Bachelor Thesis
Graduation Project Report

Development of a 3D Navigable Interface for a Touchless Showcase

Creative Technology B.Sc.
Department of Electrical Engineering, Mathematics and Computer Science
University of Twente

Hauke Gregor Wilhelm Sandhaus

Supervisor:
Ir. Edwin Dertien
Client:
100%Fat V.o.f. Enschede

1. Front Matter

1.1. Abstract

Due to widespread usage of touchscreens users have accepted interaction without haptic feedback. Commercial game consoles have introduced users to touchless input and natural user interfaces. Only recently it has become technical possible to track human hand skeleton in high detail, precision and low latency contactless. This report describes the design process for the user experience, user interface and interaction interface of a touchless showcase using skeletal hand tracking. The project extends on existing hardware, compares current approaches, researches on the user group and rebuilds the software, based on these findings, from scratch. To allow input, multiple interactions and 3D buttons were developed. In a user experiment these were tested. A final prototype was implemented on two showcases for a month and compared to the existing software. The findings suggest that users want more natural and direct interactions. Missing physical feedback, non-existent depth perception on traditional screens and unfamiliar gesture language are hindrances but can be overcome with the use of good visual cues. Future work on the software is solely on refinement. Some of the interactions investigated in this thesis will prevail, while some might appear in other contexts.

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1.4. Glossary

100%FAT – is a cross media development company and the creator of the Smartware exhibition
API - application program interface, a set of tools for building software applications. The API specifies how software components should interact. In a reference classes of this API are explained.
C# - C-sharp is an object-oriented programming language by Microsoft that aims to combine the computing power of C++ with the programming ease of Visual Basic. The Mono project provides an open source C# compiler and a complete open source implementation of the Common Language Infrastructure.
Gallery - The gallery is a shared room for several projects and small businesses, belonging to the Kennispark Twente and located on the territory of the University of Twente.
Kennispark - The Kennispark Twente is an incubation centre for small startups and innovative industrial projects in the region of Twente, located on and around the University of Twente campus and Industrial park of Enschede. It tries to bring entrepreneurship to Twente.
LEAP – The Leap Motion controller is a USB peripheral device equipped with two infrared cameras and three infrared LEDs. It uses complex mathematical calculations to identify hands and track the position of the skeletal hand bones.
PIRATE – Is a Pipe Inspection Robot, developed by University researchers to inspect low pressure gas networks with small diameters.
Showcase – is a two meter high display, built out of aluminium and glass. It has a screen in the back and a rotary plate in the centre to exhibit objects from multiple projects around Kennispark and University. It is an interactive experience for the user using a touchless sensor (the LEAP) to guide through displayed information
Smartware Exhibition – showcases flagship project of the Kennispark in the interactive showcases. Located at the entrance of the Gallery
Unity – is a multi-platform game engine and developer tool that is free to use in the personal edition.
Raycast – a virtual ray in game engines for determining lines of sight or targets hit by gunfire
Vector3 - is a representation of points and vectors in Unity. It can contain directions and positions and allows vector transformations.
GUI- a Graphical User Interface for electronic devices makes use of icons and visual indicators.

1.5. Acknowledgements

2. Introduction

2.1. Situation

For 'the Gallery', an incubation centre for business startups at the University of Twente, cross media development company 100% FAT has developed a number of 'vitrines' (Figure a); interactive displays to showcase technology developments by companies and University. The vitrine is a showcase, a canvas to exhibit objects in an innovative way. In the showcase physical objects are displayed on a rotary plate.
The showcase is equipped with technology and sensors to connect the real object to accompanying digital on-screen information. The additional information is of two-dimensional content such as images, videos and text and three-dimensional models of the physical objects. The visitor is meant to feel and understand the shown objects without studying its background.
The interaction type is of point-and-click but uses instead of a computer mouse or trackpad a 'Leap Motion Controller' - hereinafter referred to as LEAP - to control the pointer contactless and go through a presentation. Each vitrine has one static presentation fit to the object. The software is written in MAX 6 by "cycling '74" a visual programming language for music and multimedia. The vision of the vitrine is to express the significance of the objects with the visual metaphor of a showcase and give a futuristic and cool presentation so that more visitors catch interest in University Projects.

Figure a: Smartware exhibition with interactive 'vitrines' in the Gallery, University of Twente. Retrieved from: 100FAT.nl

2.2. Challenge

The look of the showcase is aesthetic, solid and professional, it can keep its current design. However, even though there is a video explanation, people that are unfamiliar with the LEAP do not always understand

how to interact with the showcase. Some user groups lose interest in the presentation after the first slides, which could be due to the conservative use of the innovative input device.
The showcase delivers information but is by itself not engaging enough and playful, it does not go beyond a slideshow presentation. The relationship between physical object and information is not obvious. The display gives information about the exhibit but does not extend the experience. The showcase should not require a tutorial for the interaction but make an experience out of it. The area in which the LEAP detects motion, hands and gestures is limited. The LEAP has to work within constraints without making the technical limitations a barrier.
The showcase should give much information in a glance without being overwhelming. The user himself needs to be able to decide what to focus on. The interaction should not feel like an unnecessary gimmick. The aesthetics of the information on the screen have to be eye catching.

2.3. Questions

From user and client interviews as well as from observed data it is proved that there is room for improvement:

- How can a user be best introduced to interact with the vitrine and to its interaction?
- What interaction works best with the vitrine?
- How can information be best presented in a virtual showcase?

2.4. Practical Aspects

The company wants to keep the look of the vitrine in its current state, therefore changes on the hardware should be minimal. However the software can be rewritten completely to exploit the potential of the LEAP fully. The software will be designed with Unity as it has example code to operate the LEAP, to communicate with Arduino and display 3D models.
The research will focus on the gestures and tools that work well with the LEAP in context of the virtual showcase. The graduation project will introduce me to game engines and scripting in C Sharp. It has a strong component of Human Computer Interaction, Interaction Design, User Interface Design and User Experience design.

3. Ideation and Product Idea

3.1. Customer Requests

3.1.1. Powered by Twente Innovation Events

They are the venture that commissioned the Smartware exhibition. It is meant as a showcase to excite people about projects from Kennispark Twente, University of Twente, Saxion BTC Twente and other high technology companies in Twente.
Highlighted was that people should get excited and secondly informed about projects. For further contact the people are meant to reach out to contact the real project, research groups and companies that worked on these project from the named stakeholders. 100%FAT came up with the current concept and realization of the Smartware exhibition.

3.1.2. 100%FAT

They wrote out the proposal to redevelop the showcase and to think of further concepts. The brainstorming started very broad and also considered hardware changes from the metal framework, sensors and motors to the platform that the software was developed on. The showcase should be extended as a platform that has appeal to other customers besides the Gallery. The implementation should be creative and implementable. The clients expected to make better use of the possibilities that the hardware could enable and for progress. The software had some technical and interaction issues but the focus of this work was to redevelop from scratch and stimulate for new and improved use of the showcase. The intention was at the beginning to develop interaction prototypes and to get help by a software engineer to test them. Because the hardware and software of gesture control were not yet ready for market adoption detailed technical research on possibilities and limitations was required. The familiarization to the required libraries and concept made it difficult to get an engineer well known to these. Therefore this was carried out within the bachelor project, too. The aim was not to make a full software application that carries over all advantages of the old software. The focus was on interaction design and exploring the feasibility of other concept over the current one. 100%FAT showed preference to integrate visual hands model and try 3D instead of 2D interaction.

3.2. Research

3.2.1. User Experience Evaluation

Since the Smartware Exhibition is successfully running in the innovation centre the Gallery at Kennispark Twente in Enschede for more than a year (April 2014) the user group of the new showcases could be observed easily in the central hall. Besides that the showcases were enabled to log activity.

3.2.1.1. Results of Data Logging

The activity logging of the showcases proves that the exhibition has frequent visitors with higher spikes during breaks and events. People stay on each showcase less than a minute and go on average 1.4 level deep into the slides.

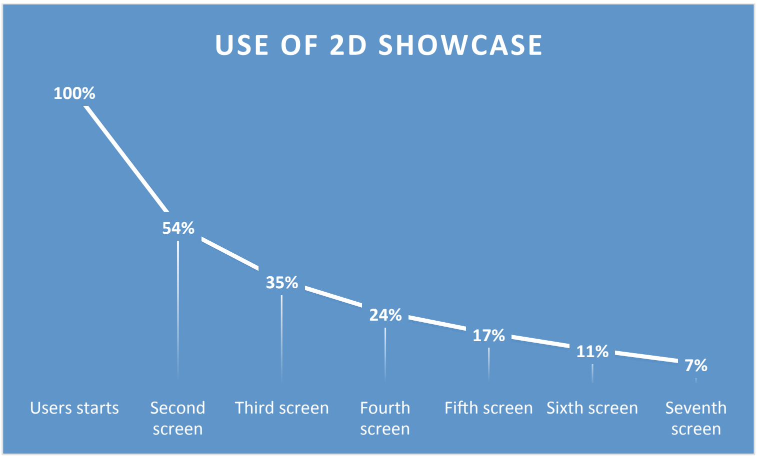

Figure b: Drop of users

3.2.1.2. Results of User Observations

To determine what people use the showcase for, how they interact with it, if it brings joy and whether a different design could improve certain aspects, user interaction was observed. For five weekdays spread across spring 2015 observation took place. After people interacted with one or multiple showcases they were approached and interviewed with less than 5 minute long, audiotaped, unstructured interviews[1]. It became evident that the recent version of the showcase fulfils most requirements made by the primary client, the University of Twente. Visitors, staff and students use the exhibition during waiting time to get informed about the showcase projects of the Twente Kennispark. Most of them understand how to retrieve information and wander from showcase to showcase. The raw unedited data of the interviews can be retrieved online [2]. Findings from the observations and interviews are summarized in this chapter.

3.2.1.2.1. Activation

The start screen was getting mixed reviews. People liked the simple user friendly movie. The word “Start” aroused interest to engage with the screen. During the observations no users were unable to activate the showcase. However some users took longer than others to recognize how interaction takes place. A few users only looked at the infographic (Figure c) after they tried to use the LEAP as a touchpad. Other users were observed to first hover with the pointer over the infographic instead of the 'start' button placed next to it. Some tried to physically reach for the start button and touched the glass. After activation succeeded and the Showcase load up the first slide accompanied by start-up sound and the rotary plate turning the object users expressed feelings of joy and success (see: 3.2.2.9 Playful user interfaces).

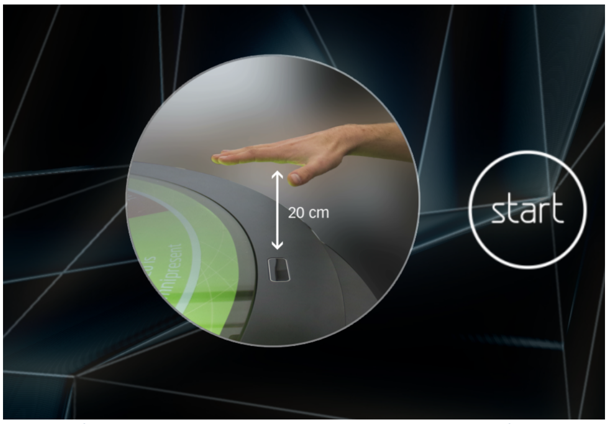

Figure c: Infographic displaying the devices detection range. Retrieved from: 100FAT.nl

3.2.1.2.2. Visual Style

Users preferred the showcases that had eye catching physical objects over the simpler ones. Moreover they preferred the showcases with rich media content such as videos over the ones with a lot of text. Additionally one showcase features an animated 3D mapping which a few people described as "eye catching". To sum up: **The quality and perceived interestingness of a project seem to be dependent on the quality and creativeness of its presentation in the showcase.**

They liked the animations that load up the movies and pictures but described them as a bit too slow. The LED lights and futuristic colour choices were positively reviewed. Some people disliked the use of a button on the start screen and described this as an uninteresting presentation because it was static and the same on all showcases. "Without activating the 2D version feels a bit dead". While a lot of people criticized the high amount of text "well not gonna read that" some users that had a lot of time liked to read it. People liked the clearness and sharpness of the display.

3.2.1.2.3. Content

People do not go further than two screens down in the current version of the showcase. They return to the showcases at another time but are presented the same information, and again go no further than two screens. These screens have yet to reveal a lot of informative content which will never be seen. For example the video of the PIRATE robot was watched not a single time during the testing period as it appears on the third screen. Visitors would need three times more than they spend on average at the showcase to even reach this third screen. Besides other users one user reported the showcase and the projects as "a bit boring but due to the nature of university projects". However the Smartware is meant to overcome this disinterestedness and excite people for projects in the Twente area. Employees, students and visitors should also get interested about less interesting projects and understand their importance. Too much of the content was displayed by using text and to long videos.

3.2.1.2.4. Pointer

The mapping of the pointer is in two axes. Thus forward-backward moving as wells as up-down movements result in up-down movements of the pointer. This unnatural mapping helped that the pointer moved as soon as the hand moved in any direction and users could see that they are in control. In some of the showcases objects placed in front of it, hid the pointer and therefore users did not notice the presence of the pointer. The graphic representation of with pointer with a circle was recognized.

3.2.2. Literature Review

From literature related to touchless interfaces, design and human computer interaction, requirements for the new showcase can be derived.

3.2.2.1. Practical advantages of touchless operation

As a lot of medical applications require sterile operations and navigations of computers a lot of research has been done in this area on touchless computer input [3], [4]. Touchless operation of electronic devices is more hygiene and does therefore require less cleaning of critical input devices, such as touchscreens, that could spread diseases or look dirty quickly. Moreover touchless operation is more secure to vandalism.
However the requirements of medical applications are very different to those of the showcase naming:
The users of the showcase should not require training on how to operate the device.
The showcase can be designed ground up and does not need to communicate with existing applications that require pointer input.

3.2.2.2. Game immersion

For games the ultimate goal that developers often seem to reach for is immersion. Immersion is sometimes measured as reduction of self-awareness[5]. To stage to total immersion two other levels of immersion have to be reached first. These are engagement and engrossment[6]. According to [6] "Total immersion is presence". Engrossment requires emotional investment. As seen from the user evaluations people prefer to spend little time at each showcase and use them during breaks to pass the time. Therefore neither total immersion nor engrossment are targeted by the improved showcase. The showcase should still keep the users engaged. To allow engagement the feedback and controls of games should enable easy access and make the player feel like an expert. Moreover the player needs to put time, effort and attention into playing. Most users were willing to do so. The environment in the Gallery draws attention to interact with the showcases. The visual style of the hardware and software create an atmosphere that further break barriers to immersion [6].

