Two Worlds, One Gameplay: A Classification of Visual AR Games

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ABSTRACT
At the end of the last century, augmented reality (AR), *i.e.* the enrichment of our perception with digital information, was said to be the new striking technology. Yet, games are still one of the fewest considered application areas although researchers have frequently emphasized that the technology is destined for games (*eg.* Feiner et al. 1997, van Krevelen and Poelman 2010). Previous works on AR games form an inconsistent field of study. In order to advance research in this fragmented field and to offer a reference point for further research and practical applications, we develop a classification of AR games using three sources: an extensive literature review, a Delphi survey (Linstone and Turoff 1975), and the usage of AR in selected fictional works. The result classifies AR games according to four criteria: the used device, the tracking technology, the setting of both the device and the player, *i.e.* where and how the game is played, and the orientation alongside the left section of the reality-virtuality-continuum (Milgram et al. 1994) in relation to the goal of the game.

Keywords
Augmented Reality, Games, Classification

INTRODUCTION
In the last century, science fiction introduced the concept of augmented reality (AR) and brought this way of human-computer interaction into our collective consciousness. In simple terms, AR means the enrichment of our perception with digital information, *i.e.* when “3-D virtual objects are integrated into a 3-D real environment in real time” (Azuma 1997, 335). Although AR enhancements can apply to all senses, we focus on visual AR due to its popularity in gaming contexts. Other forms like aural augmentation are excluded in this first step in order to provide a sound basis for further research. First attempts of AR interfaces come from pioneers in the 1960s. In the following years, the

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topic became more and more popular. The first AR conference, the *International Workshop on Augmented Reality (IWAR 98)*, took place in San Francisco in October 1998 (Mackay 1998). Nevertheless, although AR was said to be the new striking technology, it has been seen for a long time as a technology for a distant future.

One barrier for AR becoming mainstream was the fact that applications required powerful workstations or high-power computers. With technology becoming more mature and especially AR applications being introduced to smartphones, progression was facilitated (Yuen and Johnson 2011). Additionally, the concept of smart glasses evolved. Today, the goal of bringing AR research from laboratories to the industry and to widespread use seems nearly accomplished.

Generally, AR applications realize their full potential whenever rapid information transfer is critical (Yuen and Johnson 2011). As this is the case in many industries, AR has great potential to find its way into a wide range of fields. In addition to the huge application of AR in military contexts (Livingston et al. 2006), Ludwig and Reimann (2005) see possible application areas especially in three categories: presentation and visualization (*e.g.* advertising, navigation, or architecture), industry (*e.g.* product development or maintenance), and edutainment (*e.g.* museum guides, tourism, or games). Until now, the field of edutainment consists of a couple of practical applications and much research in education, such as the use of AR for teaching history and tourism (Kysela and Storková 2014) or the use of AR in museums (Cianciarulo 2015). But besides all those cases, games rather seem to disappear even though AR is a promising gaming-technology. Research projects range from Szalavári et al.'s (1998) approach to collaborative AR gaming to Jacob et al.'s (2012) thoughts on location-based AR games and further. However, these works often use a hands-on approach or look at isolated phenomena concerning the evolution and favorable design of AR games and, thus, form an inconsistent field of study.

This demonstrates that the category of AR games is still emerging. Yet, visual AR games have already reached such a wide range of cases that a scientifically sound classification is required to study their characteristics in greater depth. In order to advance research in AR gaming studies, our aim is to develop such a classification that can serve as a starting point for both further research and new practical applications. We develop our classification of AR games through a comprehensive literature review combined with the assessment of experts in the context of Delphi interviews. Additionally, we consider visions of AR as illustrated in fictional works before we discuss our results and conclude with a short summary.

LITERATURE REVIEW ON AR GAMES RESEARCH

Investigating games is not a simple intention due to the great diversity of this medium. "Games are the most culturally rich and varied genre of expression that ever existed. It is also one of the least studied." (Aarseth et al. 2003, 48). Since 2003, research on games has increased significantly and a lot of attempts to classify games have been made, too. The aim is to specify the significant aspects that constitute the basic dimensions of the mediality of games. A crossfire of ontologies arose ranging from the key-elements-approach by Rollings and Adams (2003), subdividing games into core mechanics, interactivity, and storytelling and narrative, to Fullerton's (2008) partitioning of the structure of games into the three elements form, drama, and dynamic, and further.

