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Sensor-supported Game Mechanisms for Augmented Reality

Bachelor’s Thesis

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**Abstract.** bla

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# Background

## Introduction

Augmented Reality is bigger than ever before. The recent success of the game Pokemon Go, coupled with advancements in the related domain of Virtual Reality, has spurred popular interest in the combination of real and virtual content which has long been an area of academic interest. Microsoft’s Hololens, a Mixed Reality HMD (head-mounted display), a development version of which was released in 2016, shows great potential despite a currently high price point.

This research paper seeks to provide an introduction to relevant topics before discussing a framework for sensor-supported Augmented Reality games. First, definitions and technology for Augmented Reality are presented with examples of existing applications in the fields of education and expertise transfer, industrial use, and video games, followed by a brief discussion on the potential and limitations of the medium. Afterwards, the paper goes into sensor technology and applications, with a special focus on video games, and finally design patterns. In the second half, a framework for sensor-supported Augmented Reality is conceived of and partially implemented in the Unity game engine for the Microsoft HoloLens.

## Motivation

This paper builds on the work the author performed during an internship at the Open University of the Netherlands, as part of the WEKIT project. WEKIT (Wearable Experience for Knowledge Intensive Training) is a European research project that aims to develop a new approach to expertise transfer by means of wearable technology, by means of task-sensitive Augmented Reality. During this internship, the author was able to familiarize himself with topics such as Augmented Reality and the combination of various sensors.

A focus group survey (see appendix) was conducted in preparation for this paper with 18 participants – current and former game design students, as well as one professor for game design, with at least one year of game development experience each. This revealed interest but inexperience in the usage and development of augmented reality applications; although all but one of the participants knew the term Augmented Reality, only half of them reported having used AR applications before and only three out of the 18 participants had experience developing them, 12 of the remaining 15 expressing interest in doing so. Despite this, the participants showed mixed (though generally positive) expectations of the field in regards to both the gaming industry in general and education in particular: When asked whether Augmented Reality games would be important in these domains in the future, both averaged a score of 3.388… on a Likert scale from 1 (disagreement) to 5 (agreement). The response to whether they thought using additional sensor data could improve Augmented Reality applications, especially data relating to the user such as data on movement or body posture, was more uniformly positive, averaging a score of 4.388…, although some participants noted a lack of knowledge of sensor technology.

This combination of interest offset with lack of experience and skepticism towards the future suggested that an investigation into the prospects of augmented reality gaming could prove beneficial to current game design students.

## Related Work

Fields of research that overlap with Augmented Reality include Virtual Reality (which puts the user into a completely virtual environment) or the broader term of Mixed Reality; ubiquitous and wearable computing, as well as the internet of things (See (Mattern & Floerkemeier, 2010)) all allow users to interact more broadly with their environments, to which ends a variety of sensors may be used.

(Lamantia, 2009) speaks of “[t]he convergence of mobile computing and wearable computing with augmented reality” as being “of great interest to interaction designers who are interested in the rise of everyware”, while (Papagiannakis, Singh, & Magnenat-Thalmann, 2008) similarly refer to “the convergence of wearable computing, wireless networking and mobile AR interfaces as bringing about “A new breed of computing called ‘augmented ubiquitous computing’”

Some Augmented Reality Games may also be categorized as Pervasive Games, Location-based Games,or both, though the former does not require technology and the latter is primarily occupied with spatial characteristics (Wetzel, 2013).

Pattern languages, as discussed in section 2.3, exist across a variety of fields, such as architecture and software engineering. In the case of e.g. the latter and Augmented Reality, there is also the more general field of Human-computer interaction (HCI).

# Literature review

This section comprises a summary of literature on the topics of Augmented Reality, sensors and design patterns. The content was selected first through online searches for possible areas of interest, such as the topics mentioned above, more specialized areas like AR visualization, related topics like the internet of things, and various combinations of all of the above. The author was also directed towards specific topics by the examiners of this paper. From there, the search shifted to references used in the above sources, and so on.

This section does not attempt to present a comprehensive overview of any of its topics, as doing so would be out of its scope. It does however mention papers that go more in-depth.

## Augmented Reality

In 2011, the NMC Horizon Report stated that “Augmented reality, a capability that has been around for decades, is shifting from what was once seen as a gimmick to a bonafide game-changer” (L. Johnson, Smith, Willis, Levine, & Haywood, 2011). Since then, the availability of Augmented Reality, or AR, applications on consumer-grade devices such as smartphones has been driving the field forward, as referenced by researchers like (Munnerley et al., 2012) (“The fact that these new layers can be accessed with consumer-level mobile devices means that they offer a uniquely open way to enrich environments and offer multiple, flexible learning opportunities”) and (Specht, Ternier, & Greller, 2011) (“The introduction of augmented reality applications to smartphones enabled new and mobile AR experiences for everyday users”).

This section will first present a number of definitions and taxonomies for Augmented Reality, before listing examples from the educational, entertainment and commercial sector.

### Definitions and taxonomies

The term Augmented Reality was first used by researcher Tom Caudell in 1992, according to e.g. (Olshannikova, Ometov, Koucheryavy, & Olsson, 2015), however there exist a multitude of definitions, however it has retroactively been applied to older work ((Lamantia, 2009): “[T]he functional and experiential concept originated with the head-up instrument displays and targeting devices airplane manufacturers created for military pilots shortly after World War II.” Others refer to ) and there exist a multitude of definitions.

A frequently cited general description of AR utilizes the Virtuality Continuum by (Milgram & Kishino, 1994), which places real environments on the left, virtual environment environments on the right, and Augmented Reality left from the center (under the umbrella term of mixed reality, which also includes “augmented virtuality”).



Similarly, (L. Johnson et al., 2011) refer to AR as ”the addition of a computer-assisted contextual layer of information over the real world, creating a reality that is enhanced or augmented.”

More detailed classifications show some differences. As (FitzGerald et al., 2013) point out, early research focused on “the use of AR as a primarily graphical display”. For example, (Azuma, 1997) defines Augmented Reality applications as:

* combining real and virtual,
* interactive in real time,
* registered in three dimensions.

However, over time definitions have become more broad. Just four years later, Azuma’s qualifiers had changed to:

* “combines real and virtual objects in a real environment;
* runs interactively, and in real time;
* and registers (aligns) real and virtual objects with each other”

(Azuma et al., 2001).

While both papers mention that Augmented Reality may apply to all senses, they only do so briefly, as research had at this point been focused on optical applications. As the field advanced, applications including other senses became more commonplace and classifications were adjusted accordingly. For example, (FitzGerald et al., 2013) utilize a “working definition of AR that includes the fusion of any digital information with physical world settings, i.e. being able to augment one’s immediate surroundings with electronic data or information, in a variety of formats including visual/graphic media, text, audio, video and haptic overlays.” (Munnerley et al., 2012) specifically argue for a broad definition of Augmented Reality: “There is no need for such augmentation to be limited to the provision of visual information”. (Calo et al., 2015) concede that “there is no easy definition of ‘augmented reality’” and list as features, “most of which are present in most AR systems” the following:

* Sense properties about the real world.
* Process in real time.
* Output (overlay) information to the user.
* Provide contextual information.
* Recognize and track real-world objects.
* Be mobile or wearable.

Examples of Augmented Reality utilizing senses other than sight include (Ternier, De Vries, Börner, & Specht, 2012), whose application for cultural sciences students’ field trips focused on audio augmentation, arguing that “[j]ust like a user should - while driving a car - use sight as much as possible to drive, we believe that with location based learning, a learner’s eyes must be primarily used to examine the environment.” (Benko, Holz, Sinclair, & Ofek, 2016) developed two systems that give haptic feedback corresponding to virtual objects (NormalTouch und TextureTouch), and although they used it for virtual reality (where the user moves around in an entirely virtual environment), the possibility of AR applications is brought up.

Although a trend can be observed, there exist outliers. “A Dictionary of Media and Communication” (Chandler & Munday, 2011) still lists Augmented Reality as "Vision technologies that superimpose a computer-generated object on an image of a real-world scene", while one of the earlier attempts at classifying AR, (Milgram & Kishino, 1994), also mentions haptic and vestibular AR not just in passing but as “natural [modes] of operation.”