3.2.2.3. Attractive design

For years research has tried to make design more usable and intuitive. Often beauty has been considered incompatible with usability, but: "Attractive things work better"[7]. Especially for this project the balance between usability and beauty has to be considered well as it has to be entertaining, usable, understandable, informative, and work well. Moreover the showcases have not just informative purpose but are essential to the atmosphere of the Gallery. Therefore it should be considered how the software can help to provide additional value and enhance the attractiveness of the showcases.

3.2.2.4. Perceiving power

In museum installations, engagement with interactive games could be reinforced when visitors perceived to hold power that they do not possess in other contexts [5]. Visitors seemed to perceive bigger sense of power when they were able to forget that a computer was in between them and the interaction. Therefore a mouse, pointer, keyboard and the computer interface should ideally not be visible in the realization. Especially powerful might not just be virtual interactions, but interactions that results in change in the real world. Examples would be to give users power over cameras or the orientation of the exhibit.

3.2.2.5. Technical limitations

Hardware to track freehand gestures still has its limitations in tracking performance. In research [8] high gesture recognition of American Sign Language gestures with the simultaneous, combined use of two tracking devices (Leap Motion and Microsoft Kinect) and reducing the number of gestures to distinguish was achieved.
Developers of gestural tracking devices are making progress in refining tracking accuracy and during the development of the software for the showcase multiple times the used Libraries have been updated. The

progress in the camera systems to detect hand poses is rapid. Just a little more than a decade ago those infrared systems were in the size of meters [9, p. 373] and are now in the size of centimetres.
The development of these technologies is still far from finished and now there are still new competitors entering the market but also large companies such as Microsoft refocusing their attention to Hand tracking. A recent research by Microsoft [10] targets the limitations of current skeletal trackers. These are the limitation to front-facing close-range scenarios, robustness and recovering from failed detection. This is a particularly big problem of the Leap Motion controller used in the showcases. The detection starts from an initialized pose and cannot recover during the tracking. Other approaches [9, p. 289] describe how to calculate hand poses not from multiple frames but from a single image to avoid these current limitations. Compared to the leap motion they suffer from higher computational burden and are not market ready yet, which leaves the leap motion controller as state of the art due to its low price point, fairly good documentation [11] and examples [12]. Google's Advanced Technology and Projects group announced [13] that they built their own gesture sensing chip. It uses instead of infrared cameras radar and could overcome limitations that current hardware has.

3.2.2.6. Natural user interfaces

A natural user interface is in comparison to an intuitive interface an interface that allows people to learn the interaction while they use it, whereas the intuitive interface should be able to be used without previous learning [14]. Multiple efforts to mass market full blown NUIs seem to have failed [15]. Nevertheless more and more ideas from NUIs have made their way into interfaces and are combined by traditional GUIs. Smartphones take heavy use of gestures and offer less descriptions than GUIs do due to little screen space. Users adopt natural language interfaces such as Google Now or Apple Siri. Users' intuition differs for all demographics groups. This is because cultural, social and professional background from users differs. The intuition of users stems from the applications and tools they are used to. Therefore instead of trying to make user interfaces intuitive they should be made so that the interaction is learned while using them.
Natural user interfaces have to avoid feeling gimmicky. For games a lot of interactions that relate directly to real movements can enhance immersion. But for some other applications they can easily be too demanding in physical execution. For example flipping a page on a very large screen would require too much distance to be crossed. People do succeed in using gestures to control natural interfaces [16]. Unfortunately, as mentioned earlier, very few gestures have become common sense. For example an natural interface that uses body postures to control slideshows [16] might look good in theory but it will fail in professional environments as the users are not benefitting compared to buttons and will likely feel uncomfortable holding poses in front of audiences. Gestures will only be accepted if they fit into the body language of the users before they need to use them. Systems that use gestural interface need to be able to distinguish whether the user is making intentional control movements or movements unrelated to the system.
Another example with questionable usage is the gesture-controlled microwave [17]. People were able to learn how to use it but most likely even with perfected gesture recognition there is no need to control settings with gestures. Gestural attempts often lead to encrypting simple tasks in difficult body language. Yet it is very obvious that a lot of users prefer to use control options that are 'natural'. Consider the example of zooming in and out on screens. The fewest casual users would use keyboard shortcuts to do so. For multiple years the default was to use GUI zoom buttons, but now the pinch to zoom gestures is most widespread. A natural interface would prefer this method while an intuitive interface in professional use might still rely on keyboard shortcuts just because for this user group it is the most intuitive one. Intuition is not innate but acquired to some degree.

3.2.2.7. Human-centred design vs. Activity-centred design

Human-centred design (also called user-centred design) optimizes products how users can, want, or need to use the product instead of making the user adjust to the products. This design approach relies heavily on user research and adjusting to usage scenarios. In technology firms it has become the first method to improve products usability. If not executed well, human-centred design can has its shortcomings [18]. Designs that are highly adjusted to one user group might have problems with other user groups. Companies such as apple do not carry out a lot of user research but instead focus on the vision of few designers, yet they are acclaimed for the usability of their products. This is because often users themselves do not really know what they want until it is shown to them [19]. A lot of tasks such as writing texts or playing an instrument are not user friendly at all, but still kept their way of interaction manner over centuries. E.g. the QWERTY keyboard which was not developed to easy internalize the arrangement but to keep typewriters from interlocking the heads. This is because they fit perfectly for the activity they are used for. Therefore interactivity can better be designed around the actions needed to accomplish a task instead of the preferences of the user [18, p. 15]. Therefore instead of asking the users directly, it could be better to observe them and interview them later on [20].

3.2.2.8. Science fiction movies

Researchers were always the first that try to change the human computer relationship. However the expectations users have about technology are not shaped by research but by the real products they encounter and also by the media they consume. Especially Science fiction predicts future devices and more than expected have come to the mass market. These differ from the actual technology that makes the metaphor work and from the application but influence on the aesthetics is undeniable. E.g. warp motors are not accessible yet but electrical cars already sound like them. If users see devices that work like the ones they were promised to work with in the future they are easily impressed. Uppermost user’s frustration throughout the use of interface should be kept minimal. To design interfaces that allow people to feel like superheroes or idols they know from movies could be a logical step. This might minimize the rejection of new input devices, which are often not instantly recognizable to be superior over traditional devices.
Gestural interfaces that do not require touch complemented by flying holograms are a recurring theme in Science Fiction Movies. A quick comparison of high grossing movies shows [21] that the same gestures and interactions are used in widely different contexts for different applications. However some gestures are recurring in multiple movies. Such as: wave to activate, push to move, turn to rotate, swipe to dismiss, point or touch to select, extend the hand to shoot & pinch and spread to scale [21]. These are all direct manipulations and direct analogies from physical manipulations. A lot of tasks computers are able to perform are a lot more abstract which again require graphical interfaces or for very abstract tasks voice. To sum up, gestural interfaces should make use of language that is already spread by movies through to the end users.

3.2.2.9. Playful user interfaces

As already concluded in the natural user interfaces and the science fiction movies section it has multiple positive effects to create interfaces that are visually pleasant and take metaphors from physical manipulation. Moreover the interface design for the showcase is developed to be frustration free. Therefore it might be a good option to create the interface playful. Playful interfaces (sometimes also ludic Interfaces) do not just focus on getting tasks done efficiently but to provide fun, excitement, challenges, and entertainment [22]. These playful user interfaces often have educational content, which proves that they are an appropriate use for the showcase. Playful interfaces are often simultaneously natural interfaces because fusing reality with virtual reality allows people to perceive powers and entertain (See 143.2.2.4 Perceiving power). Additionally the showcases try not to communicate in a formal manner but to enthuse people.

3.2.2.10. Public Systems

Systems developed for public use in advertisement or culture settings using non-instrumented body-tracking nowadays only use location body shape, and skeletal tracking [23, p. 26]. The major difference from the showcase as a public system to these well-tested systems is the different tracking method with hand skeletal tracking which is only very rarely seen in real public applications. Previous scientific investigations reasoned that users of public systems need a lot of visual feedback and cues. Also they concluded that non-gamers need different cues and are less confident in getting to use new systems and interfaces [23, p. 33]. One major advantage of public systems is that they can positively influence social interaction. This was also found to be true for the showcases during the observations conducted at the Smartware exhibition. The interaction mode the current showcases use (moving cursor with hand position and selecting by hovering over an interval) was successfully used by other systems such as the time viewer [23, p. 39]. The conclusion is that body motion used for input is, regardless of the content, perceived as more fun than static interaction with desktop PCs.

3.2.2.11. Gestures

Gestures are human movements that contain information. Gestures that are spontaneously generated from persons while telling a story, holding a conversation or while speaking in public are called natural gestures [9, p. 20]. In the field of gesture recognition a lot of effort has be put in analysing body language in dance and theatre, sign language for the disabled as well as recognition of drawn shapes with gestures [9]. These gestures cannot, even though they are detectable by the hardware of the showcase, be used for the Smartware exhibition because they require the users to be aware of these languages and tutorial instructions are undesirable. The amount of gestures that humans use during conversation is immense. It is not just emotions but also objective information. Fingers can be used to count, agree or disagree, give direction, point and a lot more. An extensive list is available on Wikipedia[1]. These gestures differ from culture to culture. In Indian classical dance a full gesture language matured to tell stories without tongue. This entertainment form however is dying out therefore less and less Indians understand them[2].

[1] http://en.wikipedia.org/wiki/List_of_gestures
[2] http://en.wikipedia.org/wiki/List_of_mudras_(dance)

3.2.3. State of the art

In the literature review section scientific research on gesture control is discussed. In this section examples that developers and game designers came up with are discussed.

3.2.3.1. Leap Motion Examples

A lot of projects using the LEAP for touchless controls can be seen online [12]. It is updating quickly and more and more interactions can be seen. Most of them require to be used with virtual reality glasses. The sensor is mounted to the glasses and has a field of view that matches the user's vision more closely than in desktop orientation. Additionally the movement of the virtual hands and real hands feel more natural because they occur within eye vision. Most examples take heavy use of the physics engine because it is easy to implement with unity and more impressive than gesture interaction. Another interaction that can be seen often, is drawing in 3D space. During the writing of this thesis LEAP motion released their own widgets and buttons which are however also optimized for use with 3D virtual glasses. There were few examples that used interaction types that could work outside of game contexts. One very good application is the Form and Function 3D application [24] by Brendan Polley a Biomedical Communicator[3]. It uses swipe, rotation and selection gestures to explore 3D models of human body's organs (Figure d).

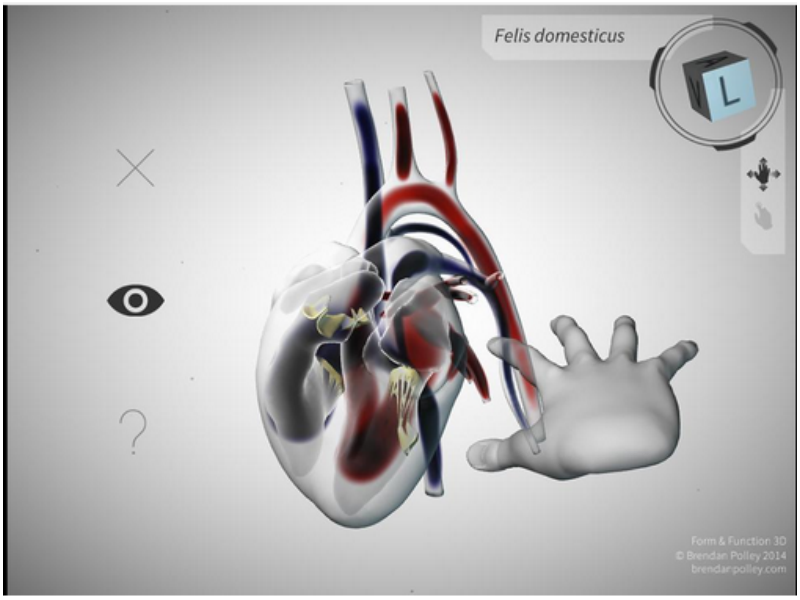

Figure d: Form & Function 3D, Brendan Polley. Retrieved from: brendanpolley.com

In these 3D models all parts are explorable. They can be touched with the 3D hand and information appears. The selection with the index finger and menu navigation needs some time to get used to but works fairly robust depending on the current tracking accuracy of the LEAP. It also implements the best swipe detection that could be found[4]. The application makes heavy use of transparency otherwise the hand would obscure too much information.

HandWAVE is one of the many LEAP applications that try to make touchless control of desktop computers possible. It provides multiple gestures to scroll, start and stop music etc. These gestures do not work natural

[3] http://brendanpolley.com/

[4] https://community.leapmotion.com/t/form-function-3d-leap-motion-application-for-undergraduate-anatomy-education/1047/15?u=haukesa

yet most of them are a translation of keyboard shortcuts or mouse controls. Therefore it is still preferred to use these input devices. However it comes with a good tutorial that explains to unexperienced users very cleverly the workarounds to the restrictions of the LEAP hardware (Figure e). The tutorial is playful, it uses good animations and might be the best experience of this app. To help users with depth perception the position of the hand is shown additionally at the faces of box. Again this application renders everything transparent to allow the users to constantly see where the hand is.

