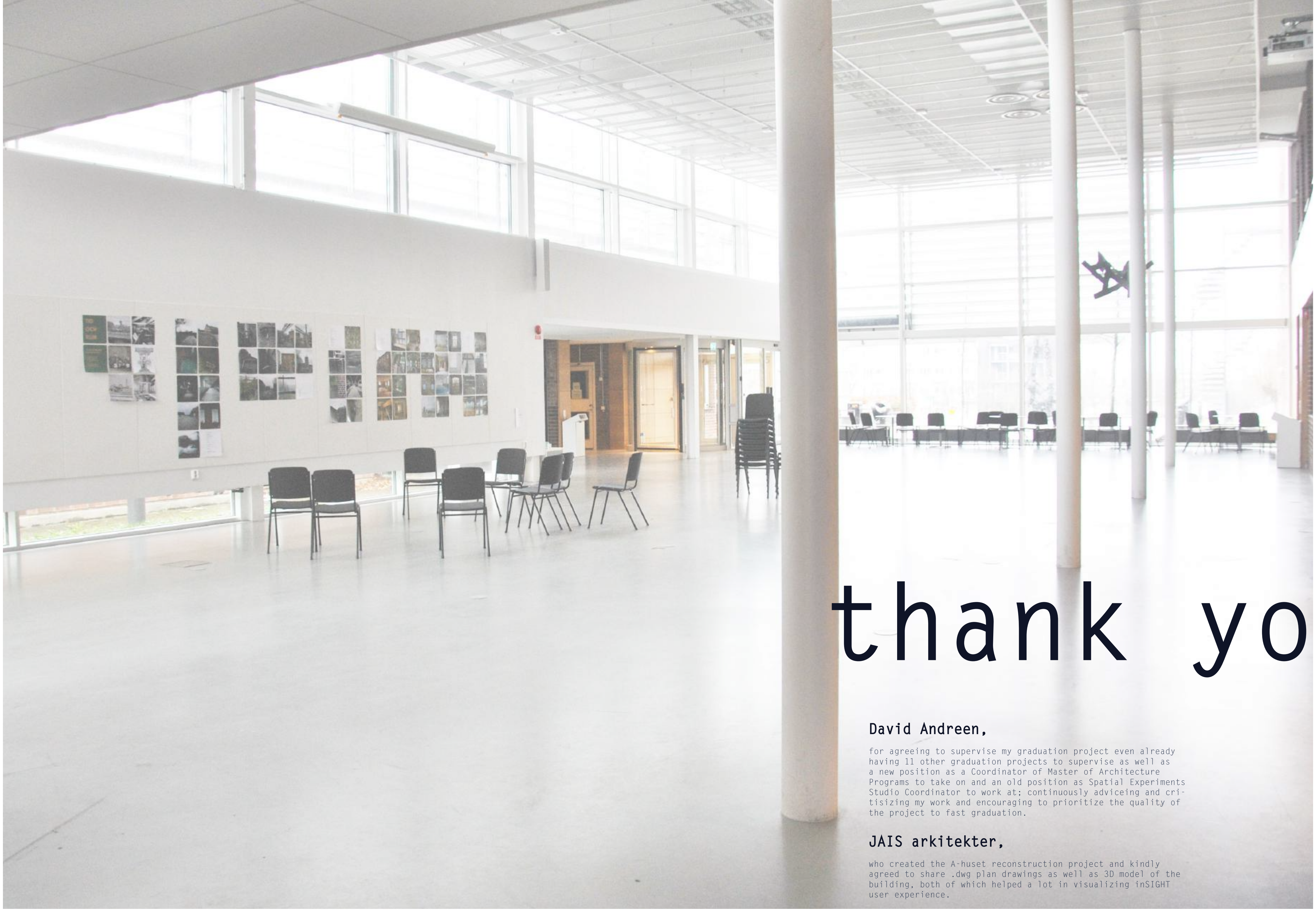
# inSIGHT

## An Augmented Reality Platform To Digitally Manipulate Physical Transparency

LUND UNIVERSITY

Master of Architecture Thesis Project by Sigita Pociute

2017



# thank you

## David Andreen,

for agreeing to supervise my graduation project even already having 11 other graduation projects to supervise as well as a new position as a Coordinator of Master of Architecture Programs to take on and an old position as Spatial Experiments Studio Coordinator to work at; continuously adviceing and critisizing my work and encouraging to prioritize the quality of the project to fast graduation.

## JAIS arkitekter,

who created the A-huset reconstruction project and kindly agreed to share .dwg plan drawings as well as 3D model of the building, both of which helped a lot in visualizing inSIGHT user experience.

## Family and friends,

for versatile support, constant reminders of the importance of education and always wishing me well.

To get the most out of the publication, use ROAR scanner app to scan pictures marked with this sign and access additional content.

# introduction

**inSIGHT began as an exploration of the fuure relationsip between virtual world and physical architecture. It ended up being a proposal of an augmented reality platfrom for digital manipulation of physical transparency.**

Augmented reality is a fairly recent development in technology. For this reason some of the readers might not be so well aquainted with it, just like I was when I started working on this project, and just like some of those with whom I have spoken about inSIGHT throughout the past several months. Inevitably, an important part of the process was getting aquainted with the development and evolution of parralel realities before diving into particularities of one of them. Naturally, the research will be presented in the first chapter of this book as it laid an important foundation for developing inSIGHT.

During the research phase an idea emerged of digitally manipulating physical visibility with the help of augmented reality. Now visibility is a broad term and can be interpreted in a number of ways. Chapter two is a collection of some of those interpretations. Presented are spatial manipulations that could be possibly achieved by digitally altering one's visibility.

inSIGHT, the proposal of the digital platform for physical transparency manipulations is presented in chapter three. The proposal emerges from the first two chapters. It suggests using the up-and-coming augmented reality technology explored in the reseach phase, and combines it with the most fundamentally architectural spatial manipulations explored in chapter 2. The digital platform does not aim to replace physical world and would be unable to if it tried. It rather suggests new ways of interacting with the built environment with the help of the digital world.

inSIGHT is an innovative approach towards architecture and might be difficult to imagine and even understand without creating visual simulations in a form of collages or moving pictures. Therefore an existing building of A-Huset in Lund, Sweden, was chosen to simulate inSIGHT user experience in. The simulation is presented in the last chapter of this book. It aims to provide the reader with a beter insight into how the platform works and expands regular perception of physical architecture.

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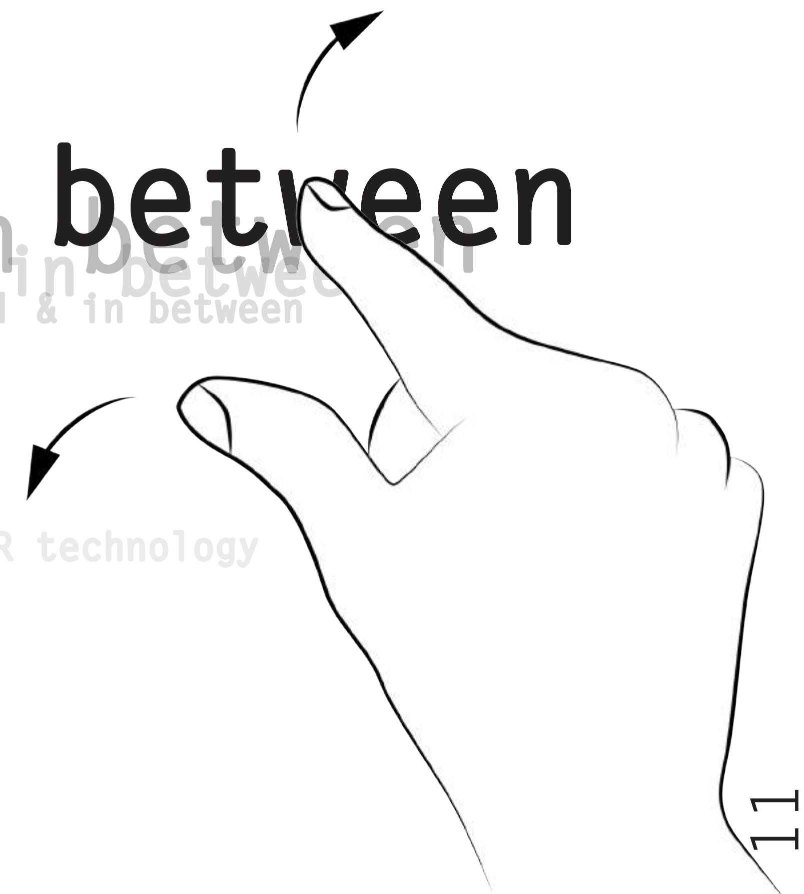
# RESEARCH

## part one

# physical, virtual & in between

physical, virtual & in between
physical, virtual & in between
physical, virtual & in between



evolution of AR technology

# competition


*Figure 1.* gURROO mission statement diagram (Source: gURROO, n.d.)

## Starting point of the project was creating a proposal for the Innovative Minds 2017 Cybernetic Framework architectural design competition.

"*Innovative Minds 2017 is an exploration into the relationship between the virtual world blending with physical architecture. The virtual world – built on the framework of vast data networks – is becoming increasingly referential to the nervous system. Architecture strives to tangibly enhance humanity's wellbeing through the design of complex systems. As cybernetics increasingly interconnects the virtual and physical worlds, how will this relationship influence architecture and its physical context to solve complicated problems?*

*As humans continue to design the virtual and physical worlds, how can cybernetics bridge these domains? Inherent challenges are evident in every site associated with physical architecture. Use these site-specific characteristics to investigate a cybernetic framework that will expand architectural strategies such as environmental contextualism, user interaction, building function, and/or construction techniques.* (gURROO, 2016: p. 1)"

Competition was chosen as a thesis topic because of its relevance in the contemporary fast-paced technology-filled world and the need of innovative thinking. Neither the location, the scale, nor the perspective of how to look at the topic were strictly predefined by the competitions requirements, therefore there was a lot of space to personalize the project in those regards.

# exploring parallel realities

Figure 4. The eyes of social media (Source: Shawn, 2015)

Figure 2. Blekinge tekniska högskola, 2014

Figure 3. Litexpo, 2015

**As cybernetics become a more and more important part of our lives, the world collides into physical environment and virtual world.**

As cybernetics become a more and more important part of our lives, the world collides into physical environment (*Figures 2 & 3*) and virtual world (*Figures 4 & 5*). Every human being is familiar with the physical environment as we live in it and interact with it all our lives. Virtual world however is more recent and therefore older generations may be less acquainted with it. Even more recent than virtual world is augmented reality, a combination of the latter two (*Figure 6*). Further in this chapter all three - physical environment, virtual world and augmented reality - will be described, focusing on their unique qualities as well as limitations.

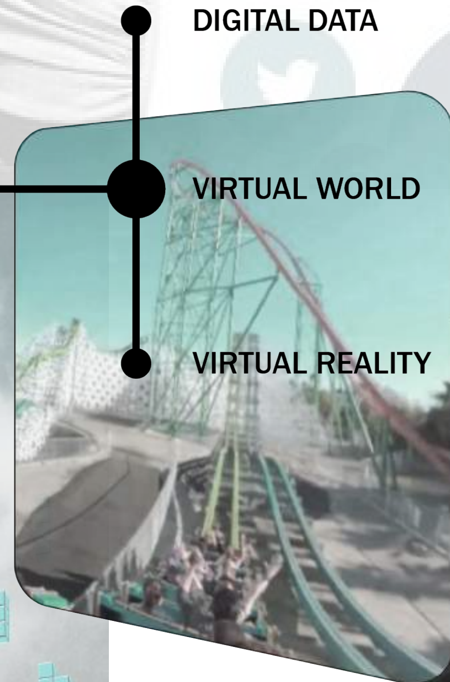



Figure 6. Celoscape (Source: Malishev, 2014)

Figure 5. Virtual reality experience (Source: Judkins, 2016)

# physical environment

Physical environment is a part of human environment that includes purely physical factors. Within the field of architecture physical environment contains human made buildings and structures. *(Figure 7)*

Those are the structures that have been designed and constructed seeking to improve the quality of life for people by providing operational qualities such as shelter (from cold, heat, precipitation, wind), safety (from criminals and other unwanted factors), privacy.

**Physical environment, in addition to operational qualities, contains other physical characteristics, such as texture (the way that element feels when touched), light (ability to block, filter, alter or transmit it), structural support (ability to bear or hold up a load or a mass).**

Despite its undeniable and indispensible qualities, physical environment has some limitations as opposed to digital environment. It takes a long time to construct a physical building and is also often rather expensive. These reasons make it disadvantageous to modify the building often. Different materials have different physical characteristics, some are more durable to certain environmental factors (fire, wind, precipitation) than others. All physical materials wear out whitin a certain amount of time and therefore require constant maintainance.

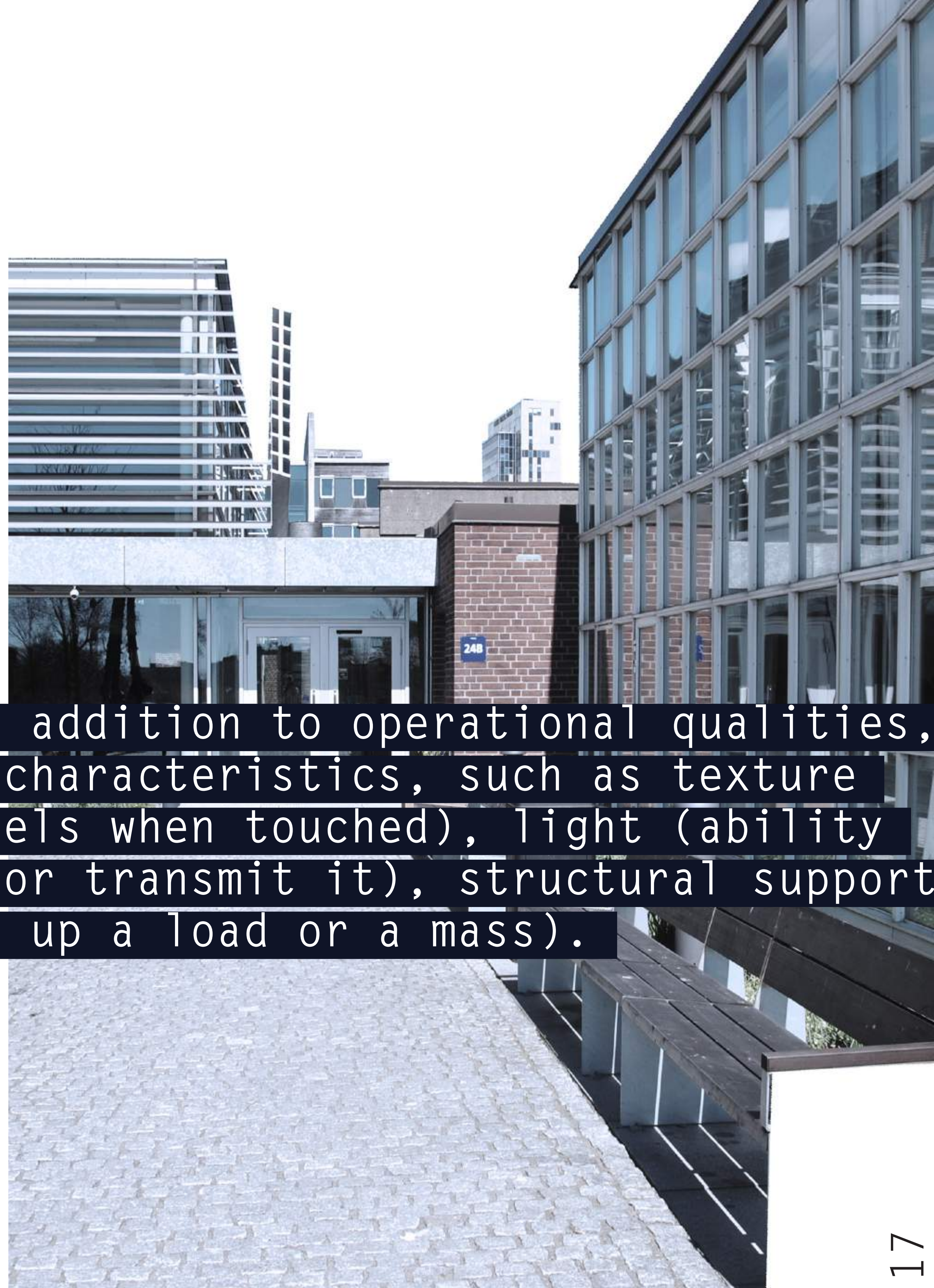


*Figure 7*: A-huset, Lund University

# virtual world

**Virtual world could be subdivided into inhabited virtual world (or digital data) and uninhabited virtual world (or virtual reality (VR)).**

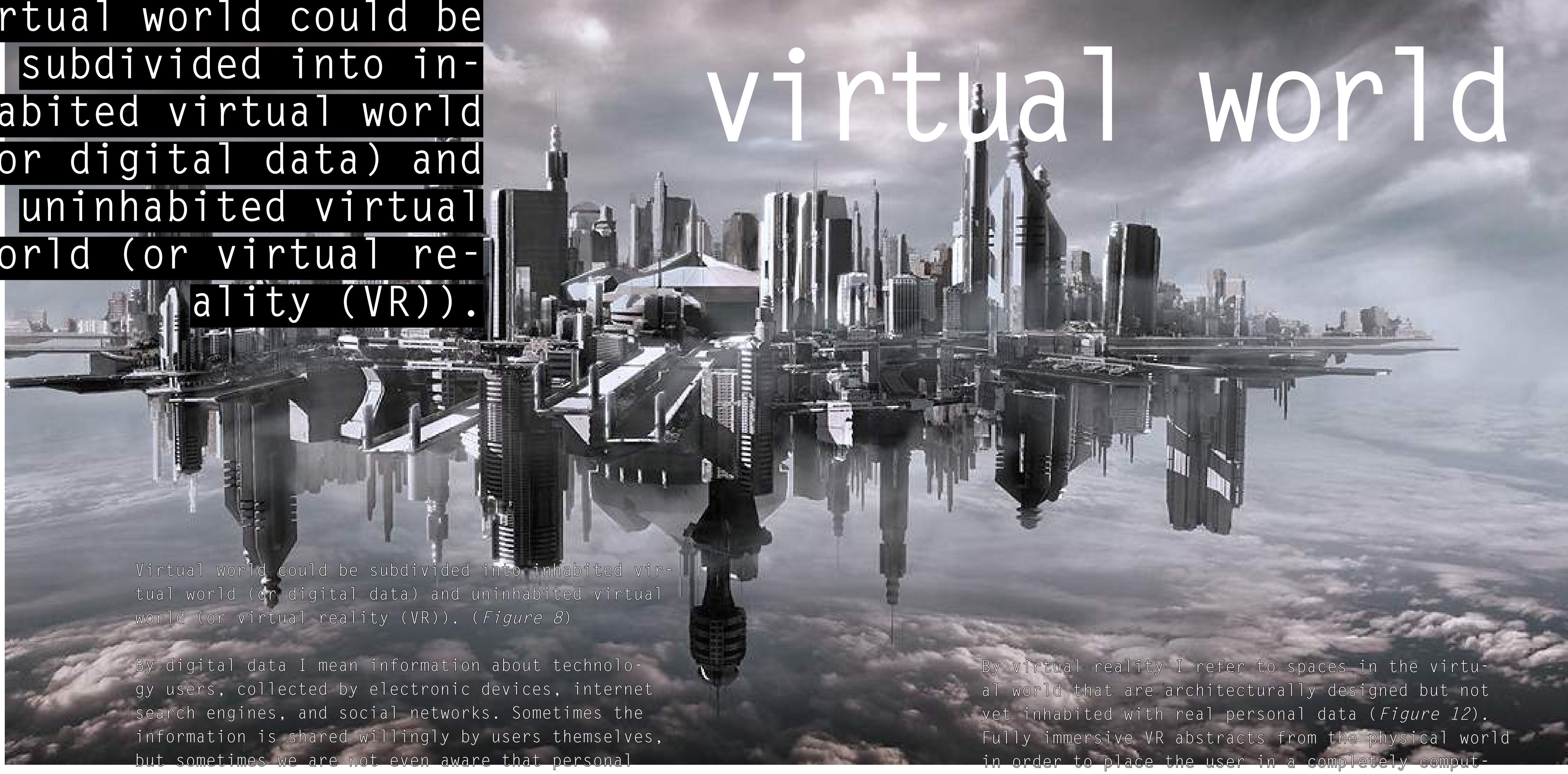


*Figure 8*. Cloud city (Source: Popescu, 2007)

Virtual world could be subdivided into inhabited virtual world (or digital data) and uninhabited virtual world (or virtual reality (VR)). (*Figure 8*)

By digital data I mean information about technology users, collected by electronic devices, internet search engines, and social networks. Sometimes the information is shared willingly by users themselves, but sometimes we are not even aware that personal data is being collected by third parties. Advantages are many - world wide web helps people connect to one another instantly (social networks, professional networks, electronic mail); location tracking helps one navigate, (finding directions and your own location on a map) and find objects (GPS tracking system in cars, phones), (*Figure 9*); data tracking leads to more customized received information (advertisements, article suggestions based on previous searches online), overview of previous financial expenses (*Figure 10*), physical activities (*Figure 11*) allow us to effectively improve the current results (smartphone applications such as Runkeeper and Goodbudget). There are a number of ways in which tracking various data benefits our daily lives. However, issues with privacy naturally arise.