(Specht et al., 2011) are critical to over-generalization, stating that ”[w]e find these definitions too generic and in direct conceptual conflict with closely related systems such as context-aware or immersive systems, mixed reality, and personalized adaptation.” It should however be noted that their working definition still includes senses other than vision, being “a system that enhances a person’s primary senses (vision, aural, and tactile) with virtual or naturally invisible information made visible by digital means (…) where ‘view’ also includes other primary human senses.”

Another venue for discussion is the role of real environments, reflecting Augmented Reality’s place on a continuum without easily definable borders. (Azuma et al., 2001) bring up applications that “require removing real objects from the perceived environment, in addition to adding virtual objects. (…) Some researchers call the task of removing real objects mediated or diminished reality, but we consider it a subset of AR.” Similarly, (Wetzel, Mccall, Braun, & Broll, 2008)question whether the game The Eye of Judgement is in fact Augmented Reality, since, although a camera uses physical playing cards as input, ”[t]he real playing field is never seen on the screen as it is completely overlaid by virtual characters and objects.” Bringing up discussions about the seemingly disappearing borders between Augmented Reality and Virtual Reality, (Schell, 2015) predicts that “by 2025 we’re gonna have VR things and we’re gonna have AR things (...) because you want them both to be good and to be good they’re gonna need to use different technologies and systems.”

### Approaches

This section is concerned with the ways in which Augmented Reality systems have been and can be constructed. It makes a distinction between technology, techniques and software frameworks. Generally, section 2.1.2.1 demonstrates ways in which information is conveyed from the device to the user, while the techniques in section 2.1.2.2 serve to transfer information from the environment to the device, and the software frameworks in section 2.1.2.3 represent a bridge between these tasks. In other words, a framework uses techniques to gather information which is then presented to the user through technology.

This distinction is not perfect, as there eixsts some overlap. For example, (Azuma et al., 2001) groups both displays, which are discussed in 2.1.2.1, and tracking, which is a subject of 2.1.2.2, under the category of “enabling technologies”, while (Papagiannakis et al., 2008) makes a distinction between “technological characteristics” and “the applicability in different environments like indoor or outdoor”, both of which fall under “Technology” in this paper. Despite this, for the purposes of this theis, at least, the present categorization should serve to provide some structure.

#### Technology

(Sutherland, 1968) is frequently considered to have created the first true Augmented Reality display(Calo et al., 2015; Feiner, MacIntyre, Höllerer, & Webster, 1997). The way his device differs from later Augmented Reality platforms highlights several areas of interest.

Firstly, there is the distinction between mobile and stationary (or desktop) AR. Though Sutherland’s display was restricted by the technology of the time, he stated that “[e]ventually we would like to allow the user to walk freely about the room”, leading (FitzGerald et al., 2013) to state that“developers have always aimed to make AR portable.” (Calo et al., 2015) went so far as to include mobility in their list of features of AR (see section 2.1.1), explaining that “[i]n the long term, we expect that many augmented reality systems will be wearable (…). However, a system does not need to be wearable to technically be considered an AR system;”

The first truly mobile Augmented Reality system, or MARS, (Mulloni, Dünser, & Schmalstieg, 2010; Papagiannakis et al., 2008) was the Touring Machine by (Feiner et al., 1997), which allowed the user to walk around relatively unconstrained, by wearing a backpack and a head-mounted display.

A topic which is closely related to this is type of display. The main distinction to make in this regard is between video see-through and optical see-through. A discussion on the advantages and disadvantages of these can be found in (Azuma, 1997). Optical see-through refers to the projection of information while still affording the user a view of the real world. Video see-through displays on the other hand provide no direct view of the real world; instead, cameras are used to record the outside world, the video is combined with visual augmentation and the result displayed. A method which might be considered optical see-through but is not as easily classified, functions by projecting information directly unto the world (outside of the device itself). A few systems have achieved this by simply using commercial projector technology, such as (Ishii, Wisneski, Orbanes, Chun, & Paradiso, 1999; Yamabe & Nakajima, 2013), which compromises privacy by making information visible for anyone and doesn’t allow multiple users to see different images. (Azuma et al., 2001) bring up reflective systems that do allow multiple users to see different images, while making the information visible only along the line of reflection; however this requires objects in the world to be coated with retroreflective material, further reducing its applicability in mobile AR. While (Kruijff, Swan II, & Feiner, 2010) still bring up projector-camera systems, the majority of dedicated Augmented Reality systems developed today seem to utilize other kinds of display technology, as demonstrated by (Calo et al., 2015)’s list of “Some specific examples of AR being marketed or developed today” not including any such setups.

While most devices listed by (Calo et al., 2015), as well as (Sharma, Wild, Klemke, Helin, & Azam, 2016) are head-worn displays (also referred to as head-mounted displays), other types of displays such as hand-held and wrist-worn ones have also been used (Papagiannakis et al., 2008), most notably smartphones (see section 2.1.3 for various examples).

#### Techniques

There are fundamentally two different approaches to Augmented Reality: Location-based and vision-based.

Location-based (also known as geolocated, marker-less or gravimetric (FitzGerald et al., 2013; L. Johnson et al., 2011; Munnerley et al., 2012)) AR outputs information based on the user’s position. According to (Munnerley et al., 2012) Points of Interest (POI) are defined and associated with virtual assets – “When a user (…) explores a space the POIs are revealed and the content can be accessed.” This exploration can be based solely on location – usually provided through GPS – as in (Ternier, De Vries, et al., 2012), or take into account user orientation for increased precision, as in (Hol, Schön, Gustafsson, & Slycke, 2006).

Vision-Based (also known as artefact-based or marker-based) (FitzGerald et al., 2013; Munnerley et al., 2012) Augmented Reality functions by using computer vision techniques to identify and track patterns known as fiducials in the environment. (You & Neumann, 2001) name as examples for fiducials corner features, square shape markers, circular markers and multi-ring color markers, while (Munnerley et al., 2012) refers to barcodes and QR codes and goes on to state that “recent developments in image recognition and mobile technology allow for any image to be used as a marker as long as it is pre-defined in the AR code.” (Papagiannakis et al., 2008) differentiates these passive markers and active fiducials like light-emitting diodes.

Both of these approaches have their advantages and disadvantages: Fiducials can only be used if the system has been trained to recognize them and conditions like inadequate lighting do not interfere with them (though (Papagiannakis et al., 2008) mentions that using infra-red lights can vastly improve tracking quality) and thus vision-based approaches are best suited to prepared environments. Meanwhile location-based systems can suffer from inaccuracy or loss of tracking (for example GPS does not work indoors) – marker-based tracking can be a “much more stable and a simple yet often times effective solution.” (Wetzel et al., 2008)

The solution may lie in the use of hybrid systems as described by (Schall et al., 2009) or image understanding, which (Furmanski, Azuma, & Daily, 2002) explain “attempts to recognize structures and features with the aim of automatically describing the contents of an image.”

#### Software Frameworks

*Software erwähnen? – Layar, AR Toolkit, Vuforia, früher MORGAN AR/VR Framework / Magic Lens Box* (Wetzel et al., 2008)*)*

(Specht et al., 2011)*: “Scanning a QR-code by means of the integrated camera provides an easy way to launch a URL that starts the game on the smartphone. The URL resolves to an OpenGamaray dimension – an XML document with MIME type ‘application/gamaray-gddf’. Via this MIME type, the Android browser can automatically launch the Gamaray client to render the dimension.”*

(Lamantia, 2009): “In addition to the spate of mobile applications—including **Augmented ID, Wikitude, Layar, Nearest Tube, and the still unreleased TwittARound**—augmented reality is increasingly visible in popular cross-media experiences.”

(Henderson & Feiner, 2009): “Our AR application software was developed as a game engine “mod” using the Valve Source Engine Software Development Kit.”

