow on the display.
- High screen/high resolution/large space

<u>Problems</u>:

- <u>**Accommodation vergence problem**</u>: if you try to touch e.g. a table in CAVE room, you cannot exactly see both your hand and the table, because they are in different physical distance.
- Problem of <u>**simulator sickness**</u>: the nausea you feel (but here not so much because of the latency of rotation)

HMDs Head-mounted Devices

- **You wear glasses** (the HDM devices)
- Designed to be used by a <u>single user</u>.
- Lower resolution/ flexible in their space requirements

<u>Problems:</u>

- Problem of **simulator sickness:** the nausea you feel – the feeling of disorientation because of the of the plethora of graphics views (higher grade than that in the CAVE room).
- Problem of **proprioception** (body position awareness): it can be solved by a putting an avatar of yourself. This setup can be supported by a Kinect sensor
  - Contrary to the CAVE system where you can see yourself, here you cannot find yourself leading to a poor experience.

Notes:

You can have VR applications with multiple users, but each one will need their own display device, i.e. a CAVE or HMD.

HDM - Windows Mixed Reality

- Windows Mixed Reality is a VR platform. Details: Windows Mixed Reality on the Microsoft Website
- Windows MR (as it is often called) was released by Microsoft in Autumn 2017, and it is built into the latest version of Windows 10. It is an open platform in the sense that anyone can develop a headset. This is similar to Microsoft's normal strategy, they don't develop proprietary computers (like Apple) but build a platform (Windows) that can be used by many hardware developers. They have worked with a number of hardware companies who have released headsets.
- Windows MR is a 6DOF platform that supports both rotation and position tracking in the headset as well as two position tracked controllers that are similar to the HTC VIVE controllers or the Oculus Touch. One of the biggest innovations is that it uses inside-out tracking. The position tracking is done using cameras on the front of the HMD, not external cameras. This makes the set up a lot easier.

Windows MR headsets have very similar capabilities to other high end VR headsets like the Oculus Rift and HTC VIVE and it is a good third option for high end VR. For example, we have tested the ACER Mixed Reality Headset, which features an innovative design, but otherwise feels very comparable to the Rift and VIVE.

- Details about ACER HMD:

Windows Mixed Reality and Oculus GO

ACER and Windows MR

ACER Windows Mixed Reality Hands On

HMD | Oculus GO

- The Oculus GO is an HMD, details: Website:
- The Oculus GO is a mobile VR platform that is very similar to the Samsung Gear VR (in fact they can run exactly the same software).
    - However, it is completely stand along, it does not need a mobile phone to be inserted into it, all the hardware is in the HMD. That makes it a very cheap and easy way to get into VR. At $100 it is a bit more expensive than the Gear VR, but you don't need to buy an expensive Samsung phone. That means it is likely to be a popular gateway to VR.
    - Nevertheless, as a mobile platform, it is less capable than a high end VR platform, and in particular does not support position tracking.

Windows Mixed Reality and Oculus GO

Oculus GO — hands on

HMD | Oculus Quest

The Oculus Quest is a "High end VR" but in a mobile package HMD, details:

Website

Oculus Quest Development in Unity

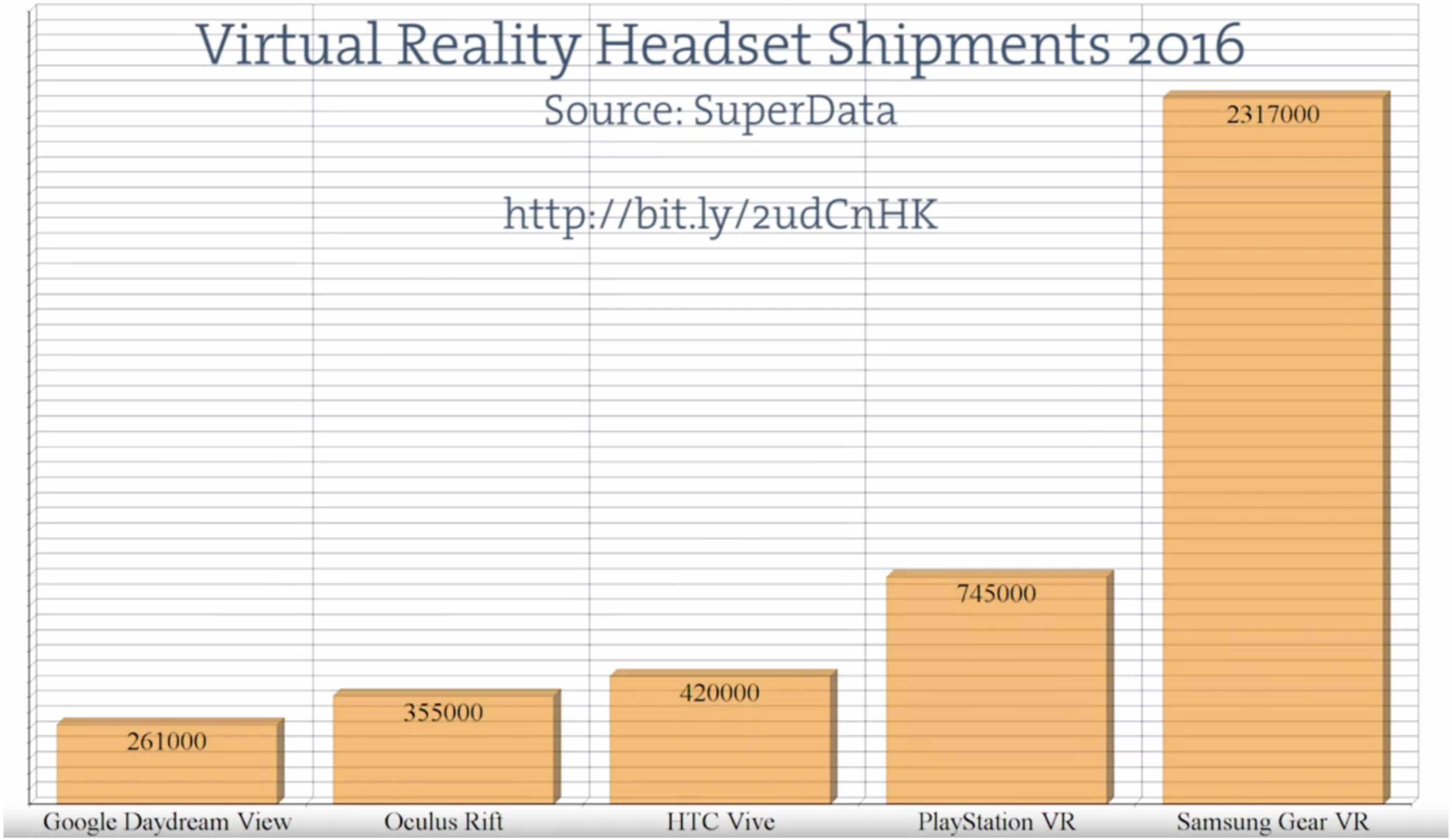
Head Tracking

The built-in tracking system tracks the user’s head rotation and position.

- Head rotation: via accelerometer or gyrometer or both.
    - Same technology is used in smartphones for autorotation when you flip your phone e.g. from vertically to horizontally
- Position tracking: via external optical tracking devices

Controllers

- The so-called wand, the thing we hold in our hands,
- In order to use the wand to interact with objects in 3D in a realistic way, we should track the wand's position and rotation,
- They often come with a joystick or touchpad in order to enhance the virtual navigation,
- They also can give **haptic** feedback through vibration (feeling of touch),


Virtual Reality Headset Shipments 2016
Source: SuperData
http://bit.ly/2udCnHK
261000
355000
420000
745000
2317000
Google Daydream View
Oculus Rift
HTC Vive
PlayStation VR
Samsung Gear VR

Category	Cost ($)	Tracking	Name	Resolution	Refresh Rate (Hz)	Weight (gr)	Controller
Mobile VR	< 500	Rotation	Samsung Gear VR	1280x1440	60	318 + phone	Some rotation tracked
Console VR	~1000	Position + Rotation	PlayStation VR	960+1080	120	610	Rotation, Position, Tracked vibration
High-end HMDs	>2000	Position + Rotation (external camera /light house)	Oculus Rift CV1 / HTC VIVE	1080x1200	90	555	Rotation, Position, Tracked vibration

Ways to offer a VR application:

1. **Mobile VR application**
    a. User can download the app-application
    b. You could develop an app-application for high-end HMD users and upload it e.g. to the Oculus (but this will exclude users with mobile VR devices)
    c. Samsung Gear is integrated with VR phones (only Samsung)
        i. You put the phone on the HMD
    d. Google Cardboard is even cheaper than the Samsung Gear, but it only provides rotation, not positioning

2. **High-end HMD**
    a. E.g. you have invented new technology to enhance the VR experience, and you want to show it in an exhibition.