The main goal of our classification is the analytical determination of essential differences between AR games in order to better understand this new class of games. Most aspects of general approaches on classifying games could be adopted for a classification of AR games to a certain extent as AR games still have the basic characteristics of games like rules and player effort (Angelides and Agius 2014). But, on the other hand, AR games form a new class of games due to the fact that the gameplay moves into the physical environment (Oda et al. 2008) and prior classifications do not suffice anymore.

According to Magerkurth et al. (2005), AR games are a subgroup of pervasive games, *i.e.* games that "focus on a game play that is embedded in our physical world" (Lindt et al. 2005, 62). In this work, AR games shall be defined as games utilizing the technological concept of visual AR. To explore the insights that research provides regarding such games, we conducted a comprehensive search for relevant and on topic literature using variations and combinations of the following terms in English and German: 'augmented reality', game, play, and gamification. We used search engines and databases with no particular academic focus (Google Scholar[1], JSTOR[2], Bielefeld Academic Search Engine[3], and ScienceDirect[4]). On average, we surveyed the first 300 results of each search engine. The results of the search revealed 181 different relevant results in total. The terms "'augmented reality' games" and "'augmented reality' gaming" showed the most relevant results. German terms hardly delivered any results. Subsequently, we analyzed the content of the articles in detail to identify research aim, method used, and results, among others. Backward and forward reference searches provided additional relevant sources.

To focus the search's results on the requested visual AR gaming applications, we excluded findings on AR games that augment reality by stimulating senses other than vision. In addition, games that are only location-based without any visual augmentation, such as Google's *Ingress*,[5] have been disregarded. AR applications where gamification has been applied have been included in the search in order to broaden possible results as gamification issues are a popular application for AR (Dunleavy et al. 2009). However, we only considered those results when the gaming character was predominant. Papers on applications that only use game mechanics for reasons of gamification and do not represent an original game are not included.

The amount of research related to AR in general is multifaceted. Even within the specific search for applications of AR in a gaming context, the results extend to various other areas. An investigation of prevailing AR research topics by Zhou et al. (2008) reveals the dominance of technological aspects. Focused research in AR games has only been around since the late nineties with Ohshima et al. (1998) being one of the first. In order to provide a concise summary of the fragmented field of AR games research, this chapter is subdivided into three groups of research streams which include classification categories but also describe the foci of research on AR games so far: (1) theoretical classification attempts, (2) practical research about technological implementations of AR games in order to test novel technologies, (3) practical research relating to game design issues. We use the latter two research streams to validate and enhance previous classification attempts.

(1) Research concerning the **understanding of AR games on a theoretical level** is still in its infancy. Classifications are developed unsystematically, are not extensive enough,

or focus on isolated phenomena. In addition, they do not include important aspects of the mediality of games as outlined in the beginning of this chapter. Under the general distinction between indoor and outdoor AR applications (Avery et al. 2006), Bernardes et al. (2008) classified AR games by the size of their gaming area. They observed the evolution of AR games and traced the scope of AR games primarily back to the different underlying technologies. The main classifying aspect, however, is based on the physical space in which the game takes place, "separating games that require large areas from the ones that need limited and prepared areas" (Bernardes et al. 2008, 234). The size of the area in turn has an effect on playability and the used technology. Additionally, Bernardes et al. (2008) categorized AR games according to the way they are played, *i.e.* traditional or electronic, and map the advantages of augmented reality for games to these different types.

As some kind of side-effect in Broll et al.'s (2008) work on the next generation of mobile AR games, they extended Milgram et al.'s (1994) reality-virtuality-continuum, which indicates the positioning of AR between reality and virtuality, with two further dimensions: the grade of ubiquity (stationary to mobile) and the one of multiplicity (single use to multiuser) which refers to the amount of concurrent users. These two dimensions supplement the original approach of ranking AR in respect to its degree of reality. The new 3D taxonomy now also considers how and where AR applications might be used.

Tönnis et al. (2013) are not researching AR games in particular, but developed a taxonomy for classifying AR applications from a technological point of view. They investigated five orthogonal dimensions for the representation of virtual information in an AR application:

- "Temporality: continuous versus discrete representation of virtual objects.
- Dimensionality: the number of features (dimensions) that virtual and physical objects possess as well as methods to visualize and render them.
- Viewpoint reference frame: ego-centric versus exo-centric and ego-motion-based control of viewpoints.
- Mounting/registration: spatial relationships between objects.
- Type of reference: concepts regarding the visibility of referred-to-physical objects." (Tönnis et al. 2013, 997f.)