Studierstube *(Überall erwähnt)*

-> (Papagiannakis et al., 2008) (*Nicht alle Frameworks, die Ibid erwähnt hier gelistet*): “Schmalstieg et al [45] introduced the ““Studierstube”” collaborative AR platform, based on a heterogeneous distributed architecture. Studierstube’’s software development environment has been realized as a collection of C+ + classes built initially on top of the Open Inventor (OIV) scenegraph toolkit and later on top of Coin3D.”

Ibid: “Using the MORGAN framework developed by Ohlenburg et al [41], distributed multi-user VR/AR applications can be implemented much faster. (...) It currently supports many devices, including mouse and keyboard as well as haptic input devices, object tracking systems and speech recognition libraries.”

Ibid: “Hollerer [8] built a series of Mobile AR systems (MARS) prototypes, starting with extensions to the 1997 ““Touring Machine”” from Feiner et al [3] and leading up to their most recent system, MARS 2002. This featured a shared central Java and Java3D infrastructure which enables AR, VR and desktop-based indoor/outdoor communication. (...) A main innovation from this system was a rule-based architecture for adaptive MARS interfaces and UI management.”

Ibid: “Wagner et al [38] recently introduced Muddleware, a communication platform for mixed-reality multiuser games that is light-weight and highly portable, as shown in several MR game projects that was employed. A hierarchical database built on XML technology allows convenient prototyping and simple, yet powerful queries.”

Ibid: “While many passive fiducial-based tracking implementations for AR exist, none can match the ubiquity of the freely available ARToolkit system.”

*UNITY!*

### Applications

Erwähnen, dass es auch z.B. Militär, Medizin gibt, die Arbeit sich aber nicht darauf richtet

Allgemein: Patterns?

#### Commercial and Industrial

(Schall et al., 2009): „[V]isualization of underground infrastructures, such as water mains and electricity lines” (=Obscured Information Visualization (OIV) (Furmanski et al., 2002))

(Azuma, 1997; Azuma et al., 2001)

(FitzGerald et al., 2013): “recent technological advances have enabled the use of any kind of image defined within the AR technology (e.g. the ‘Aurasma’ mobile phone app [<http://www.aurasma.com>] used primarily for marketing).”

(Munnerley et al., 2012): “Augmented reality has been embraced in the world of **advertising and marketing** for its potential to make additional information available to customers. What started out as a simple marketing device has become away for a company to project its brand image wherever its products are (for example, Smirnoff’s recent use of artefact-based AR centres around limited edition bottles), or to provide additional information or guidelines about products (e.g. Lego’s use of artefact-based AR to provide images of structures that can be made from their kits).”

(Vedrashko, 2009): Listet 7 AR Promo microsites

(Calo et al., 2015): Beispiele für kommerzielle Anwendungen (“Applications include hands-free instruction and training, language translation, obstacle avoidance, advertising, gaming, museum tours, and much more.”)

(Nilsson, Johansson, & Jönsson, 2009): “This paper presents a study where Augmented Reality (AR) technology has been used as a tool for supporting collaboration between the **rescue services, the police and military personnel** in a crisis management scenario.” *(Forest fires)*

Ibid: “The results of the study clearly indicate that the AR system was experienced as a possible future system not only for the task used in the scenario but also for other tasks within the three organisations.”

“One of the most interesting findings in this study was the fact that the participants in most issues gave the AR system an equal or better score than the regular paper map.”

(Tang, Owen, Biocca, & Mou, 2002) *höchstens erwähnen* (“Experimental Evaluation of Augmented Reality in Object Assembly Task”)

(Henderson & Feiner, 2009): *Militär-/mechanikeranwendung –* “The **augmented reality condition allowed mechanics to locate tasks more quickly** than when using either baseline, and in some instances, resulted in less overall head movement. **A qualitative survey showed mechanics found the augmented reality condition intuitive and satisfying** for the tested sequence of tasks.” *(ABER: Completion time nicht groß anders)*

(Henderson & Feiner, 2009): “**Maintenance and repair operations represent an interesting and opportunity-filled problem domain for the application of augmented reality**. The majority of activities in this domain are conducted by trained maintenance personnel applying established procedures to documented designs in relatively static and predictable environments. These procedures are typically organized into sequences of quantifiable tasks targeting a particular item in a specific location.”

* “There has been much interest in applying AR to maintenance tasks. This interest is reflected in the formation of several collaborative research consortiums specifically dedicated to the topic—ARVIKA [11], Services and Training through Augmented Reality (STAR) [20], and ARTESAS [2]. **These and other efforts have resulted in a sizable body of work, much of which is surveyed by Ong, Yuan, and Nee [18].”**

(Olshannikova et al., 2015) über AR in Big Data visualization: “The use of it in the visualization area might solve many issues from narrow visual angle, navigation, scaling, etc. For example, offering a way to have a complete 360-degrees view with a helmet can solve an angle problem.”

#### Education and expertise transfer

(Radu, 2014): “A **relatively high amount of research studies** have investigated the potential impact of augmented reality to benefit student learning.”

(L. Johnson et al., 2011) – Horizon Report 2011: Time-to-Adoption 2-3 years (“likely time frames for their entrance into mainstream use for teaching, learning, or creative inquiry.)

* (L. Johnson et al., 2016) – Horizon Report 2016 Higher Education Edition listet es auch als Two to Three Years.

“While the most prevalent uses of AR and VR thus far have been in the consumer sector, tools for creating fresh applications are becoming even easier to use and more viable in the education sector.”

“While AR has appeared in several previous editions of the NMC Horizon Report, recent advancements in VR technology are bringing about fresh perspectives.”

(FitzGerald et al., 2013): “At a first glance, the shift from low-tech to mobile-tech and to AR may seem merely quantitative: **augmenting/adding to reality has always been a part of outdoor education**, whether it is through informative signposts at a site, costumed re-enactments of historical events, or straightforward on-site tuition by a teacher or parent. **We change our perspectives, understanding and meaning-making of reality** by augmenting it with additional information.”

(Dunleavy, Dede, & Mitchell, 2009): “Three complementary technological interfaces are now shaping how people learn, with multiple implications for K-12 education (Dede 2002).

* “The familiar ‘‘world- to- the- desktop’’ interface”
* “Emerging multi-user virtual environment (MUVE)”
* “Augmented reality (AR) interfaces””

(Azuma, 1997) erwähnen? Besser nur moderne Vergleiche?

(Dunleavy et al., 2009) (Alien Contact)

(Yamabe & Nakajima, 2013): Augmented Reality Go, EmoPoker, Augmented Calligraphy, AR Drum Kit

(Athletik/Physische Abläufe speziell erwähnen, hier können andere eingebunden werden, z.B.: (Soga, Nishino, & Taki, 2011) (Skeletal tracking (Bogenschießen, Visualisierung des Experten) **(Quelle eingeschränkt, also am besten nur am Rand erwähnen)**), (Rahman, Mitobe, Suzuki, Takano, & Yoshimura, 2011))

(Ternier, Klemke, Kalz, van Ulzen, & Specht, 2012) (ARLearn)

(Schmitz, Specht, & Klemke, 2012) (Edu. potential): “For the review we focused on motivational and knowledge learning outcomes. Learning outcomes that relate to manual or physical learning outcomes, e.g. exergames (Lucht et al., 2010; Yang and Foley, 2011) or console games we did not consider, as they have a different didactic approach. (…) Due to the educational focus of our analysis, we excluded any study focusing at technology aspects, such as the study on ‘The Eduventure’ by Ferdinand et al. (2005) or the ‘Museum Scrabble’ by Yiannoutsou et al. (2009).”

(Dunleavy, 2014): “A review of the literature reveals the following three design principles as instructive: 1. Enable and then challenge (challenge): 2. Drive by gamified story (fantasy); and 3. See the unseen (curiosity).”