3. **Clients come to you**
    a. E.g. training via simulation, therapy.

How to choose your VR HMD

- **Summary of VR HDMs**: Comparison of VR Headsets

- **Devices with position tracking:**
    - HTC VIVE (powered by PC): https://www.vive.com/
    - Oculus Rift (powered by PC): https://www.oculus.com/rift/
    - Sony PlayStation VR (powered by Console): https://www.playstation.com/en-gb/explore/playstation-vr/
    - Windows Mixed Reality (a range of headsets powered by PC): https://www.microsoft.com/en-us/windows/windows-mixed-reality
- **Mobile VR Devices (without position tracking):**
    - Google Daydream (powered by phone): https://vr.google.com/daydream/
    - Samsung Gear VR (powered by phone): http://www.samsung.com/global/galaxy/gear-vr/
    - Oculus Go (stand-alone): https://www.oculus.com/go/
    - Google Cardboard (powered by phone): https://vr.google.com/cardboard/

Comments on HMDs on medium: https://medium.com/virtual-reality-virtual-people

Where to Download VR Apps

- **Oculus Rift:** https://www.oculus.com/experiences/rift/
- **HTC VIVE:** http://store.steampowered.com/
- **Sony PlayStation VR:**
  - Games: https://www.playstation.com/en-gb/explore/playstation-vr/games/
  - Experiences: https://www.playstation.com/en-gb/explore/playstation-vr/ps-vr-experiences/
- **Gear VR:** https://www.oculus.com/experiences/gear-vr/

VR Components | Technical Framework

By understanding the technical framework, you can understand the VR application.

1)VR Display

- It provides surrounding 3D stereo vision.
- Allows dynamic control for the user of their view point, their precision and rotation tracking.

2) VR Content

- Refers to the images that are on display that you can sometimes interact with.

Types of VR Content: 360 Video vs. Model Based VR

360 Video

- ❖ Stored with images rather than 3D objects -> not interactive as the Model Based VR.
    - Everything is video-recorded; if you make a random move now, this will not be reflected in the 360 VR.
- ❖ It is based on pre-captured images.
- ❖ It restricts user's viewpoint to one specific position.
- ❖ Can be viewed by a mobile VR, the VR content limits on how it is displayed.
- ❖ Restricted, specified rotation and position tracking.

https://www.wired.com/2017/02/shoot-360-video/

https://creatoracademy.youtube.com/page/lesson/spherical-video?hl=en-GB#yt-creators-strategies-1

Volumetric capturing: https://youtu.be/kZ-XZIV-o8s

Photogrammetry: http://www.theastronauts.com/2014/03/visual-revolution-vanishing-ethan-carter/

Model Based VR

- It uses computer generated 3D graphics.
- Users have control of the virtual camera in real time and look from any point of view (users can move closer to an object if they want to).
- Hence, it encompasses rotation and position tracking
- Real time interaction.

3) VR Interaction

- It is a pair of VR controllers which support 3D user interaction with our hands (to select and manipulate objects in VR, to gesture and interact socially).

Being Someone Else

- Jane Gauntlett: In My Shoes

http://janegauntlett.com/inmyshoesproject/

https://www.theguardian.com/technology/2014/jan/15/virtual-reality-theatre-puts-first-hand-experience-of-brain-damage-centre-stage

http://www.themachinetobeanother.org/?page_id=820

Levels of Immersion

An ideal VR environment would display all sensory systems (ultimate display), i.e.

1. vision
2. sound
3. touch
4. smell
5. taste

Basically all our five senses could ideally be simulated in an ideal VR system.

Technically speaking, System A is more immersive than system B, if system A can simulate system B, or in other words, if system B is a subset of system A.

Haptic Sense

2 levels of haptics:

- Sense of touch: Something you touch in the VR (in a Model Based VR), e.g. you catch an object and feel something.
- Force feedback: Something else touches or pushes you in the VR.