By virtual reality I refer to spaces in the virtual world that are architecturally designed but not yet inhabited with real personal data (*Figure 12*). Fully immersive VR abstracts from the physical world in order to place the user in a completely computer-generated universe. Examples of such spaces could be exciting three dimensional environments like virtual reality roller coaster experience (*Figure 13*) and computer games. Virtual reality environment allows to instantly change the surroundings and is not restricted by the force of gravity or material cost. Yet, exessive use of virtual reality can cause social isolation and addiction which can already be seen in computer game industry.

A new phenomenon, merged platforms of the two - inhabited and uninhabited virtual worlds - are currently being developed. A good example of this is Facebook Spaces, a new virtual reality version of Facebook, pictured in *Figure 14*. (Kelly & Larsson, 2017)

*Figure 9.* Location tracking

*Figure 10.* Internet banking

*Figure 11.* Smartwatch (Source: Runkeeper, 2014)

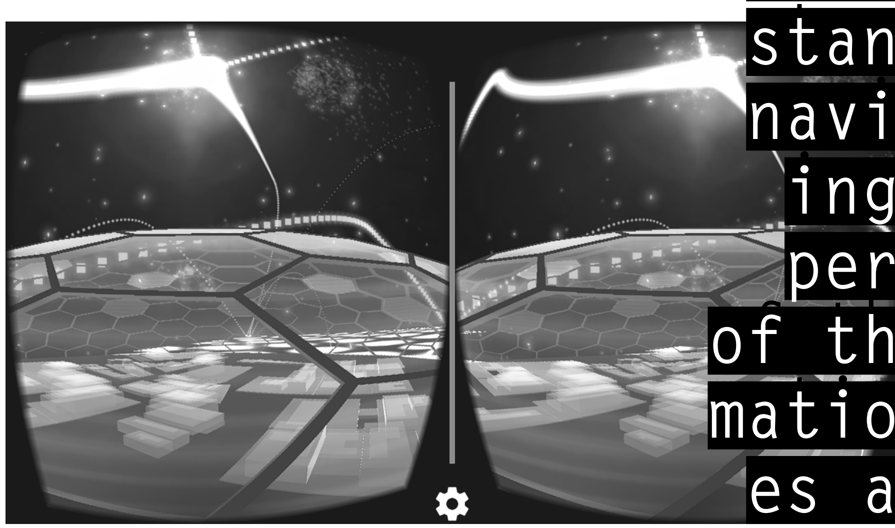


*Figure 12.* Virtual reality environment (Source: Cisco, 2017)


*Figure 13.* VR roller coaster (Source: Frag, LLC, 2015)

*Figure 14.* Facebook Space demo (Source: Facebook, 2016)

Digital world helps to connect people instantly, GPS helps to navigate, data tracking helps to improve performance. Yet all of this digital information collection poses a threat to privacy.

Virtual world, even though creating fully immersive experiences, poses a threat of addiction and isolation.

# augmented reality

**Augmented reality (AR), broadly defined, is the process of viewing the real world and virtual objects simultaneously, where the virtual information is overlaid, aligned and registered with the physical world.**

*Figure 18.* Snapchat filters

*Figure 15.* Pokemongo

*Figure 16.* IKEA catalogue app

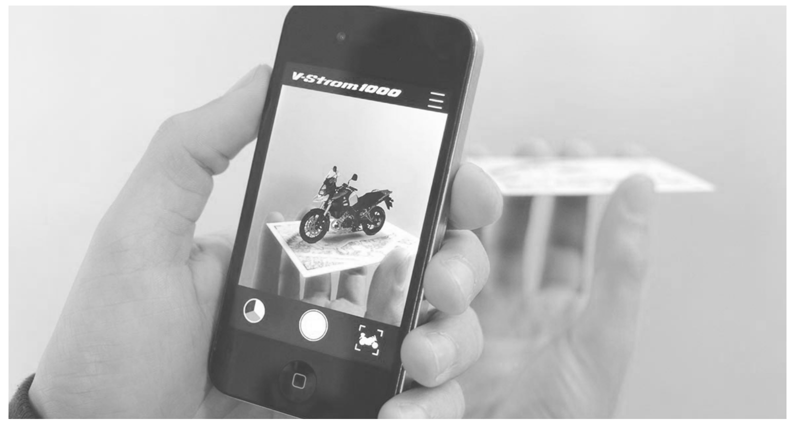



*Figure 17.* Augmented reality app

Augmented reality has the potential to enrich the material world without posing the threats of isolation and addiction, which aren't uncommon to virtual reality.

There are functioning and popular augmented reality platforms already - Snapchat (*Figure 18*), Pokemongo (*Figure 15*), IKEA catalogue app (*Figure 16*),  - to name a few. It seems that the future of the digital is moving towards exporing the full potential of augmented reality.

**There has been a number of video simulations created trying to picture the future of augmented reality.**

One of the future visions of AR, Hyper-Reality, has been created by Keiichi Matsuda in 2016. *(Figure 19)* Another worth mentioning vision of the future AR is the short futuristic film by Eran May-raz and Daniel Lazo, who created the video for their graduation project from Bezaleal academy of arts in 2012. *(Figure 20)*

Though most of augmented reality platforms focus on users' interaction with digital objects rather than changing their perception of a physical space.


*Figure 20.* Sight (Source: May-raz & Lazo, 2012)

**Mediating Mediums, a master thesis by Greg Tran, created at Harvard Graduate School of Design in 2011 is one of the few works that discuss material spatial perceptions altered by augmented reality.**

*Figure 19.* Hyper-reality (Source: Matsuda, 2016)

"The physical walls exist in material space, but when you look through a certain lens digital walls sync up to close the space, overlay the physical walls, and create new perceptions. It's not about the material reality on its own and it's not about the digital reality on its own. It is about the mediation of these two mediums and discovering the ways that they can enrich one another, exploring the potential when the two are blurred. (Tran, 2011)

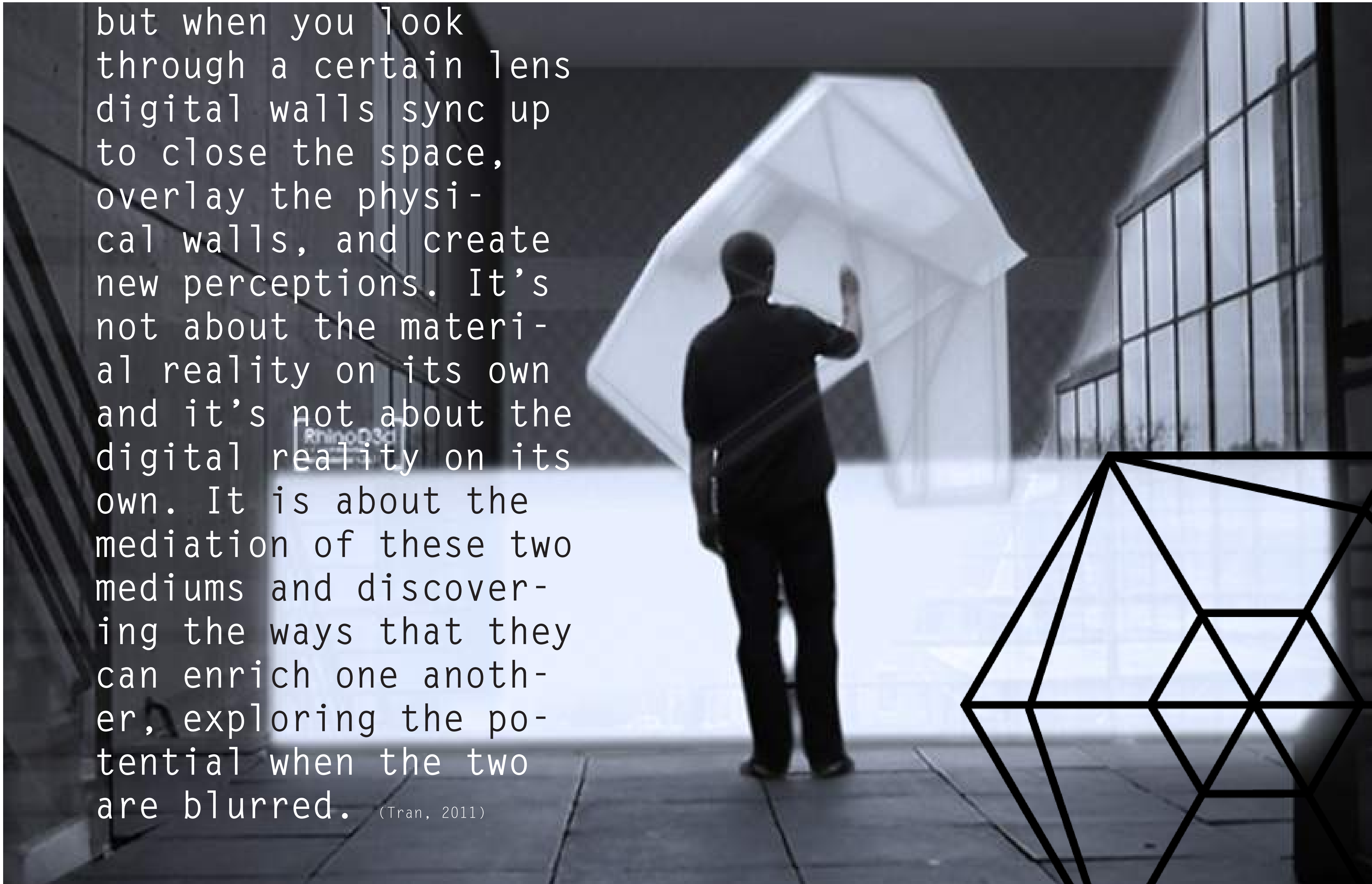


*Figure 21.* Augmented reality simulation (Source: Tran, 2011)


*Figure 22.* Variety of augmentations (Source: Tran, 2011)

## In his thesis project Greg Tran divides the digital 3d into two parts - the visual and the operative.

According to G, Tran, when the material and digital are alligned, digital material overlays (experiential and informational) as well as simultaneious visual realities are possible, when looked at through a certain lens. Visual barriers can be created in site specific locations and they can be programmed based on things like time and group. With the two forms of geometry alligned one can allow new forms of transparency, broader spatial awareness of proximity and spatial expansion. The digital 3D can be used for way finding. It can also alter material treatment or material scale.  Because the digital 3D is a material, it can create counterintuitive effects like a simulated interior-exterior condition. Spatial depth is replicated through expansion or compression of space and can function in collaboration with visual privacy barriers. It is most powerful when it draws on the material context that blurs the line between real or render. (*Figure 22*)

G. Tran describes operative digital 3D as the idea that invisible spatial barriers are able to turn functionalities on and off. A wireless network is a perfect example of this functionality, he says. It represents a weak spatial boundary. When you are in the certain radius you are able to access your programs and files, but when you leave that space, that functionality turns off, some of your digital abilities are lost. If that weak boundary was made spatial and even more site specific, then person's location relevant to it would become even more important. Such boundaries could be used as subsets - visible or invisible - within buildings, and be tied to material walls. These borders in changing functionalities already exist within the space of 2D. When your location changes, it allows you for different levels of access, interactivity, production or visualisation. Like the space of the internet, these representations in immaterial updates are characterized into three types. What user sees, can be based on location, time or group. All of these realities can be seen simultaniously by the three different groups.

Although the digital 3D can change perception and action, it is fundamentaly unable to replicate material effects like shelter, texture, touch, light and privacy. The new medium is not meant to replace material reality and would be unable to if it tried. The tools simply provide new potentials for architects, to create a site specific condition, which can empower. (Tran, 2011)

# conclusion

The first objects ever created were material 3d objects, such as tools and weapons, eventually sculpture and architecture. Later writing, cave paintings were invented and can be categorized as material 2d. Then photography and moving image (digital 2d) were created and developed rapidly. (Tran, 2011)

**Now the developement of digital 3d - augmented reality and virtual reality - are gaining momentum and have the potential to alter the way we live considerably.**

Both - the physical environment and the virtual world - have valuable qualities and some limitations. It seems that the future lies in the combination of the two, taking advantage of using the qualities from both environments to complement one another. **The emergence of augmented reality provides an alternative to virtual reality and can alter technology from a synthetic, universalizing network to a sensitive site-specific condition.**

With the forms of geometry alligned (the physical and the digital) one can allow new forms of transparency, spatial compression and expansion. **Such ability would fundamentally change one's perception of existing physical environment.**

The next chapter will provide an overview of the existing AR technology and the technology that is being developed and could possibly allow for digital expansion and compression of the physical environment.

# evolution of AR technology

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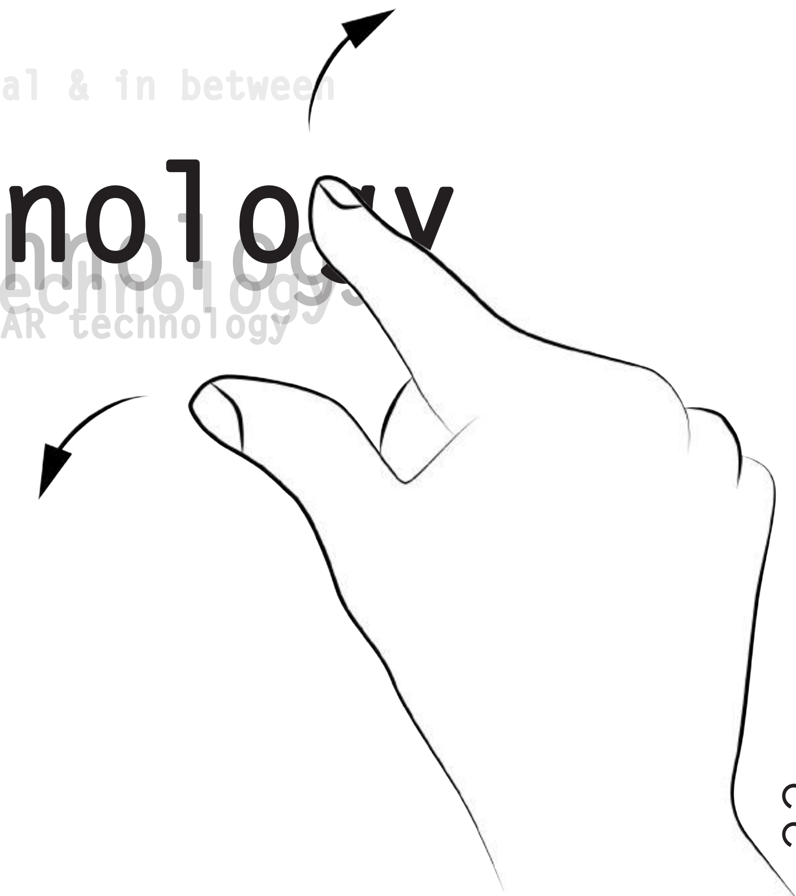


# AR concept

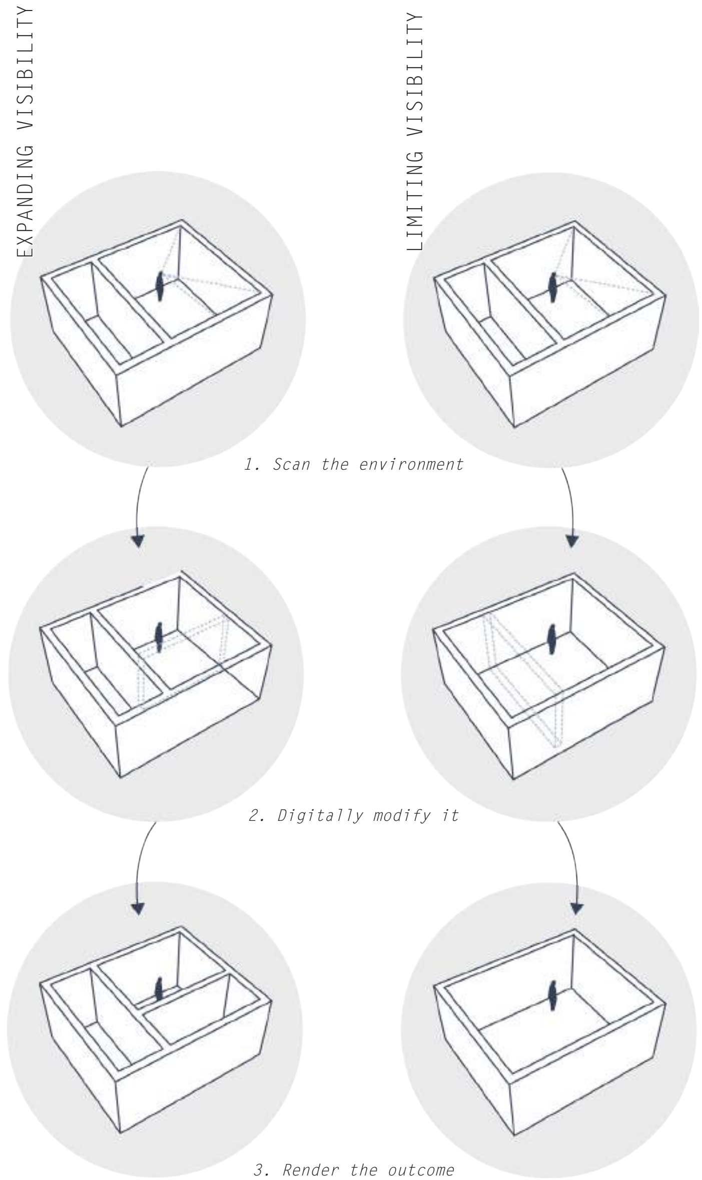



*Figure 23.* AR concept

**The basic AR concept includes three steps - scanning physical environment, creating digital content & alligning it with the physical environment, rendering the outcome, as shown in *Figure 23*.**

Respectively, there are three key hardware components neccessary to create augmented reality. Each of them are further described more in detail.