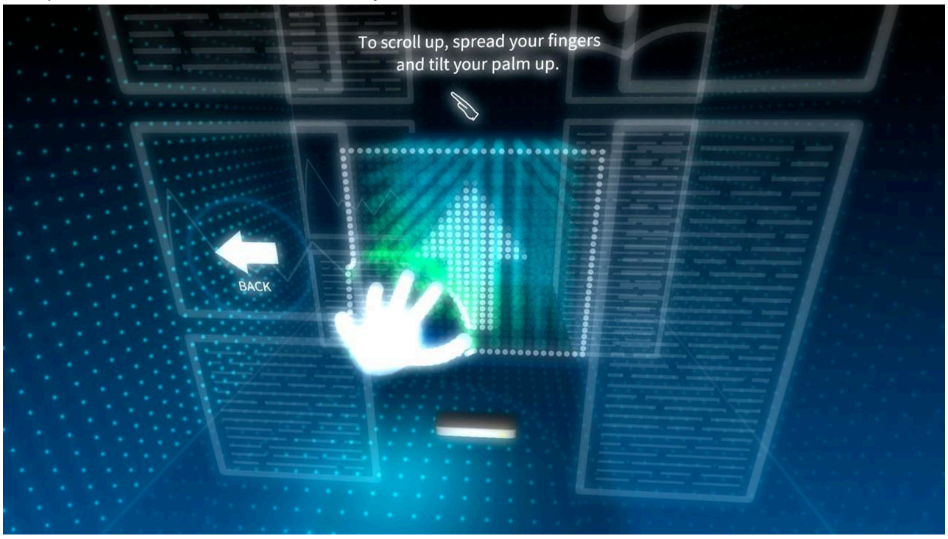

Figure e: HandWAVE tutorial. Retrieved from https://apps.leapmotion.com/apps/handwave

Other apps showed what gestures or interaction in general not to use. A robot chess game that comes with the LEAP as an example was considered as unplayable because the 16 chess figures on the board are too close to each other to select easily.

3.2.3.2. Other non-game examples

Hovercast[5] and Arm Hud[6] are virtual reality menus that use the position of hand and fingers to position buttons for interactions (Figure f). This is a traditional interface that can be seen in a lot of science fiction movies. It works relatively well (besides common tracking issues), because humans have a natural sense of where their hands are located. If this location is not aligned with the view, use it without virtual reality glasses, it gets very difficult to locate the buttons because the tendency is to look between screen and hands back and forth.

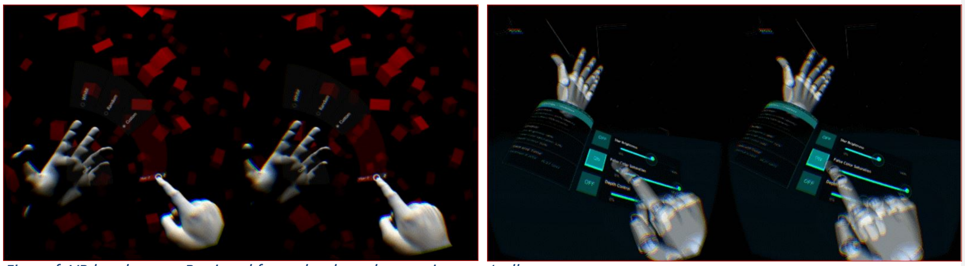

Figure f: VR hand menus Retrieved from: developer.leapmotion.com/gallery

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[5] https://developer.leapmotion.com/gallery/hovercast-vr-menu
[6] https://developer.leapmotion.com/gallery/arm-hud-vr-alpha

Apps like Touchless[7] and Shortcut[8] try to replicate the mouse, touchpad or touchscreen. They place an artificial floating touchscreen in front of the screen. If the fingers pass beyond this threshold actions such as scroll and click are triggered. Because the interfaces are not adjusted for this imprecise input, scrolling is the only mouse interaction that can be used with little failure. For other controls there are some adjusted interfaces for music control or application switching (Figure g).

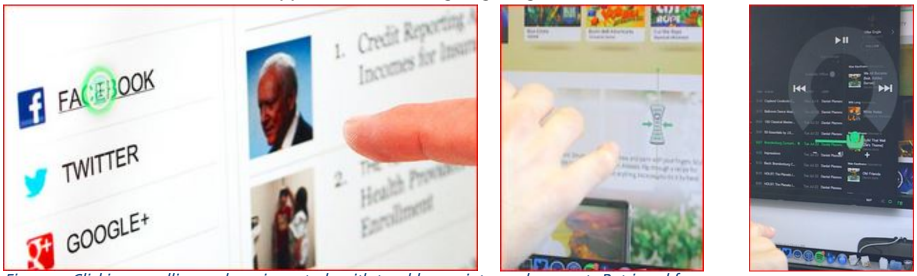

Figure g: Clicking, scrolling and music controls with touchless pointer replacements Retrieved from: developer.leamotion.com/gallery

Intel RealSense is a combined depth sensing camera, capable of tracking hand positions. Intel released it in mid-year 2015 with a lot of fuss, encouraging developers with cash prices to release apps into their app showcase. This camera is already embedded in consumer hardware but without any touchless applications[9].

3.2.3.3. Buttons

Buttons are the most common interaction method in human computer interaction. The concept of the button is very old and still very little has changed because it provides a simple switch mechanism to trigger events. From mechanical push buttons, mouse, keyboard, program icons in Graphical interfaces, links in the web, touchscreen icons, car controls buttons are everywhere. Usually they convey with graphical hints that they are interactive. The visual style of buttons differs widely. In GUIs Objects with 3D cues, with shadows and glossy effects, popping colours, rectangular shapes or underlined text are all expected to be buttons. Users like buttons. They give them the impression to be in control. Buttons that do not give back visual feedback are frustrating to users. Users started to get used to expect everything to be a clickable because these visual cues are not standardized (Figure h).

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[7] https://apps.leapmotion.com/apps/touchless-for-mac/osx
[8] https://apps.leapmotion.com/apps/shortcuts/windows
[9] https://appshowcase.intel.com/en-us/realsense/ (June 2015)

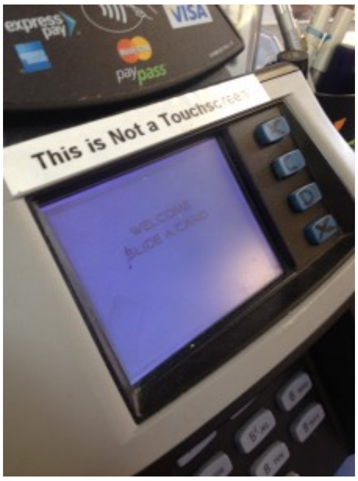


Figure h: No touchscreen Retrieved from: yourdesignonline.com/apple-ruined-world

This is comparable to the expectation of users that public screens are usually touchscreens. The supposed paradigm was for a long time that buttons are to be pressed inward. With its material design Google rethought this, because on touchscreens the button and fingertip are always separated by a pane. Instead activated buttons get lifted up to the finger [25]. Strangely Google calls these Buttons still pressed in their raised state (Figure i).

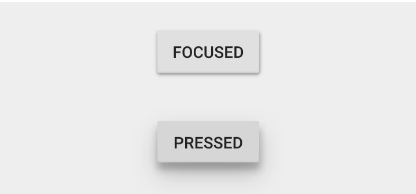


Figure i: Material Design Buttons Retrieved from: google.com/design/

This shows how different interaction methods behave depending on the input device. Therefore it was decided that for the 3D touchless interaction own buttons needed to be developed. They should differ from normal buttons with their visual design, look more playful, engaging, organic, and do not make users expect interaction that they are used to from other applications.

3.3. Analysis & Conception

3.3.1. Personas

From the analysis of the unstructured interviews seven personas that are all typical users of the interactive showcase are created.

Sjors van der Meer, Industrial Design Bachelor Student

Sjors van der Meer is an Industrial Design Engineering student at the University of Twente. He is 20 years old and in the second year of his study. He feels home at the University and in Enschede, however he does not know a lot about other studies and research fields of the University Twente. He takes his study serious but also leaves time for his hobbies, which are wakeboarding, gaming and hanging out with friends with whom he especially likes to watch superhero action movies.

Because Sjors likes to game and studies industrial engineering he is aware of very different interfaces and interaction types. He is very confident and interested in computers. His visual taste is strongly influenced by games and Hollywood movies. He knows exactly what he thinks is cool and what is not.

The current showcases in the gallery he would describe as boring and not even as progressive. However during the awarding of his propedeuse (pass of first year courses) he proudly took around his parents over the University Campus and also used the Smartware exhibition to impress them.

Joel Austin, University Researcher

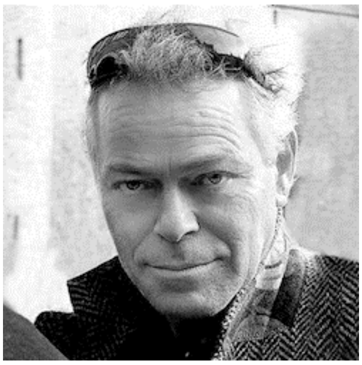
Joel Austin (42) is a proud employee of the University of Twente. He is part of the Robotics Research Group and frequently in the building of the Smartware exhibition to pick up colleagues, for meetings or to present the work of his group to external parties. He was very active and sportive during his younger years but now his biggest hobby is his job. He is married and has one child. He is a researcher and grown up with desktop PCs. However he was one of the first to own a smartphone and is very positive about technical progress even though he gets frustrated quickly if a program is not responding as he wishes it to be. If clients are visiting he brings them during lunch to the cafeteria in the gallery and shows them their flagship project on the showcase. Moreover during open days he was showing his family what he was working on.

Edward Carter, Investor

Edward Carter is 37 years old and a very successful venture capitalist from California, USA. On the behalf of his company he travels all over the world and watches out for new companies and projects to invest in. He knows everything about technical progress and earlier than everybody else. He is married but cannot see his wife often. Sometimes his daily life is too strict and boring. Currently he was on a business trip travelling through the Netherlands. He stopped by in Enschede and was guided by Kennispark employees through the gallery. They used the showcases to show-off some bigger projects that he might be interested in. And indeed he is considering if one of the Twente startups fits to his company's portfolio. He sees a lot of different projects in short time and often smaller projects do not catch his attention. However because of the showcases he pays some attention even to small side projects.

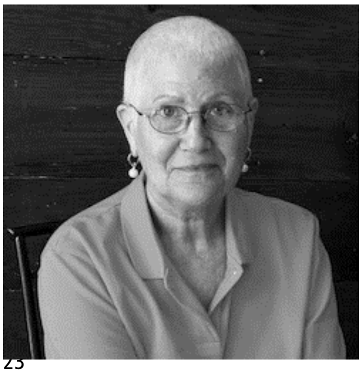
Anne-Marije Visser, Employee Reception

Visser is 39 and married with one child. She works at the university already for 6 years. She is not confident with technology. She feels emotionally attached to her smartphone but still fails to use some more hidden functions of it. She studied communication studies at a University of applied sciences and works now at the reception of the gallery. She likes her jobs even though it is sometimes a bit lacking in variety. A few weeks ago Visser got explained how the showcases work so that she can introduce visitors to them. It is a welcome change of routine when she can see people play with the showcases. On her own she does not interact with them because it seems inappropriate to play at her workplace. Often she answers people's questions for directions to projects and workgroups of the university. She still does not know what they are about.



Marc Doornbosch, Senior Staff

Marc Doornbosch is already 57 years and one of the most influential people at the university. He is married and his children are already studying. He comes from a generation that values hard work, productivity and reputation. He has worked hard to establish the university as a widely recognized research facility. Doornbosch has heard of the concept of the paperless office but still makes his secretary print out everything. He owns a Laptop with touchscreen and touchpad but still carries his bulky mouse everywhere. He often has to represent the University to the government or visitors from abroad. He takes them at almost each time to the gallery and explains projects. It is important for him that both the projects and he himself in front of the showcases are looking good.



Madelaine Kleine, Visiting Grandmother

Madaleine Kleine (69) is a retired housewife. The thing in her life she is most proud of are her two grandchildren. Both of them are already studying. They study programs she already has difficulties with remembering their names. During the open days the whole family makes a visit to the University. The grandchildren walk her around and show the campus. She does not know what the projects are about but everything looks professional and futuristic. She is proud how self-confident her grandchildren have become but sometimes feels a bit like she is only dragged around. However with the showcases in the gallery the grandchildren are able to encourage her to get a bit more engaged herself.

Li Qin T'an, Chinese Visitor

Li Qin T'an, 37 is a computer scientist from South Korea. Currently she is running a project to increase cooperation between Korea and European countries. She used to work in one of the biggest Korean companies and led multiple successful projects. Before she comes to universities and research facilities she already researches online about projects and research groups so that she can ask more detailed questions. However when she arrives at the University she still gets first the standard walk across the campus. The showcases do not offer her much as she already saw the pictures and read the descriptive texts online. However Li Qin T’an still stops by to use them as a starting point to talk with the researchers.

3.3.2. Use Cases

3.3.2.1. Professional showcase tool

It was seen that researchers and employees like to guide distant colleagues or customers around and make use of the showcase to provide insight in own projects. Therefore often groups of people are arranged around showcases with one person explaining their work to others. The showcases help to guide conversation with the physical objects and media. Because one person knows already how to use the showcase, he animates his fellowship to do the activation step. The pointer can be used as an actual pointer to draw attention to e.g. pictures that the researcher wants to talk about.

3.3.2.2. Flagship projects of the region

The Smartware exhibition is meant as a flagship project of the region. The Kennispark Twente foundation established the Gallery as a centre to develop entrepreneur's climate in the region of Twente[10]. Government and investors from abroad visit this complex because companies are concentrated on dense space. In the observations the showcases succeeded in drawing interest of investors to projects. Because each showcase contains a different project from a different group it helps to get a quick overview about multiple developments in the Twente area. These visitors scan for the most interesting projects and have for each usually less than a minute of time.

3.3.2.3. Reminder of success

People that work in the Gallery or on the University Campus are likely to have work presented in the showcases that belong to their team. When they have breaks or wait for somebody in the entrance hall they usually focus their attention on their own project first. It helps them to realize that their work is not for nothing and is recognized by the real world. They might play around with the interface of the showcase a bit but will not read the details of it, as they already know about them.

3.3.2.4. Waiting hall

The entrance of the Gallery, where the Smartware exhibition is located, functions as a waiting hall. People wait to get picked up by colleagues. They might take a smoke outside or are waiting in the hall to pick someone else up. In the meantime people pay attention to the showcases and their contents. They dominate the hall with the bright LED lights, big screens and futuristic appearance. If people have time they tend to activate showcases that they did not look at before. People wait usually not longer than three minutes in the central hall.

3.3.2.5. Students

They have more time than the working people. In the observations they were less interested in text information and the projects themselves. They can be categorized in two groups: Gamers and non-gamers. Non-gamers reported fun in using the showcases but gamers reported the experience as "boring". They paid a little less attention to the projects and more to the technology itself. They were still successful in catching interest. The amount of information is a bit overwhelming at first but students return to the gallery as well and use the showcases multiple times.

3.3.2.6. Family & Friends

If students, employees or researcher of the university have family or friends visiting them they walk them around. Some target the gallery and use the showcases to impress them. The showcases can bridge generations and help to carry enthusiasm over. Even grandparents were able to use the showcase on their own or after explanation from their grandchildren.