Following this theoretical classification, Tönnis et al. also exercised the taxonomy with 314 different AR applications. The resulting overview on the dispersion of the used technology in AR applications could give researchers and developers a reference point to arrange their work to. Nevertheless, it is not clear whether this technological classification can be transferred to a general classification of AR games

(2) In the landscape of AR research, **technological aspects** are the dominant research stream. However, in the past years the technological implementation has gradually started to become not the most important aspect determining possible ways of using AR anymore. Nevertheless, research is still progressing in this field. In the course of sampling and testing technology, a couple of research gaming applications have been generated. For example, following the *Tinmith System*, a context-aware wearable computer system developed by Wearable Computer Lab for the implementation of *ARQuake* (Thomas et al. 2002), various other frameworks, set-ups, and systems have

been generated to provide platforms for AR gaming applications including *STARS* (experimental setup for gaming applications integrating specialized graphical user interface devices for gaming purposes; Magerkurth et al. 2004), *TARBoard* (tangible AR system designed for tabletop game environments; Lee et al. 2005), or *ART* (prototype platform employing AR technology in order to provide a virtual table for playing trading card games; Lam et al. 2006). In addition, Sujaatha and Threspine (2014) suggest an AR gaming scheme to support game developers. Beyond that, several prototypes have been created, such as the *Invisible Train* (Wagner et al. 2005), a testing game to study the suitability of handheld devices for AR applications. *Invisible Train* was also "one of the first AR systems on a handheld device that could track fiducial markers and render 3D graphics in real time" (Huynh et al. 2009, 136).

In matters of tracking technology, researchers try to outstrip the use of markers or predefined models for visual augmentation as this causes several restrictions. In 2007, Chekhlov et al. (2007) developed *Ninja on a Plane*, a simple game to test and illustrate an implemented discovery algorithm that aimed to achieve real-time interactivity. Using the visual SLAM (simultaneous localization and mapping) framework together with the extended Kalman filter, planar platforms are discovered and integrated in the game world at runtime. Methods of that kind enable much more flexibility in developing games and allow dynamic integration of real surroundings in the game environment.

The implementation of AR games is by now technically advanced, but there is still much room for improvement. One of the latest works in research on technological aspects of AR games is Lv et al.'s (2015) approach on designing a touch-less motion interaction technology for AR games on vision-based wearable devices. This technology enables users to interact with virtual game objects with the aid of dynamic hands and feet gestures and is composed of two parts: vision-based wearable hardware, *e.g.* frameworks on wrists or knees, and touch-less interaction-based AR games software that tracks the interaction gestures. The algorithm for gesture recognition and tracking uses the CTM (Contour based Template Matching) algorithm and the TLD (Tracking-Learning-Detection) framework. The technology runs on three devices (handhelds, hybrid wearable frameworks, and smart glasses) and has been tested with three primitive games to "demonstrate the usefulness, viability and flexibility of the touch-less interaction approach" (Lv et al. 2015, 565) for AR games.

Regarding our classification, research on technological aspects demonstrates the variety of different possible implementations of AR. That indicates that the selection of the used technology impacts the characteristic of the game. Above mentioned former AR games classification approaches largely neglect technological aspects. Tönnis et al.'s investigation (Tönnis et al. 2013) confirms the relevance of technological aspects, which suggests considering them in our classification as well.

(3) Research has adapted to the possibilities of the advancing technology and, by now, emphasizes non-technological aspects of AR in games, mainly **practical game design aspects**. Besides the technological implementations discussed above, many hands-on applications have been developed in order to sample game mechanics. With the classification approaches of games in general as outlined in the beginning of this chapter in mind, we reviewed the works in this area according to the following four criteria: performance, narration, ludition, and context (Koubek et al. 2013). Performance

comprises all performative aspects relating to the player effort and the use of the game, narration includes narrative aspects like story, setting, characters, and more. Ludition incorporates all ludic aspects relating to the gameplay (rules, dynamics, physics, non-player characters etc.) and context describes the meaning of the game depending on culture and discourse, for instance. These four criteria do not cover the entire range of digital games as, for instance, audio-visual or technological aspects are missing. Since we have already covered these above, the mentioned four criteria can serve as a foundation to analyze game design aspects.