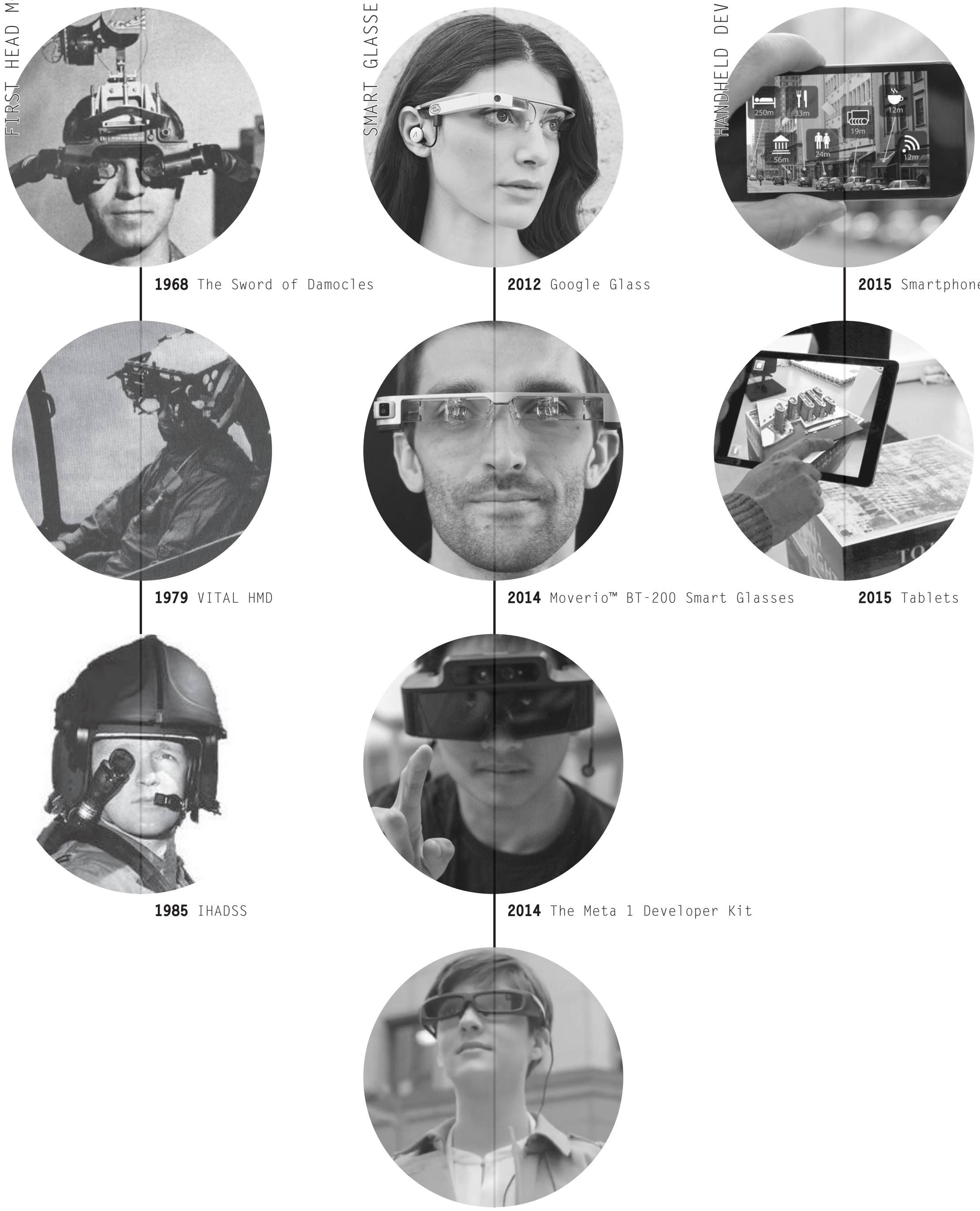
[1] Sensors and cameras visually scan the surrounding area and collect its data. The device determines where surrounding physical objects are located, then formulates a digital model to determine appropriate output. Depth sensing cameras, for example, work in tandem with two ‘’environment understanding cameras’’ on each side of the device. Another example is a standard megapixel camera (similar to the ones used in smartphones) to record pictures, videos, and sometimes to assist with augmentation.

[2] Processing devices, which are basically mini-supercomputers packed into tiny wearable devices. These devices require significant computer processing power and utilize many of the same components that smartphones do. These components include a CPU, a GPU, flash memory, RAM, Bluetooth/Wifi microchip, global positioning system (GPS) microchip, and more. Advanced augmented reality devices, such as the Microsoft Hololens utilize an accelerometer (to measure the speed in which user’s head is moving), a gyroscope (to measure the tilt and orientation of the head), and a magnetometer (to function as a compass and figure out which direction the head is pointing) to provide for truly immersive experience.

[3] Lenses or screens trick the brain into perceiving three dimensional images.

EVOLUTION OF AR TECHNOLOGY

# AR hardware



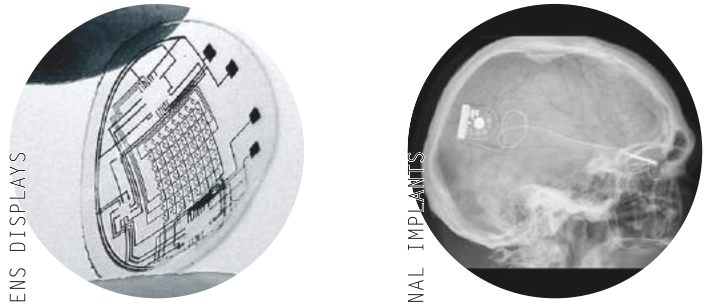




*Figure 24.* Selected examples from the evolution of AR hardware

**Like most technological devices, AR hardware has evolved over time, become lighter, more accessible, easier to carry and use.**

The Sword of Damocles, which is considered to be the first virtual reality and augmented reality head mounted display (HDM) system, was created in 1968 by hall of fame computer scientist Ivan Sutherland with the help of his student Bob Sproull. (Carden, 2015) The first HDM systems, just like first prototypes of a computer, were big, heavy and had very limited capabilities. That is until a lighter and more advanced version was created in a form of smart glasses. Then, in the beginning of the twenty-first century, with the rise of smartphones and tablets, augmented reality platforms have become accessible to most of the population via handheld devices. Over 10 years ago University of Washington professor Babak Amir Parviz and his students had been developing contact lens displays. Now big companies such as Samsung, Sony & Google are walking in his footsteps. None of the LCD displays have ever been put in a living eye yet. (Templeton, 2017) But it is hard to disagree with the fact that as reality technologies continue to advance, augmented reality devices will gradually require less hardware and will eventually be applied to contact lenses and retinal implants. (*Figure 24*)

# user interaction

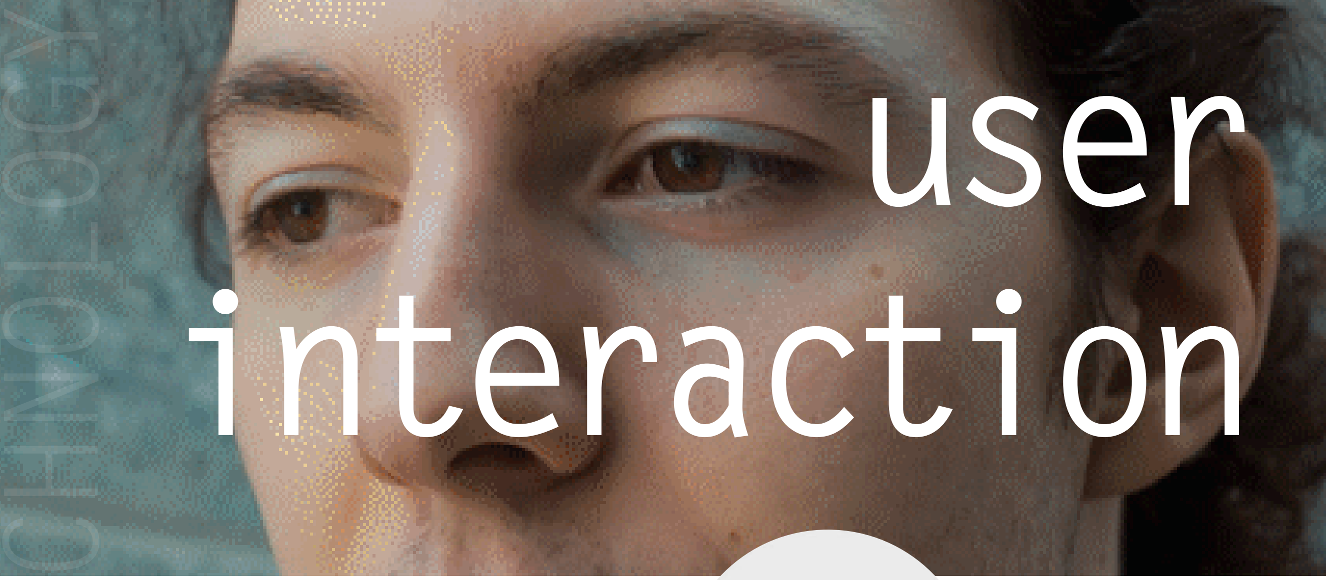
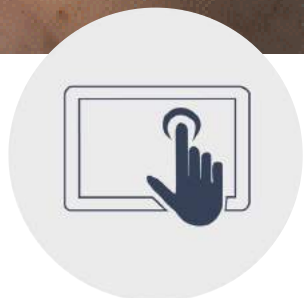


*Figure 25.* Alter_ID
(Source: Magni & Lacharite, 2016)

*Figure 26.* Alter_ID
(Source: Magni & Lacharite, 2016)



Currently most augmented reality devices are controlled by either touching a pad or voice commands. The touch pads are often somewhere on the device that is easily reachable and work by sensing the pressure changes that occur when a user taps or swipes a specific spot.

Voice commands work similarly to the way they do on smartphones. A tiny microphone on the device picks up the voice, then a microprocessor interprets the command. Voice commands, such as those on the Google Glass augmented reality device, are preprogrammed from a list of commands that one can use. On the Google Glass, nearly all of them start with “OK, Glass,” which alerts the glasses that a command is soon to follow, e.g., “OK, Glass, take a picture”.

Hands-free gesture control for augmented reality is currently being developed by a number of institutions. NASA, for example, aims to accomplish hands-free operation by utilizing radar-based gesture recognition transceivers as they precisely measure motion in 3D, allowing for gestures adapted to limited ranges of motion. (Furuya, 2016)

Gaze control is relatively well known as a human computer interaction method and has been already applied to several versions of smart glasses. Eye tracking allows for information to be superimposed onto objects as well as gaze-triggered interaction. Eye tracking technology by EyeX Tobii has been used in Alter_ID by Thibault Magni and William Lacharite, an application of multifold reality based on an eye lens. (*Figures 25 & 26*)

Figure 27. Tesla Suit

# haptics

**Haptic technology is a tactile feedback technology that makes AR and VR more immersive as it recreates the sense of touch by applying forces, pressure, ressistance, vibrations or motions to the user, usually by using electric actuators, pneumatics or hydraulics.**

Some data gloves track hand motion and use air bladders to harden and restrict a grip, so that a hand would feel like it is holding a ball in VR or AR. There are also more advanced solutions such as the CyberGrasp or Hiro III. The CyberGrasp is a wearable exoskeleton that uses tendons and actuators to apply resistance to each finger individually. (*Figure 28*) The Hiro III is a robotic hand that transmits touch information to the fingertips of the user.

The haptic exoskeleton concept can be extended to the entire body in a form of pneumatic suits or body worn vibration packs to simulate touch, temperature, pressure. However, large pneumatic, hydraulic and electromechanical haptic systems aren't practical for mainstream use, therefore current attempts at haptic suits use neuromuscular stimulation similar to the technology used for therapy. The Teslasuit intends to use this technology to add full body touch, giving sensations of impacts, hot, cold, and others. (*Figure 27*) At the same time it provides full body motion tracking which can be used for multiple purposes.

One of the biggest issues in the development of haptic technology is simulating the feeling of texture. Walt Disney company has been working on this issue for some time and has come up with "textured" touchscreens. Rather than using shape changing programmable material it uses electro-vibrations and an algorithm that tricks human brain into perceiving texture.

Haptics is undoubtedly going to contribute to the immersiveness of the future AR and VR experiences. It is a fast evolving area and as augmented and virtual reality technologies are maturing, it is likely that the demand for haptics will also intensify. (VRS, 2017)

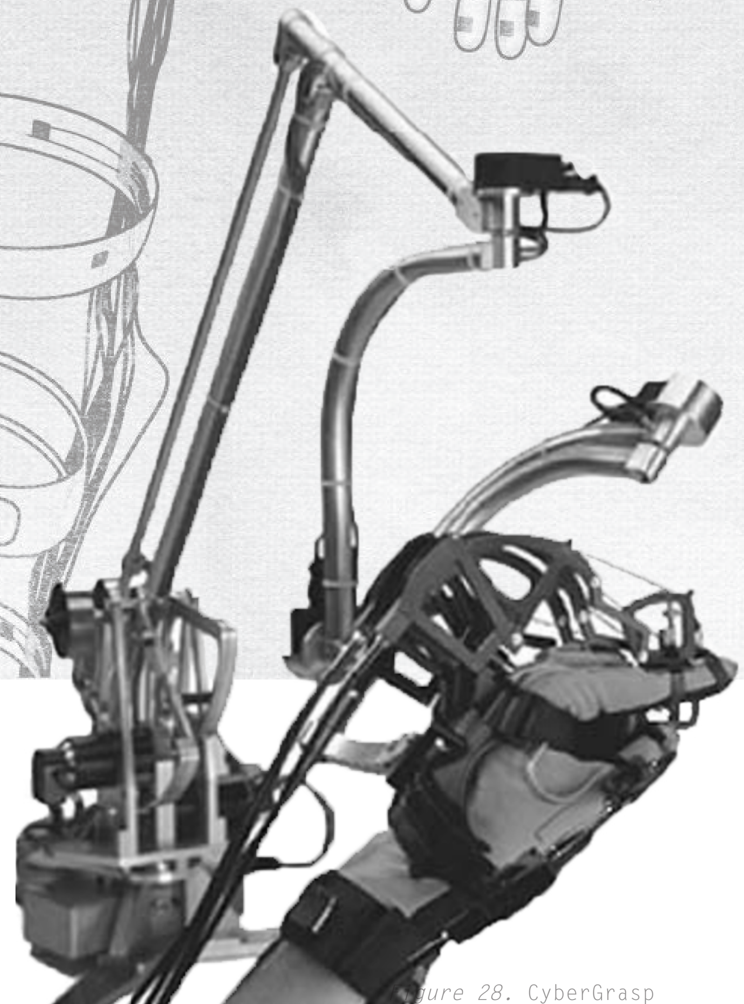


*Figure 28.* CyberGrasp

# tech for transparency

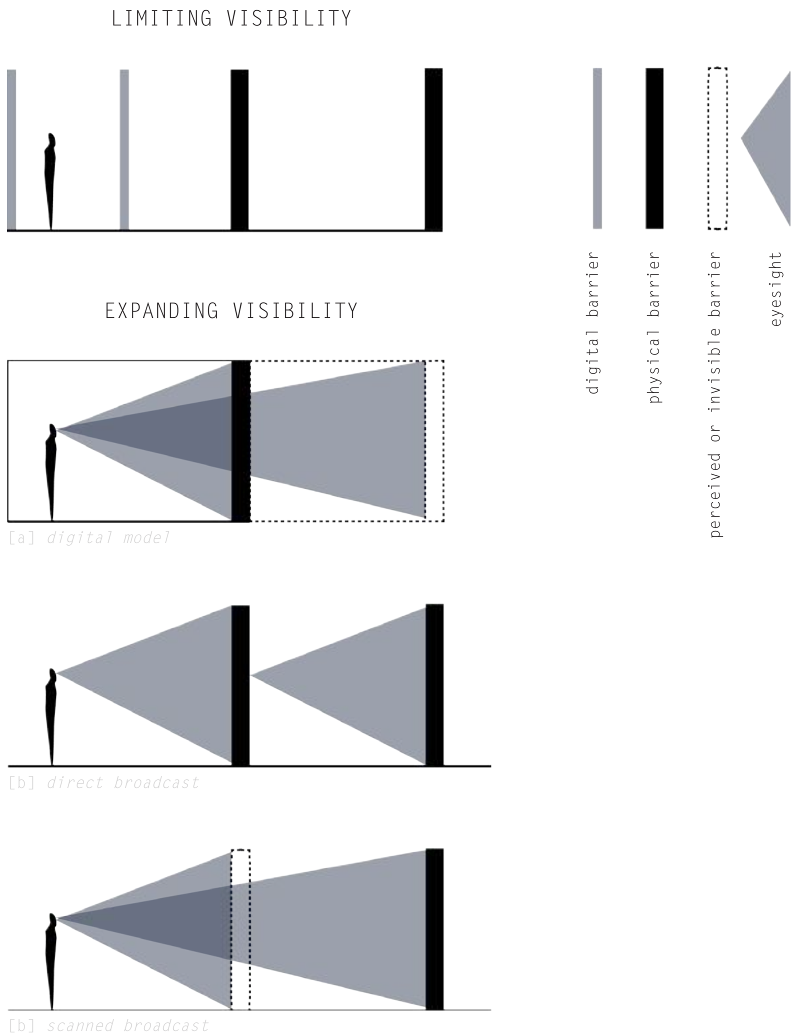



*Figure 29.* Technology options for transparency manipulation

As mentioned in the conclusion of the research part, one of the aims of this chapter is to explore the technological means (both - developed and under development) that could potentially allow to perceive digital expansion and compression of a physical space and an actual change in physical environment.

**Digitally limiting physical visibility can be rather easily achieved by creating digital barriers, as showed in *Figures 23 & 29*. It is the illusion of transparency, or in other words, digitally removing physical barriers, when it gets more complicated.**

There are three ways to create an illusion of transparency.

One way to achieve it is to use a 3D model of the building, allign it with the physical building in scale 1:1 and render desired spatial modifications. (*Figure 29*, [a]) However, this option would not allow to see changes in the building made after the last update of the digital model, such as remodeling, different furnishing solutions and people.

Another option could be having multiple cameras in the building and replacing the person's real eyesight with the broadcast of the camera that is located behind the physical barrier. (*Figure 29*, [b]) This would allow seeing all the changes in the evironment as they happen. However, it would require a great number of cameras in the buiding and it might be difficult to match the angle of the camera with the motion of a user moving towards the perceived space.

Lastly, there is 3D scanning. In theory, a person could scan several rooms around her/him, remove barriers in the scanned model and project the result as if the barriers were never there. (*Figure 29*, [c]) In practise, most of the cameras and scanners used in augmented reality only register the surroundings up to the point where the barrier begins, and do not register the environment behind the barrier.

# environment recognition

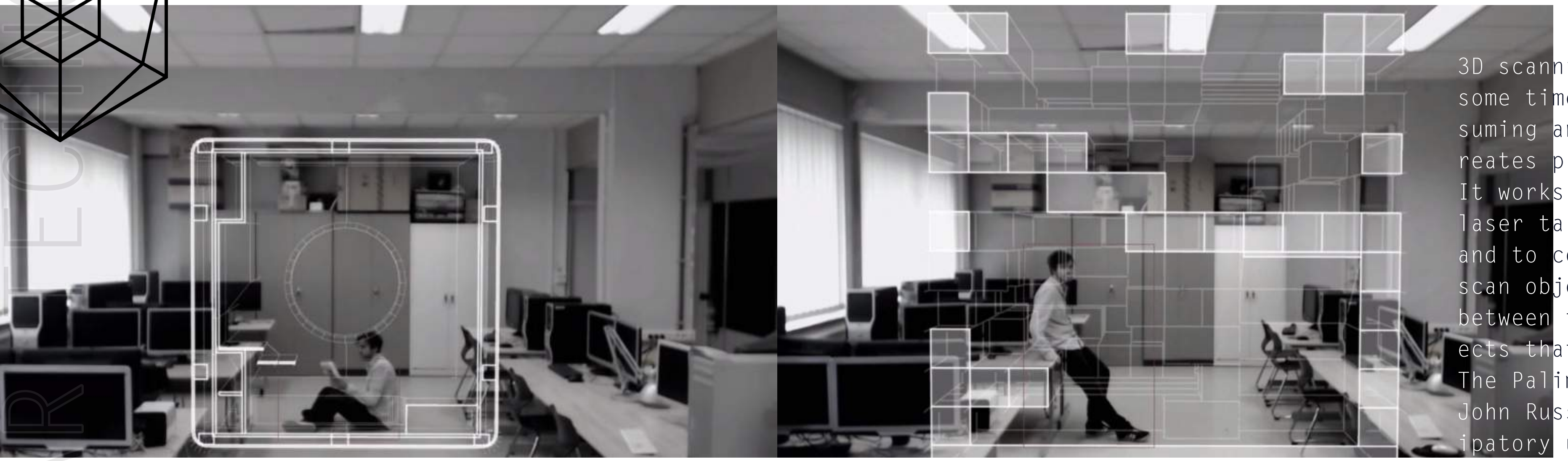


*Figure 30.* Perspectiva Virtualis (Source: Lachard & Rippinger, 2016)

**There are multiple environment recognition technologies being used today and quite a few still under development. There are several though, that I would like to point out due to their potential to be used for digital manipulations of physical transparency.**

## DEPTH CAMERA

A good environment recognition example is Microsoft Kinect. The device has several sensors, one of which is IR emitter that projects a pattern of infrared light into a room. As the light hits a surface, the pattern becomes distorted, and the distortion is read by another sensor. The depth camera then analyzes IR patterns to build a 3D map of the room as well as objects and people in it. An example of using depth recognition camera for an augmented reality in architecture project is last years winning project of the gUURROO Innovative Minds 2016 competition Perspetiva Virtualis by Arthur Lachard and Julien Rippinger. The project explores the relationship between two spaces: one virtual and one tangible and build. (*Figure 30*)

## LASER SCANNING

3D scanning has been used in architecture for quite some time now, mostly laser scanning. It is time consuming and requires powerful equipment, but it recreates precise digital models of physical buildings. It works by the principle of measuring the time that laser takes to hit whatever object is in the space and to come back. Therefore, it can only be used to scan objects that aren't blocked by any obstacles in between the object and the scanner. One of the projects that utilized 3D scanning and virtual reality is The Palimpsest by Takashi Torisu, Haavard Tveito and John Russell Beaumont, a proposal to improve participatory urbanism. (*Figure 31*) In this project a real environment was scanned using the FORD Focus 3D X 330 Laser Scanner. The scanner collected environmental point data around itself three dimensionally in 1 to 1 scale and generated that data into virtual environment, in which participants were allowed to walk around. (Torisu, Tveito & Beaumont, 2016)

## SCANNING THROUGH BARRIERS

3D scanning through barriers is a topic that is being explored by various scientists. Israeli based tech startup Vayyar has developed a sensor that uses radio waves to generate 3D images of objects hidden behind obstructions. (Lynley, 2015) MIT scientists been working on a prototype for a time of flight microwave camera which can be used to image objects through walls, in 3-D. (Ackerman, 2015) The result images of both technologies are still primitive, but promising.