[10] http://www.kennispark.nl/about/

3.3.2.7. Conferences

The gallery is used for organizing conferences and open days. During these days the activity on the showcases is a lot higher. In addition, the users are from outside and will not see the exhibition again. People gather around in the central hall have welcome drinks and talk. Some people that were not too interested in socialising could be observed to pay attention to the showcases instead. When they found something interesting they used this to re-establish conversation with other conference members.

3.3.2.8. Visitors from different cultures

The showcases are in two languages but Dutch is enabled first. The language selection is not always visible and when people missed this they stopped paying attention on one showcase and looked at another one. People that changed the language were often very eager in reading. This could be because for them the information provides additional insights than for people that think and write in the same style as here. Still people do not go much further than two pages because the second page provides information in the same visual style than the first.

3.4. Summary & Problem Definition

The research phase lead to conclusions that are summarized here. The current version of the showcase is not taking full advantage of technology. Very different users with very little time use the showcases. The showcases have both one-time visitors and multiple time visitors. Very few users make it through to the end of the presentation. Users from university return to "their" showcase but see the same content. Users walk around and activate multiple showcases, they prefer diversity over profundity. Users dislike to read a lot of text before they understand the purpose of an object. Users understand how to use the showcase. They might have minor problems with locating and navigating the cursor. It uses the most simplified interaction that was reported to work for users [26]. The identical idle screens, similar content between showcases and similar content from slide to slide keeps users from going deeper into the content and activating more showcases. Users have difficulties figuring out the relationship between the exhibited object and the content. The current interface design does not address different target users specifically. It has minor technical issues that could be resolved. Nevertheless the focus of this thesis is to think further than that and develop from the ground up.

The research questions to be answered are:

- How can a user be best introduced to interact with the vitrine and to its interaction?
- What interaction works best with the vitrine?
- How can information be best presented in a virtual showcase?

4. Product Specification

4.1. Design Principles

To develop the prototype of the new Interface parts of Google's Android Design Principles[27], which are very broad and describe major keys to successful interaction design, can be applied.

- Delight me in surprising ways
- Real objects are more fun than buttons and menus
- Keep it brief
- Pictures are faster than words
- Only show what I need when I need it
- I should always know where I am
- Sprinkle encouragement
- Make important things fast

The state of the art in user interface design is Googles Material design announced in 2014. It unifies elements of interface design across multiple platforms, puts emphasize on the importance of animations, applies physics to them and thinks of interfaces not as flat but arranges the elements also on the virtual depth of the screen [25].

4.2. Developing an interaction toolbox for the vitrine 2.0

As the showcase is meant to display a variety of diverse objects having the most suitable controls for each one of them is important. In this context I examine several interaction possibilities that could be implemented with the current hardware of the showcase and study whether each of them fits to the required demands.

4.2.1. Requirements

The interactions need to fulfill:

Label	Requirement	Description
SE	self-explanatory	Understand by seeing.
EX	explainable	If not SE quickly explained
EN	entertaining	The opposite of boring.
SA	satisfying	Not to be frustratingly difficult.
RO	robust	Technical faults e.g. from tracking accuracy to not detract

RE	reusable	Not to be limited to one exhibit

4.2.2. Input gestures

Below a list of common interactions developer use the LEAP for derived from the State of the Art section or considered as useful for the design of the new showcase. These gestures are proven to work either in other computer interactions and users might expect them to work with touchless interaction, or were discovered in the research phase.

Interaction	Description
Rotation	One of the most frequent uses is to rotate an object or to rotate the camera around.
Touch	Buttons, sliders and checkboxes are well known from desktop computers and websites. It needs to be determined how these can be activated without physical feedback such as clicks from pointing devices or without touch as from touchscreens. The leap API distinguishes key taps that are aligned downward from screen taps that are aligned forward.
Grab	Is one of the most common interactions humans use their hands for. The LEAP does report a grab strength in percentage which can vary by users hand sizes.
Accelerate	Objects that are in grabbed state could be thrown. Also this interaction is implemented using the physic engine of game engines.
Pointer	The LEAP Api is capable of tracking pointing tools of long cylindrical shape such as pencils. As appearance and shape of these can differ this could broaden the interactions with tools that act similarly but convey a different mind-set. Pencils, brushes, flashlights, laser pointer, water hose or chisel are such tools with very different uses in real life.
Count	The number of extended fingers can be seen by the LEAP this can be used to count and might provide a more natural input than using buttons to enter numbers.
Drawing	Specific interactions could be enabled with drawing gestures such as circles, numbers etc.
Steering	The rotation of one hand of two hands can be used to steer objects or steer through space. More advanced hand position such as from steering wheels could also be used for this interaction. Steering is one of the most frequently used gesture by games and known from Wii, Kinect and mobile handhelds.
Scale	The first use of multi-touch gestures which became common in the mainstream was the two finger scale to shrink and enlarge content. The distance between two fingers could be measured to create something familiar.
Swipe	Swipe gestures are commonly used on touchscreen interfaces to swipe to another navigation overlay.

4.3. Design Iterations

In user interface design it is common to iterate through multiple prototypes, considerate their advantages and morph these into other prototypes [28, p. 168]. First designs were sketched with pen on paper. From over a dozen paper prototypes the best were selected and further refined.

4.3.1. Media Galleries

As the showcase could be used for different intents the prototypes first focused around media explorations. All prototypes and interaction sketches are designed for a 3D representation. It was decided to put a 3D model inside the interface, visualizing the real object that is on the rotary plate (Figure j). This could help to relate the real exhibited object to the background information on the display. It was centred on a virtual plate to have it virtually centred and not floating in space.

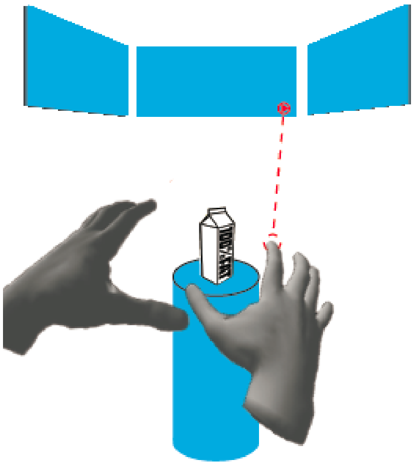


Figure j: Ray selection

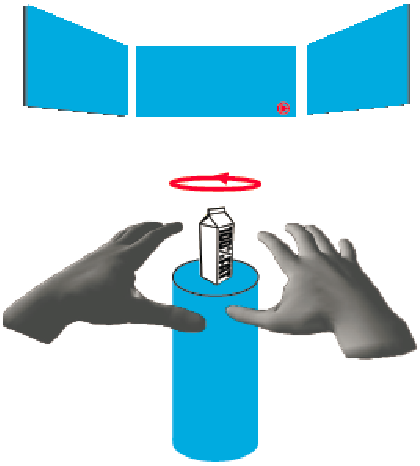


Figure k: Two hand object rotation

The first prototypes concerned how users could get a better overview of the content available for exploration. Right now the users do not have choice other than to follow the rigid sequence of the presentation. One information comes after the other. From the Ideation phase it was concluded that people need to be able to choose the type of media they want to consume or look at on their own. Therefore a media gallery with floating 3D screens, each displaying different information, was created.

4.3.2. Selection

Because 3D space needs other selection methods than 2D space it was investigated whether pointing at content felt in the 3D showcase as natural as it is an interaction in the real world (Figure j). Another selection method that was considered to work with the showcase was "rotate and lock". The user could rotate the object and content with one or two hands and the centred media item gets activated. This is similar to the swipe concept (Figure l). Which does not allow the user to rotate freely but use left and right swipes to rotate and auto-playback content.

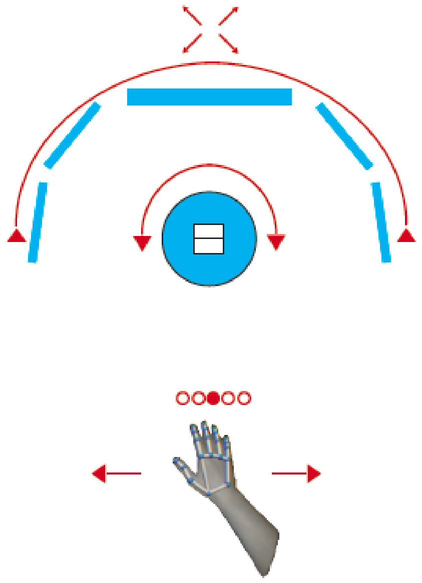


Figure I: Swipe selection (top view)

4.3.3. Hand movements in the virtual reality

Video screens were meant to be touched directly to playback. However the space required for enough video players on the vertical screen was too small. The placement far from the camera made them too far to reach with the virtual hands. It was explored with different mapping techniques to make the hands reach further in virtual space. Coordinates have to be mapped from the Leap space to the Unity world space. If simply scaling all vectors up the hand would be able to reach to objects further in the back. The disadvantages of this method were that the control got very imprecise. Moreover because the camera projection is in perspective, while the hand projection is parallel, the hands get out of the camera view quickly. They do not come together and the movement feels unnatural. Additionally if users place their hands within the detection are of the LEAP they cannot just end up out of the camera view but also far in the back and be too small to get noticed. It was important for this projects that users immediately draw the connection between virtual hands and the movement of their real hands. To achieve this hands have to be always within the camera view, thus appear on screen when they are tracked.

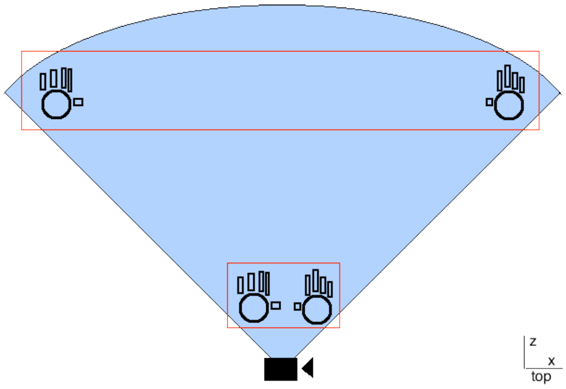


Figure m: Extended range hand mapping (top view)

A different mapping scheme for the virtual hands was developed which puts the hands always within the screen space (Figure m). This scheme had the advantage that everything the camera renders can be touched but still keeps the hands within view [29]. Additionally the hands movement have a higher sensitivity in the front. Unfortunately this use together with the hand representation needs some time to get used to. In the showcase it did not serve its purpose but distract. The mapping of the coordinates might have use in games and allow players to reach further than their actual hands allow, thus make players gain superpowers such as the popular Rayman character has[11]. In the user test this method was implemented with a 3D cursor instead of hands.

4.3.4. Combined media gallery approach

Elaborated from the content gallery approaches these concepts got refined (Figure n). The user would need to be able to watch video in full screen. Therefore the video players could be activated with virtually pressing them following a zoom to full screen. Multiple interaction methods such as edge scroll, hover to rotate object, swipe to next video and press firmly to return to overview are combined.

[11] https://en.wikipedia.org/wiki/Rayman_(character)

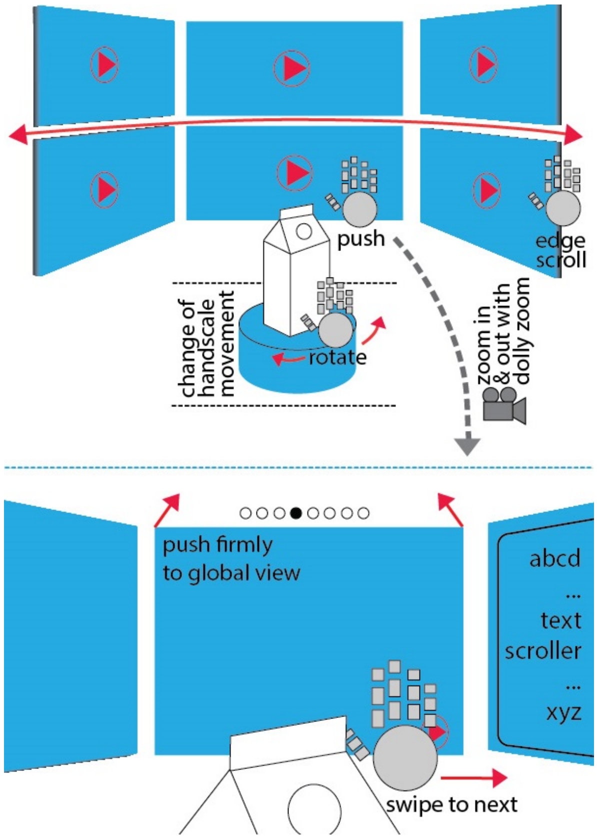


Figure n: Combined approach

4.3.5. Object Explorer

The media galleries revealed to be usable. However they do not help to relate the content to the object. The media galleries do not explain to the user what he is seeing and where it belongs. The content is displayed in a grid with everything equally important. It might overwhelm the user with information. The media gallery might have it advantages for scenarios where there is a lot of informative content that people want to process but the Smartware exhibition should tell people already a story without making them go through too much information. It was decided that the content has to relate to the virtual object, thus making advantage of the set up with the showcase which exhibits physical objects.

In these concepts the virtual objects get overlays with multiple highlighted information points. The focus here is on giving information about the object that actually is exhibited and help users understand the details. It might also be used by researchers to explain their objects to other people. Because the information overlays are placed on a more dense space they can be touched directly. The other method of interaction is similar to the rotation selection of the content browser. It enables only one information and locks the view. The degrees of rotation around the object are object information assigned. In this mode the physical rotary plate and the virtual plate should be in sync.