Insights reveal that practical research roughly concentrates on four major facets of AR games: genre, collaboration, mobility, and embedding. Regarding the first, educational games form a dominant category (Kysela and Storková 2014). Regarding the second, many AR games focus on collaboration and social interaction, as AR is said to be predestined for collaboration issues (Alem and Huang 2009). This performance aspect conforms to Klabbers' (2003) view of actors as an important element of gaming and is included in Broll et al.'s (2008) dimension of "multiplicity". Regarding the third, augmented tabletop games have been a popular approach to adopt game mechanics for AR applications at first but with ubiquitous computing the trend goes to mobile AR. Location-based AR games represent the counterpart to augmented tabletop applications concerning the mobility of AR games (Ebling and Cáceres 2010). Mobility is a performance aspect that has not been considered in research on game ontologies at great length yet, although it is also covered by Broll et al. (2008) as the "ubiquity" of AR games. Regarding the fourth, research has begun to extend to ludic issues such as the optimal embedding of the augmented world into the gameplay and especially the connection to a virtual environment (Cheok et al. 2002).

Only one of these groups (embedding) directly relates to one of the four gaming categories mentioned above. Categories like narration or context do not play a particular role in practical research on AR games yet. At most, mobility and collaboration could be counted among "performance". The aspect of genre is added and could relate to "context", especially in the field of educational games, but that depends strongly on the individual game. All in all, this overview underlines that many important gaming aspects are not in the focus of research on AR games yet. Nevertheless, our classification can benefit from practical research on AR games as follows:

Allocating existing AR games to various proven genres besides the dominant genre of educational AR games is not beneficial as there is no specific AR genre yet. In the course of time, video game genres like action, role-playing, educational, or adventure games have emerged (Arsenault 2009). These genres can also be used to classify AR games. Specific AR genres have not yet emerged, but could in the future. Thus, genre should be kept in mind when creating a classification.

Collaboration and the broader "multiplicity" (Broll et al. 2008) have addressed a seemingly simple aspect of games, the number of players, but have also revealed its importance for AR games. Although the amount of single-player and multiplayer games is almost balanced, the number of players seems to be an important distinction for AR games and should therefore be considered in the classification.

Performance aspects play an important role for analyzing or classifying games, especially on mobile devices. Relating to AR games, implementations range from mobile to tabletop AR games. Therefore, the mobility or ubiquity (Broll et al. 2008) of AR games should be included in a classification.

Embedding virtual and real world is one of the core features of any AR game and one of the greatest challenges at the same time. There are different technological approaches, which each lead to different opportunities and barriers for gameplay. Thus, a classification of AR games should contain not only a technological view on embedding, but also a ludic view.

METHODOLOGY TO DEVELOP A CLASSIFICATION OF AR GAMES

The insights from the literature review underline the need to comprehend AR games better. Classifying them according to specific characteristics would provide a solid foundation for future discussions. The objective of any classification is to find categories that supplement existing ontologies and are not overlapping, arbitrary, or incompatible. For this purpose, three data sources are combined: (1) As a first step, interviews with four AR game experts following the Delphi method (Linstone and Turoff 1975) provide a basic classification that takes different perspectives into account. The Delphi method is a multi-phase communication technique that “may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem” (Linstone and Turoff 1975, 3). In consideration of specific preconditions, we followed the default process of the Delphi method: preparation (operationalize question and prepare questionnaire), evaluation (collect results, find discrepancies, and report anonymized findings to participants), iteration on the basis of the participant’s feedback. The loop is conducted until a consensus is found (Linstone and Turoff 1975). (2) As the value of the results of Delphi studies is methodologically restrained and often only allows statements on a meta-level, we adapt the study’s results using the findings from the preceding literature review to cover possible additional aspects not thought of by the experts or dismiss criteria found in the literature because all experts explicitly did not find them beneficial. (3) As a third step, to verify this adapted classification, the use of AR games in selected fictional works is analyzed in order to broaden the view on possible means of usage and adapt the classification, if necessary. The spectrum of fictional works used for this last step is mainly limited to movies as books and other works are less suitable for illustrating technological inventions.