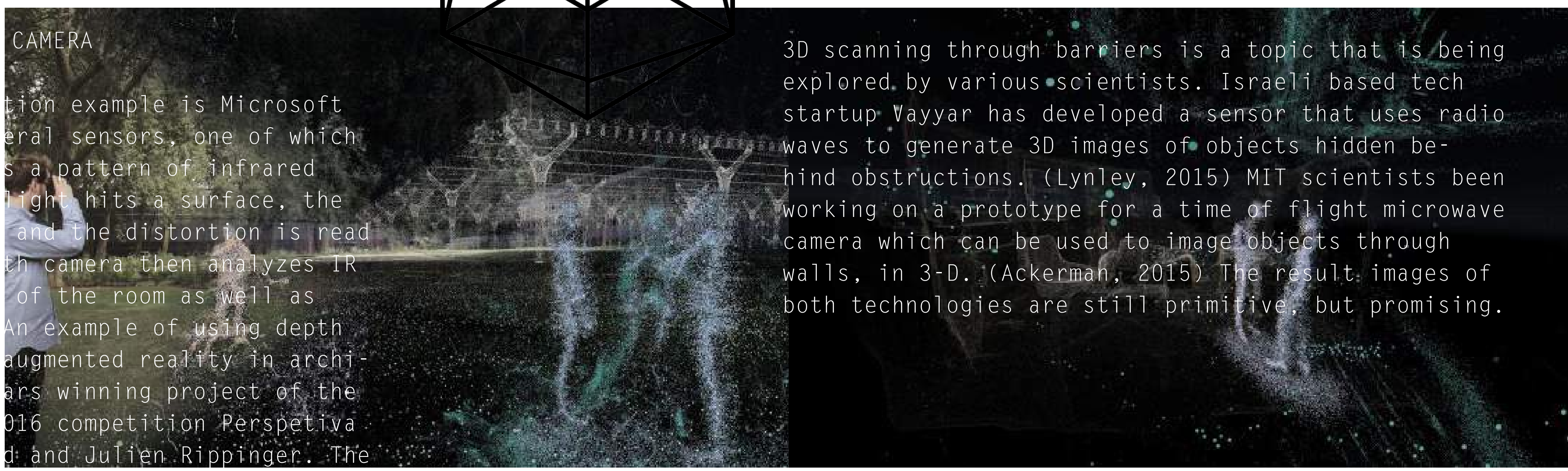


*Figure 31.* The Palimpsest (Source: Torisu, Tveito & Beaumont, 2016)

# conclusion

Technology as proved by computers and smartphones is evolving quickly, getting smaller and cheaper, therefore more accessible to consumers.

AR and VR is getting more and more immersive. Development of AR contact lenses, haptic technology as well as gaze, gesture and voice control are going to contribute to the immersiveness even more.

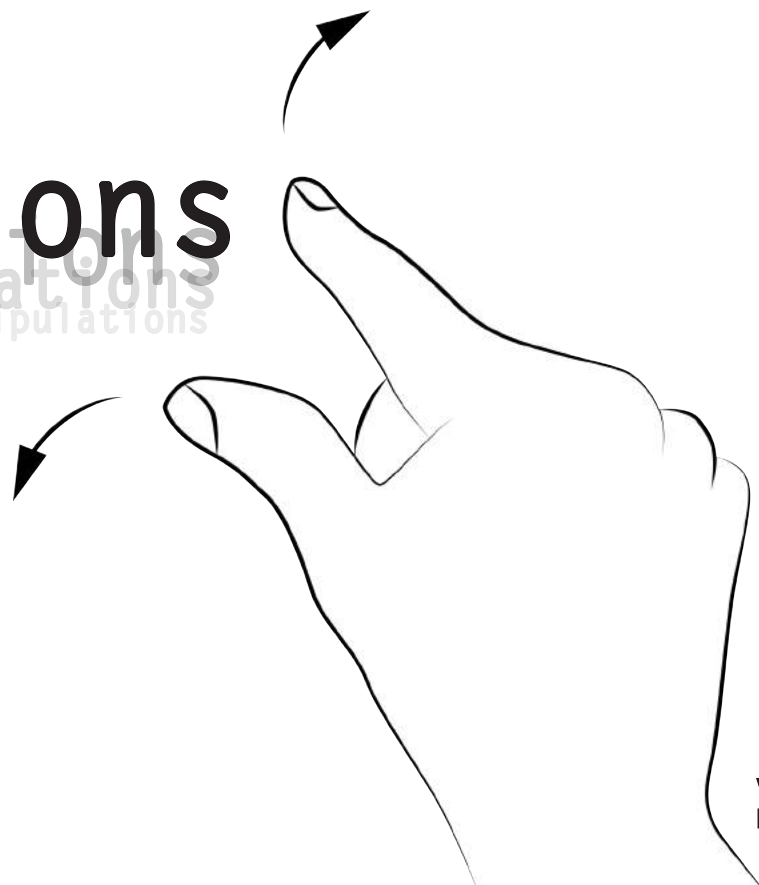
There are several possible technological concepts that could allow us to digitally manipulate physical transparency, such as using an online digital 3D model of a building, direct broadcast or sophisticated environment recognition technologies.But once it is made possible, what ways should spaces be manipulated in?

# EXPLORATION

## part two

# spatial manipulations

spatial manipulations
spatial manipulations
spatial manipulations



# transformations

**There are a number of ways to digitally manipulate physical visibility.** *(Figure 32)*

This chapter is presenting a collection of thoughts on ways to spatially augment physical architecture. To introduce spatial transformations as clearly as possible six chapter sections will follow, each of them presenting a different approach. *(Figure 33)*

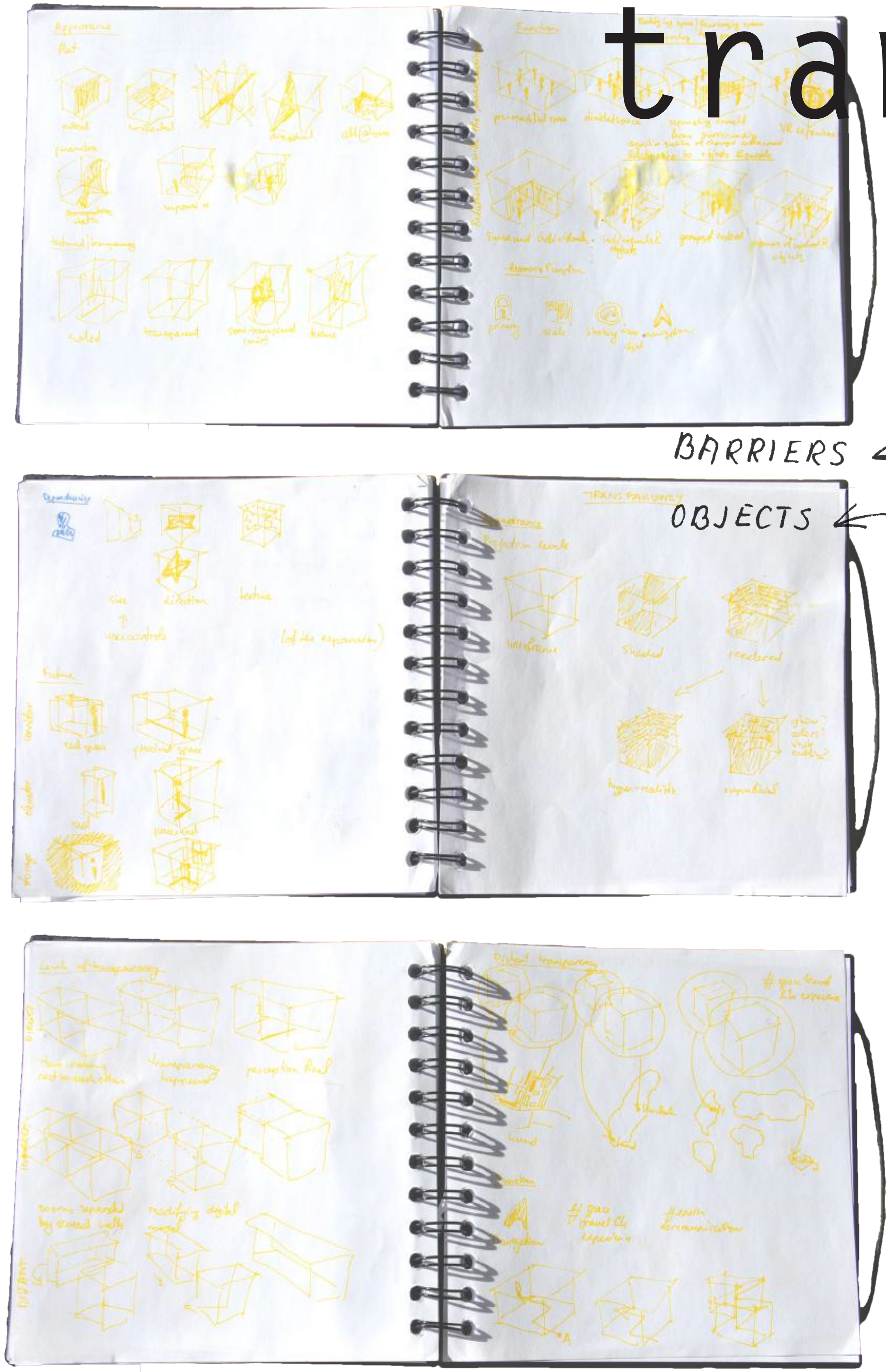


*Figure 32.* Sketches

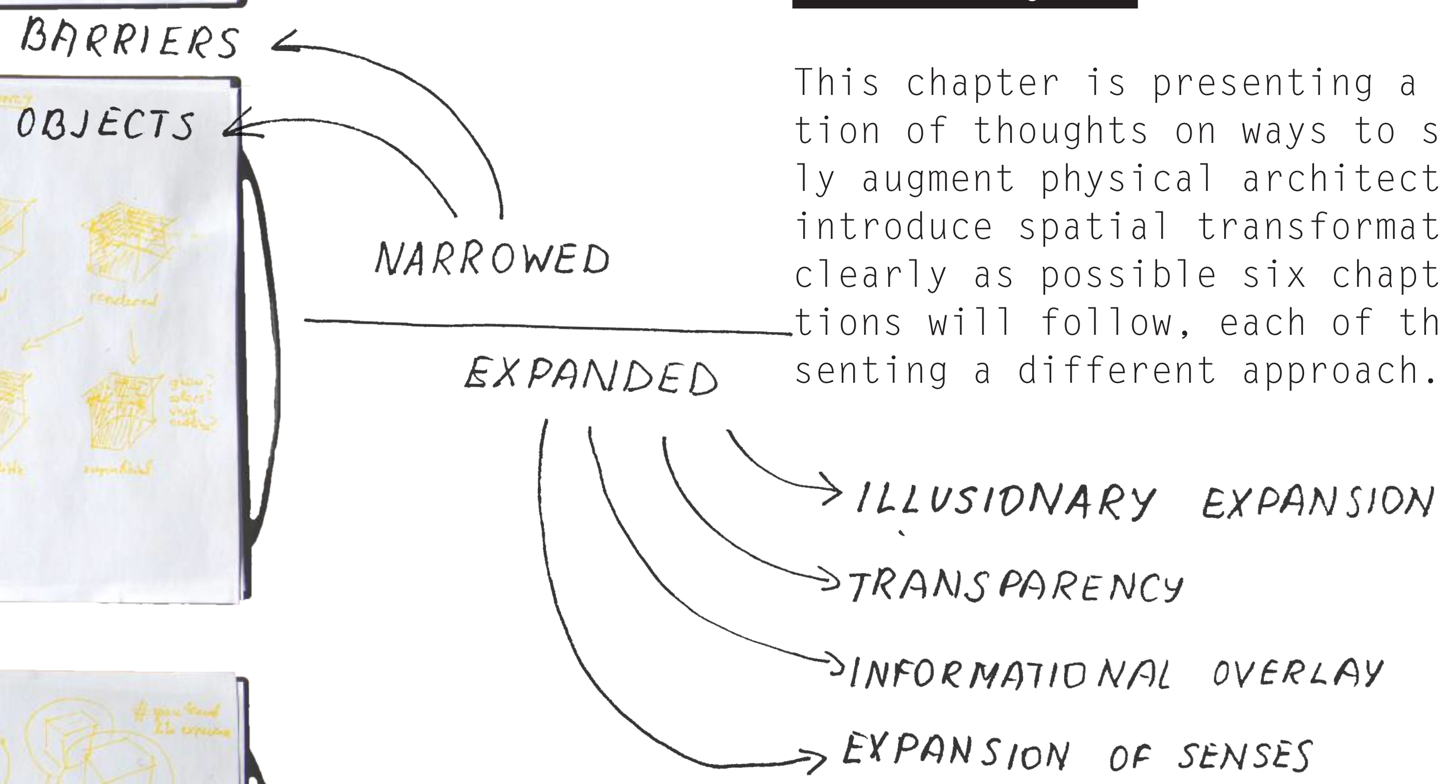



*Figure 33.* Transformation categories

Visibility can be narrowed by creating digital barriers, also through manipulation of physical objects in the room. Visibility can be expanded in different ways - creating an illusion of expansion of the space, creating an illusion of real transparency, overlaying space and/or objects with additional information, expanding visibility through senses other than sight.

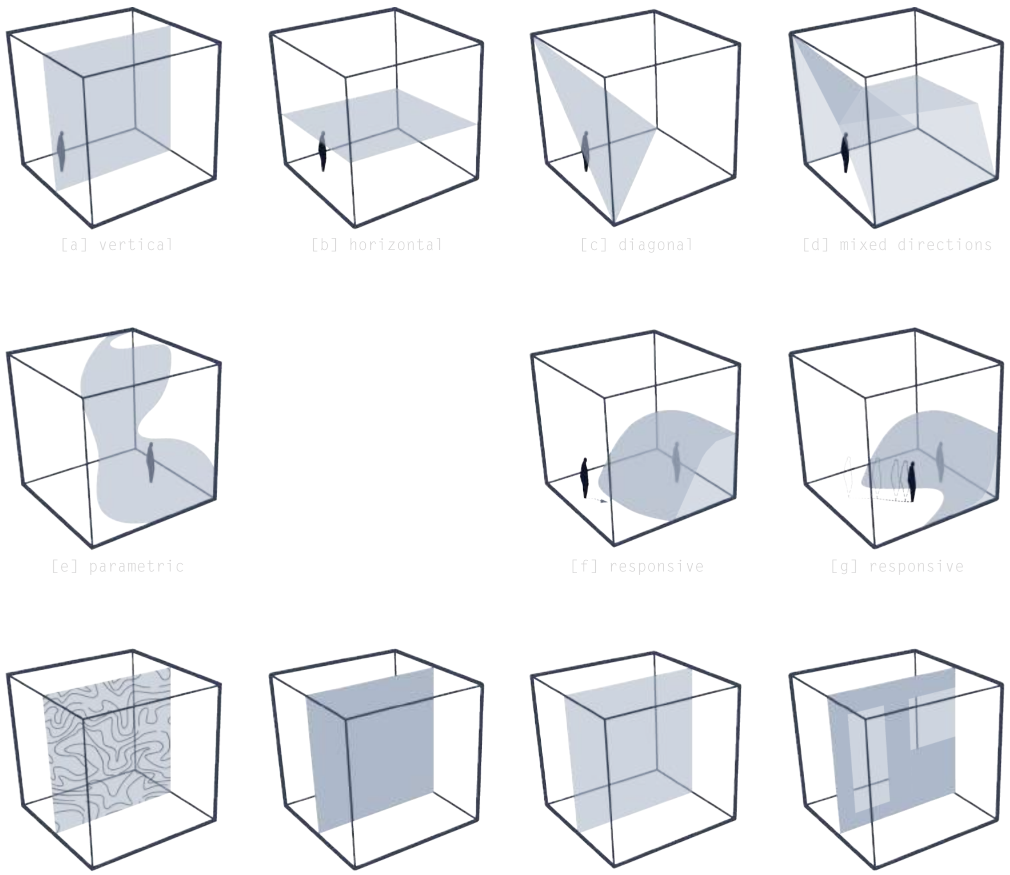
# barriers

## APPEARANCE

Barriers could be flat - vertical, horizontal, diagonal. They could also be parametric and responsive to the environment, e. g. a personal space could shrink and expand depending on the people's movement in the surrounding area. *(Figure 34)*

Barriers could be of a solid texture, or transparent, or semi-transparent. Transparency could represent the desired level of privacy.

*Figure 34.* Digital barriers' appearance variations



[a] vertical [b] horizontal [c] diagonal [d] mixed directions

[e] parametric [f] responsive [g] responsive

[h] textured [i] solid [j] transparent [k] semi-transparent

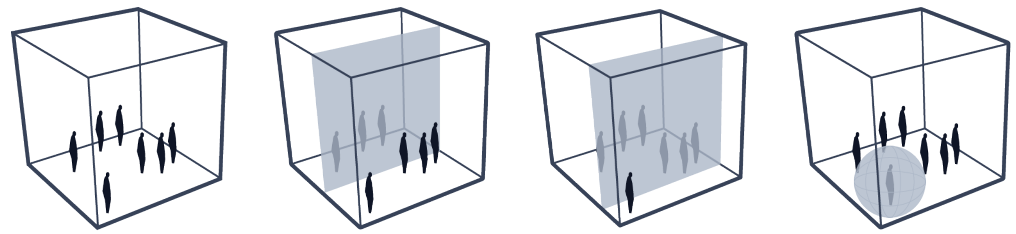
## PERSONALIZATION

Barriers and spaces they create could be personalized by using pictures, adding objects, creating a representation of a familiar space by adjusting size and texture of the barriers. Personal spaces could be predesigned to fit the personality of a user.

## IMMERSIVENESS

The more the view of the physical world is limited, the more the personal space created by digital barriers experience will resemble the one of the virtual reality. *(Figure 35)*

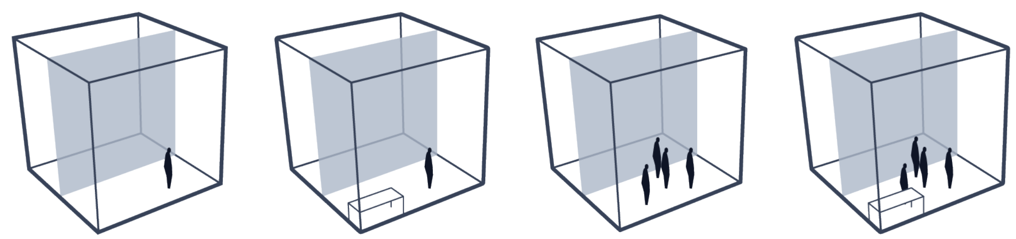
*Figure 35.* Levels of isolation



[a] space before creating digital barriers [b] isolation with other people [c] isolation with the enironment [d] complete isolation

Visual barriers could be created in digital overlay to divide the space and separate one-self from surroundings. They could also create enclosed personal spaces for users which would allow for experience similar to the one of virtual reality. Enclosed spaces could surround invividuals, groups of individuals, or groups of individuals and parts of their environment. Immersiveness of augmented and virtual reality depends greatly on a feeling of presence, or a sence of being in an environment, which is explained quite thoroughly in Torisu's article article 'Sence of presence in social VR experience'. Personal presence is a subjective feeling of being a part of the environment. Personal presence in a virtual environment could be ensured by something as simple as users'

*Figure 36.* Types of feeling of presence



[a] personal presence [b] environmental presence [c] social presence [d] mixed presence

virtual hand mimicing the movement of his real hand when moved. This way an illusion of ownership is created. Environmental presence is perception that a virtual environment exists and that the user is present within it. Social presence is about social connections that a user makes to entities within a virtual or augmented space. Most immersive experience could be reached by ensuring all levels of presence. *(Figure 36)*

## FUNCTIONS

**Reasons behind creating barriers could be vary - manipulating the feeling of privacy, bringing down the unpleasant scale of a large empty space, blocking disturbing, distracting or unpleasant view. Barriers could be used for visual expression of navigation in the space, or for blocking physical light from entering it.** *(Figure 37)*

*Figure 37. Functions*


[a] privacy [b] bringing scale down [c] bocking view [d] navigation

## COMPREHENSIVENESS

To create a complete experience of isolation, digital platform could not only affect visibility, but also hearing with the help of earplugs, headphones or other integrated technology. *(Figure 38,* [a] & [b]*)*

## DEPENDENCIES

Barriers could be turned on and off by the user when needed. The digital platform could provide suggestions, but the user should have the possibility to design and modify barriers him/her-self.