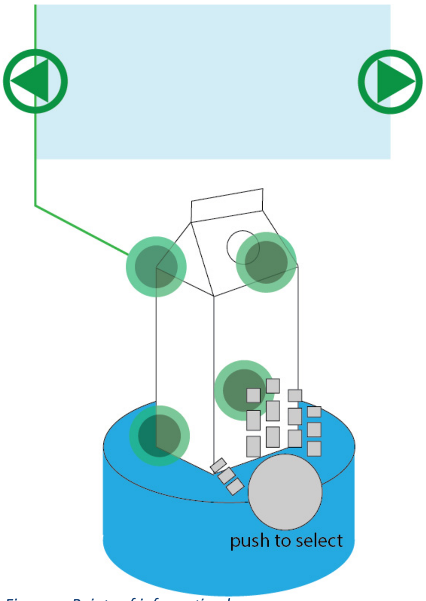


Figure o: Points of information browser

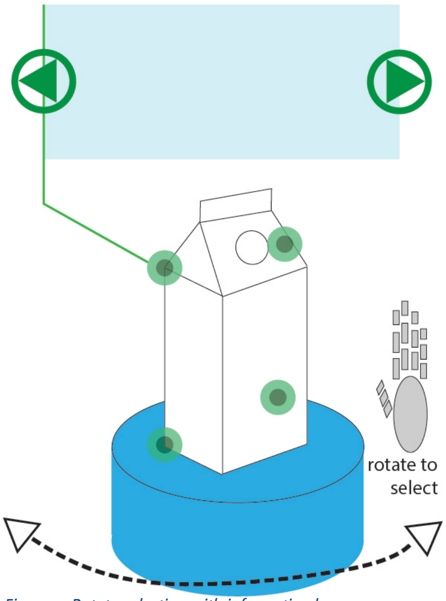


Figure p: Rotate selection with information browser

4.4. Prototypes Interaction

During the development of the first media galleries multiple interaction methods were developed, tested and refined. The unity game engine allows easily to apply physics effects, checks on colliders or rigid bodies. To access any other data from the LEAP, its API must be well understood. Aligning 3D objects or positions to the deformed mesh of the virtual hand in the world space of the unity engine can become quite tricky because the raw coordinates that the LEAP reports are mapped from LEAPs coordinate system to local coordinates of the joints relative to the palm position, before they are mapped to world coordinates. Some designs require a swipe gesture of the hand. The LEAP API does not feature full hand swipe detection but reports swipes for each finger individually and stores the last registered swipes in a Gesture List (Figure q).

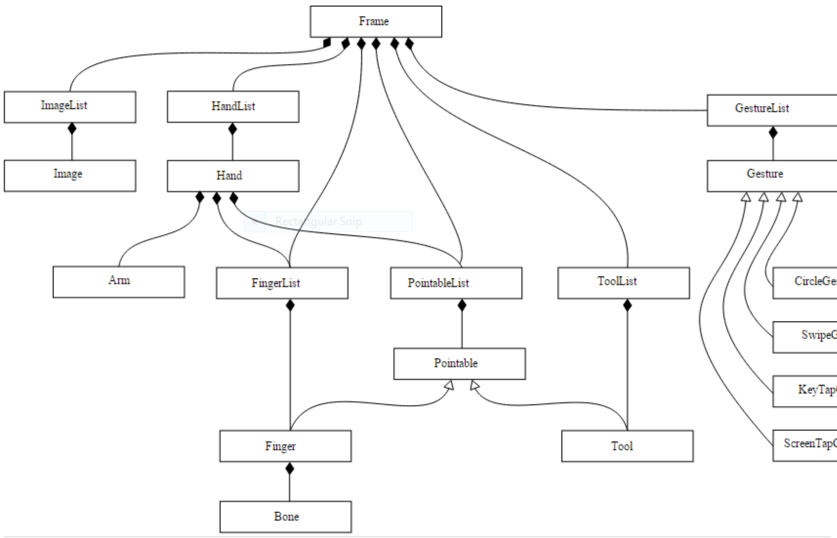


Figure q: Leap Motion, Inc (2015) tracking API structure retrieved from: https://developer.leapmotion.com/documentation/csharp/api/Leap.Controller.html

In the implementation a swipe is registered if swipes from multiple fingers are registered after a cool down. The ray or laser is using the raycast from unity which is commonly used for shooting guns in first person games. This cast has the advantage that it can send messages to hit objects. To visualize the ray a line renderer is drawn from the raycast origin till the vector where it hit something. Additionally if the ray hits a forward force is applied which makes the ray work with objects that use physic triggers to check states. The vertical hand could be implemented using the roll factor from the hand and its position converted into absolute floats to use it for rotation. For edge scroll rectangular areas in which this event is triggered were defined. Grab for camera rotation checks if a threshold of grab strength is passed and compares the change of hand position between the current frame and its previous frame. Sphere uses the mapped hand position (Figure m) and updates the position of a collider object.

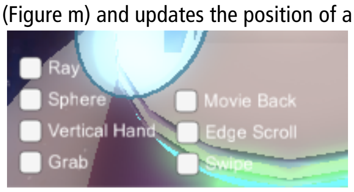


Figure r: Implemented interaction methods for testing

The current software of the showcase allows easy adjustments. Therefore a script was written that adjusts the spawn positions of the movie players to the amount of movies and content that is available.
All interaction methods can be used after training.

4.5. Prototypes Content

In the internal evaluations, the content gallery succeeded in navigation. It was an appropriate use to browse galleries with a lot of video content. Disadvantages were that it might fit better on horizontal instead of vertical screens and arranged the videos in an unorganized unrelated presentation. One of the research questions was to analyse how information can be best presented on a virtual showcase. It can be said that the media gallery approach is an appropriate use of touchless controls to navigate media content but does not fit to the concept of showcases. The interaction methods developed for the gallery browser were used for other concepts.

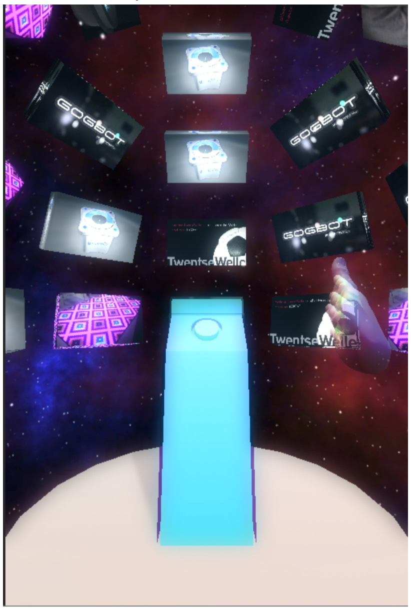


Figure s: 3D media content player with edge rotate

4.6. Buttons

As concluded from the research section and design iterations own 3D Buttons needed to be developed. Because touchless buttons are fundamentally different from touchscreen buttons and normal GUI buttons different technical and conceptual implementations needed to get tested and compared. Because rounded objects are friendlier to look at, which is known as the contour bias [30, p. 62] the buttons here are spheres. These buttons are meant to be used for the Object Explorer design and represent information bubbles. Visitors of the Smartware exhibition have to succeed at navigating immediately. To avoid cluttering of too much screen space, still have the buttons big enough to activate them with the full hand and keep the virtual hand from being invisible because it is overlapped the buttons should be transparent. Big squared buttons might feel clunky in these sizes that's why spheres were chosen instead [31]. Prior to the design of the buttons it was chosen that a button in 3D should not have a front side as this allows it to be activated only from one side. In internal tests this made the locations that buttons could be placed very restricted and difficult to use if the virtual hands are behind, above, below or next to it. The recommendation is to make buttons usable no matter from which side they are approached. The buttons from the Leap motion developers do not allow doing so (Figure t).

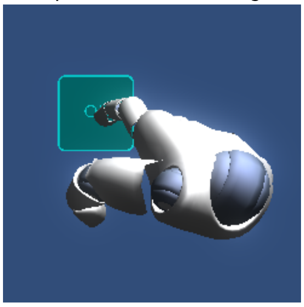


Figure t: Leap Example Button

4.6.1. Direct buttons

Three designs for buttons that can be interacted directly with were chosen. They appear in the same space the virtual hand can appear. Therefore they should never be placed out of reach or at locations that can become out of reach if the tracking quality of the LEAP is low. The range the buttons can be placed in is a bit larger if buttons can be activated from all sides.

4.6.1.1. Push button

Push buttons were implemented with a collider that triggers an event if it is pushed a distance from its origin. They have a drag coefficient that drags them back to the origin from where it can be triggered again.

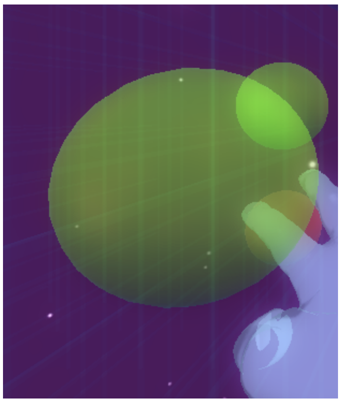


Figure u: Push Button

4.6.1.2. Hover button
Hover buttons check for collision between the hand and the button and get triggered after a time threshold is passed. To visualise to users if they are hitting a button currently they grow in size if triggered.

4.6.1.3. Squeeze button
Because in the observations people tended to grab after the buttons, a squeeze button that resizes with grab strength were developed. They get triggered after a threshold of grab strength is passed.


Figure v: Squeeze Button

4.6.2. Indirect selection
Because the media galleries have a lot of content that cannot be placed all in the direct reach of the virtual hand alternative selection methods were created.

4.6.2.1. Index ray

A ray is casted from the tip of the index finger and thrown in the direction the index finger is aiming at. If the ray hits a target the buttons are triggered after the time threshold is passed.

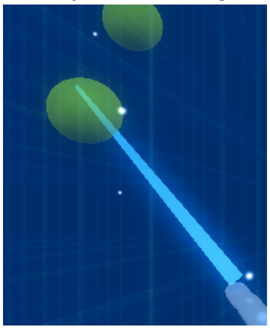


Figure w: Ray selection

4.6.2.2. Ball selector

A spherical cursor is drawn at a position that is mapped to the world space. This is the position as in the alternative hand mapping (Figure m), which allows reaching everything that is in the camera view. The sphere selector works with push and hover buttons. The ball selector has the same size as the buttons so that users can approximate the depth of it.

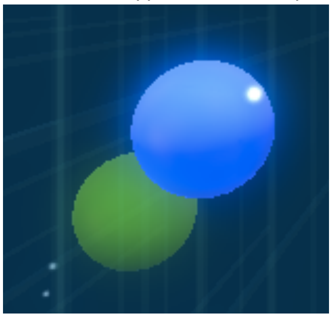


Figure x: 3D ball selector

4.6.3. Test Game

To quickly test the performance of different buttons a game was created. This allowed to test which buttons are activated easier than others, which ones get activated without intention and which ones users preferred. Additionally the area in which buttons are reachable could be tested. The Game consisted of 6 levels. In the first three levels direct buttons were tested. The buttons are spawn randomly with a minimal distance to each other in 3D space. After a button is triggered new buttons are spawn within the official device range of the LEAP. The testers had to trigger green buttons as quickly as possible. If they accidentally triggered red buttons the amount of activations to finish a level increased by 2. All buttons had the same size so that the performance could get easier compared and users get cues about the distance from the camera. In the last three levels indirect selection was tested and the buttons were spawn in a larger area that was out of reach of the virtual hands but not the ray and sphere selector. For each level testers had 30 seconds to activate three green buttons before they would fail and forced in the next level. This helped to keep the test time short and always under 3 minutes. The levels had only one word of instruction, the current mission, to see whether the method to trigger buttons was self-explanatory. Red and green flashes were used to narrate success and failure. The time of the tests was kept short so that many users could get tested quickly and because the observations showed how little time users have to use the system. During the game it was seen that additional cues about the buttons, sphere selector and virtual hand could help users with depth perception. The cues in the game were the size of the buttons, and dust particles. Shadows could further help users to approximate 3D positions. In addition grids can help users to estimate the depth but distract and are visually unpleasant as they add noise to the designs developed so far.

Figure y: Test Setup in the DesignLab

4.6.4. Results

The experiment was carried out for the period of a week at three different location of the University of Twente. At first in the SmartXP, the main study hall of Creative Technology. To get more test subjects the test was conducted in the Edu Café, the main study hall of electrical engineers, computer scientists and applied mathematicians, for one day. Furthermore the test was carried out in the DesignLab, a cross-disciplinary workplace for students from all fields, for two days.

Test subjects could approach the game independently and play. Detailed data of the plays, required time to finish each level and falsely activated buttons were logged. During 4 days the experiment was guided, people were approached and asked to participate. Details about the background of the experiment were explained to the subjects and they were asked to fill in a survey. 61 times users finished all levels of the game. Only these full plays were taken into account. Users were told to figure out themselves how to activate the buttons. If they asked for help hints were given. E.g. the 3D pointer was not always recognized as such because the virtual hands were visible at the same time but disabled. Besides that, subjects that had problems to select a button that was difficulty placed were encouraged to enable an easier one. Another problem that occurred was that some users were only moving their hands up and down at first, focus on this test was to compare the buttons against each other, and therefore they were told to move also within the depth.

4.6.4.1. Logs

In Figure zthe time users needed to select one correct button is graphed. Only users that did not fail these levels, took no longer than 30 seconds, are taken into account. It can be seen that the direct selections perform similarly in time that users needed to activate the three green buttons for a level. Because each wrong button added up to buttons that needed to be activated and with the push buttons subjects failed considerably more often the different methods might have equalled out.

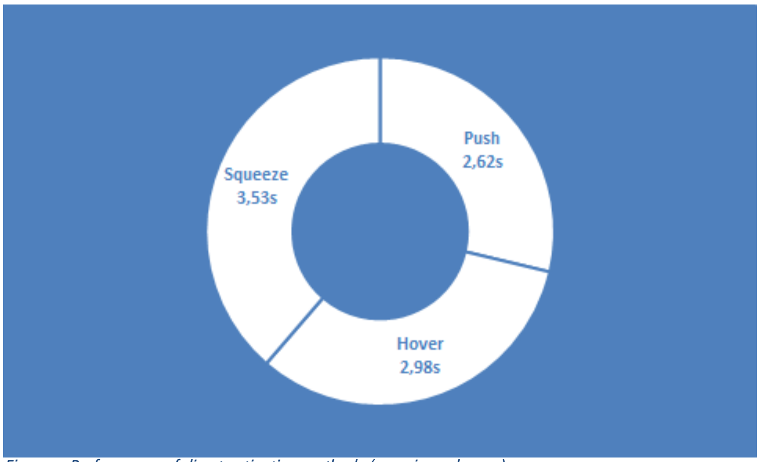


Figure z: Performance of direct activation methods (experienced users)

The time that subjects needed for a push button in comparison to a hover and a squeeze button was shorter but also was the error rate higher (Figure aa). With the push buttons users were hitting 16% wrong buttons while with hover, squeeze and the 3D pointers less than half that many. It has to be taken into account that the amount of correct and wrong buttons was not equal. Per 3 green buttons were only 2 red buttons, these were spawn within reach of the hand but not at locations the hands occupied.