Sensorimotor

Sensorimotor contingency means the set of implicit rules whereby we use our body to perceive the world across all senses.

The 3 Illusions

1. **Place illusion** (illusion of place) “I am here”
    - The (grade of) illusion I am there, even though I know I am not there.
    - The illusion of being involved in the place you are navigated in the VR, feeling the presence, feeling you are there.
    - *Perception.*
    - The system depends particularly on the sensory-motor contingencies
        - How you can use your body to perceive that you are within that place of illusion
            - This is something impacted by the system’s hardware and software capabilities

2. **Plausibility:** “Am I really here?” “What is happening?
    - The (grade of) illusion of what’s happening is really happening, even though I know it is not
    - How real do I take the events to be? (grade of belief you are in VR)
    - *Cognition.*
    - The events that are happening in the place illusion.
3. **Embodiment Illusion** - Illusion of body ownership “Is this my body – this is my body”
    - The (grade of) illusion that the body of avatar is really your own body.
    - *Proprioception effect* (body position awareness).

        - Proprioception drift of illusion, e.g. that the virtual hand is my real hand.
    - Embodiment illusion can be enhanced via the so-called visual tactile & the visual motor synchrony, i.e. when you seem able to "feel" the touch even though is not your real body touched (visual tactile) and when e.g. the movements of the avatar tend to be synchronized with the movements of the real body (visual motor).

Other terms:

- **Credibility**: When the VR scene does not depict the expectations of the reality, e.g. I am not supposed to see a dinosaur because in real life they no longer exist.
- **Break of Presence**: When place illusion breaks it could come back because it is more *perceptual*, but when *plausibility* illusion breaks it would be more difficult to have it back because it is more *cognitive*.
- **Immersion**: it is the way to describe the system itself, it has nothing to do with people's responses.

Challenges & Problems in VR

VR environments should be photorealistic producing a realistic lighting.

Illumination Realism & Graphics

Types of Illumination

- **Local Illumination**: We only consider lights that come directly from the light source.
- **Global illumination:** We also consider the inter-reflection between objects.

Types of Reflections

- How lights are reflected on the 3D objects:
  - In real life we have the combination of the following light reflections:
    - ***Diffuse* reflection** (fabric): It reflects light evenly and equally in all directions/ it is considered computationally **cheaper** to be produced
    - ***Specular* reflection** (metal): Things made from metal (like a black frying pan): lights are reflected toward a certain direction which produce a highlight effect /they are considered more expensive to render and mathematically more complicated to be produced.
    - **Mirror surfaces – extreme example of specular reflection (glossy/mirror)**: The most expensive to be produced.

Animation

Particle System: the system in a game engine that can be used to generate effects such as smoke, fire, and snow.

Navigation

Navigation in VR devices with Position Tracking

- You can shift your body naturally to see what's behind an object in front of you, and walk around with your legs just like you do in real life.

Navigation in Mobile VR

- Here there is no position tracking.

- You will need to use the VR controllers for both: to shift your view point or to move to a different place.

Types of Navigation

1) **Physical Navigation:** You can move and this can be reflected as in real life
   - It is considered the most natural way of navigation of all kinds
   - **Problems:**
     - you are limited by the physical space you're in
     - not compatible with mobile VR, as we cannot track where a user is in the 3-D space via a mobile
2) **Virtual Navigation:** users control their movements entirely using the *joystick* or *touch pad* that comes with their VR controllers
   - **Problems:**
     - Nausea
3) **Walk in Place**: participants walk in place by doing the walking motion with their legs without actually moving forward, and they can also use their arms to indicate the direction in turning
4) **Teleporting**: Like in the street view of google maps when you jump to a new place

**** Those are relevant only to model based VR, since in 360 the user only has access to view the environment from the fixed precision where you filmed with your camera.

Nausea in VR

- Also called **simulation sickness**: It's mainly caused by the conflict between information received in the brain from our vestibular system and our visual system.
  - Your visual system thinks you are moving, but your vestibular system thinks you are not.

Sources:

https://developer.oculus.com/design/latest/concepts/bp-generalux/

https://developer.oculus.com/design/latest/concepts/bp-locomotion/

Meeting People in VR

Nowadays when we can't physically be together with someone, we often use video conference calls. But there is one thing we're much better at doing in person rather than through video conference calls and that is negotiation. This is because when it comes to negotiation, a lot of things are important.