Each building could to a certain extend pose its own design limitations and restrictions in order to ensure security, prevent evacuation paths from being obstructed, architectural consistency of the modified space. *(Figure 38,* [c] & [d]*)*

*Figure 38.* Comprehensiveness & Dependencies

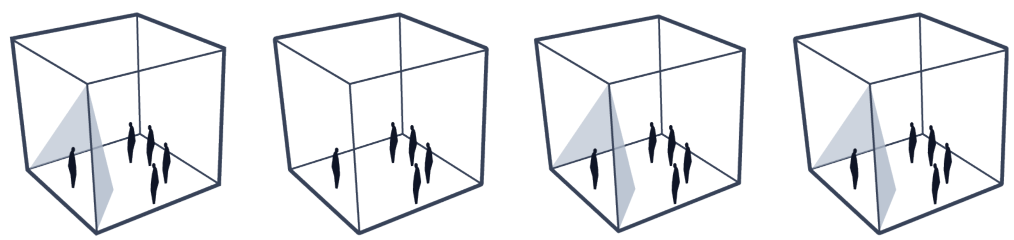

[a] airplugs [b] headphones [c] user [d] building

## PERCEIVED PRIVACY VS REAL PRIVACY

If a digital platform allowing to manipulate digital transparency was put to use today, digital barriers would not guarantee real privacy, only the perceived one. That is simply because such platform would not be used by every single person in the building immediately, and therefore the digital barriers would only be seen by the person who created them. If, however, in a certain amount of time the technology became as popular as a smartphone has become now, and almost everyone had and used it, then the definition of privacy created by digital barriers could be questioned. If everybody had the technology and using it had become a social norm, then a possibility of real privacy, even if created by only digital barriers, could emerge. *(Figure 38)*

Should everyone see each others digital barriers?
If so, the possibility of real privacy emerges. If, taking a step even further, everyone were obliged to see each others barriers, then real privacy could be assured. If not, however, then space could be used more efficiently - one could choose what to see and what not, their view would not be overloaded with everybody elses realities.

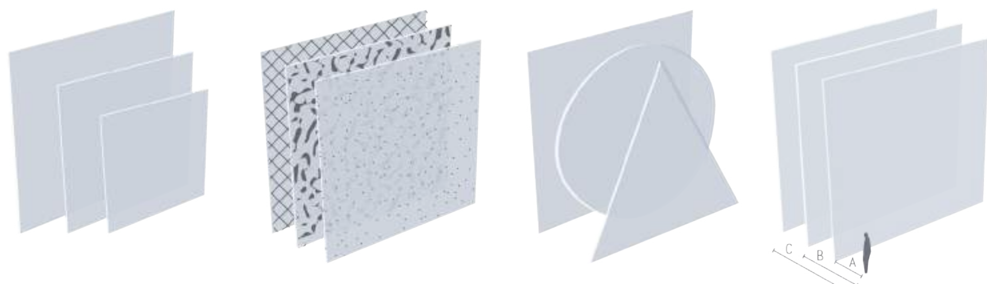
*Figure 38.* Perceived privacy VS real privacy


[a] perceived privacy, user's perception [a] perceived privacy, others' perception [b] real privacy, user's perception [b] real privacy, others' perception

# objects

## PARAMETERS

**Once the environment is scanned, each of its elements could be evaluated based on certain parameters such as size, materi-al, shape, or distance from the user** *(Figure 39)*



[a] size [b] material [c] shape [d] distance

*Figure 39.* Objects' evaluation parameters

Objects could be grouped if needed and their visi-bility could be altered, the space could be project-ed with the emphasis on selected objects or, on the contrary, without them at all. *(Figure 40)*

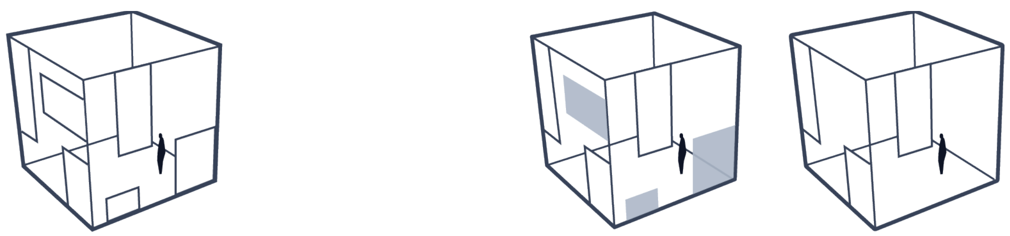

[a] physical objects [b] emphasis of selected objects [c] alleviation of selected objects

*Figure 40.* Objects' manipulations

## APPEARANCE

When removing objects, the view of the space stays the same except for the lack of the missing objects. When emphasizing objects, either the surroundings could fade into greyscale or monochrome palette, or the selected objects could be projected with the emphasis on them by changing their color, adding a contour line or a glow.

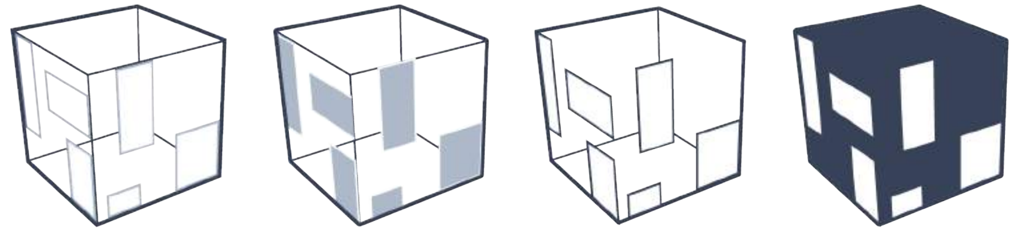

[a] contour [b] color [c] faded surroundings [d] alleviated surroundings

*Figure 41.* Appearance variations

## DEPENDENCIES

The option should be switched on and of by the user according to the need. The user should also set the evaluations criteria.

Resulting view of course depends on the user's view-port direction and surrounding objects and their physical qualities.


[a] user [b] viewport [c] objects

*Figure 42.* Dependencies

# illusionary expansion

Small spaces could be visually expanded by showing the room bigger than it physically is, whilst visual space not being representative of an actual space inside the building, or in other words, - using digital overlay to create an illusion of a bigger space. *(Figure 43)*

Such method could be used for psychological reasons - to alleviate the unpleasant claustrophobic feeling in elevators or other uncomfortably small spaces.

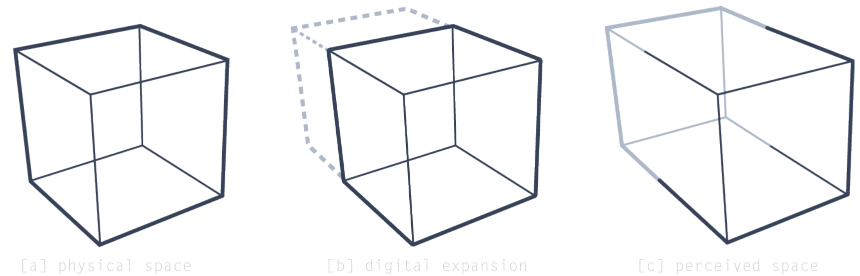



*Figure 43.* Illusionary expansion

## APPEARANCE

For most natural appearance, both - the physical space as well as the digital expansion - should have the same materials and textures. *(Figure 44)*

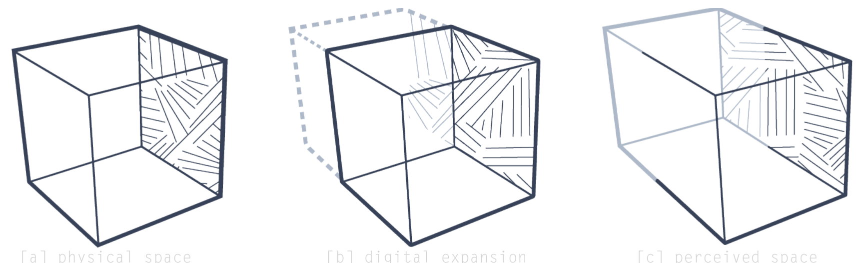



*Figure 44.* Texture

## DEPENDENCIES

The option should be switched on and of by the user according to the need. The user should also be able to control size, direction and textures of the expanion. *(Figure 45)*

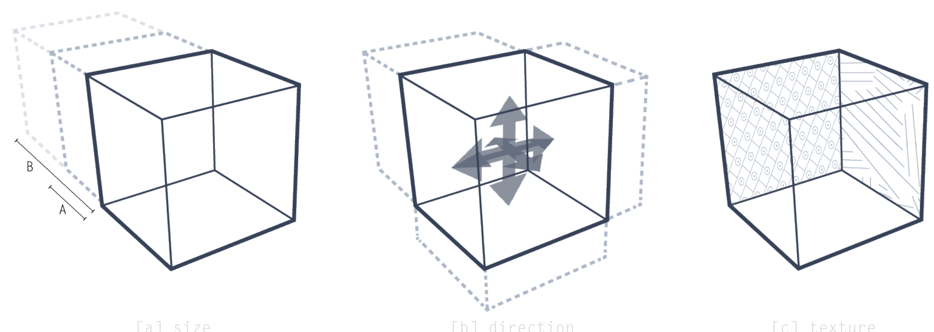



*Figure 45.* Control parameters

If in a distant future, the digital overlay were to become a norm in people's everyday lives and a consideration in every architect's project, illusionary expansion could be used every time if the actual needed physical space in a building is small, but becomes unpleasant when designed so, e.g. elevators, narrow corridors, dark storage spaces. In such case, spatial modifications would be predefined in a building and everyone would see them without having to set it up first. *(Figure 46)*

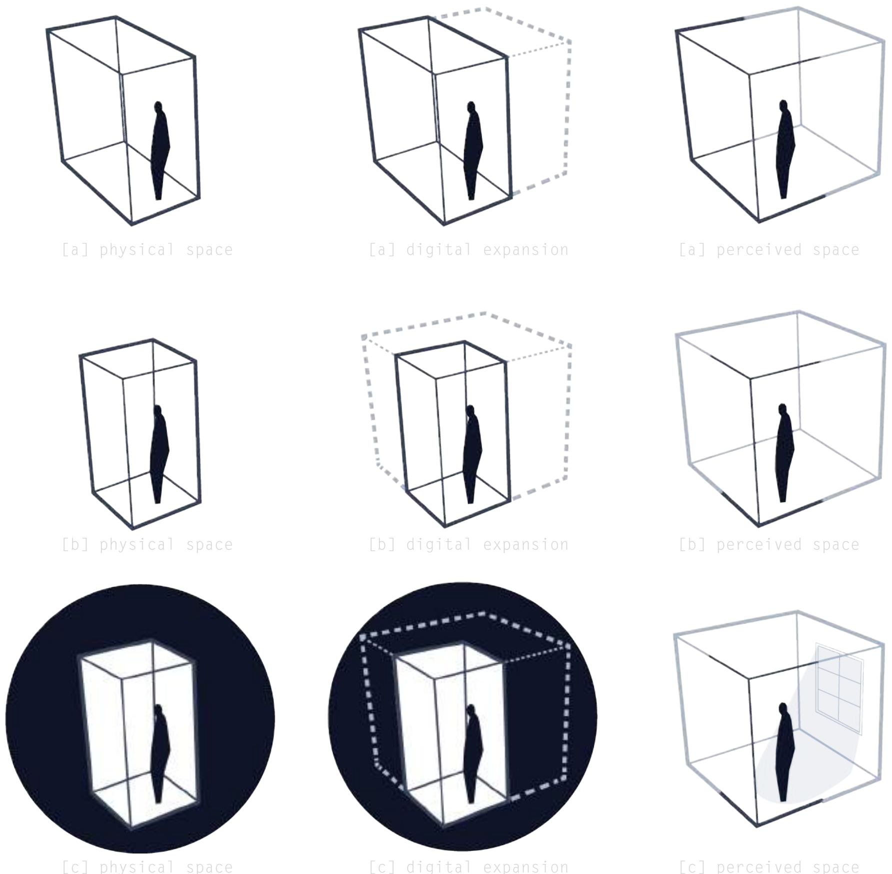



*Figure 46.* Examples of use in a narrow corridor [a], elevator [b], storage room [c]

# transparency

**The difference between illusionary expansion and illusion of transparency is that in case of simulating transparency, a representation of a real physical space instead of an imagined one is projected as an extension of the room.**

## TRANSPARENCY LEVELS

Several levels of transparency could be achieved by the digital overlay. Direct transparency can be achieved by digitally removing physical walls and therefore creating perceived merged spaces with meaningful visual connections between people and space, people and people or people and objects. *(Figure 47, [a])* Indirect transparency contains merging spaces that are separated by several walls and creating a perception of the two rooms as one space. *(Figure 47, [b])* On an even broader sense, distant transparency could be achieved by digitally merging spaces that are not physically located in the same building (e.g. several university departments could have their

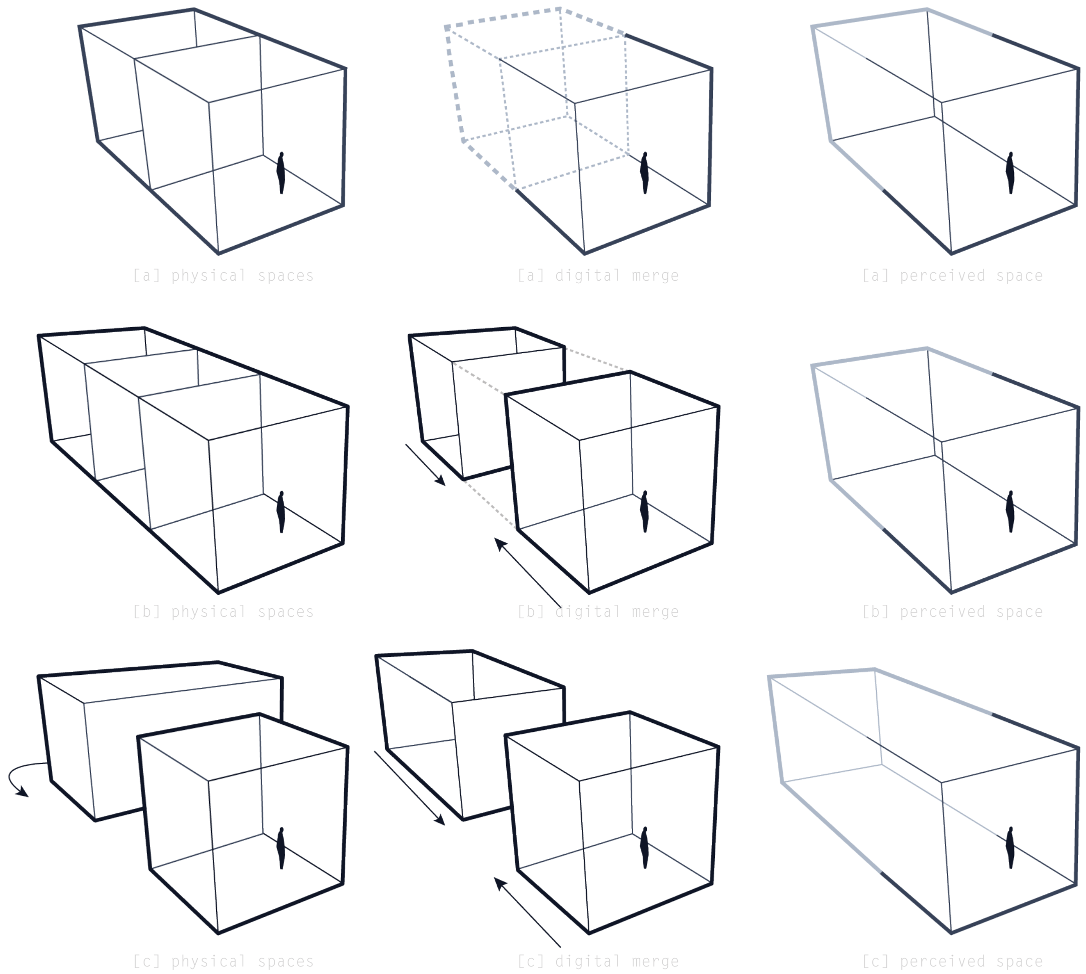



*Figure 47.* Transparency levels: direct [a], indirect [b], distant [c]

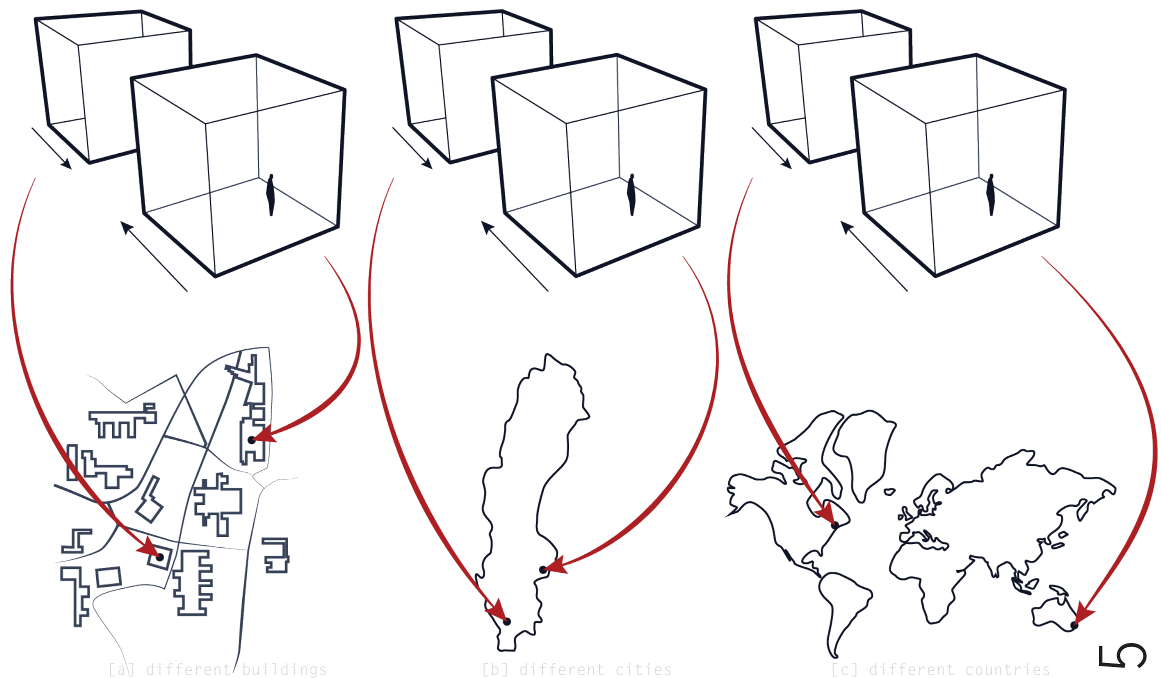



*Figure 48.* Examples of distant transparency

conference halls connected through a digital platform; headquarters of an international company that is located in sveral continents could have their conference rooms perceptually connected). *(Figure 47,* [c]; *Figure 48)* Each one of the transparency levels distorts one's understanding of buildings and space.