**Wichtige Übersichten**: (FitzGerald et al., 2013) (“We make two important contributions to the field: a discussion of underlying pedagogies associated with the use of AR; and a taxonomy that classifies different aspects of mobile AR for learning in outdoor situations.”), (Bower, Howe, McCredie, Robinson, & Grover, 2014), (Radu, 2014)

FitzGerald et al. Taxonomy:

* + *Project*
  + *Device or Technology*
  + *Mode of Interaction / Learning Design*
  + *Method of Sensory Feedback*
  + *Personal / Shared Experience*
  + *Fixed/Static or Portable Experience*
  + *Learning Activities or Outcomes*

(Dede, 2009): Immersive Learning (Referenziert von (Ternier, Klemke, et al., 2012) ((Brown & Cairns, 2004) könnten erwähnt werden, ist aber fragwürdig (auch weil Ternier das gleiche macht)))

(Bower et al., 2014) kritisiert Ansätze: “In the vast majority of instances described above, Augmented Reality is being used by educators to provide students with pre-packaged learning experiences. This can lead to the situation where Augmented Reality only develops lower order thinking skills by supporting understanding and application, without encouraging higher order integrative thinking skills such as analysis, evaluation and creation.”

(Bower et al., 2014) schlägt stattdessen Design als Alternative vor (und gibt Beispiel dafür): “The students, accompanied by their teachers, were invited to select a sculpture of their choice from the University Sculpture Park and then, using the Aurasma Augmented Reality platform (http://aurasma.com), design and create an Augmented Reality overlay that would be triggered by the sculpture. These Augmented Reality designs could then be used by visitors to the sculpture park so as to enhance their artistic experience.”

(Bower et al., 2014): “Augmented Reality technology is advancing so rapidly that educational research has not been able to keep pace. Future research needs to move beyond Augmented Reality as a novel learning technology to examine learning and teaching issues of import.”

(Radu, 2014): “presents a comparison between various media, ranging between books, desktop PCs, smartphones, and head-mounted displays. Different media are compared across factors that provide educational affordances, such as range of representation, ability to align representations, support for interactivity, etc.”

(Radu, 2014): *Beispiele für erfolgreiche Anwendung/Ergebnisse in Bereichen* *(sollte das in Possibilities?)*:

* Learning spatial structure and function
* Learning language associations
* Long-term memory retention
* Improved physical task performance
* Improved collaboration
* Increased student motivation

(Radu, 2014): *What factors influence learning in AR?*

* Content is represented in novel ways
* Multiple representations appear at the appropriate time/space: *spatial/temporal contiguity effect*
* The learner is physically enacting the educational concepts: “Research shows that physical activity is linked to conceptual understanding of educational content: Shelton and Hedley, in their studies of spatial learning in AR [39], hypothesize that visuospatial comprehension is enhanced by physical interaction with 3D content.”
* Attention is directed to relevant content
* The learner is interacting with a 3D simulation: “Digital simulations in general are effective tools because they allow students to experience phenomena that are impossible or infeasible to experience otherwise (...), they are dynamic and interactive allowing student control over the educational content (...), and they scaffold and assess user learning (...).”
* Interaction and collaboration are natural *(Interaktion speziell auf Gestensteuerung etc. bezogen)*

(Radu, 2014): “There are also several topics that need to be addressed in order to ease the adoption of this technology into school classrooms. First, AR experiences need to be designed with curriculum and pedagogy in mind. (...) Further, future work can investigate the investment costs for teacher training, as well as investments in hardware and other infrastructure required to integrating AR in classrooms. There are also space considerations, because due to the high degree of physical interaction, AR experiences typically require a larger space than computer experiences. Finally, classroom applications will typically benefit from networked connectivity, such that students can collaborate around virtual content, and so that teachers can monitor and control the experience, thus requiring infrastructure for wireless networking.”

#### Augmented reality games

(Wetzel, 2013): “The advance of modern smartphones has finally made it possible to develop such games outside the realm of research and for the first time a large base of potential users can be reached to make such games economically feasible (at least in theory). This rather young strain of game development has however not yet formed a cohesive and structured understanding of what makes these games fun to play, how they function and what needs to be taken into consideration when designing, developing and staging them.”

(Wetzel, 2013): “Terms with similar definitions are Location-based Games (which require spatial change) [20] or Pervasive Games (which do not necessitate technology) [17]. All three terms are often used interchangeably, and the majority of games from each group arguably also belongs to the other two.”

*(Full definition of location-based and pervasive games?)*

(Wetzel, 2013) gibt Beispiel (Füllmaterial), unter anderem Geocaching *(Passt das in einen strikten AR-Bereich?)(FitzGerald sieht es wohl nicht so (sagt es nicht explizit))*

(Wetzel, 2013): “Commercial games which fully exploit the power that modern smartphones enable are still few and far between with Shadow Cities and Ingress perhaps the only two with a large player base. This lack of successful games is on the one hand certainly caused by the aforementioned complications concerning the development of MMRGs, but arguably also because the games are still relatively new and therefore knowledge is lacking about how best to design and develop these games, what pitfalls and common errors to avoid and how to best engage players.”

(L. Johnson et al., 2011): “Augmented reality is an active, not a passive technology” -> Geeignet für Games

* (FitzGerald et al., 2013): “It is not enough to state that AR consists of availability or presence of digital media within a particular location, as this could encompass passers-by playing music on their mp3 players as they travel through that environment.”

*Trennung zwischen akademisch und kommerziell, Edugames erwähnen (auch oben schon)*

*Eye Toy als erstes kommerzielles? (Zitat* (Wetzel et al., 2008)*)*

*Pokemon Go*

(Dunleavy, 2014): Dino Dig (“Although the main purpose of Dino Dig was to entertain, these same design principles of enabling and then challenging could be used in an AR experience with specific learning objectives.”)

(Antonaci, Klemke, & Specht, 2015): “[L]ittle is known on how to systematically apply game-design patterns to augmented reality.”

(Wetzel, 2013) proposes patterns for Mobile Mixed Reality Games: “While on the one hand the language covers direct game mechanics and therefore game design considerations, it also aims to provide similar for other aspects of mobile mixed reality games, namely authoring, content creation, interfaces, orchestration as well as testing and logging. Eleven patterns based on these aspects are described in more detail.”

Ibid (Struktur für Pattern): “Name, Categories, Problem, Solution, Examples, Description, Effects, Connections”

(Wetzel et al., 2008): “When playing an AR game, the player needs to be equipped with **appropriate hardware** [6]. In addition to a computer, this hardware often involves technologies for detecting the position and orientation of the player or other game entities. Some games also require communication mechanisms that enable team play or data sharing.”

(Wetzel et al., 2008): “In addition to games developed within research groups, there exists a small amount of commercially available AR games. The first was **Eye Toy®**.” ***DIESER TEIL KÖNNTE AUCH IN SENSORS.***

(Wetzel et al., 2008) *vergleicht 2 selbst entwickelte Spiele und The Eye of Judgement (PS3).(Eye of Judgement=AR??)*

*Can You See Me Now? (Referenziert in* (Lundgren & Björk, 2003)*)* ”features two kinds of players: some play online using avatars, moving the avatars across a map of the city while other players roam the actual city, chasing the avatars using handheld computers (PDAs) that inform them about the avatars’ whereabouts.”

(Ishii et al., 1999): PingPongPlus nicht nur als Erweiterung, sondern Transformation des Grundspiels (versch. Spielmodi): “We have designed and implemented over a dozen different application modes on the PingPongPlus table.”, Beispiel Water Ripples Mode, Painting mode, …

(Specht et al., 2011): Locatory (Weiterentwicklung Memory)

### Outlook

#### Possibilities

(Dunleavy, 2014): “This ability to scaffold and support positive interdependence to accomplish an objective situated within a physical space is the most frequently reported affordance of AR (Dunleavy, Dede, & Mitchell, 2009; Facer, Joiner, Stanton, Reid, Hull, and Kirk, 2004; Klopfer and Squire, 2008; Squire, 2010; Perry et al., 2008; Squire, Jan, Matthews, Wagler, Martin, Devane and Holden, 2007).”

