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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 into Augmented Reality and sensor technology and applications, with a special focus on video games, before attempting to design and implement in the Unity game engine a framework for sensor-supported Augmented Reality games.

## 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.

# Literature review

## Augmented Reality

### Definitions and taxonomies

Azuma: 1. Combines real and virtual

* 2. Is interactive in real time
* 3. Is registered in three dimensions
* -> Keine 2D Overlays (Text scheint zu widersprechen - 2D Overlays okay, solange sie an Elemente im Raum gebunden sind?)

Kontrast Azuma (2001):

* 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.

Dictionary: "Vision technologies that superimpose a computer-generated object on an image of a real-world scene."

Milgram & Kishino (1994) erwähnen Möglichkeiten von Audio, Haptic, Vestibular AR („**haptic AR can almost be considered the natural mode of operation** in this sense. **Vestibular AR** can similarly be considered a **natural mode of operation”).** Benko et al. (NormalTouch und TextureTouch) als Beispiel für mögliche Haptic-Anwendung, auch wenn für VR angelegt

Durlach, Ternier (2012) (Audio VR)

* Azuma (2001): “**AR can potentially apply to all senses**, including hearing, touch, and smell.”

Azuma et al. (2001) “Certain AR applications also require removing real objects from the perceived environment, in addition to adding virtual objects. For example, an AR visualization of a building that stood at a certain location might remove the building that exists there today. Some researchers call the task of removing real objects **mediated or diminished reality**, but we consider it a subset of AR.”

Specht et al. (2011):”Milgram and Kishino (1994) describe augmented reality (AR) as “relating purely virtual environments to purely real environments” (p. 1321). Rice (Shute, 2009) gives an even broader perspective on augmented reality, stating that it should cover any media that is specific to your location and the context of what you are doing. We 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.** For the purpose of this article, at least, we therefore want to specify augmented reality as **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.”

Milgram (1994): Spectrum => Sheridan (1992), Robinett (1992) taxonomies  
Milgram aber auch: “[AR] refers to all cases in which the display of an otherwise real environment is augmented by means of virtual (computer graphic) objects.”

Milgram (1994): “An (approximately) three dimensional taxonomy is proposed, comprising the following dimensions: **Extent of World Knowledge** ("how much do we know about the world being displayed?"), **Reproduction Fidelity** ("how 'realistically' are we able to display it?"), and **Extent of Presence Metaphor** ("what is the extent of the illusion that the observer is present within that world?")”

Chronologisch ordnen?

Sheridan (1992) (Faktoren für Presence):

* “Extent of sensory information
* control of relation of sensors to environment
* ability to modify physical environment

Robinett (1992) (synthetic experience) (“a taxonomy for classifying systems that incorporate an HMD”): Klassifizierung nach causality, model source, time, space, superposition, display type, sensor type, action measurement type, actuator;

Klassifizierung AR:

* Causality: Transmit
* Model source: Scan
* Time: 1-to-1
* Space: Registered
* Superposition: Merge
* Display: HMD
* Sensor: FLIR (forward-looking infrared)
* Action Measure: -
* Actuator: -

### Technology

Sutherland als erster - “**Eventually we would like to allow the user to walk freely about the room**, but our initial equipment allows a working volume of head motion about six feet in diameter and three feet high.”

* HMD/HWD vs Desktop

Azuma (1997)

Yamabe et al. erwähnen (Projector)

Video vs optical (projection erwähnen (ist noch in Kruijff et al. (2010)))

* Azuma (2001): “**Another approach for projective AR relies on headworn projectors, whose images are projected along the viewer’s line of sight at objects in the world**. The target objects are coated with a retroreflective material that reflects light back along the angle of incidence. Multiple users can see different images on the same target projected by their own head-worn systems, since the projected images can’t be seen except along the line of projection.”

Location-Based (geolocated/marker-less) vs Vision-Based (artefact-based /marker-based) (Munnerley et al. (2012), FitzGerald et al. (2013)) -> Hololens hervorheben als alternativen dritten Ansatz

Marker-based: You & Neumann listen Arten von Fiducials (5.1) (corner features, square shape markers, circular markers, and multi-ring color markers)

marker, computer vision, outdoor Probleme und Lösungsansätze (Schall et al. (2009), Hol et al. (2006))

Moderner Vergleich

Hololens speziell?

Furmanski et al. (2002) unterscheiden: “Processing methods can be classified into image enhancement and image understanding techniques. With image enhancement, qualities such as contrast, brightness, and transparency are manipulated to improve visibility of important features or highlights. Image understanding attempts to recognize structures and features with the aim of automatically describing the contents of an image.”

Azuma (2001): “One category for new developments is enabling technologies. Enabling technologies are advances in the basic technologies needed to build compelling AR environments. Examples of these technologies include **displays, tracking, registration, and calibration.**”

### Applications

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

#### Industrial

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

Azuma (1997 und 2001)

#### Education and expertise transfer

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

Yamabe et al. (2013): Augmented Reality Go, EmoPoker, Augmented Calligraphy, AR Drum Kit

Ishii et al. (Athletik speziell erwähnen, hier können andere eingebunden werden, z.B.: Soga et al. (2011), Rahman et al. (2011), )

Ternier et al. (2012) (ARLearn)

Schmitz et al. (2012) (Ed. 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).”

Antonacci et al. (2015),

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), Bower et al. (2014), Radu (2014)

Soga, Nishino & Tashi: Skeletal tracking (Bogenschießen, Visualisierung des Experten) **(Quelle eingeschränkt, also am besten nur am Rand erwähnen)**

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

#### Augmented reality games

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

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

Pokemon Go

Design Prinzipien von Wetzel el al. (2008)

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.”)

### 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.”**

#### Limitations

Azuma (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

Antonacci 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.

Dunleavy et al. (2009) erwähnt Wetter als Störungsfaktor

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.”

## Sensors

### Overview – sensors and actuators

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

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.”

### Sensors in games

### Sensors in augmented reality

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, Schön, Gustafsson 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, S., & Neumann, U. (2001): Vision + Gyro. Referenziert andere, z.B. Feiner, S., MacIntyre, B., Höllerer, T., & Webster, A. (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. (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.”

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

# Declaration of authenticity

# Appendix