## APPEARANCE

Appearance of the added spaces by removing barriers could vary as much as graphics vary in architectural renderings. Spaces could be projected as wireframe, shaded, or rendered. Rendered view could be hyper-realistic making it difficult to tell which spaces are physical and which not, or they could be slightly less realistic so that one could tell the difference between physical space and digital overlay. *(Figure 48)*

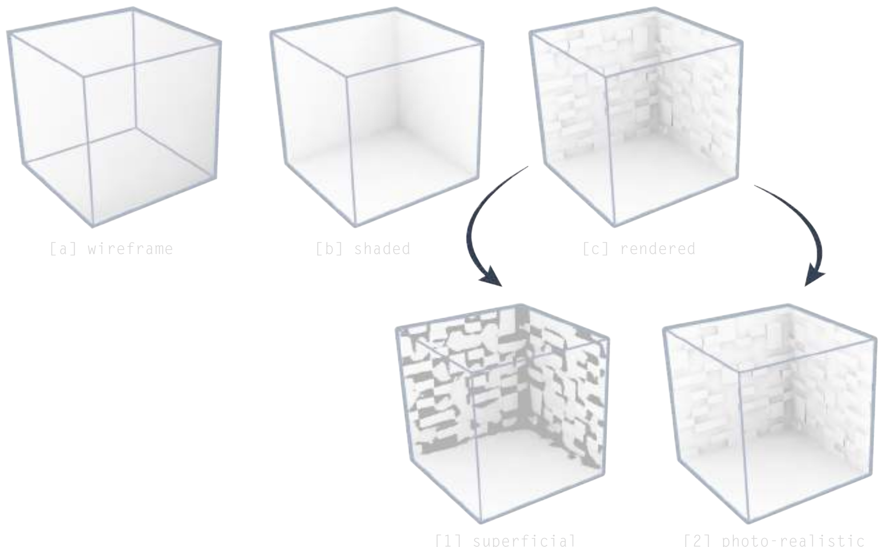



*Figure 49.* Transparency projections' appearance variations

## FUNCTION

Transparency could be used to visualize navigation within the building. *(Figure 50,* [a]*)* It could also be used to create meaningful visual connections between people and space, people and people or people and objects. *(Figure 51)* Indirect transparency would allow for a teleportation like experience. *(Figure 50,* [b]*)* Distant transparency would make spaces that are far away more accessible. It would also allow for easier and more immersive communication between people, institutions, companies. *(Figure 50,* [c]*)*

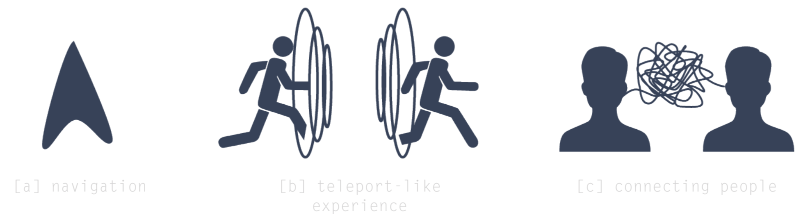



*Figure 50.* Function

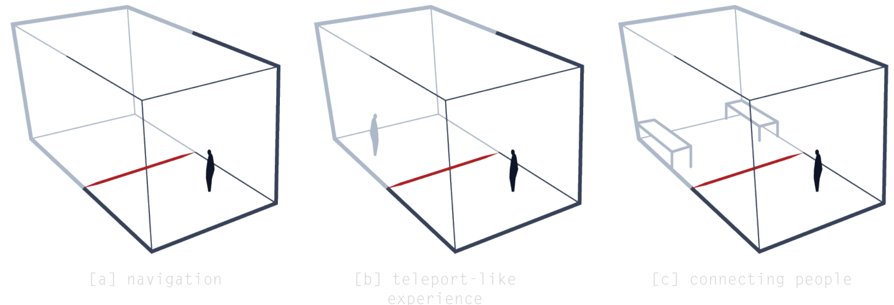



*Figure 51.* Function

## DEPENDENCIES

The option should be switched on and off and modified by the user according to the need.

To only allow a certain level of distortion of the building, site specific restrictions could be introduced, e.g. only several rooms can be brought to the viewport in the main hall; full scale lab can only project expanded space on the wall facing north, etc. *(Figure 52)*


*Figure 52.* Dependencies

## MOVEMENT

When the virtual and the physical blends together, and spatial perceptions are distorted, it can get difficult and even dangerous to orient oneself and move around the space. There are four main types of spatial relationships between the physical space and the added projection of another space. A room could be projected on an interior wall, unabling one to walk into it. *(Figure 53,* [a]*)* A room could be projected as an addition to the building, which would enable one to walk inside from the outdoors. *(Figure 53,* [b]*)* Walking through the space would also be possible if the projected space was fully or partially inside of a bigger physical space. *(Figure 53,* [c], [d]*)*

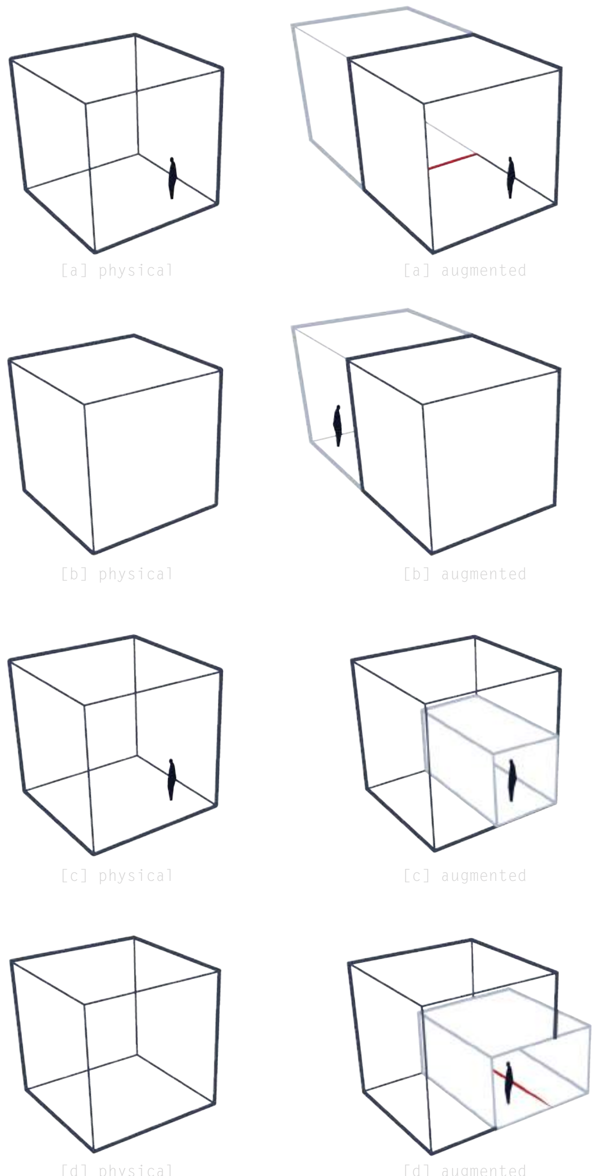



*Figure 53.* Mobility variations based on the relationship between physical and virtual spaces

## MULTI-FUNCTIONALITY

If each user saw the room expansion that they chose to see, then a minimal amount of physical space was used to achieve a great diversity of functions satisfying each of the users' needs (e.g. different lectures projected on an eastern wall of the main hall at A-huset). *(Figure 54)*

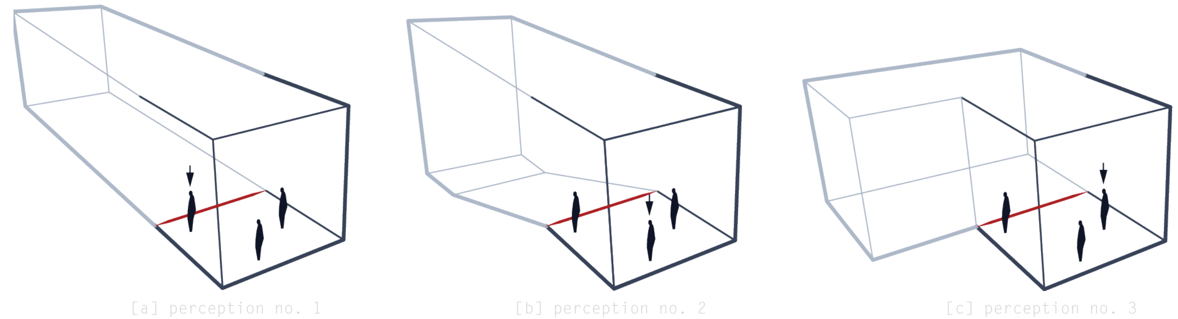
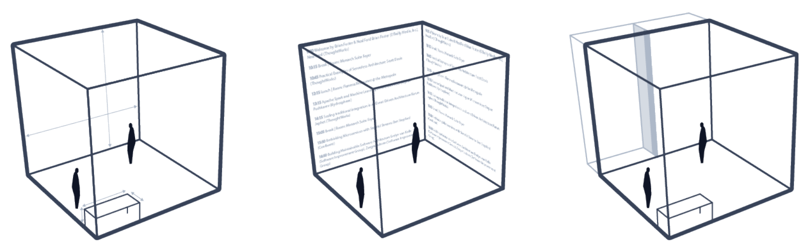



*Figure 54.* Multi-functionality

# informational overlay

**Informational overlay could present the data which expands the perception of space and objects in it**

Examples of this could be showing dimensions of objects, room activity information, presentation of materials & construction. *(Figure 55)*

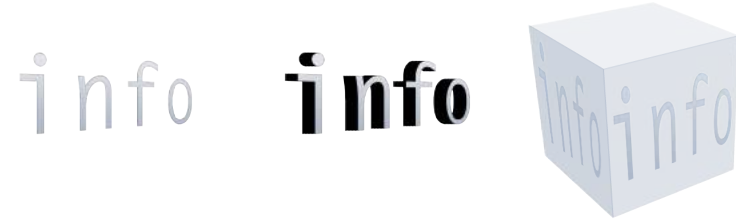


[a] dimensions [b] activity information [c] construction

*Figure 55.* Types of overlay

## APPEARANCE

Such overlay would most likely be two dimensional and contain textual information. *(Figure 56)*



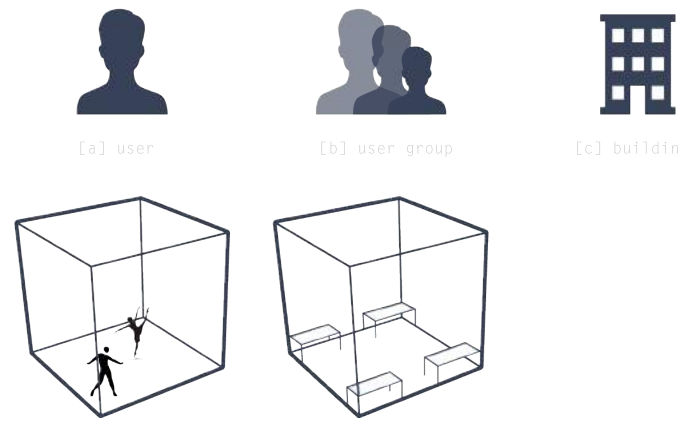

[a] 2D [b] 2D with depth [c] 3D

*Figure 56.* Appearance

## DEPENDENCIES

User should be able to choose which data to see and when to see it. Access to information could be restricted based on user groups (e.g. most access to professors, a lot to students, not so much to visitors).

Information projected would depend on the typology of the building, use of spaces, and objects within the spaces. *(Figure 56)*



[a] user [b] user group [c] building [d] use of space [e] objects

*Figure 57.* Dependencies

# expansion of senses


*Figure 58.* Senses

Our perception of space is not limited to only visibility. We perceive spaces by hearing sounds and noise, feeling texture of material, smelling (e. g.cafeteria, wood workshop, courtyard, bathroom). What if those senses could be used to enhance our visibility and perception of space as well?

There have been a few attempts to create a desired perception by using other senses than human body normally would to register specific signals. A couple of interesting examples are mentioned bellow.

## FEELING THE DIGITAL

One way to expand perception through senses could be introduced by the development of haptic technology. Originally it offers the physical experience of touch and texture in virtual environments of virtual reality. But perhaps such technology could be implemented to enhance experience of extended augmented reality spaces.

One example of using haptics to alter the perception of the environment is David Eagleman's VEST (Versatile Extra-Sensory Transducer) that enables people who are deaf in both ears to understand speech by feeling vibrations rather than hearing the words. (*Figure 60*)

## HEARING COLORS

Neil Harbisson is a color blind cyborg, who learned to 'see' (recognize) color through sounds. What is such technology could be used to expand regular visibility? One would gain a possibility to 'see' things that would be invisible otherwise. (e. g. see/hear if someone is walking behind you, expand one's visibility from 180 to 360 degrees; see in the dark). (*Figure 59)*

*Figure 59.* Neil Harbisson

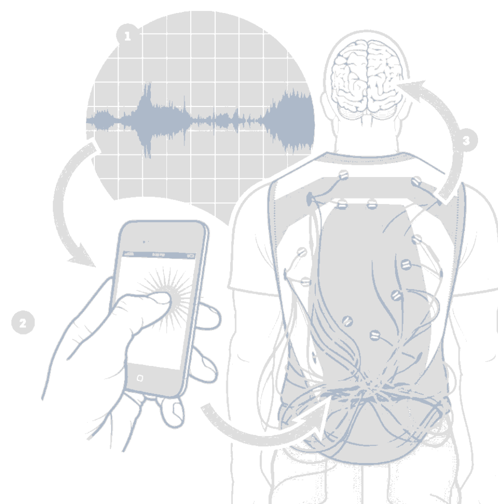


*Figure 60.* The principle of VEST

# conclusion

There is a number of different ways to digitally distort physical visibility - creating barriers, filtering objects, creating an illusion of expansion or transparency, - to name a few.

The content of this chapter suggests that manipulating physical visibility is a very broad topic and couldn't be covered comprehensively in itself because of its complexity.

**As a result of this, a smaller subtopic is chosen and inSIGHT is being further developed as an augmented reality platform to manipulate physical transparency.**

Transparency is being chosen as the key angle of spatial manipulations due to its inner complexity, lack of being talked about among augmented reality platforms and unquestionable ability to influence perception of space.

part three

# PROPOSAL

# inSIGHT, the digital platform

inSIGHT, the digital platform
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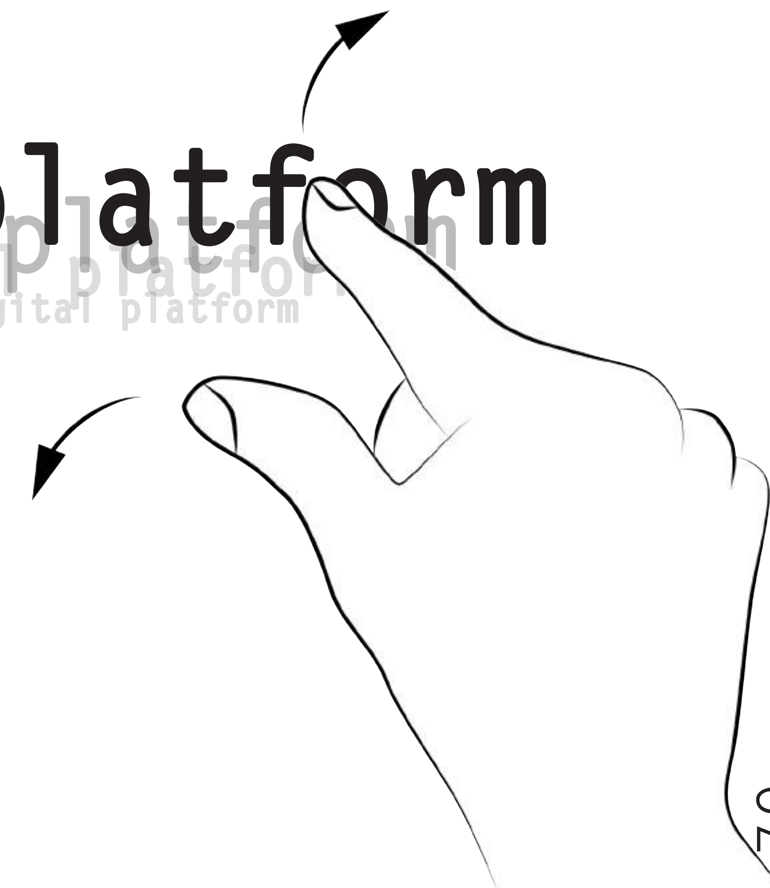
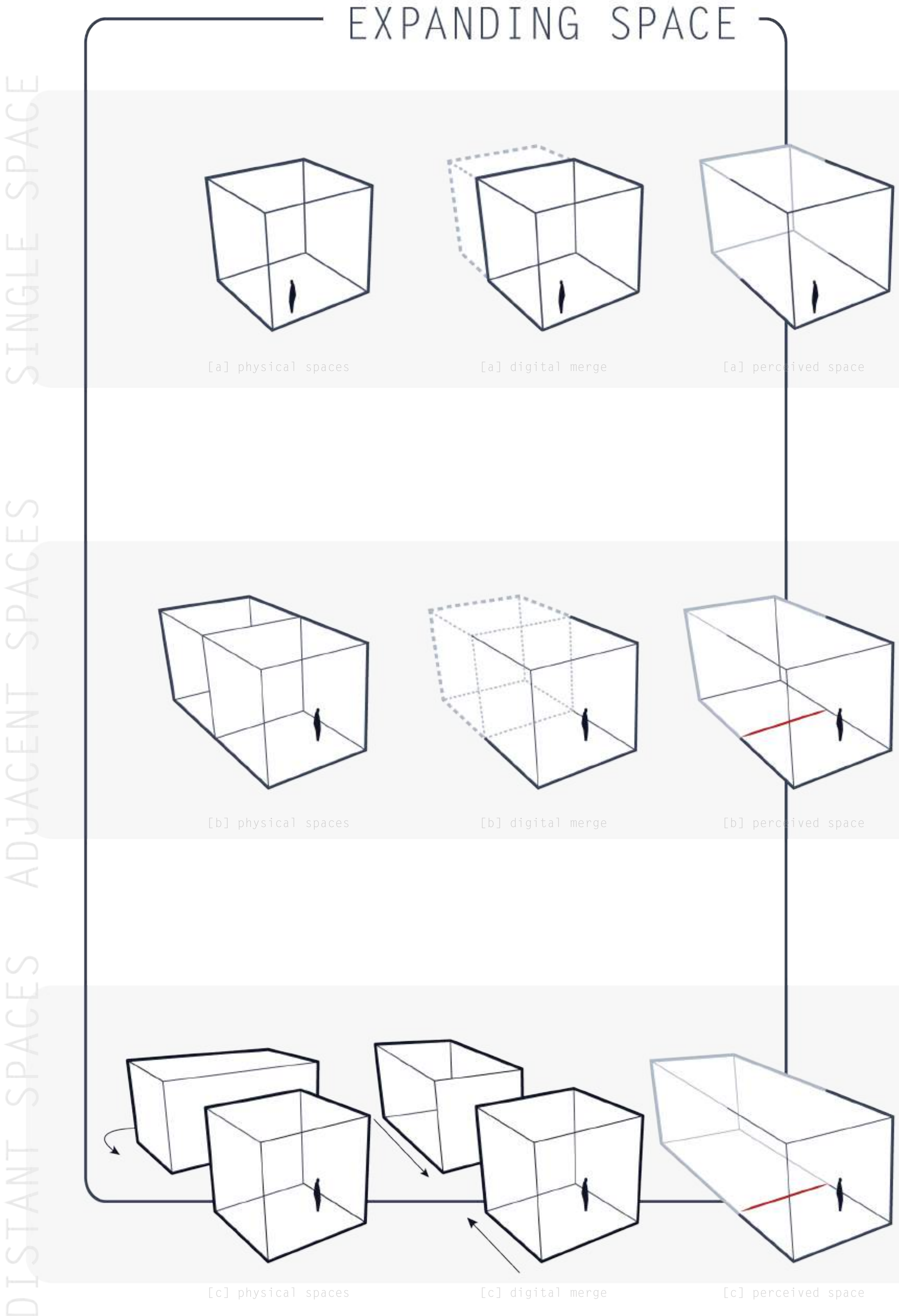
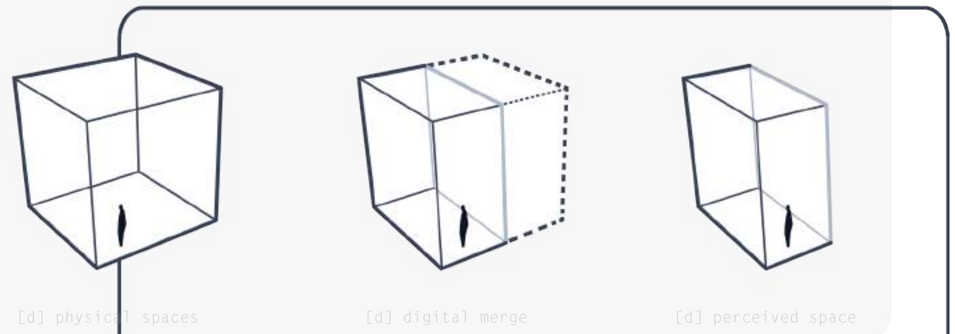





# inSIGHT

inSIGHT is an augmented reality platform allowing to digitally manipulate physical transparency - alleviate, and more importantly, enhance it. inSIGHT distorts the way people perceive physical architecture.