(Robinett, 1992) sieht großen Einfluss auf Gesellschaft voraus: “There will be many databases registered with the real world and able to be superimposed onto it, for example, labels, maps, notes to specific people, diagrams, paths, grafitti, as well as the actions from earlier times recorded in the experience database. It will be a matter of choice which, if any, of these overlays are viewed by each human at any given moment.”

(Dunleavy et al., 2009):”**Unique affordances of AR** include the greater fidelity of real world environments, the ability of team members to talk face-to-face with its bandwidth on multiple dimensions, and the capacity to promote kinesthetic learning through physical movement through richly sensory spatial contexts.”

(Dunleavy et al., 2009): “One of the more intriguing findings from this study is the documented engagement and motivation of students who had previously been disengaged and disinterested in school. Across sites, teachers reported a significant difference in the behavior and engagement of students during the AR implementation as compared to their normal classroom behavior.”

(Schmitz et al., 2012) -> Patterns und Einordnung motivational effects, cognitive effects. ABER: „ The studies we reviewed did not explicitly focus on this but on a set of diverse patterns embedded in the games. Therefore, **the impact of one particular pattern on knowledge gain is difficult to determine.”**

(FitzGerald et al., 2013) et al. (über (Luckin & Stanton Fraser, 2011)): “The study [Luckin & Stanton Fraser] identified other positive aspects of AR, including **ease of use by young children, fun factor, flexibility across age groups and subject domains, ease of use in reference to installation/mobility of hardware, and the immersive and engaging nature of 3D AR visualisations.**”

(Dede, 2009): “Studies show that immersion in a digital environment can enhance education in at least three ways: **multiple perspectives, situated learning, and transfer.** Further studies are needed on the capabilities immersive media offer for learning, on the instructional designs best suited to each type of immersive medium, and on the learning strengths and preferences these media develop in users.”

“Many academically **low-performing students do as well** as their high performing peers in River City, especially on performance-based measures (...).”

(Calo et al., 2015): “AR can **confer new information** in real time or **alter the user’s actual experience or skillset** (...). AR also changes the experiences of the people around the user, whose features and actions may now be **recorded and analyzed** (...). Moreover, AR makes it possible that **two or more people perceive the same environment differently**. (...) For some populations—notably, those living with disabilities—**AR may fully or partially replace a sense.** (...) These and other non-mainstream experiences must be kept firmly in mind when enumerating the potential use cases of AR, and as we contemplate rules and possible exceptions.”

#### Limitations

(Azuma et al., 2001): “**Problem areas in AR displays.** See-through displays don’t have sufficient brightness, resolution, field of view, and contrast to seamlessly blend a wide range of real and virtual imagery. Furthermore size, weight, and cost are still problems.”

Ibid: “We’ve grouped the major obstacles limiting the wider use of AR into three themes: t**echnological limitations, user interface limitations, and social acceptance issues.**”

(Kruijff et al., 2010) (“created with a visual processing and interpretation pipeline in mind.”): “We organize issues into ones related to the **environment, capturing, augmentation, display, and individual user differences.” ->** Genauere Klassifizierung auch in Research Diary

(Antonaci et al., 2015)

(Furmanski et al., 2002)(Interfaces überdenken)

(Dunleavy, 2014): “One of the most frequently reported AR design challenges is preventing student cognitive overload during the experience” (+Quellen);

Ibid: “The mobile device as a lens rather than a screen is a critical design metaphor as **several studies have documented that students have the tendency to become fixated on the mobile device rather than observing the environment** (Dunleavy et al., 2009, Dunleavy & Simmons, 2011; Perry et al., 2008; Squire, 2010). While location-based and vision-based AR can provide powerful and compelling experiences, **it is critical that designers do not create experiences where the technology becomes a barrier to the environment. Rather the technology needs to drive the students deeper into the authentic observation and interaction** with the environment and with each other if AR is to grow beyond a novelty technology.”

(Dunleavy et al., 2009): “However, while the AR simulation provided potentially transformative added value, it simultaneously presented unique technological, managerial, and cognitive challenges to teaching and learning.”

(Dunleavy et al., 2009): “As students navigated through the game space, they were frequently observed ignoring the physical space around them to focus exclusively on the data being presented via the handheld. The research team recorded multiple examples of students being **so engaged in the game environment that they lost track of their real environment.** Beyond the obvious safety concerns related to students ignoring their environment while walking in an urban setting, **this engrossment could actually be counterproductive** if the AR simulation is designed to incorporate the physical space into the learning experience.

* (Ternier, De Vries, et al., 2012) sehr ähnlich (über andere Quelle): “The Locatory app absorbed all of the attention of the users, which might lead to dangerous situations. While playing the game, observers had to highlight the danger of cars entering and leaving the campus. We found that the way users perceived the game environment relates to tunnel vision.”

(Dunleavy et al., 2009) erwähnt Wetter als Störungsfaktor ((FitzGerald et al., 2013): “Top-of-the-range geolocation systems are (...) very expensive: cheaper tools are only accurate to several metres. Their accuracy can be further degraded by **local environmental conditions** (...).” “Other concerns include ensuring the screen can be read in bright sunlight and that the device can function in the rain or after being dropped.”)

(FitzGerald et al., 2013): Einschränkungen von GPS: “**GPS requires line of sight** for satellite communication and so cannot be used indoors with any great accuracy (…).“ (Ternier, De Vries, et al., 2012; Ternier, Klemke, et al., 2012) ähnlich (Auch draußen durch Infrastruktur beschränkt) in Florenz.

(Dunleavy et al., 2009): “The findings from this study emphasize how engaged students become simply by using similar tools to learn. While this use will continue to be a motivating factor regardless of content due to the inherent novelty effect, we can safely predict that this **novelty engagement will fade as the students become accustomed** to this method of learning.”

(FitzGerald et al., 2013): “One of the most sensitive issues relates to **knowledge of a user’s location**. This is a basic requirement of geolocated AR, but may be off-putting for users who are not aware exactly what data is being collected or who are wary of being tracked or targeted by companies which provide **personalised marketing** (Hamilton, 2012).”

* (Wetzel et al., 2008) ähnlich (über Games allgemein): “When players encounter AR games for the first time they are typically impressed, enjoy playing them and have ideas for other AR games. However, this observation does not mean that all AR games are “good”, rather it is often related to **the experience of the new and novel technologies**.”

(Julier et al., 2000): “If a graphics-based AR system is to be effective, care must be taken to ensure that its display is not cluttered with too much information.” -> Lösungsansatz: Filtertechnik.  
“An informal domain analysis of our application scenario suggested to us that the filtering mechanism should take into account the following properties:

* Users will perform a broad range of tasks, from maintaining general situational awareness of their environment, to searching for specific objects, to attending to a specific set of objects involved in an activity.
* Any object, of any type, at any point in time, can become sufficiently important that it must be able to pass the filtering criteria.
* Certain objects are important to all users at all times.
* Certain objects are important to all users whenever they are performing a particular task.
* Some objects (such as the way points that define a route) are only important to the activities of a particular user.
* All things being equal, the amount of information shown to a user about an object is inversely proportional to the distance of that object from the user. (...)”

(Feiner et al., 1997) ähnlich: “Labels seen through the headworn display are grey, increasing in intensity as the approach the center of the display.The one label closest to the center is highlighted yellow.”

(Feiner et al., 1997): “Although we feel that it provides a good testbed environment, there are many technical issues that will need to be addressed for commercial versions of such systems to become practical: Quality of displays. (...) Quality of tracking. (...) Loss of tracking.”

(Ishii et al., 1999): “We used a Mitsubishi LCD projector LVP-G1A for the experiments, but the brightness of this projector was not enough. To see the graphics on the surface of ping-pong table, we had to darken the room, making it difficult for human eyes to track the ball.” -> Problem bei allem mit Projektion, also auch optical see-through HMDs

(Specht et al., 2011): This technology is also related to one of the most researched areas in AR, the **registration problem** (Bimber & Raskar, 2005), which is the challenge of linking the real-world perception of a mobile AR user and the presentation of the augmentation layer. Thus, the registration problem is closely linked to what we refer to as synchronization.”