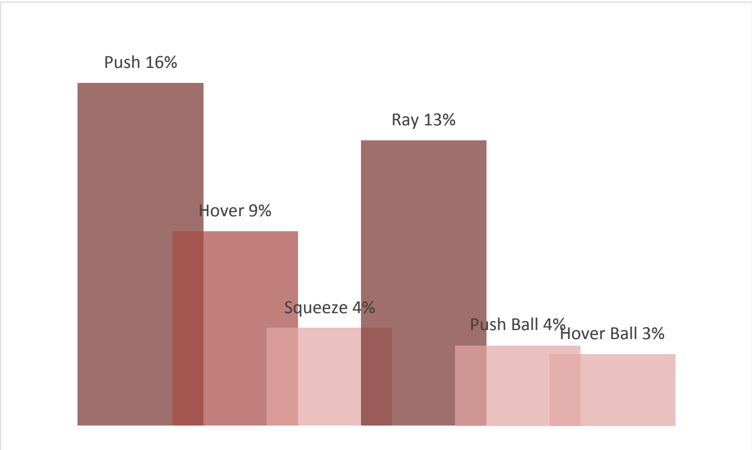


Figure aa: Wrongly activated buttons (all users)

The 3D pointer levels required subjects almost thrice the time than the push levels (Figure bb). Most of this time was not the actual activation of the button but the time subjects needed to get used to the different coordinate mapping. A lot of time wasted with the ray selection was that users pointed behind the ball and not on it. It was difficult for subjects to approximate the angle of the ray and they got quicker when they stopped trying to point from only one position and changed their hands location as well.

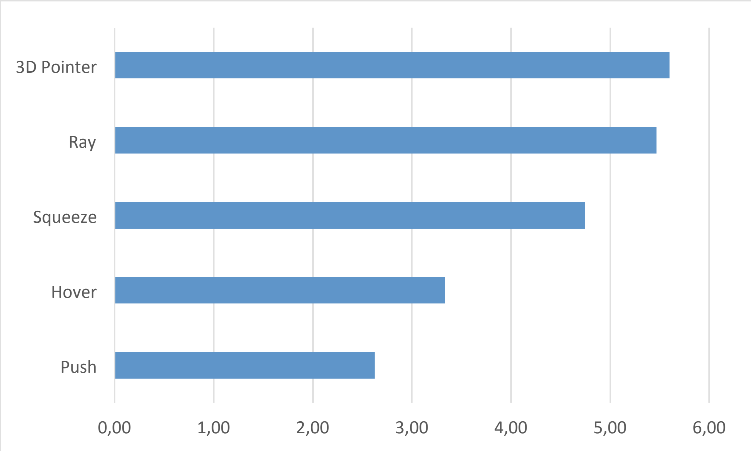


Figure bb: Time to finish a level divided by the three required button activations (all users)

4.6.4.2. Survey

Besides playing 30 subjects filled in a survey after finishing the button test game. Because the tests were conducted at the university most of the subjects were students (Figure cc).

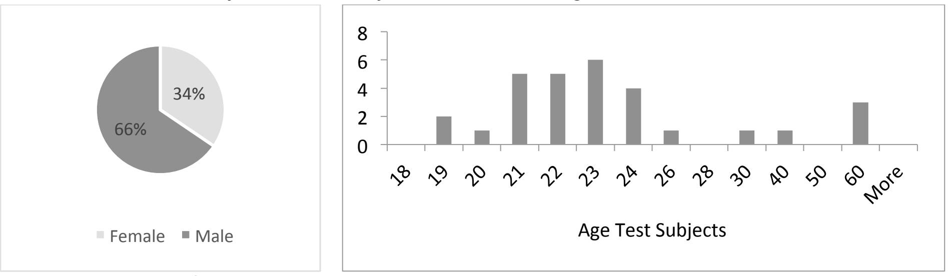


Figure cc: Demographics of button test game

As already reported the first obstacle that subjects had to overcome was to realize that to activate buttons they needed to be reached at the correct depth and not only hover in front of them. Because 2D screens do not convey depth information the major hint about depth was the size of the buttons. This size needs to be the same throughout otherwise the only option left would be shadow information. And indeed Figure dd subjects reported that they needed some time to both recognize that they can and have to move their hands in all directions and to recognize the balls as buttons needs at least some thought.

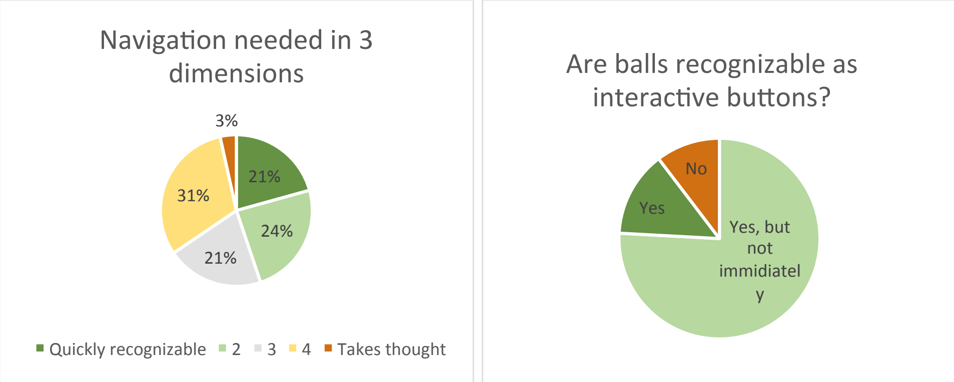


Figure dd: Comprehension of buttons

The poll asked subjects to rank the levels and thus the interaction on both their perceived difficulty and on the enjoyment. In Figure ee are the results ordered with the average difficulty and average enjoyment from left to right. The direct selection methods were all perceived as easier. As most fun squeeze and push were ranked. Here the ray was ranked as third. The ray seems to divide opinions it received considerably more often the firs and the last spot of enjoyment. The rankings of "fun" seem to be a bit dependent on the skill of the subject.

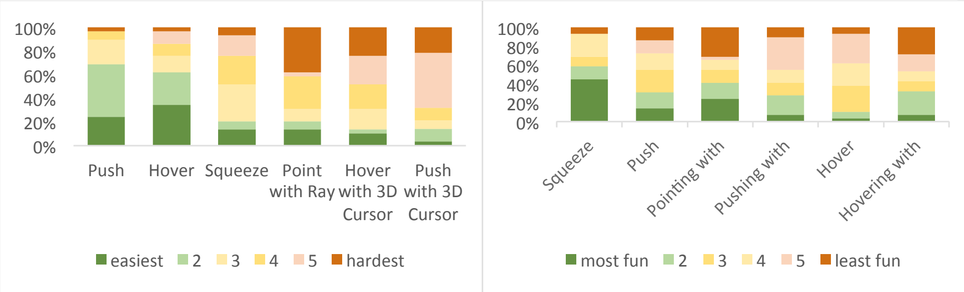
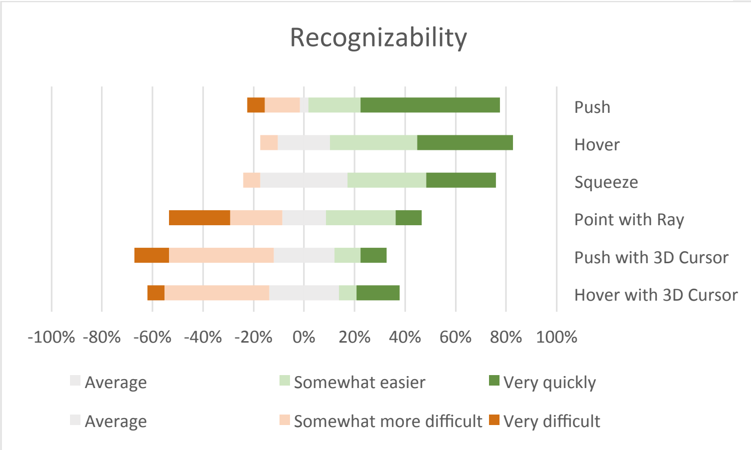


Figure ee: Ranking of interactions on difficulty and enjoyment

In Figure ee the subjects ranked how easily they recognized the method to activate the buttons just from the short descriptive text and from the visual cues. The interactions are sorted from top, quickest to bottom, most difficult. The results here are very similar to the overall perceived difficulty. Which indicates that recognition of the interaction is the more difficult than execution.



4.6.4.3.

Figure ff: How easily users understood the interaction method

At last subjects were asked what interaction they would expect if not instructions were given or visible. The majority choose grabbing (squeezing), which makes grabbing both the most natural and the most fun interaction. The shape of the buttons communicates that they would fit inside the hand easily and therefore users wanted to grab them. These findings support the expected outcomes in the literature (3.2.2.6 Natural user interfaces).

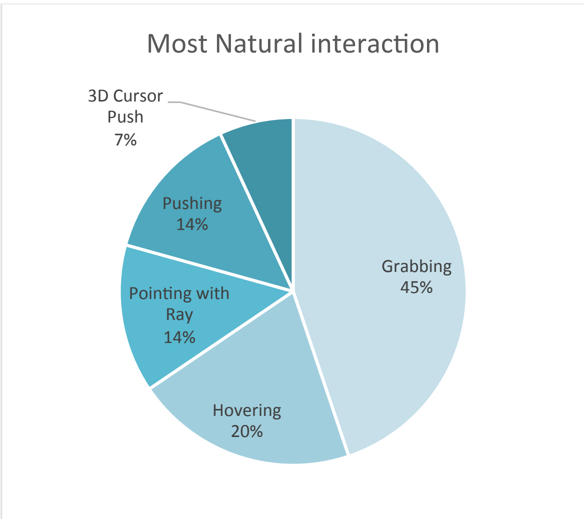


Figure gg: Natural interaction

All in all the button test results are useful to decide for interactions, support the claims made and help to compare the performance of buttons.

4.6.4.4. Observations

4.6.4.4.1. Push button

All users were confident and successful in using the direct hand push. Some saw the buttons respond to touches and at first wiggled at the surface before they did the full push. There were differences in usage, most pushed with the full hand but a few used an extended finger to push. Most subjects pushed the buttons from all sides. Only very few navigated around the buttons to push from the front. Some subjects thought the buttons were not responding when they were in front (2D Space) of the buttons but the buttons were actually further in the z-space of the game. After the first successful activation of a button that lied further in z space all users figured out that they needed to navigate in full 3D space. This problem could be avoided with 3D grids, which are not pleasant to have continuously on the whole display. 3D virtual reality glasses and 3D screens also could avoid these problems.

4.6.4.4.2. Hover button

The hover button performed about as equally well as the push buttons. They have a different animation when they get activated. They grow in size while the other buttons move in the direction they are pushed. Some users were too restless in playing and did not wait half the second the button needs to activate.

4.6.4.4.3. Squeeze button

Some users needed to be pointed out to read the description before they realized how to activate these buttons. Some users at first did not use the full hand to grab and squeeze the ball but only two fingers. A very few subjects players were playing the game not with open hands but with fists. This still allowed to activate the buttons but made it more like the push interaction. A very few players were not fully closing their hands directly. Users intention was often even in the first level to grab after the spheres.

4.6.4.4.4. Index ray

The index ray suffers both from the poor tracking quality if users overlap fingers and from the problem that users forget that the full hand and arm movements, not just the index finger itself, have influence on the position it is aiming towards. As soon as they saw a ray some users stopped moving the full hand and only tried to aim raising, bending and moving the joints of the index finger only. To get the full range it would have been more comfortable or ergonomic to use the arm angle to aim instead. Indeed in an example [32, p. 154] researchers did not use the index finger for pointing but emit rays from the back of the full hand. Sometimes subjects were shooting the ray behind the spheres and not on it. They could have avoided this by aiming more straight and changing the position of the hand instead of just changing the angle of the hand or finger. The ray had only a small trigger timer of less than 0.2 seconds; therefore and because sometimes users were aiming at a button in the back and hitting a button in the front, more wrong buttons were activated. The possibility to emit a laser ray from the index finger felt powerful for users. One player described it as "E.T technology". Overall this interaction was distinct from the others and therefore very entertaining. The selection could have been easier if the buttons were arranged on the same depth in space, but still testers needed very little time to get used to the interaction.

4.6.4.4.5. Push ball

The push ball works more like a pointer because it maps to the whole screen area. Unfortunately the hand was not disabled during this so first players needed to realize that these buttons would not interact with the hands but the violet sphere (Figure x). It helped users to realize this when the sphere entered the screen prominently from the front and not the sides. Users thought this was the most difficult interaction. Interestingly two test subjects that were older than 50 years perform with this interaction similar good as with the others. It might be that this is because they are from a generation that is a lot more used to pointers than to other input devices or games. After users recognized that they needed to knock against the balls, they were able to finish this level. Some used too much force and aiming became imprecise.

4.6.4.4.6. Hover ball

Hover ball performed better than push ball. Because users aimed slower they got used to the aiming quicker. Also hovering with the ball might relate more to mouse controls than pushing against something with a pointer. A trick players used was to bring the hover ball and the button the same size, which was the same as bringing them on the same location.

5. Product Realisation

5.1. Final test prototypes

Two final test prototypes were developed, and the software of two of the showcases in the Gallery was updated to these (Figure hh). The showcase of the client company 100%FAT and the showcase of the supervisors research institute CTIT (Centre for Telematics and Information Technology). This way no unexpected changes would displease any other stakeholders.

Figure hh: Final prototypes with no information activated

5.1.1. Highlight buttons

The buttons used for the prototype were the hand facing push buttons. These could be activated even accidently. It had to be seen if users would understand them, even without expecting a game. They were rendered with a self-written transparency shader. They should be visually distinct from the other objects but still in no case cover the hands. Moreover with transparency enabled the big size of the buttons becomes less obtrusive. The buttons change their colour and alpha transparency to convey their current activation state. They have a small wobble effect so that users can see that the buttons are interactive and that they are close to activation of a button. Only one button could be activated at the same time. This allows to choose freely the content and makes backwards or disable buttons unneeded. The buttons are placed all to be reached easily and have at least two hand spaces in between so that no other buttons are activated unintentional. The videos are linked with the buttons so that the position can easily get changed, users recognize the amount of content that is available, and that the software can easily get changed for new objects. In the current version very few users passed through till the end of the information content.