SHRINKING SPACE

With the help of inSIGHT, the perceptual space can be shrinked and expanded, according to the situation and need.

A single space can be manipulated by digitally pushing physical barriers to create an illusion of a bigger space, or digitally pulling them to create an illusion of a smaller one.

Adjacent spaces can be digitally merged together and seen without the barrier that physically separates the two.

Digitally merged and perceived as one room could also be two spaces that are not adjacent, but are rather on different sides of a building, or in different buildings, or in different cities, or in different countries and even continents.

**inSIGHT aims to propose new ways to interact with the physical environment and expand our perception of architecture. There are multiple ways to use inSIGHT to our advantage in every day life.**

By creating digital barriers one is able to create a feeling of isolation and privacy, to a certain extend. The feeling of claustrophoby can be alleviated by creating a perception of the space bigger than it actually is.

Digitally merging rooms, whether they are physically separated by a wall or an entire ocean, helps to connect the world on a spatial 3D level. It allows one to achieve a teleport like spatial experience.

In addition to all of the performances mentioned above, inSIGHT allows one to change surroundings instantaneiously and it also allows for multi-functionality. By multi-functionality I mean that the same physical space can be used much more efficiently because each user of the inSIGHT sees the space they choose to be in. *(Figure 61)*

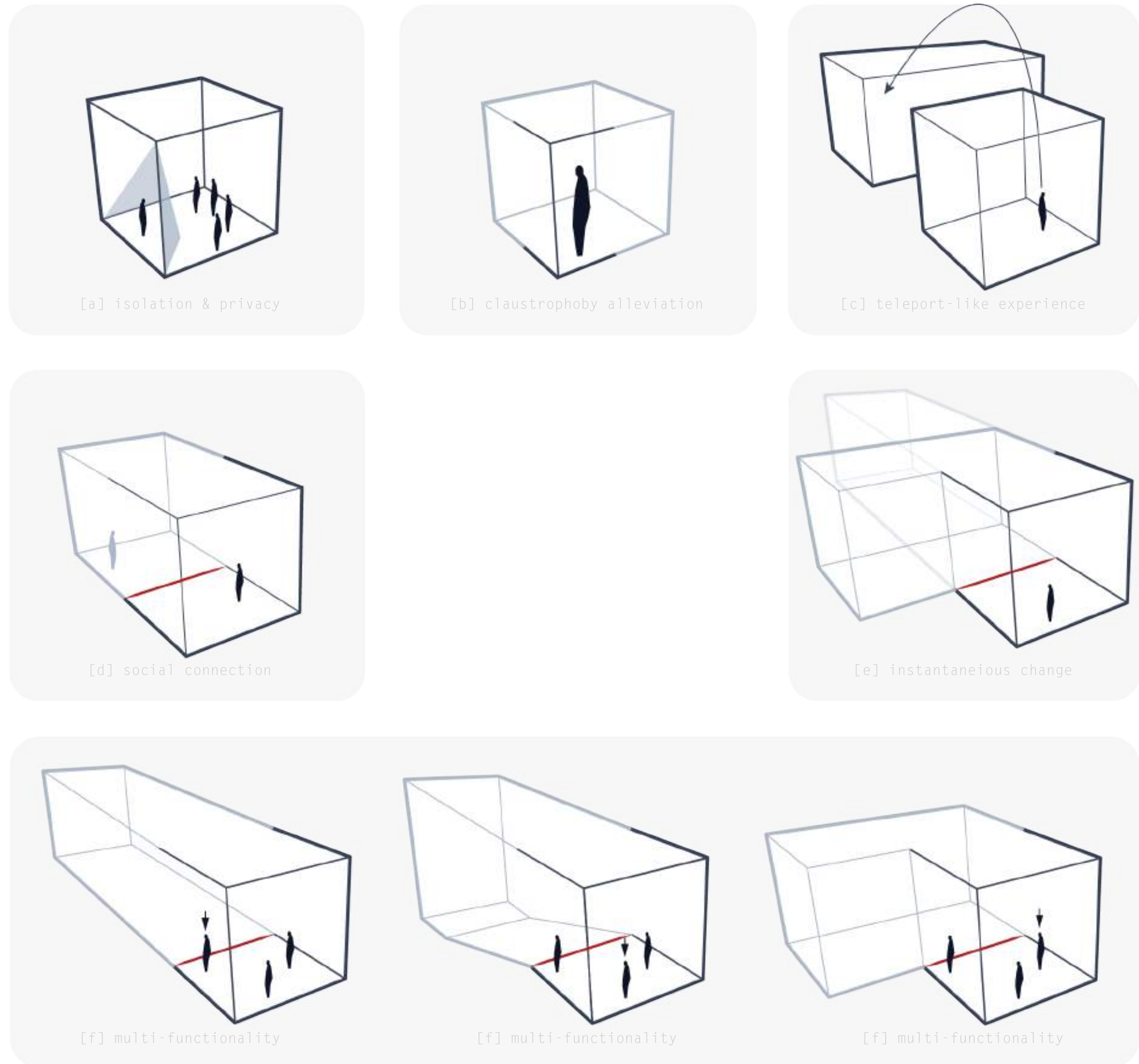



*Figure 61.* Benefitiancy

# technological concept

**inSIGHT functions on the basic augmented reality (AR) concept - scan, modify, position, render.** ***(Figure 62)***

It requires AR hardware - a 3D scanner, a computer and a screen. When the room is scanned, a digital model of it is created. The digital model can be modified - barriers pulled and pushed, textures changed, different lighting arranged. Finally, changes of the digital model are overlayed on top of the physical space and rendered to create the perception that the physical space has been changed as well.

To allow the perceptual merging of two physical spaces, an online database is created and used. Everyone using inSIGHT is benefiting to the database by automatically sending data of their current environment. This way, when adding a digital extension to a space, the user can pick a room from any building in the world and seamlessly merge it with the room they are in right now. *(Figure 63)*

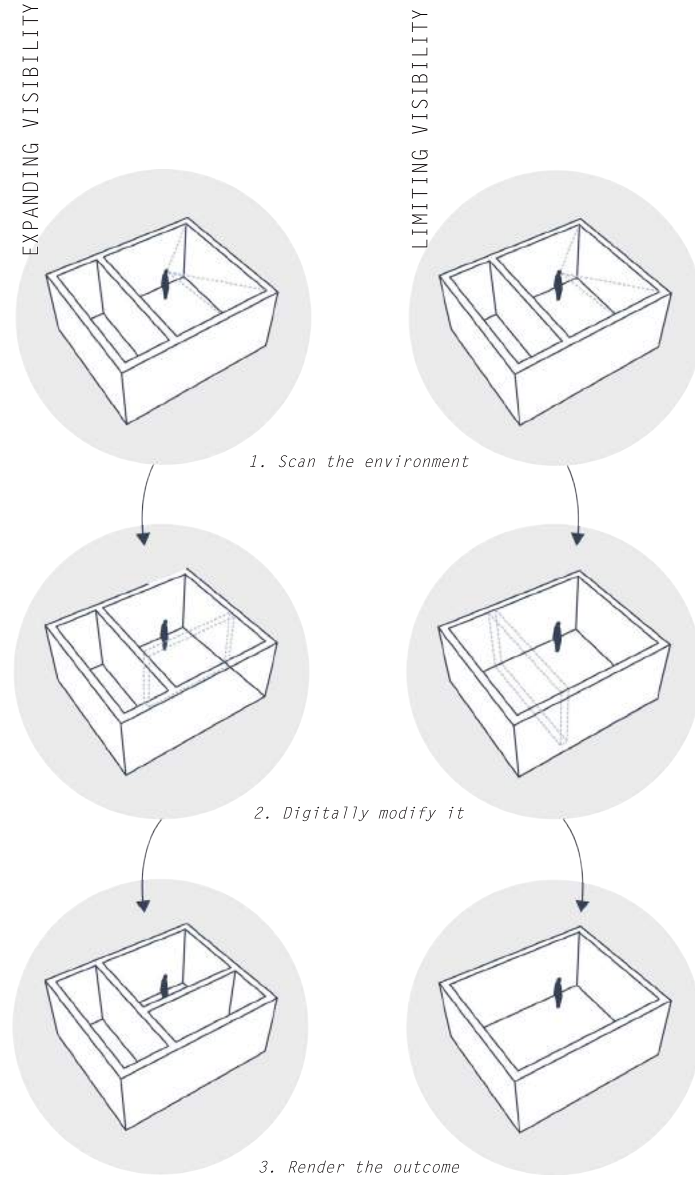



*Figure 62.* AR concept

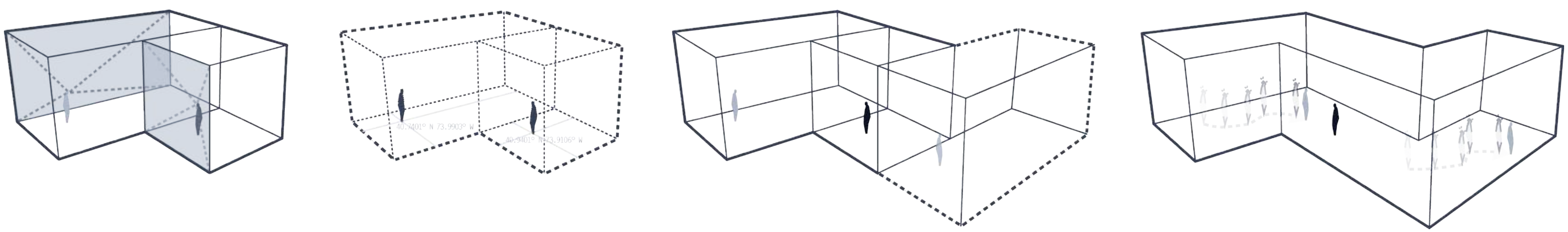



*Figure 63.* Open Source Database


*Figure 64.* inSIGHT devices now


*Figure 65.* inSIGHT devices in the future

# hardware

*Figure 66.* User interaction


As mentioned earlier, inSIGHT needs a lense, a computer and a scanner. These devices are already developed and are able to be adjusted to support inSIGHT. *(Figure 64)* However, current devices take a lot of space, are heavy and not easily portable.

Fortunately, looking back at the past few decades one notices that the growth within technology development is exponential. If technological growth keeps its speed, which it probably will, then in the future all the devices mentioned above will evolve into small portable ones. And this would allow for seamless inSIGHT integration into our every day lives. *(Figure 65)*

Addition of adequate sound system and haptic technology would create an even more immersive inSIGHT experience. As mentioned in the first chapter, voice commands and touchscreen control are already used fairly broadly on computer devices, so they could be quite easily implemented to inSIGHT hardware. Gaze and gesture control though are more difficult to accomplish at the moment as they are only currently being developed. But once generated, they would certainly inhance immersiveness of inSIGHT . *(Figure 66)*

# the boundary

When the virtual and the physical blends together, and spatial perceptions are distorted, it can get difficult and even dangerous to orient oneself and move around the space. There are four main types of spatial relationships between the physical space and the added projection of another space. A room could be projected on an interior wall, unabling one to walk into it. *(Figure 53,* [a]*)* A room could be projected as an addition to the building, which would enable one to walk inside the digital while being outside the physical. *(Figure 53,* [b]*)* Walking through the space would also be possible if the projected space was fully or partially inside of a bigger physical space. *(Figure 53,* [c], [d]*)*

**To ease the navigation within the mixed physical and digital space, two safety precautions are being introduced.**

First, the boundary of the physical room, if smaller than the perceived room and therefore visible, is always marked as a red line on the floor. *(Figure 53)*. Second, when the user gets closer than 1,5 meter to the unperceived physical barrier, the barrier becomes partially visible *(Figure 54)*.

*Figure 54.* Unperceived physical made visible

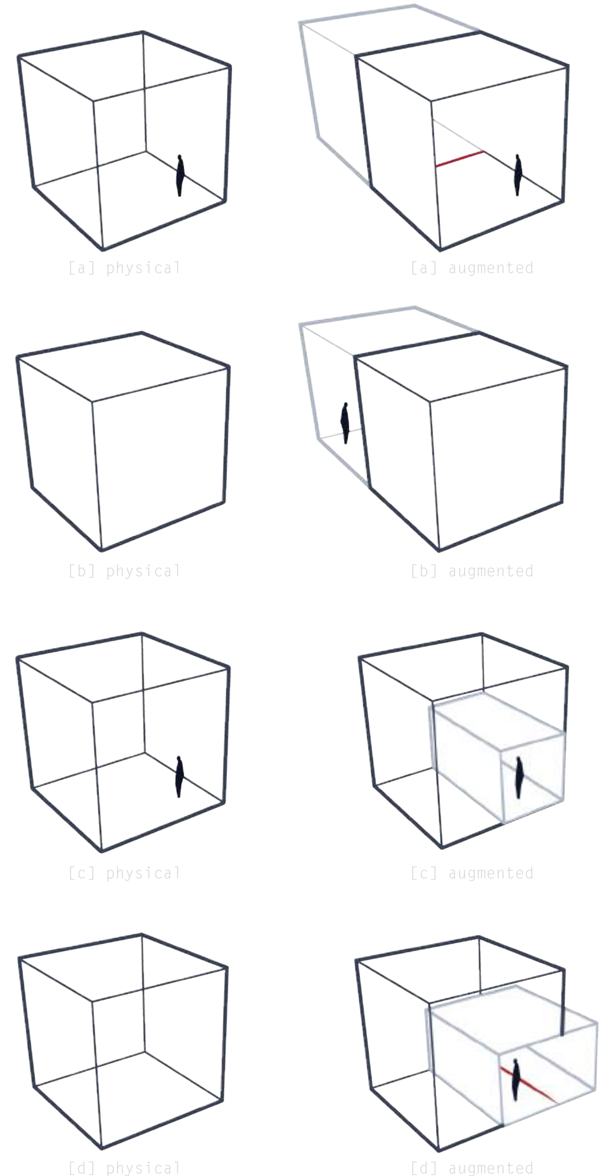



*Figure 53.* Mobility variations based on the relationship between physical and virtual spaces

# conclusion

**inSIGHT is a speculative project, because the expected technology is not yet developed to the advanced enough level to perform the desired function. However, judging by the evolution of the technology so far, one could expect it to continue develop exponentialy and exceed expectations.**

inSIGHT, as a platform for digital manipulations of physical transparency, has a huge potential to completely change the way we perceive surrounding spaces.  There is a number of operational qualities that can be manipulated by such digital overlay as well - privacy, claustrophoby, social and environmental connection, multi-functionality, personalisation, responsiveness.

However, like any radical invention inSIGHT has issues to consider and solve. Such issues like privacy invasion, maneuvering through the mixed digital and physical space as well as esthetics must be put into consideration before introducing the platform to the public use.

But once the issues are dealt with, all that we are left is endless possibilities. inSIGHT has the potential to empower every one of us and completely change the way we interact with the built environment in our daily lives. And that is an exciting thought for the future.

It is very likely that AR platforms such as inSIGHT will be implemented in the future. The questions that will matter are those: who will be producing AR content; what are the main dangers to consider before releasing the platform to the public; what will it mean for the society; what will it mean for the buildings (the existing ones and those just being designed); what will it mean for the architect's profession?

## PRODUCERS

Quite possibly there will be a few main AR developing companies emerging as well as some big companies shifting their production towards augmented reality content (e. g. Facebook Face).

Hopefully some of the AR platforms will be open source, run and maintained by a team of crowdfunded developers. Another level of maintainance could be managed by a group of volunteers and lastly, every user could benefit to the platform by adding data (e.g. existing envirnment and designed environment in the case of inSIGHT).

## DANGERS

Having the example of smart phones in mind, it is easy to imagine how quickly the technology can spread once presented to society, and how dangerous can this be to the users in terms of privacy issues. Now while we still don't have that many AR platforms available for the public use is the time to think about all the issues such platforms can bring. Privacy issues with AR platforms such as inSIGHT could be possibly reduced by simply revising privacy settings, where every user could choose what information to sell, in exchange to more access, or they could choose to not send any information at all (which might in turn benefit to not receiving any information in exchange).

## SOCIETY

It is easy to imagine entertainment industry start using AR platforms to attract customers and generate money. Most of the AR platforms we see and use today are indeed created for entertainment. But the technology has much more potential than that.

There are many ways to use AR to add and enhance operational qualities of physical spaces. Digitally manipulating physical transparency is one of them. InSIGHT could be used to enhance the activity performance in the buildings of different functions. Office buildings, school buildings, cultural buildings, healthcare buildings and many others could be further explored in this regard. Spaces for learning could be based on personalisation. The more personalized learning spaces are, the more personalized is the learning experience. Spaces for work could be based on flexibility. One needs to change the envirnment fairly often to keep being productive. Instantly changeable inSIGHT envionments could possibly lead to better office productivity and better working envionments.
Enhanced social interactions could be explored and adapted to the homes for the elderly, thus solving the social problem of the elderly feeling lonely and antisocal in their living quarters. Yet another interesting topic to explore could be indoor/outdoor situation of the mixed environment. Being outdoors increases ones health and happiness. It would be interesting to see how much of such positive outcome can be reached be dimulating nature virtually.

## BUILDINGS

Currently buildings preserved from former ages are being admired by many and taken good care of by professionals. What will we do in the future about the buildings we create today? Will they be handled with such care as well? What about the distant future when we will have to decide how to treat the buildings that we'll design in the next several decades, perhaps even with augmented reality overlay as an integral part of the building? doubt the limitations of augmentation.

If any space could be translated on any wall, physical or imagined, would physical architecture become irrelevant? Definitely not. The strength of augmented reality spaces lies in the fact that spaces - physical and virtual - are combined and potentials of both are used. Secondly, we need a variety of spaces that perform differently, and have different qualities, spaces that physically accomodate us together and individually, spaces that create pleasant micro-climate. AR alone is unable to accommodate those needs and shouldnt try to. Instead it tries to enhance the qualities that physical architecture already has. Finally, no matter how far AR or VR evolve, physical architecture will always have its charm,. One could compare it to ebooks which are more convenient and easier portable than regular books, yet many still prefer to read the paper book instead, just because of the way paper feels between the fingers. But then again, with the rapid development of haptic technology and its amazing ability to recreate the experience of feeling texture in VR, one could really start to doubt the limitations of augmentation.

## ARCHITECT'S PROFESSION

InSIGHT focuses on the effects AR might have on existing buildings as that it the first step of AR implementation on architecture. The next step will be designing with AR in mind, which might as well completely change our practise and the way buildings are used and designed. An example of such design situation could be a narrow corridor space, which doesn't have to be wide to accommodate the ergonomic needs. However, if designed as narrow as it is enough to be, it still feels claustrophobic and unpleasant. In this case, AR feature could be predefined in a building, programing the perceptive space to be much bigger and lighter that it physically is every time a user enters the space.