(Lamantia, 2009): “**gaps in the interactions current AR experiences support**. In calling out these missing patterns, I’m speaking primarily to the UX community. The AR community is already hard at work on addressing some or all of these needs.”

* + ***Loner*** (“reliance on single-person, socially disconnected user experiences.”)
  + ***Secondhand Smoke*** (“indirect experience of augmented reality”)
  + ***Pay No Attention to the Man Behind the Curtain*** (“AR experiences that identify people by face, marker, or RFID tag could severely challenge our ability to do ordinary things”)
  + ***The Invisible Man!*** (“AR experiences might take active measures to reinforce social mechanisms such as privacy or anonymity by actively altering the mixed-reality environment”)
  + ***Tunnel Vision*** (“limiting their ability to react to stimuli beyond their narrow, monocular view”)
  + ***AR for AR’s Sake*** (“developing interaction patterns that address these everyday activities is essential”)

(Calo et al., 2015): “Issues related to the collection of information include:”

* + Reasonable expectations of privacy
  + The third party doctrine
  + Free speech
  + Intellectual property

“Issues related to display of information include:”

* + Negligence
  + Product liability
  + Digital assault
  + Discrimination

(Biocca & Rolland, 1998): “Among the most critical issues in the design of immersive virtual environments are those that deal with the problem of technologically induced intersensory conict and one of the results, sensorimotor adaptation.”

Ibid: “Engineering design restrictions in this generation of video see-through HMDs require displacing human vision. The cameras that record the physical world and the video displays that present the physical world to the viewer cannot occupy the same position in space.” -> *Erwähnt besonders medical als Feld, das dadurch Nachteile hätte*

Ibid: “Performance on a manual task requiring hand-eye coordination took 43% longer with the see-through HMD. (…)“[T]he negative aftereffect was measurable for at least thirty minutes after using the see-through HMD.”

Ibid: ABER: “Subjects began to adapt almost immediately upon putting on the HMD (...) The amount of error dropped further (by approximately 33%) as subjects further adapted to the sensory rearrangement while performing a task that required quick and precise hand motion.”

Ibid: UND: “Although the control HMD matched the weight, center of mass, field of view and discomfort of the see-through HMD, it failed to control for the **poorer resolution** of the latter unit.”

(Olshannikova et al., 2015) “In this section, we overview important challenges and possible solutions related to future agenda for Big Data visualization with AR and VR usage:” *[Ganzer Bereich detailliert als hier]*

* Application development integration
* Equipment and virtual interface
* Tracking and recognition system
* Perception and cognition
* Virtual and physical objects mismatch
* Screen limitations
* Education (“users need to be educated and trained”)

(Papagiannakis et al., 2008): Challenges:

* Limited computational resources
* Size, weight
* Battery life
* Ruggedness
* Tracking and Registration
* 3D graphics and real-time performance
* Social acceptance and mobility
* Networked Media

(Radu, 2014): Learning detriments:

* ***Attention tunneling***
* ***Usability difficulties:*** “In several studies, users rate AR systems as more difficult to use than the physical or desktop-based alternatives.”
* ***Ineffective classroom integration***
* ***Learner differences:*** “Some studies reported that for some students, AR may not be an effective teaching strategy. (...) Potentially, the AR-based educational content was too limited in scope and did not contain novel information for the high-achieving students.”

## Sensors

### Overview – sensors and actuators

*Frage, ob der Bereich so sinnvoll ist*

(Ishii et al., 1999): Benutzt Mikrophone unter dem Tisch, um Aufprallpunkt des Balls zu bestimmen

EMG (z.B. bei (Rahman et al., 2011))

(Schmitz et al., 2012): “By now, supplementary core technologies, such as Global Positioning System (GPS), portable displays, Radio Frequency Identification (RFID) reader or augmented devices such as the smart phone’s Bluetooth, Infrared or camera, are an integral part of almost any up-to-date mobile device.”

(Mattern & Floerkemeier, 2010) *haben jede Menge über RFID*

(Wetzel, 2013): “Locationing technology utilizes a wide **variety of sensors** like GSM cells, GPS, fiducial markers, natural feature tracking, NFC/RFID as well as WiFi and Bluetooth-based proximity sensing”

-> (Papagiannakis et al., 2008): “Due to the fact that networked mobile AR users are enabled with wireless radio communication network interfaces (such as Wi-Fi), protocols that provide location estimation based on the received signal strength indication (RSSI) of wireless access points have been recently becoming increasingly accurate, sophisticated, and hence, popular.”

(FitzGerald et al., 2013): “**Recent advancements in GPS and networks** have enabled location accuracy to within 5-10 metres for single-point receivers (Ordnance Survey, 2012); carrier positioning accuracy (or ‘survey grade GPS’) improves this to **less than 1cm**.”

(Sharma et al., 2016) (WEKIT): “Next, we provide a mapping of high level functions or tasks (associated with experience transfer from expert to trainee) to low level functions such as: **gaze, voice, video, body posture, hand gestures, bio-signals, fatigue levels, and location of the user in the environment.** In addition, we link the low level functions to their **associated sensors.** Moreover, we provide a brief **overview of the state-of-the-art sensors in terms of their technical specifications, possible limitations, standards, and platforms.**

We outline a set of recommendations pertaining to the sensors that are most relevant for the WEKIT project taking into consideration the environmental, technical and human factors described in other deliverables.”

Ibid:“Finally, we highlight common issues associated with the use of different sensors.“

Ibid: “In design synthesis, the product or system is defined in terms of the hardware and software components which together make up and define the system. The result of this phase is the process output in the form of the physical architecture, or the system prototype where each component must meet at least one functional requirement, and any component can support many functions [[3]](https://paperpile.com/c/ufunOV/jxDQ). “

Ibid: “The **transfer mechanisms** include: remote symmetrical tele-assistance, virtual/tangible manipulation, haptic hints, virtual post its, mobile control, in situ real time feedback, case identification, directed focus, self-awareness of physical state, contextualisation, object enrichment, think aloud protocol, zoom, and slow motion. In this section, we decompose the different transfer mechanisms to low level functions and their associated state-of-the-art sensors.”

Ibid – Kinect funktioniert nicht mit anderen

* **Einschränkungen in der Kombination von Sensoren!**
* Hier auch (Ibid): “In the design of a system recombining the various different sensors identified above (all using different data rates and different standards for storage and communication), several notable challenges arise:
  + Compatibility and support of Unity development engine across different hardware sensors
  + Support of sensors across different operating systems and programming platforms
  + Compatibility of the different hardware drivers associated with the sensors.
  + Interference due to, e.g., noise generated by sensors.
  + Local and efficient storage of raw and processed data of the various sensors.
  + Synchronization of data owing to different data rates of the sensors (e.g., EEG, Augmented reality glasses, microphone).
  + Compatibility of the communication standards and protocols (for instance, Bluetooth, and WiFi) and their data transmission range.
  + The computational complexity and processing load needed for processing the data associated with different sensors.
  + Design of the WEKIT capturing system that integrates all the sensor hardware as a wearable system.”

Jesse Schell – Design Outside the Box: “Sensors are what’s happening now”

“There’s gonna be sensors everywhere, detecting so many things in your life, and these things are gonna be able to be used for gameplay”

“We’re before too long gonna get to the point where every soda can, every cereal box is gonna be able to have a CPU, a screen and a camera on board it, and a wi-fi connector so that it can be connected to the internet”

### Sensors in games

(D. M. Johnson & Wiles, 2003): “With less cognition required for remembering or finding input commands, the user is better able to achieve concentration and engagement, and thereby flow, when completing the task.”

(Lundgren & Björk, 2003) ähnlich: “An alternative to everyday input devices such as keyboards, mice, joysticks, etc. is the use of sensors to collect data. This makes the system more autonomous, and can free the user from tedious input tasks (…).