5.1.2. Activation

In idle state the camera rotates slowly around the object to represent a screensaver and give an animate showcase that attracts attention. Throughout the idle state a ghost hand is floating in the virtual air wiggling and pushing. The ghost hand is encouraging users to put their own hand on a similar height in the air and mimic these movements. During the observations people reached for the start button with their hand, therefore the ghost hand might lead users to hover their hands instead. Furthermore it is expected that the three dimensional design makes users expect more playful interaction.

If the first activity in front of the showcase is detected, either by the motion camera or the LEAP, the showcase switches into the activated mode with LEDs turned on, with the virtual object in position and the camera centered to the front.

5.1.3. Virtual camera

If the showcase is idle the camera rotates around the object to convey that it is actively waiting for interaction. When hands get in the view or a user is detected in front of the showcase by a depth sensor or camera the camera rotates to the front position and locks the camera at that position. The users can grab into the air and rotate the view. It will snap back in its original position so that the buttons are always in reachable positions.

5.1.4. Motor

The motor has an internal logic that rotates it to positions. Each button was assigned a position. The initial idea was that users can rotate the object freely on their choice. This should maybe implemented in a future version.

5.1.5. Virtual showcase

The virtual showcase was rendered to look similar to the real showcase. With LED rings, screen and rotary plate. During the test phase the buttons just showed videos. In the concept version they are meant to highlight functional aspects of the exhibited object. E.g. the showcase as a touchless input sensor (informative video about sensing technology). It has a rotary plate (Graphic or video about motor plate).

5.1.6. PIRATE showcase

The PIRATE is an autonomous pipe inspection robot with the capabilities to travel through t-pipes in low pressure gas networks. To give visitors an idea about this the robot enters the screen through a t-pipe during activation. Information that should be on the highlight buttons instead of the videos could be: The pirate has inductive charging (info video). The PIRATE is equipped with infrared sensing technology (Video of infrared lasers).

5.1.7. Text & content

The showcases use less long text parts and more videos. During the final tests the content on the showcases was not yet tailor fit to give high quality information because the major focus was on interaction. For continuous application the content would need to be more refined and provide more context.

5.1.8. Background

The virtual objects are placed in skyboxes that fit to the theme of it. The showcases was placed in a universe with stars because it fit to the futuristic visual style of the showcases LED ring. The pipe inspection robot was placed between old tubes. This conveys information about its application area. The colors of the backgrounds have to be toned, changed in brightness and saturation so that they do not distract. 360

degree backgrounds are not always easy to find free to use. If so both flickr.com and Google images allow to search for non-copyrighted images. Commercial websites have a broader offer. Nowadays with software such as Microsoft's Image Composite Editor or Photosynth they are not that difficult to create. To use them in a game engine they need to get converted to skyboxes or 6 sided cubicles which some tools are available for[12].

5.1.9. Object

If there are 3D models of the objects available in STL or OBJ they can be put immediately into unity engine. Otherwise they might be converted with a 3D software such as Blender or Cinema4D. If the models have a lot of polygons, because they were not intended for real-time 3D use, they should be reduced in their amount of polygons with a polygon reduction system. Otherwise if a 3D model is unavailable an appropriate replacement has to be found online or modeled. The object prototypes used were the showcase itself and the PIRATE.

5.1.10. Communication of the system

Unity is a game engine and not meant to control motors, LEDs or cameras. Therefore cycling' 74s MAX was used for communication with these peripherals. Unity and MAX send UDP messages back and forth.

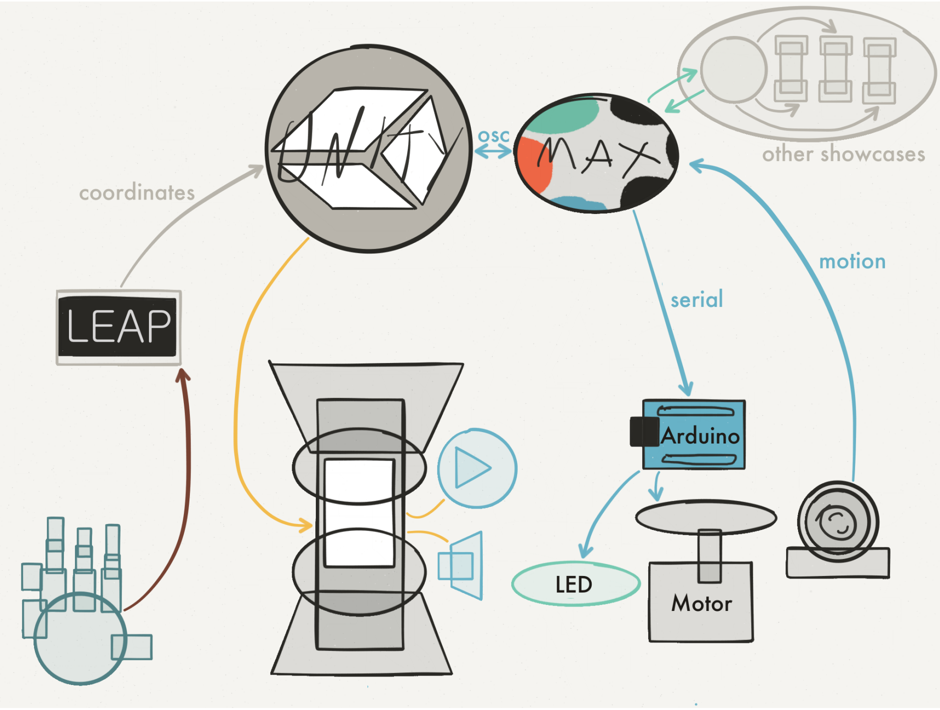


Figure ii: Component diagram of the showcase

[12] http://gonchar.me/panorama/

6. Evaluation and Conclusion

6.1. Logs during test month

From the 21.05.2015 till the 22.06.2015 activations on the old showcases and the prototype showcases were logged. The time from the first push of a button till the reset of the showcases was counted as one activation. On average each showcase was activated 3.5 times each working day. Two showcases logged very high activity in a distance two times the standard deviation from the average. During the observations it was seen that one of these got activated randomly without any users activating it. This could potentially happen from infrared light inferences that activate the start button by accident. If these two showcases are excluded the daily average activations were 2.8. In Figure jj the average daily activations are visualized as a fraction of one standard deviation above the mean. In blue the updated showcases are graphed. In dark grey the two possible outliers are visualized. They got activated 4.2 and 3.6 times daily. During the test day one subjects were guided to one of the old showcases to compare to the new version. The data was cleaned from test activations and guided activations. During the test month 1495 total autonomous activations were logged. 115 confident activations were logged on the PIRATE showcase and 96 on the 100%FAT showcase.

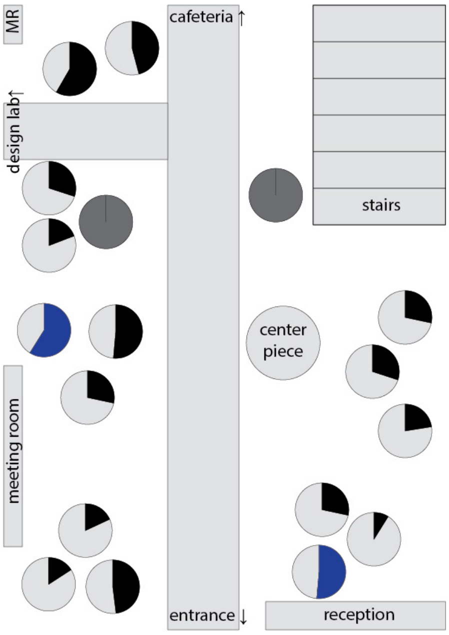


Figure jj: Average daily activations during test period

In Figure jj it can be seen that the location of the showcase as a high influence on activations. Showcases that are close to the free passages get activated more often. Despite being not in top locations the 3D showcases were activated more often than comparable showcases.
Sparks in activity can be seen on the 4th of June as a conference took place. During weekend and holidays no activations were recorded. On the test day the activation sparked, these activations were removed from the data, as well as the frequent debug and test activations (Figure kk).

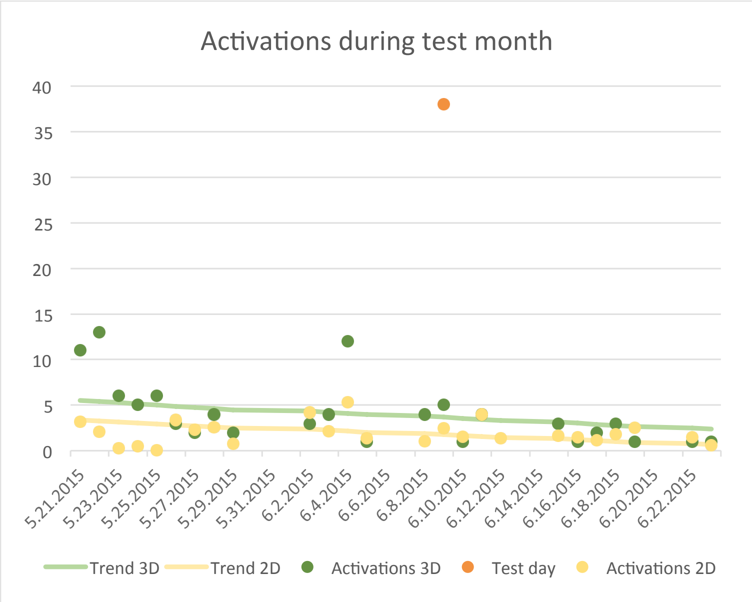
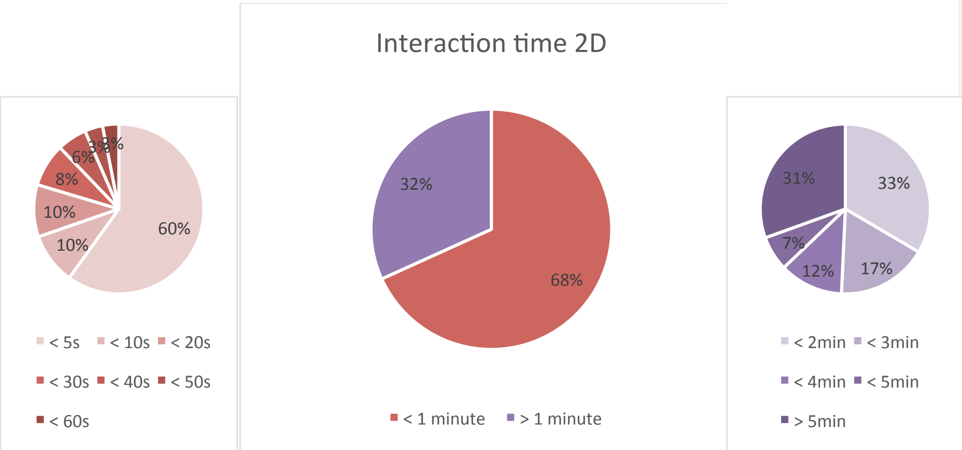
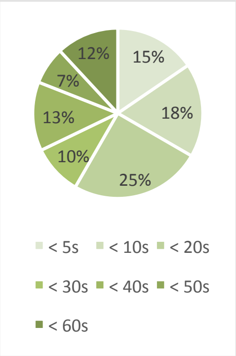
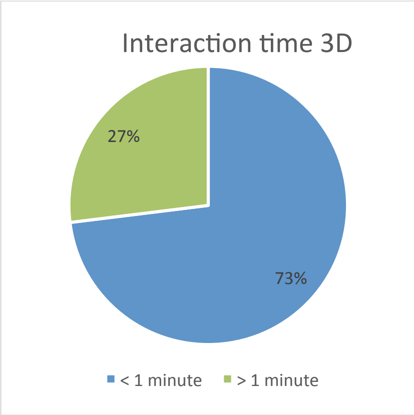


Figure kk: Total activations of the PIRATE showcase vs. average daily activations per 2D showcase

In Figure ll the average time that subjects spend from the first moment of recorded activity to the last recorded activity is graphed. Only real activations of buttons are counted, not if hands were within view. Due to the very different concepts of the showcases is this data not easy to compare. The amount of people that spend more than a minute and less than a minute on the showcases is similar. This could be that the subjects that spend more time on a showcase fall in the category of waiting people. People that spend less than a minute on the showcase might just took a quick look and did simply have not enough reason to spend more time. The 2D showcase had more users that spent less than 5 seconds on it. These are the users that just activated the showcase and did not read or watch anything on it. Also the 2D showcase had more users that spent more than 5 minutes on it. The 2D showcase is more encouraging to finish till the end while the 3D showcase encourages more to quick exploration and subjects most likely do not want to watch all of the videos.







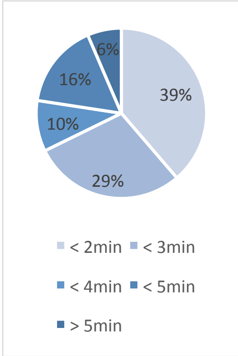


Figure ll: Time till last recorded interaction in 2D and 3D Version

6.2. Feedback

6.2.1. Survey Results

25 users ranked the 2D showcase against the 3D showcase. Half of the user preferred the 3D version overall. About one quarter preferred the 2D version and the rest did not have a strong preference. It has to be mentioned that users sometimes tried to make mental pictures of completed non prototype versions or contrariwise mentioned that if the 3D version would be final with sharper images might have preferred it. Thus these rankings only give a tendency but are not objective (Figure mm).

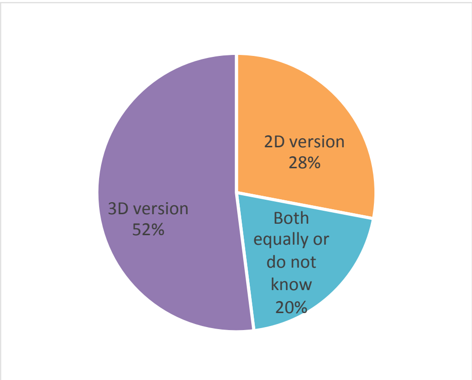


Figure mm: Subjects preferences for the two versions

In Figure nn it is visualized how test subjects ranked their impression of individual traits of the two showcase versions. The 3D showcase is outperformed on comprehension (Which version is easier to understand?). It was ranked a bit lower on the ease of navigation but performs better on the enjoyment and creation of attention. Users felt that the 3D version fit better in the environment of the Gallery because it is "newer", more "futuristic" and "not yet seen somewhere else". A lot of subjects ranked the aesthetics of the new version immediately higher. Interestingly "older" subjects had a higher tendency to be unsure about their preference or prefer the 2D version. An assumption that is not visible in the data could be that they prefer organized 2D text because they grew up without games, internet or blockbuster science fiction movies.