(1) Following the described process, we undertook four rounds of **Delphi interviews** in order to develop a basic classification. As the Delphi method requires qualified experts, we selected specific AR game experts: two participants with regards to game content and two with regards to game technology, in each case one practitioner and one academic:

- Entrepreneur Evgeni Kouris from AR games developer *Toywheel*[6] (content, practitioner)
- Digital games professor Dr. Jochen Koubek from University of Bayreuth[7] (content, academic)

- Senior business developer Sascha Kiener from AR software developer *Metaio*[8] (technology, practitioner)
- AR games engineering professor Gudrun Klinker from Technical University of Munich[9] (technology, academic)

Purpose of round one is the introduction of the participants to the subject and the collection of ideas with open-ended questions: In which aspects do AR games differ from other games? In which aspects do AR games differ from each other? The answers concerning the first question were comparatively clear, the ideas of distinctions between AR games amongst themselves differed to a greater extent. Summing up the answers resulted in a compilation of ten possible criteria for a classification of AR games: device, dispositif, field of view, genre, goal of the game, immersion, interactivity, interface, proportion real world – interface, and technology.

The second round serves to narrow down these results. For this purpose, we distributed the combined answers to all participants along with the following questions: Is it possible to merge criteria? Where do interactions or dependencies occur? Can you prioritize the criteria with regard to a classification of AR games? Which criteria are highly relevant for a classification and why? Which ones need not to be considered and why? Due to the different specializations of the participants, the dependencies have been evaluated in different manners. In the same way, the conclusions concerning the relevant criteria for a classification of AR games have been highly diverse. Summarizing all answers, a preliminary classification could be developed to provide a more advanced basis for the next round instead of working with another open questionnaire. This preliminary classification contained the aspects context (viewing perspective, setting), mounting (tracking technology, device), and content (number of players, goal of the game). Due to most participants' explicit objection, the following criteria have not been included in the classification: dispositif, field of view, genre, interactivity, interface, immersion, and proportion real world – interface.

The goal of the third round of the Delphi method is the evaluation of the intermediate data in order to obtain a preliminary result for a classification of AR games. We gave the results of the second round to the participants with the following questions: Can you agree with the suggested classification? Where are still weak points or room for improvement? Main annotation has been the confusion about the denominations and the breaking down in main categories and sub-categories. On the basis of the comments from the third round, we could derive an appropriate basis for a classification. We distributed these results once again in a fourth Delphi round to the participants in order to complete the Delphi survey and verify the consensus. Participants agreed to the classification shown in Table 1 with only two remarks: First, "setting" could be broken down into a setting for the player and a separate setting for the device, *i.e.* a player-setting and a device-setting, for games such as *Just Dance*[10] that use a fixed device and enable mobility of the player. Second, the criteria of "orientation" is difficult to understand and to handle.

Criteria	Specifications
Device	Handheld, Wearable, Spatial
Tracking	GPS-based, Marker-based, Environmental Detection, Thermal Detection, ...
Setting	Indoor+Fixed, Indoor+Mobile, Outdoor+Fixed, Outdoor+Mobile
Orientation	Physical Goal of the Game, Digital Goal of the Game

Table 1: Preliminary results from the Delphi survey.

(2) The classification developed during the Delphi survey is mostly in accordance with the findings from above **literature review** on AR games. For example, research on technological aspects of AR games indicates that the technological implementation still is a decisive criterion for the design of AR games. Thus, technological criteria need to be included in the classification. The result of the Delphi survey corresponds to this with two technological criteria (device and tracking technique). However, with the literature review in mind, some adaptions to the classification have to be made. The thoughts of Broll et al. (2008) on mobility and ubiquity are transformed and, together with space, melted into the criterion "setting", which is also justified considering literature (Carmigniani and Furth 2011). Furthermore, genre is excluded as there is no AR specific genre yet. Instead, another criterion is included: orientation. This criterion distinguishes digital games that are enhanced with real objects (*e.g. Invizimals*[11]) and analogue games that are enhanced with digital information (*e.g. Scotland Yard – Master*[12]). The distinction is made according to the location of the goal of the game, *i.e.* whether players have to achieve a goal in the real world or in a virtual environment. Finally, other more game related classification criteria regarding narration, ludition, and context are not included. Similar to genre, there are not enough AR game specifics yet to justify including these in the classification.