(Lundgren & Björk, 2003): “Sensors can for example be used to detect presence of, or changes in, light, sound, electromagnetic fields, ultrasound, bending, acceleration, proximity, pressure, or movement. Of special interest in this context are RFID (Radio Frequency ID) techniques which can read and change digital data”

(L. Johnson et al., 2011) (Horizon Report): “Thanks in part to the Nintendo Wii, the Apple iPhone and the iPad, many people now have some immediate experience with gesture-based computing as a means for interacting with a computer. The proliferation of games and devices that incorporate easy and intuitive gestural interactions will certainly continue, bringing with it a new era of user interface design that moves well beyond the keyboard and mouse.”

***Kinect!***

(Zhang, 2012): “Kinect was launched on 4 November 2010. A month later there were already nine pages containing brief descriptions of approximately 90 projects, and the number of projects posted on KinectHacks.net has grown steadily.”

(Zhang, 2012): “The Kinect sensor incorporates several advanced sensing hardware. Most notably, it contains a depth sensor, a color camera, and a four-microphone array that provide full-body 3D motion capture, facial recognition, and voice recognition capabilities.”

*Ansprüche: “*The innovation behind Kinect hinges on advances in skeletal tracking. The operational envelope demands for commercially viable skeletal tracking are enormous. Simply put, skeletal tracking must ideally work for every person on the planet, in every household, without any calibration.”

(Bauer, Wasza, Haase, Marosi, & Hornegger, 2011): Kinect in Radiation Therapy

(Xu et al., 2009): EMG + 3D Accelerometer in virtuellem Rubik’s Cube

(Lundgren & Björk, 2003): ***Biofeedback Games:*** “These games use **input from biosensors** attached to players to influence the game, meaning that body control is a critical element of the game. Examples include Brainball [11], where players’ brainwaves guide a ball towards the opposing goal, and Relax-to-Win [2], where relaxation is required to win a race

### Sensors in augmented reality

(Papagiannakis et al., 2008): Übersicht.

Hier z.B.: “RFID (radio frequency identification) tags have also been recently used in mobile AR systems. RFIDs consist of a simple microchip and antenna which interact with radio waves from a receiver to transfer the information held on the microchip. RFID tags are classified as either active or passive, with active tags having their own transmitter and associated power supply, while passive tags reflect energy sent from the receiver.”

Auch hier: “The use of inertial sensors such as rate gyroscopes and accelerometers is wide-spread in virtual and augmented reality applications.”

Auch hier: “The complementary nature of visual and inertial sensors has led to the development of a number of hybrid tracking systems.”

“**How to interact with wearable computers effectively and efficiently** is an area of active research. Mobile interfaces should try to minimize the burden of encumbering interface devices. **The ultimate goal is to have a free-to-walk, eyes-free, and hands-free interface** with miniature computing devices worn as part of the clothing”

(Sharma et al., 2016) (WEKIT) kann auch hier nochmals (?) erwähnt werden

(Robinett, 1992): “[The HMD] is not simply a visual display technique, but rather a multisensory display technique (involving vision, the vestibular system, and the proprioceptive system) in which the visuals depicting the surrounding three-dimensional (3-D) virtual world are generated so as to match the user's voluntary head movements.”

(Hol et al., 2006): „Tracking in unprepared environments requires unobtrusive sensors, i.e., the sensors have to satisfy mobility constraints and cannot modify the environment. The currently available sensor types **(inertial, acoustic, magnetic, optical, radio, GPS)** all have their shortcomings on for instance accuracy, robustness, stability and operating speed [14]. Hence, **multiple sensors have to be combined for robust and accurate tracking**.”

Sensor Fusion zur Verbesserung von AR-Genauigkeit (Kalman/EKF erwähnen): (You & Neumann, 2001): Vision + Gyro. Referenziert andere, z.B. (Feiner et al., 1997) (erstes(?)outdoor MARS(GPS+compass+tilt sensor)), (Schall et al., 2009): „fusion of Differential GPS (DGPS) or Real-Time Kinematic (RTK) based GPS with barometric heights and also for an inertial measurement unit with gyroscopes, magnetometers and accelerometers to improve the transient oscillation (…) we additionally apply a visual orientation tracker which is drift-free through online mapping of the unknown environment.”

(Benko et al., 2016) (NormalTouch, TextureTouch, Vibrotactile) als Beispiel für Sensor (Location, Finger Force Sensor (FSR)) + Aktuator – System -> „ [O]n several occasions we observed people trying out our devices when they were not well calibrated (…). To our surprise, people often claimed that the device accurately rendered the surface when in fact it was obviously incorrect.”

(Sharma et al., 2016): “At the moment, there are few solutions available for using **eye tracking with augmented reality glasses**, for example, Pupil labs[[116]](https://paperpile.com/c/ufunOV/Zawg), provide eye tracking add-ons for Oculus Rift DK2, HTC Vive Binocular, and Epson Moverio BT-200. However, there are no eye-tracking solutions available for Microsoft Hololens.”

(Bower et al., 2014): “Future developments in Augmented Reality will undoubtedly include new trigger types **(sound, temperature, smell, voice recognition, etc.)**, more intelligent input recognition **(e.g. more accurate gesture detection** as is already being evidenced by products such as Leap Motion) and increased sophistication of expression types (for instance, **vibration, more complex 3D interactive models, scripts to networked devices** such as printers and lights as outlined by “Internet of Things” proponents).”

(Wetzel, 2013): “[Mobile Mixed Reality] games have certain peculiarities that make them arguably more complex to develop and maintain than traditional videogames (e.g. **reliance on inaccurate sensor data**, close coupling to the real world context they are played in).”

(Wetzel, 2013): “It is fair for a videogame developer to assume that the players have precise interfaces for input (controller, mouse, keyboard, etc.), have perfect view of the screen, good sound equipment as well as a fast and reliable internet connection. None of this is true for MMRGs. **Different sensors have different strengths and weaknesses that completely change the way a game might work.**”

*Abschnitt zur HoloLens?*

(Wetzel et al., 2008) (könnte auch in andere Bereiche passen): “A simple **sound sensor** connected to one of the phones via Bluetooth reacts to playing the magical flute and sends the information to the game server that in turn evaluates the notes.”

(FitzGerald et al., 2013): “smartphones contain an increasingly sophisticated **array of sensors**, enabling AR to become more personally meaningful and situated.”

(Specht et al., 2011): *Kann unsichtbares sichtbar machen -* “**Naturally invisible information**, on the other hand, includes things that the human senses do not register, e.g. **compass orientation, invisible light (infrared, ultraviolet, X-rays, etc.), ultrasound, or barometric pressure**.”

## Design Patterns

### Overview

(McGee, 2007): Führt Patterns zurück auf Architektur, Christopher Alexander speziell

Ibid: “Such Patterns are **precise but flexible design rules** that express a relationship between particular design contexts, forces (psychological, social, or structural constraints), and desired (“positive” or good) features.”

Ibid: “More importantly, there is very little in the literature – beyond Alexander’s initial sketch [2]) – about the process of identifying and articulating the information necessary for a well-formulated Pattern. There seems to be an unspoken assumption that this is a social process of trial and error. Thus, **there is very little in the way of proposals for particular tools or guidelines for creating and refining the content of a Pattern.**”

Ibid: “**[Björk and Holopainen]** explicitly claim that one potential function for their Patterns is “idea generation.” (...) their model of design Patterns differs from the typical “best practice” model (...) for Bjork and Holopainen, “game design Patterns are semiformal interdependent descriptions of commonly recurring parts of the design of a game that concern gameplay” [4]. (...) Specifically, their game design Patterns are largely **descriptive rather than prescriptive** (or rule-like).”

(Wetzel, 2013): “**Design patterns** were first introduced for the use in architectural and city planning contexts [1, 2]. These design patterns ranged from large-scale ideas about how to develop towns and cities in a country to setting-up lively neighborhoods and all the way down to minute details of room construction. Together they formed a pattern language aimed at offering insights and guidelines into how to design for everyday use as well as offering a common ground and vocabulary for discussion.”