- Relationship building, trust, our ability to read each other's body language and facial expressions and the timing of when to say what.

We rely on social skills we have developed over the years to create a more positive relationship which will lead to a more desirable outcome. A lot of these social skills are very subtle and often operate at a subconscious level. So when you hear someone say, “I don't think he's trustworthy but I can't quite explain why”. That is actually a very reasonable statement backed up by scientific evidence.

So in order to fully utilize my social skills, I will really want to be able to express myself as much as possible. If I have to do it in VR through my avatar, I will have to animate it with real-time motion capture data which captures both my gestures and facial expressions. But an obvious problem is that if I'm wearing an HMD, half of my face will be obscured.

Challenges in the VR world:

- Tracking eye movements
- Tracking facial expressions

Social interaction in VR technically difficult:

- real-time facial capture.
    - Within the most ideal situations, certain features will be very hard to track. These include eye gaze, blinking, pupil dilation, subtle emotion changes such as blushing and sweating and also any subtle facial muscle movements. We can track some of these features with volumetric capturing. But a problem is that this cannot be done in real time because it requires post processing. Again, this is not possible if the user is immersed in VR themselves with an HMD.
    - Secondly, another challenge in social VR is that the current technology

does no support socially meaningful physical contact with another person.

- For instance, with the current VR controllers, you cannot shake someone's hand or tap them on the shoulder. Therefore and in that sense, you might probably just use a video conference call instead.

Haptic Feedback

Tracking technology & **vibration feedback** via the VR controllers

- Need for VR gloves giving
    - Those gloves that give <u>**force feedback**</u> (when you e.g. grab and hold an object) are called <u>exoskeleton VR gloves</u>
    - <u>Those gloves that give tactile feedback (mainly for games) -> feeling the force when you are punched by an opponent</u>

Chapter 4 | Building Interactive 3D Characters and Social VR

Social VR and Virtual Characters

- Verbal Signal -> speech
- Non-verbal signals -> body language

- We can replace verbal signal (speech) with typing, and we can use emoticons for expressing part of body language.
- Although there are some fundamentally basic emotions, some people express their feelings and expressions in a different way => if we then try to digitize those => people lose their personal identity.

The aim is to capture, as much as possible, our expressions (via facial expressions and body language) and apply those to the digital representations of ourselves, our avatars, so we can have high fidelity social interactions, where we can not only hear each other's words, but also sense their emotions through their nonverbal cues.

VR Characters | Realism

Human-like avatars

- Cartoon-like
- Photorealistic

Appendix | Assignments (Course 1 / Week2+4)

<u>Motivation</u>: Describe your VR application, and what you would like to achieve with it. Similar to existing VR applications reviewed in this course, your VR application should be designed to solve a problem, share an experience, create a new business opportunity, or explore new ways to express yourself. You should explain your motivation behind your VR application:

In the era of the Covid-19 pandemic, the idea I had in the past of digital fashion shopping seems to be more than imperative to be implemented. Based on the technological improvement and innovations, both in hardware and software, as well as with high computational capabilities, this idea now seems that it can be created for real.

A Virtual Reality Shopping would help all the retail sector which suffers in the era of our pandemic. However, I believe that the transition to VR Shopping is something that eventually would take place sometime in the future; the pandemic probably acts both as a cause and as an accelerator for the creation of VR e-shops.

Lastly, I believe this idea could take place on any kind of e-shop, however, in this project I will be focusing on clothing since I believe it is a product that needs VR more than other commodities, e.g. you may not need to view a book or a suitcase in a 3D in VR, but it would be so great if you could fit a cloth on your own body in a VR environment.

<u>VR technical specification</u>: Give details of your VR app regarding the following three aspects: VR display, VR content, VR interaction:

I believe there would be 3 main steps for this VR application:

1) creating our virtual avatar (customer)

2) Scanning products, i.e. the clothes (retailing stuff)

3) The customers fit those together, i.e. the virtual avatar of themselves along with the clothes that they want to try out in their body in the VR environment .

Based on the above:

1) **VR display**:

   It would allow dynamic control to the user of their viewpoint with regard to the clothing product fit on their body.