(3) In order to broaden the view on possible means of usage and verify or adapt the classification, we analyzed **fictional applications of augmented reality in selected movies**. For a selection of appropriate works, four sources have been used:

- Personal fund (13 movies)
- Survey of students of media studies (18 movies)
- Listing on Pocket-lint[13] (11 movies)
- Movies previously mentioned in research (9 movies)

These four sources are merged using the personal fund as a foundation. This fund is complemented with recommendations of students of media studies leading to a collection of 26 movies in total. The listing on Pocket-lint extends the collection to 29 movies altogether. Schweinitz (2006) mentions in his article on total immersion in cinema and video games other examples that deal with VR, but these nevertheless complement the picture of pervasive games in movies and, thus, complete the collection of then 35 different relevant movies on the whole. We compared and sorted the results according to the type of application of AR they show.

Insights reveal that applications of AR in a gaming context are uncommon in movies, but the general employment of AR in movies is astonishingly popular. Just to name a few, movies range from *Earth vs. The Flying Saucers*[14] (1956; AR helmet) and *Terminator*[15]

(1984; cybernetic eyes) to *Iron Man*[16] (2008; spatial UI) and further. With regard to games, movies rather broach the issue of virtual reality like the VR video game simulations in *Nirvana*[17], *Strange Days*[18], or *eXistenZ*[19].

The only two movies that portray AR in a gaming context are *Star Wars: Episode IV – A New Hope*[20] and *Jellyfish Eyes*[21]. In *Episode IV*, R2-D2 and Chewbacca, two Star Wars characters, are playing *Dejarik*, a kind of holographical chess that is played upon a so-called hologame table. According to the developed classification, this game could be characterized as follows:

- Device: Spatial
- Tracking: Other
- Setting: Indoor + Fixed
- Orientation: Physical goal of the game

In 2013, Takashi Murakami directed the fantasy-comedy *Jellyfish Eyes*, in which AR plays a central role. It is about a suburban town in Japan where children possess virtual creatures that look like jellyfishes. It does not become apparent how the creatures are created, but by means of special devices, the children have the possibility to control those creatures and can make them fight one another. In this regard, the use of AR reveals the gaming character. According to the developed classification, this game could be characterized as follows:

- Device: Handheld
- Tracking: Other
- Setting: Indoor/Outdoor + Mobile
- Orientation: Digital goal of the game

Although most of the identified applications of AR in movies are not gaming applications, we classified exemplary results into the proposed criteria in order to detect weaknesses of the classification. This examination indicates that the classification is suitable with no further adjustments being required.

RESULTS AND DISCUSSION

As argued above, AR games can be classified based on four criteria: tracking, device, setting, and orientation (see Figure 1). “Tracking” distinguishes mainly between marker-based and marker-less (*e.g.* environmental) tracking techniques, but covers also other forms like GPS-based and thermal tracking. The used tracking technique influences gameplay and user experience in matters of spatial flexibility, accuracy, and immersion. “Device” includes both display positioning and display technique and therefore also affects, for instance, the field-of-view. Device also determines the possibilities of interaction. “Setting” picks up Bernardes et al.’s (2008) and Carmigniani and Furht’s (2011) idea and describes the spatial area where the game is played. It therefore distinguishes between mobile and fixed as well as indoor and outdoor and the number of players. This distinction also includes whether the game is an augmented tabletop or a mobile AR game. Finally, “orientation” describes the reality/virtuality of the game in relation to the goal of the game: a digital game enhanced by the physical world or vice versa. Orientation therefore indicates the alignment of the game along the left section of Milgram et al.’s (1994) reality-virtuality continuum.