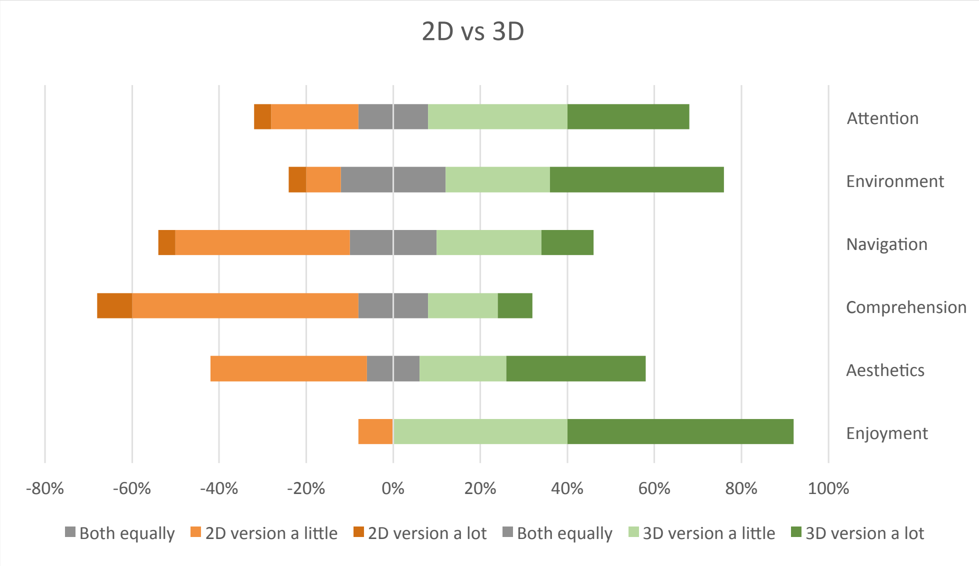


Figure nn: Subjects ratings for individual traits

6.2.2. Observations and Interviews

During multiple days users were observed in the gallery and left on their own. On one test day users were approached and encouraged to test the new system (Figure kk). They were observed on their performance and interviewed. Questions that were asked followed naturally from the conversation. As starting points for interviews these questions were used:

Why did you stop by and interact (not interact) with the showcase? I saw you trying to (...) why did you do that? What makes the showcases interesting? What makes them eye-catching? Why are you here at the moment? If you are in the Gallery do you interact with them? How does interacting with hands vs. cursor make you feel? What gets lost with this different version? How is this version better/worse? Prefer explanatory text, infographics or figuring out yourself? Following your intuition how would you move hands? Following your intuition how would you activate the buttons? What is interactivity to you?

The raw data from the interviews is available online [2]. In total 23 subjects allowed to be interviewed and recorded.

Users that approached the new showcases on their own were all already known to the old ones. They recognized the change of the graphical style and wanted to see what the differences were. A women noticed the different "bubbly style" of the test showcase and was drawn to it. During the observations users that felt comfortable seemed to playfully toss around with the system. When groups of multiple people used a showcase on their own they made comments about it: "I do not know what I am doing, wait, look there is my hand in it!" Especially the possibility to rotate the camera and to wiggle the buttons seemed to invoke some fun. The videos did not play with sound therefore most people did not spend enough attention to them. Also the line from the button to the video players was not yet animated and all buttons stayed active after a video got played. Therefore people continued to push wiggle and tried to unlock more features of the system. The 3D version was described as "cool", "futuristic" and "already a lot better". One women mentioned she would like to know beforehand what video she would watch and wanted descriptive text on the buttons. One businessmen was very critically asking about choices of the design and one mentioned that the 3D showcase would be a bit of an overkill just for watching videos. Only two persons mentioned that the changes are unnecessary. It was noted that the initial step to understand what can be done would take longer but afterwards the navigation was described as more natural. Moreover some users called the two axes mapping of the old showcase irritating, compared to the hand mapping during use. Some users at first felt uncomfortable being watched during the operation. And defended themselves as unexpired computer users. These computer-afraid-users were more hesitant to try things out on their own. The Ghost hand seems to be enough of a hint on how to operate the device, users tried to grab for the screen and saw a brighter, their, hand popping up. Some found the "start" message of the old showcase as an invitation to interaction. Users really wanted to be able to rotate the physical object and to keep the camera position from resetting. The 3D invites to and some wanted to interact with the 3D object directly instead of the buttons. Most problematic was when users did not grasp that they needed to also move their hands back and forth besides up, down, left and right. People said that more interactivity and 3D is better even without justification. Sharpness of the screen was a major evaluation point for users.

6.3. Recommendations

6.3.1. Future work

6.3.1.1. Restricted interaction area

The small interaction area of the leap compromises user's experience. All interaction is possible to be performed within the LEAP range. However large or small users might need get easier out of range then others. To keep users from accidentally hitting against the glass, during the tests the virtual hands were mapped a bit too far in the back. Therefore sometimes the hands popped up behind the buttons and not in front which could make it more difficult to sense them. The showcase does not use all of the LEAP view. Some of the tracking area is inside the showcase (Figure oo).

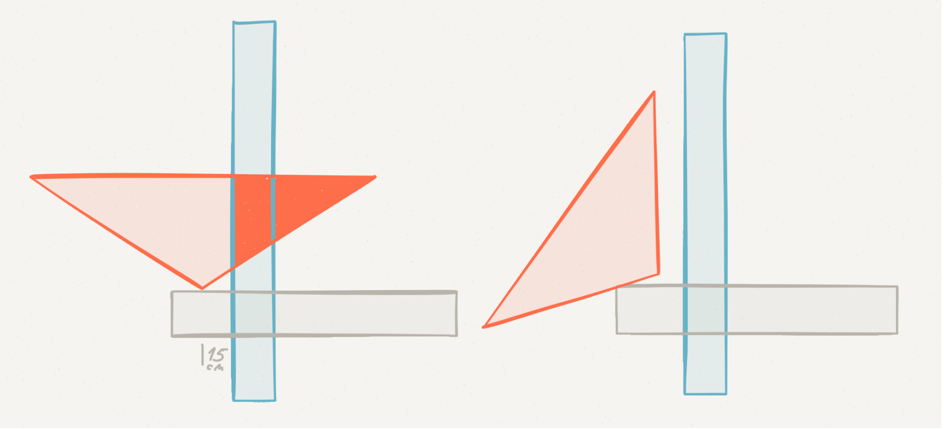


Figure oo: Side view showcase and LEAP field of view

If the LEAP sensor would be tilted more of the field of view could be used. With the current version it might be difficult to remap the area but Unity which is used in the new software is quick at vector transformations.

6.3.1.2. Acknowledgments & contact information

The prototype does not name legal information and contact details for the research groups or companies. If graphics or 3D models from online sources are used the sources have to be mentioned within the application.

6.3.1.3. Projection mapping

The showcases have the option to be extended by a beamer. Only the showcase of the client 100%FAT makes use of it. The beamer could be used to relate the object to the content further. An overlay beamed onto the object would show points of interest or which part of the object is highlighted at the moment (Figure pp). It might be best to use a second lightweight application such as processing[13] to draw this overlay and just send coordinates from Unity to it.

[13] https://processing.org/

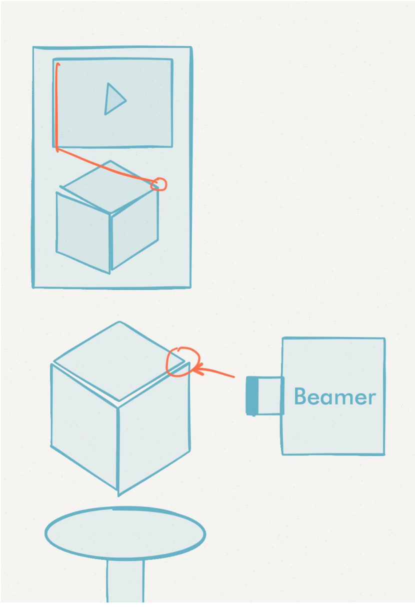


Figure pp: Point of interest projection mapping projected on cube

6.3.1.4. Squeeze

The showcases was enabled to use the easiest interaction discovered during the test period. From the survey it became clear that users found grabbing after a button or squeezing it both the most natural and the most fun. In the observations people were able to enable the buttons but did not stop pushing more buttons. The action to enable playback of a video needs to have a more distinguished state between play and pause. Pushing buttons should still be used to see what content is tied to which button. If the content is selected squeeze could be used to start the playback.

6.3.1.5. Animations

The older showcase version has more guidance about where the user should look at. The videos and photos are fading in from the top to the bottom, giving flow to the screen. The new version should have smoother camera movements, animate the ray, video and text overlays so that attention is drawn towards them from the interaction up to the content.

6.3.1.6. Motor

The motor position should be aligned with the screen. Users want to be able to control the object rotation freely. Because unwanted user behaviour such as tooling around with the motor needs to be prevented it could update only after a delay.

6.3.1.7. One interaction simultaneously

A very few users used fists or tried moving the camera and pushing buttons simultaneously. It is not intended to do both at once. Moreover users wanted to explore more of the showcase after they understood the first interactions. They positively reacted that both hands can be on the screen. It might be an option to change one hand grab rotation into two hand rotation.

Hauke Sandhaus 30.6.2015 03:17

Kommentar [1]: Teile über code fehlen conclusion für mich nicht ersichtlich, was hast du jetzt konkret erforscht und rausgefunden. Conclusion was leute finden fehlt. Auswertung von game und interviews fehlen. Manche grafiken noch nicht beschrieben im endteil, fliegen noch random rum. Was denkst du was hast du rausgefunden bis jetzt nur zusammengetragene information in sortierter reihenfolge, führen aber zu nichts. Kommt einem so vor als hättest du nur research und interviews betrieben.

6.3.1.8. Better related content

The prototype of the showcase did not have the content adjusted tightly into the infographic it should be. Videos should be linked to the parts of the objects they belong to. Only high quality content should be embedded. The videos should also have best quality. Unity's embedded converter and publicly known converters do not provide sufficient video quality. The only option found, is to use ffmpeg2theora[14].

6.3.1.9. Game concept

The activation of the showcases is the part users had most fun with. Therefore a different approach could be to turn the showcase into an educative game. This would have the advantage that users are more likely to excuse difficult controls. Games are meant to be difficult sometimes. Also it would couple the information more tightly to entertainment and allows to tell stories to the users. One scenario for PIRATE could be: "Swipe the robot to the exit of the gas network. Do inspect all leaks." For each inspected leak summarized information is displayed. E.g. "Did you know that 100.000km of the Dutch gas network cannot be inspected easily?"

6.3.2. Refined prototype

Based on these recommendations the final prototype got refined. It fits better into the proposed concept. And addresses sum of the findings. The movies have a distinct activation, squeeze, to play with sound. It has an additional ghost hand to encourage squeezing the button. As found in the button tests this was the most natural interaction and therefore will work with a high likelihood. The camera will not rotate anymore if only one hand grabs. It will keep the position users chose when rotating a few seconds and also make the motor follow this rotation. It uses content that is very short and give quick info about detailed parts of the object. When playing the video the other buttons get deactivated so that the users will focus on the video.

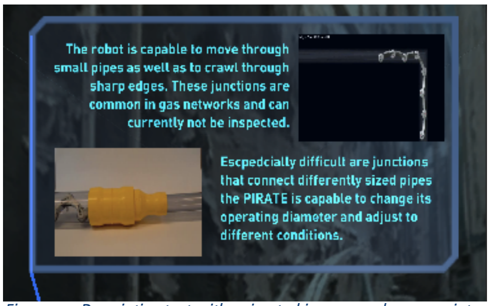


Figure qq: Descriptive text with animated images and squeeze interaction preview

[14] http://v2v.cc/~j/ffmpeg2theora/

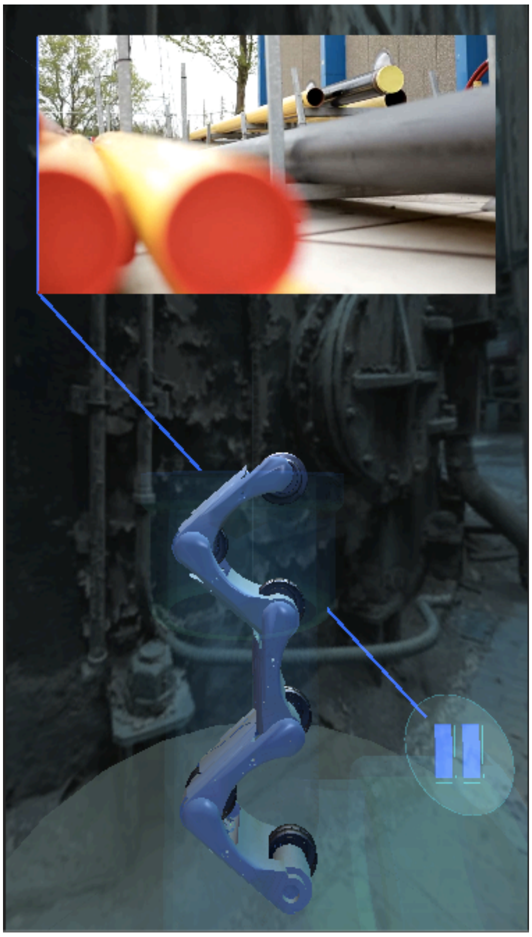


Figure rr: Play high quality video with audio

6.4. Conclusion

The direction that interface design will go in will finally be more natural. It will certainly include touchless input methods, and more 3D elements. Transparency is becoming again a more widely applied design element. The communication that users have with machines is blurred down more and more. Machines are seen less as simple calculators or input output devices and more as devices that can be communicated with. Speech is one of the communication methods that computing devices are currently trained to. Wiser and more fitting interactions are rising. Computers start to allow humans to be imprecise but still deliver the expected response. The interactive showcase is an example that could show how interfaces will change. Users will need less effort to pull out sense from machines. Instead they will have it nicely arranged and focus on making the communication with them effortless and playful. Users are able to learn new interactions, even though some metaphors have become hardwired into the brains of users, visually different interfaces and cues can help to prevent confusion. At first users might be negative against change because they do not want to give up on learned skills, but recently it can be seen that even hesitant users will accept change in the end.

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