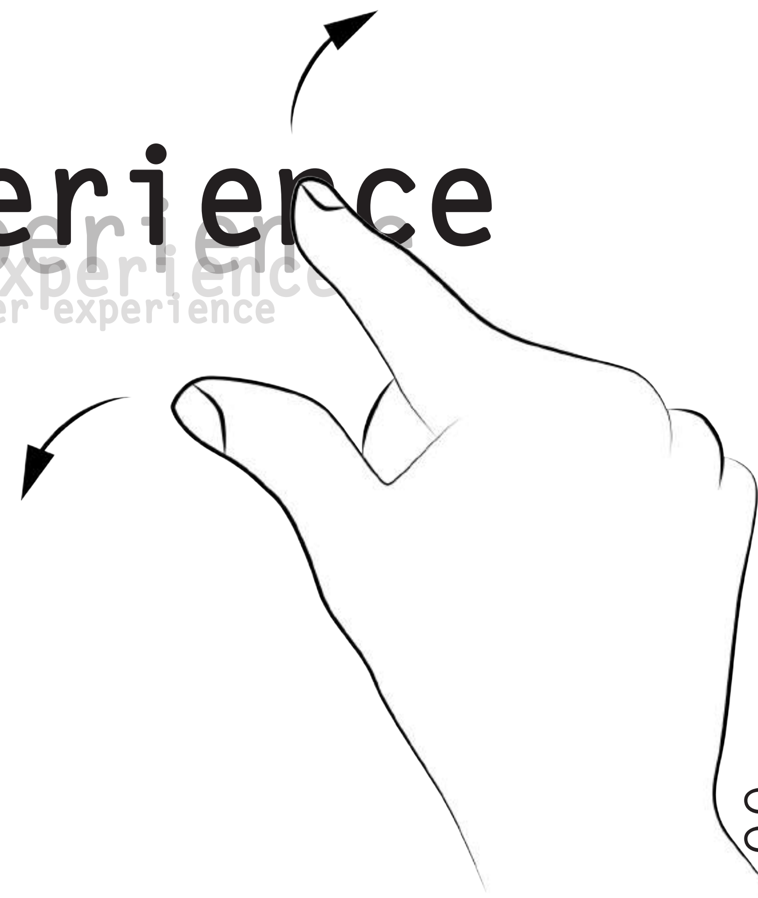
InSIGHT as a proposal of an augmented reality platform to digitaly manipulate physical transparency. This thesis project suggests a structure of the hierarchy of key transformations, solutions to ease navigation within the mixed enviroment and discusses the possible use of the platform. But above all, this thesis project seeks to spark a conversation among architects and related fields' professionals and encourage them to think more about augmented reality as well its implications in architecture.

part four

# SIMULATION

# inSIGHT, the user experience

inSIGHT, the user experience
inSIGHT, the user experience
inSIGHT, the user experience



# why and where?

**The strength of inSIGHT lies within its ability to challenge spatial perception. Spatial perception and changes within it can be much easier communicated through images as oppose to words. That is why this last chapter is vital in presenting inSIGHT, the digital platform.**

To immitate inSIGHT user experience an existing physical building was chosen. The building is called A-huset and is the architecture department at Lund technical university in Lund, Sweden. The building was chosen because of its location, availability, public function and spatial features (having a variety of different spaces).

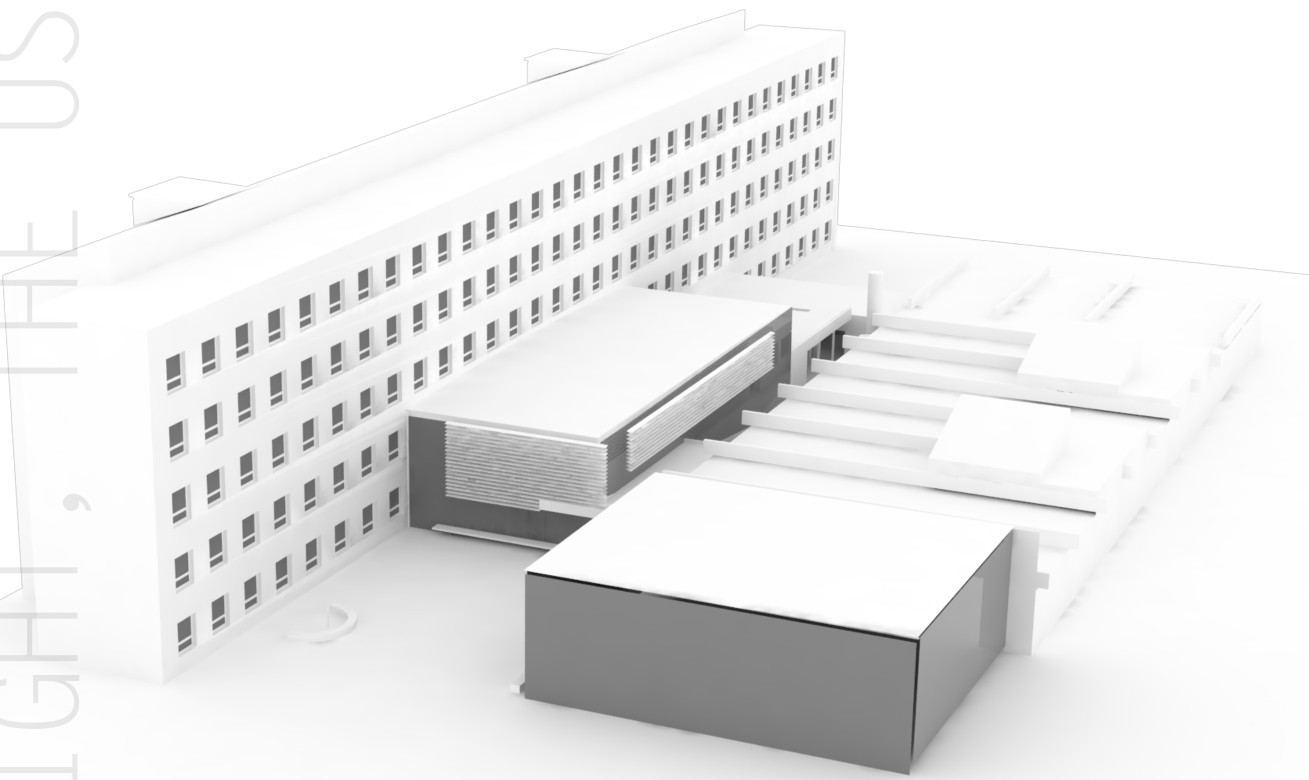


*Figure 55.* 3D model of A-huset in Lund, Sweden

# trajectory

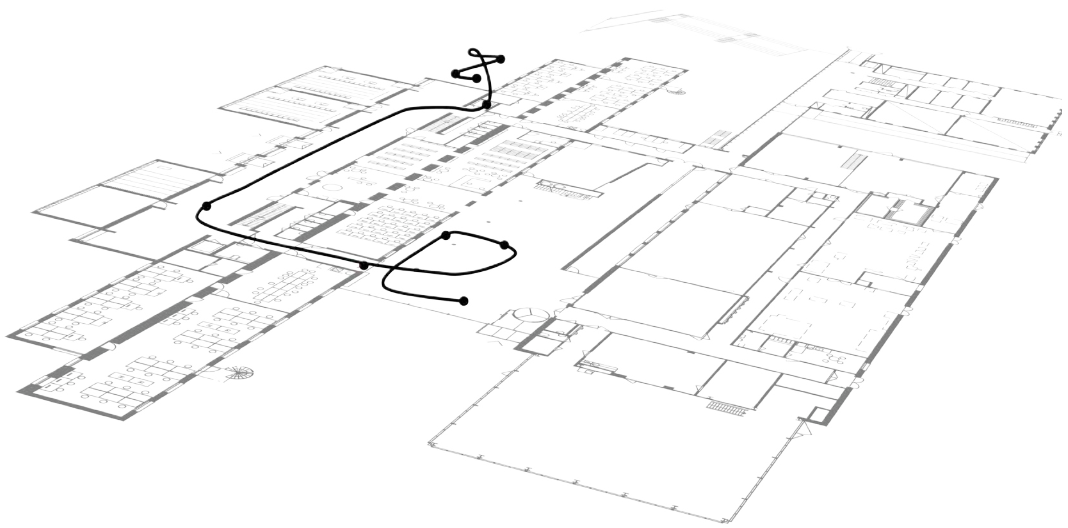


*Figure 56.* Simulation trajectory with the comparison to the ground floor plan

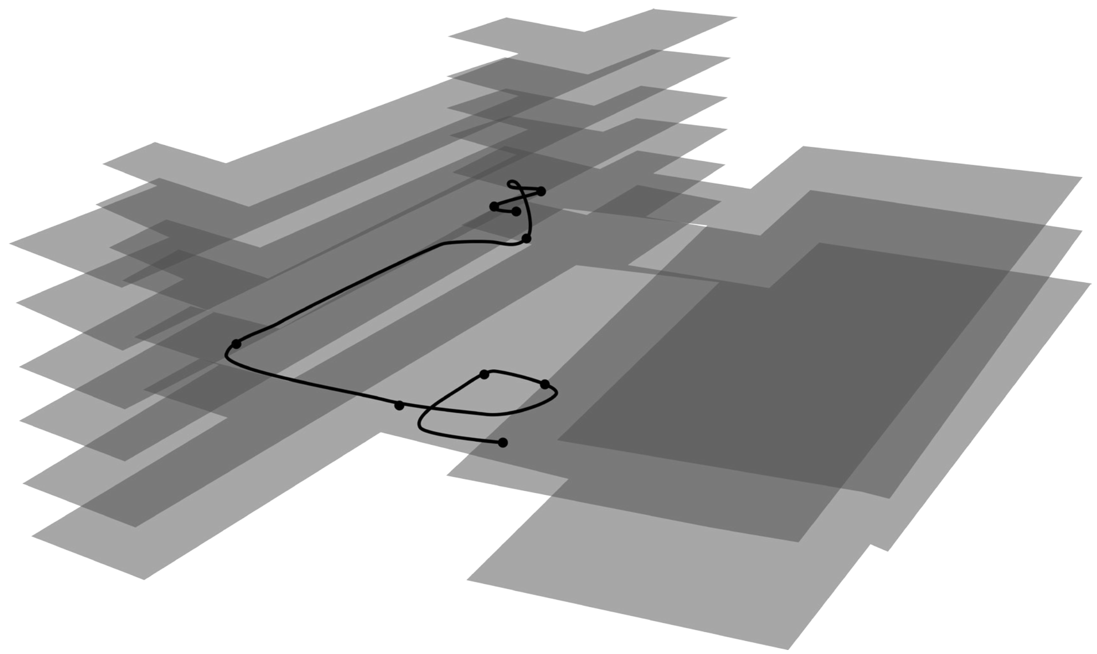
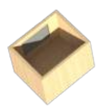


*Figure 57.* Simulation trajectory with the comparison to the building mass and levels

One of the aims of creating simulation trajectory was to cross different types of rooms/spaces that have a number of functions and sizes. *(Figures 56, 57)* By taking advantage of spatial variety, a number of different inSIGHT transformations can be simulated within chosen A-huset spaces. *(Figures 58-66)* privacy

isolation



virtual reality

**transformation 1**

scale

distant transparency

international merge

spatial expansion

**transformation 2**

personalization

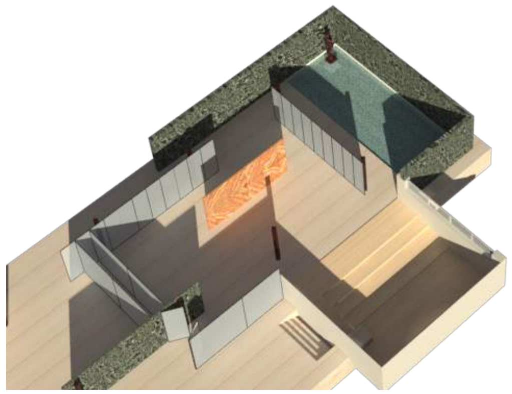
distant transparency

INSIGHT, THE USER EXPERIENCE

transparency

multi-functionality

navigation boundary

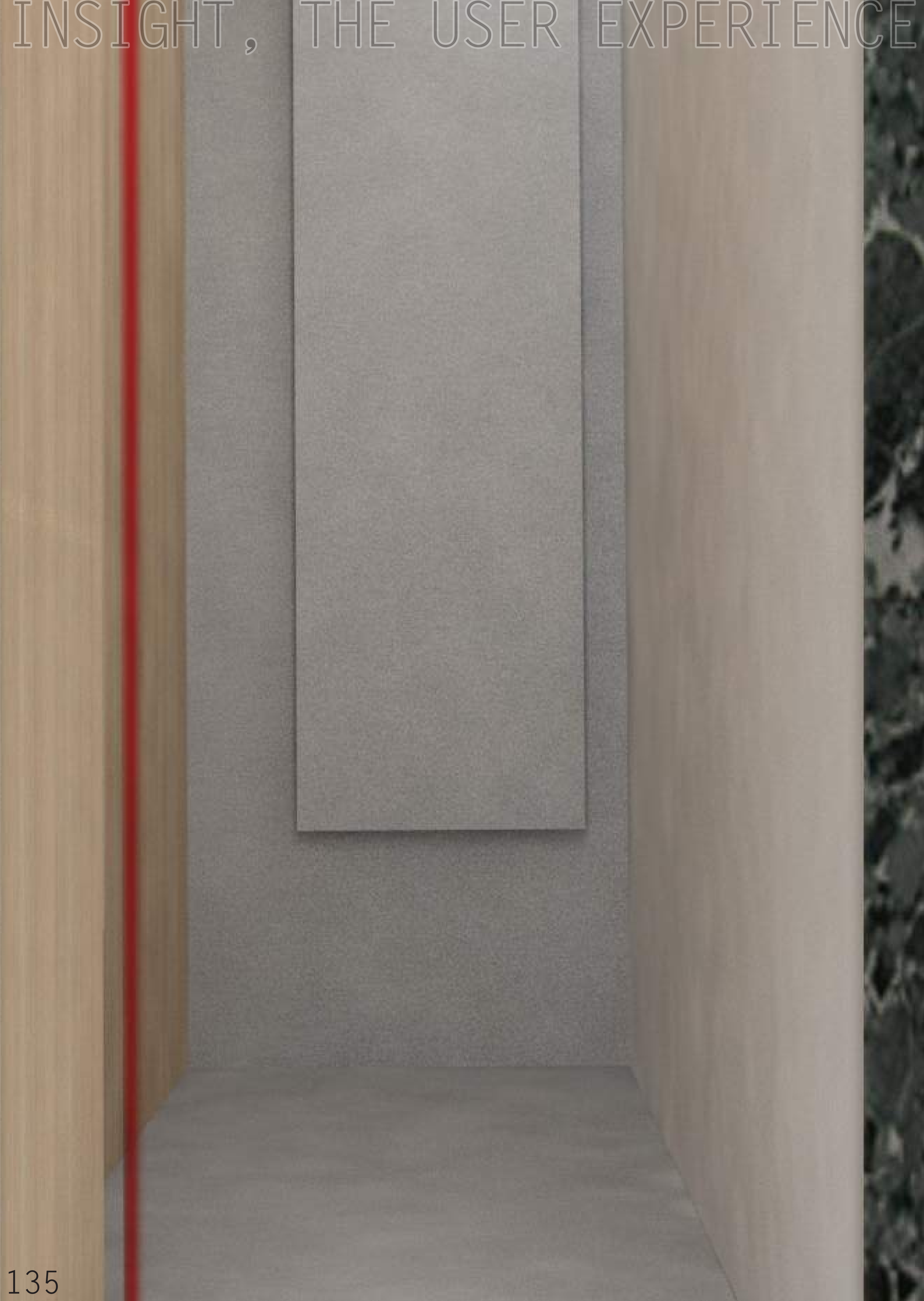


spatial expansion

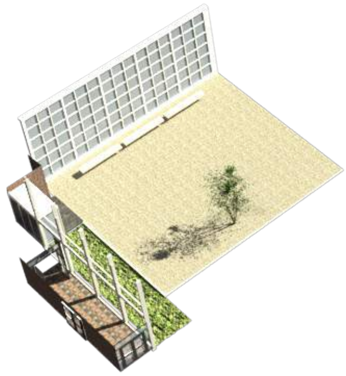
**transformation 3**

social connection

teleport



distorted indoor-outdoor perceptio



transparency

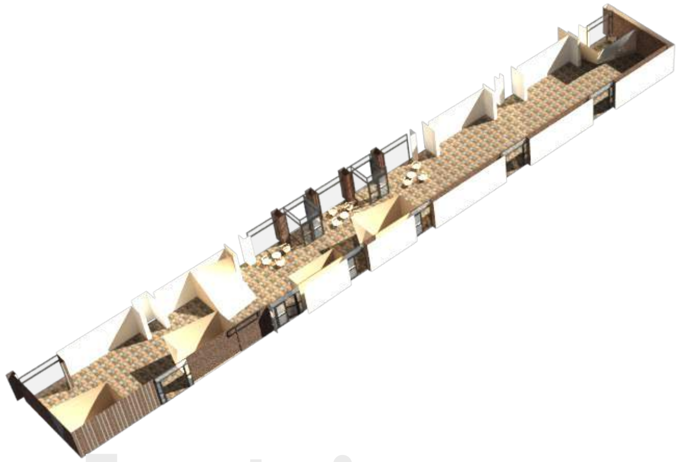
instantaneious
change

transformation 4

spatial expansion

social division

privacy



isolation

instantaneious change

virtual reality

**transformation 5**

scale

personalization

# RE FE RE N SES

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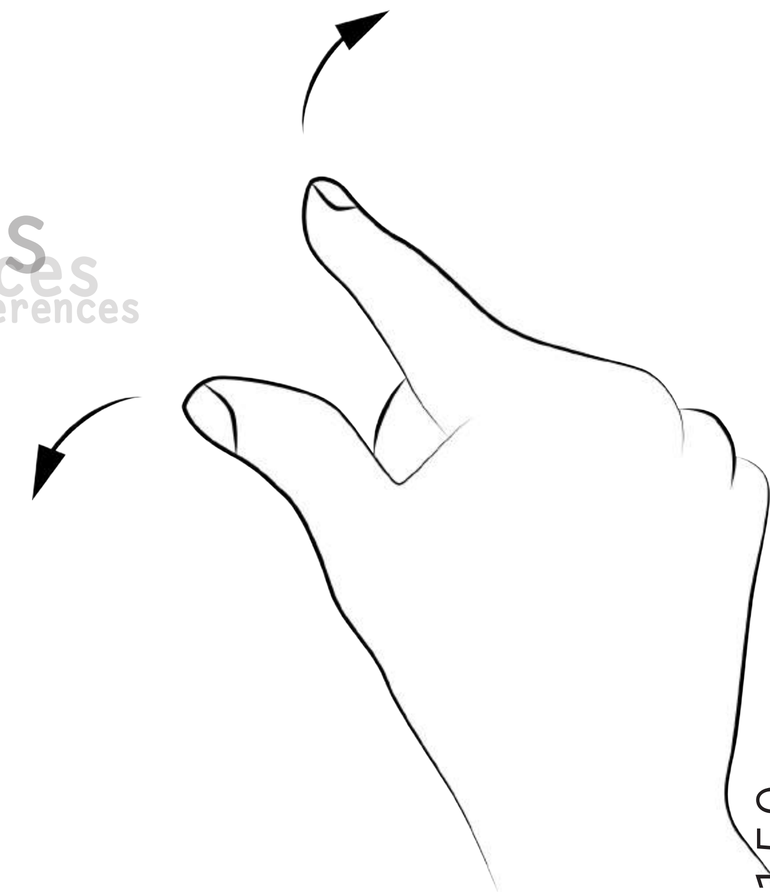

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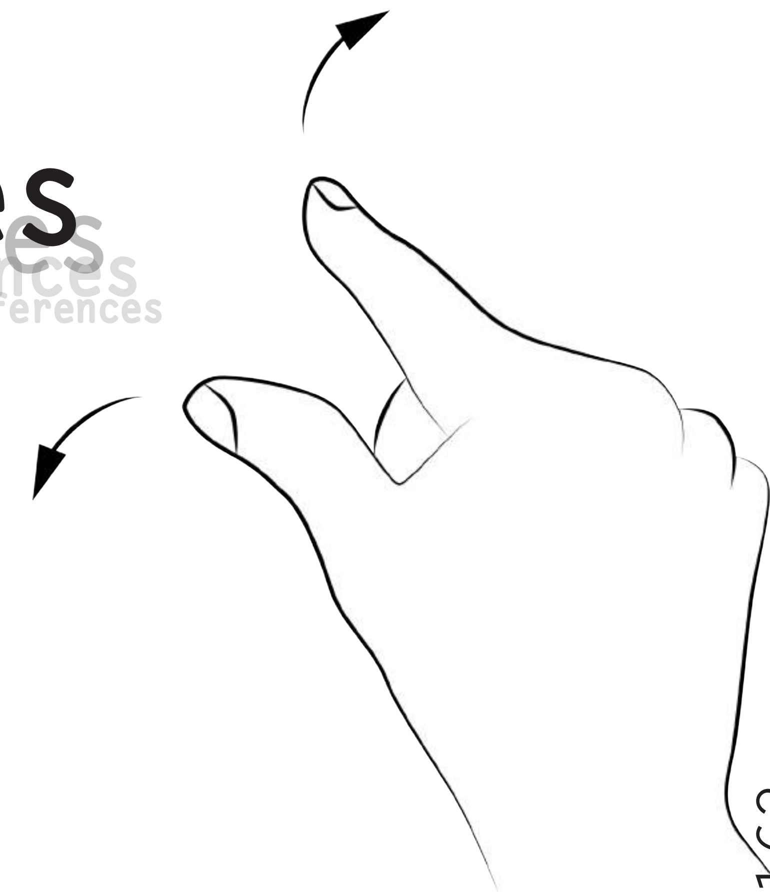

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