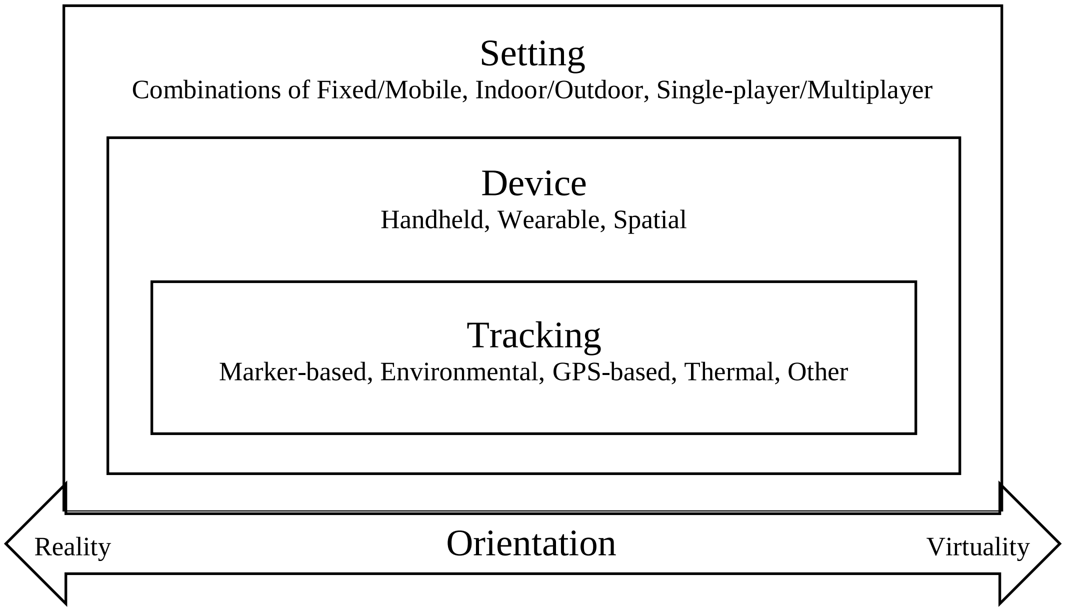

Figure 1: Classification of AR games

The general challenge of classifying games has already been addressed. Basically, it is possible to characterize AR games with most of the criteria used to characterize other games such as, for instance, audiovisuals, genre, rules, or narration. But these criteria do not allow to capture the specifics of AR games in full. This does not only relate to technological aspects, but also on gameplay aspects such as the goal of the game. This is one of the fundamental issues of a game, but has a special importance for AR games as the goal can either be located in the physical or virtual world.

However, there is substantial evidence that the classification presented above will need to be reviewed when AR games have become more mature. Genre is an aspect that has to be reconsidered once AR game genres are emerging. Furthermore, technology will also evolve, leading to a need for refinement as soon as the scope of AR is used to full capacity. Finally, other aspects regarding narration, ludition, and context might need to be included in the future. All in all, the proposed classification has to be considered as a supplement to existing game taxonomies. Its point is primarily to discover the decisive attributes that distinguish AR games and to serve as a basis for further research on them.

These findings mean that especially practitioners need to be aware of the whole scope of opportunities, but also of the threats that AR technology offers. Yet, the opportunities seem to be much greater than the threats, considering that today's AR technology's potential is far from being fully exploited. In addition, the classification offers a set of important criteria that should be considered while developing an AR game. For research, the classification could serve as a foundation to classify existing games and thus reveal areas that are often or little considered yet. This would enable to identify trends in AR development and predict areas AR gaming applications will cover in the future. Furthermore, the presented classification can lay the foundation for a more content- and game design-related discussion of AR games while still considering the important technological aspects.

CONCLUSION AND FUTURE RESEARCH

In this paper, we have aimed at creating a classification for AR games. After an extensive literature review, we have developed a basic classification using Delphi interviews with four experts. Then, we adapted this basic classification utilizing insights from the literature review and verified its applicability by classifying fictional AR games. The resulting classification contains the four criteria tracking, device, setting, and orientation (see Figure 1). It can serve as a foundation for further research, for example through identifying well and less investigated areas, establishing a common naming for AR game phenomena, and shifting the discussion from technology aspects to content aspects.

Probably the most restrictive limitation of the proposed classification is the constraint on visual AR games. Various other approaches such as aural or sensory AR or even so-called habit role-play games like *Epic Win*[22] or *Zombies, Run!*[23] have been created and should be considered in a later taxonomy. In this context, a distinction based on Kim's (2013) concept of context immersion could also become interesting. Furthermore, most of the current applications still use marker-based tracking due to easier implementation and better performance and stability. But markers form an obstacle for deep immersion, therefore constrict user experience, and limit the application in matters of mobility and scalability. Further research could ask for the suitability of the particular tracking techniques for AR gaming applications. With the advancing development of the technological implementation of AR, a new generation of AR games will evolve. This in turn may request a revision of the current classification. Until then, it can be used as a starting point for further research.

ENDNOTES

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