2) **VR content**:

   Ideally, it would be nice for the application to be built as a Model-Based VR app. However, since this would require computer-generated 3D graphics, and since this app would have a need for widespread usage from a big portion of the population, it would be more practical a 360 Video application, since this could be viewed by a mobile VR, and it would be more realistic towards the available equipment of the majority of clients-consumers.

3) **VR interaction**:

   Not any sophisticated VR set of controllers would be needed on this occasion; the client would just need to scroll and navigate in the mobile VR with just their hands and see how the clothes fit on their body.

<u>Existing similar apps</u>**: find 2-3 existing VR applications that:**

Either

(1) similar to what you are trying to achieve

Or

(2) share certain elements you could borrow from

They can be applications which inspired your own design. Describe the apps, give the links, and provide some explanation why you think they are similar and what can you learn from them:

I believe the following 2 links provide a ground spectrum of my idea, which basically was inspired by the content of these videos:

- https://www.youtube.com/watch?v=e8Wt2lJ51_M&ab_channel=LifelongLearners
- https://www.linkedin.com/posts/stevenouri_innovation-technology-augmentedreality-activity-6743726246959697920-sdRF/

As it can be seen, The London College of Fashion has studied and tried to implement the idea mentioned in this project, while the "zozosuit 2" created by the company Zozo Inc is a solid example of how this concept has been materialized in reality in the industry.

Why does your application need to use VR as opposed to a standard on-screen interface?

For an application like the one mentioned here, I believe it would be imperative a VR interface to be used; otherwise, I cannot think of any possible way and solution with which you could scan your body and then fit a variety of clothes on that entirely online without going out of your home at all.

<u>The three illusions</u>: describe how the three illusions are supported in your VR application.

1) **Place Illusion:**

   First of all, the ultimate goal of this application is not to make the client feel like he/she is in the physical store itself, but to make him/her feel that the particular cloth fits well and is suitable for his/her body. Thus, the level of perception here does not need to be in a high level

2) **Plausibility:**

   Cognition here would be achieved if clients feel that the application does a decent job, i.e. that clothes that would normally fit the client's body in the physical store fit also in the VR app. For example, if the client wears “medium” or “large” size t-shirts in real life, then if he/she tries in the VR app a t-shirt of size “extra-large” then the bad result-fit expected by the client should accordingly be confirmed by the avatar in the VR app as well, and vice versa for other cloth sizes.

3) **Embodiment Illusion**:

   Again, as with the place illusion, this app would not need a great level of embodiment illusion in order to properly function and deliver its objectives, at least for the short-term life of the app; the purpose would be to find suitable clothing, not necessarily feeling we have been teleporting to another place.

Market: describe who will be your targeted users and how would you try to reach out to them?
Although it is tempting to put "everybody" as your market, when designing a VR app it is actually going to be more effective if you start with a more specific market in mind - it's difficult to cater for all tastes and needs!
When designing a VR app with so many different technical/content considerations to balance, having a specific audience in mind will keep you focused when it comes to choosing your VR hardware and software:

Normally, all consumers that own and can use a mobile phone, and concurrently those that are legally entitled to make online transactions and purchases.

Evaluation: do you think your desired market can easily access the required VR hardware? Explain why and, if the answer is yes: identify any opportunities to further improve accessibility; or if the answer is no: explain how to re-address your design or point out what is missing:

I think it would to the best interest of all if mobile phones with integrated VR applications can be cheaper. In this way, the more people would be able and willing to buy those phones, the more the VR market would be further expanded.

Augmented Reality – Arloopa App

Marker-based AR

Marker-based AR: scanning a particular image (marker) with the camera of mobile device.

- The device recognizes the marker and displays the AR content on top of it.

Applications

- Artworks (bring artworks to life from the same point as captured on the image, creating a smooth effect of revival)

Markerless AR

The user does not need to scan any marker, but only needs to choose where to place the virtual content by simply hovering the device over a preferred surface

Applications

- **virtual try-on of clothing**
- accessories or retail product visualizations
- education and training simulations
- advertising, gaming to virtual art exhibitions

Location-based AR

Also known as position-based or geo-based AR: it attaches AR content to a specific location

- the user needs to be physically present at the particular location in order to unlock the digital content.

Applications

- events, concerts, stadiums
- virtual exhibitions

References

[1] https://www.coursera.org/learn/introduction-virtual-reality?specialization=virtual-reality

[2] https://app.arloopa.com/?utm_source=tldrnewsletter