(Kreimeier, 2002) -> Björk & Holopainen

(Kreimeier, 2002): (Game design) patterns als “**a shared vocabulary to name the objects and structures we are creating and shaping, and a set of rules to express how these building blocks fit together.**”

Ibid: Funktionen: Communicate, document, analyze

(Wetzel, 2013): “**In game design** (often focused on video game design) patterns have also been proposed [22] and also quite intensively covered [6]. In contrast to software and architecture patterns, these game design patterns follow less of a strict problem-solution approach but rather describe identified game mechanics, their uses, occurrences and consequences.”

(Lundgren & Björk, 2003): Game mechanics als sehr ähnliches Gebiet, schwach definiert: “a concept developed by the game design community.”

Ibid: “A **game mechanic** is simply any part of the rule system of a game that covers one, and only one, possible kind of interaction that takes place during the game, be it general or specific. A game may consist of several mechanics, and a mechanic may be a part of many games.”

Ibid: “Computer game designers also frequently use **mechanics**, or sometimes its **equivalent mechanism**, but the meaning of the term **does not seem to have been strictly defined** within this area – it can be used both in the same way it is used for board games and within technical programming contexts; **overall it seems to be used in its most general sense**.”

Ibid: “Mechanics can be regarded as **a way to summarize game rules**, and are often used to categorize games, e.g. a “trading game” or a “bidding game”. However, mechanics often have **effects not explicitly described**, typically how they affect the experience of the game and the interaction between players.”

Ibid: “Where mechanics describe solutions, patterns denominate problems, methods and solutions.”

Ibid: “However, the **non-academic origin of mechanics** was found to have caused some weaknesses; they were **neither precisely defined nor put in relation to each other** in a structured fashion.”

(Wetzel, 2013): “In summary, these are the core goals of typical pattern languages: Communication (discussion/collaboration), Analysis (representation/standardization), Creativity (outlining/planning), and Improvement (problem solving/prevention).”

Ibid: **“Furthermore they all put the pattern into context with other patterns and talk about their relations to each other.”**

Ibid: “In order for something to qualify as a pattern, it has to have been applied in several examples already. Otherwise one might argue that it does not constitute a real pattern.”

* emergent patterns, established patterns and hidden patterns

(Zagal, Mateas, Fernández-Vara, Hochhalter, & Lichti, 2005): Erwähnt zu Patterns “closely-related notion of **design rules**, which offer advice and guidelines for specific design situations.”

### Patterns for Games

(Zagal et al., 2005): “The Game Ontology Project (GOP) is creating a **framework for describing, analyzing and studying games**, by defining a **hierarchy of concepts** abstracted from an analysis of many specific games. GOP borrows concepts and methods from **prototype theory as well as grounded theory** to achieve a framework that is always growing and changing as new games are analyzed or particular research questions are explored.”

Ibid: “top level of the ontology **(interface, rules, goals, entities, and entity manipulation)”**

Ibid: “Our use of the term ontology is borrowed from computer science, and refers to the identification and (oftentimes formal) description of entities within a domain. (...) An ontology is different than a game taxonomy in that, rather than organizing games by their characteristics or elements, it is the elements themselves that are organized.”

Ibid: “**We do not intend to describe rules for creating good games**, but rather to identify the abstract commonalities and differences in design elements across a wide range of concrete examples.”

Ibid: “Each ontology entry consists of a **title or name, a description of the element, a number of strong and weak examples** of games that embody the element, a **parent element**, potentially one or more **child elements**, and potentially one or more **part elements** (elements related by the part-of relation).”

### Patterns for Augmented Reality and Augmented Reality Games

(Specht et al., 2011): (Specht et al., 2011): (Specht et al., 2011): “A HUD is the **oldest AR interaction pattern** and was introduced in the 1950s. Using a HUD in the cockpit of a fighter-jet, pilots can read information without having to move their eyes to a special instrument panel.”

(Schmitz et al., 2012) wendet Game Design Patterns für Mobile Games (Wiederum basierend auf Björk & Holopainen) auf (Educational) AR Games an, untersuchen deren Wirkung in AR learning games - Motivational effects, cognitive effects.

“The pattern **Roleplaying** is not part of the revised list by Davidsson et al. (2004). It is part of the original list of Game Design Patterns provided by Björk and Holopainen (2004). However, the pattern seems to be **highly relevant** for the design of AR learning games. We therefore included it in the study.”

(Ternier, De Vries, et al., 2012): “Augmented reality browsers like Layar and Wikitude support filtering dependent on the sensors available on the mobile device. These browsers have implemented a Point Of Interest (POI) browsing interaction pattern, delivering the same experience for every user.”

(Antonaci et al., 2015): Ansatz für Patterns für AR Serious Games. Verweist auf Björk & Holopainen.

“Below some design patterns already identified by the authors of this paper, which take advantage of AR potential, are listed:

• Localization: adding information related to the user’s position and orientation;

• Video recording and view sharing: sharing the user’s view with another user or an expert;

• Synchronous communication: using communication features while performing a task;

• Contextualization: enriching the current view by providing contextual information (e.g. distance to specific points);

• Object recognition: enhancing or enriching an object in the field of vision of the user;

(Wetzel, 2013): Patterns für Mobile Mixed Reality Games. “While on the one hand the language covers direct **game mechanics** and therefore game design considerations, it also aims to provide similar for other aspects of mobile mixed reality games, namely authoring, content creation, interfaces, orchestration as well as testing and logging.”

Ibid: “After considering the components of other established pattern languages, the following structure is proposed as a pattern language for MMRGs: Name, Categories, Problem, Solution, Examples, Description, Effects, Connections.”

(Wetzel et al., 2008): Benutzt damals nicht den Begriff Pattern, hat aber Guidelines for Designing Augmented Reality Games erstellt, die sehr ähnlich sind. “While issues relating to this area have been considered, **to date most of the emphasis has been on the technology aspects**. Furthermore it is almost always assumed that the augmented reality element in itself will provide a sufficient experience for the player. This has led to a need to evaluate what makes a successful augmented reality game.”

* Experiences First, Technology Second
* Stick to the theme
* Do not stay digital
* Use the Real Environment
* Keep it simple
* Create Sharable Experiences
* Use Various Social Elements
* Show Reality
* Turn weaknesses into strengths
* Do not just convert
* Create meaningful content
* Choose your tracking wisely
* (Lamantia, 2009): *Interaction Patterns:*
  + ***Head-Up Display*** (Fixed point of view)
  + ***Tricorder*** (“adds pieces of information to an existing real-world experience, representing them directly within the combined, augmented-reality, or mixed-reality experience.”) (“requires an external device”)
  + ***Holochess*** (“adds new and wholly virtual objects directly into the augmented experience”)
  + ***X-Ray Vision*** (“simulates seeing beneath the surface of objects, people, or places, showing their internal structure or contents.”)

# Development of a framework for sensor-supported augmented reality games

## Conception

(McGee, 2007): “General characteristics of patterns”:

* Operational and precise
* Positive
* Flexible
* Debatable (the Pattern is clear enough to criticize)
* Testable
* End-user oriented

(McGee, 2007): “How do we create new Patterns? The main method sketched by Alexander is roughly as follows. Start by noticing an architectural situation where one feels good. Now, try to identify something architectural that contributes to this good feeling: try to articulate it in the form of an architectural relationship that can clearly be present (or not) in a structure. (...) Once one feels one has identified such a Feature, work to identify the conflicting Forces it resolves. Finally, identify the Context in which it is relevant (...). Finally, test the Pattern empirically by investigating the reaction people have to structures that manifest the Pattern versus those that do not.”

Ibid: ***Grundgerüst: Name, Forces, Feature***

(Biocca & Rolland, 1998): “Although the research questions involve perceptual adaptation, a point needs to be made regarding the **distinction between the research goals of basic studies in perceptual psychology and studies in human/computer interaction.** (…) **The goal of this study is not to uncover some new form of perceptual adaptation or extend the theory of perceptual adaptation.** This study is based on a different research logic, the logic of the design sciences (Simon, 1969). Most design research on virtual environments **attempts to create technological artifacts that augment human ability** (Biocca, 1996), **not ones that manipulate human abilities solely for the purpose of experimentation and observation.**”

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# Declaration of authenticity

# Appendix