State of the Art on Augmented Reality

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(*) Action: C = Creation, I = Insert, U = Update, R = Replace, D = Delete

Executive Summary

The purposes of the document are the following:

- Explore the educational potential of Augmented Reality for children
- Assess from a critical viewpoint current applications utilising Augmented Reality technologies
- Promote the use of Augmented Reality for strengthening an educational curriculum
- AR assessment

State of the Art

Augmented Reality is an environment that takes real-time reality as its basis and includes virtual augmented elements. The augmentation can be triggered by a marker or by a PoI. AR is typically experienced on a smart phone, a tablet or a game console, but this is not a stable environment. Although this will probably change in the future, currently computer-based AR has a bigger potential.

Commercially, AR is in its early stages. Information AR depends on attracting local advertisers while Enterprise AR is in its very early stages. The biggest chances are for entertainment AR. AR has to find a commercial purpose beyond the wow-factor to be economically viable.

Educational AR shows that AR visualization engages end-users in the things they are doing, be it learning or training or reading a book. Besides facilitating cognitive processes AR can stimulate social and decision-making skills.

The following specific application areas have recently benefited from the particular technology:

- Collaboration Support
- Robotics
- Industry / Industrial Design
- Medicine
- Entertainment

AR assessment

If we accept the hypotheses that will be put forward in chapter five, we can conclude the following. In the first place, we can distinguish Augmented Self Reality from Augmented World Reality. In ASR the Self is the object of reflection. The trigger that arouses curiosity is the looking in a kind of mirror.

If there is no augmentation, the looking in the mirror will cause a self-narration to collide with the self-representation and, as a result, the self-narration will be adjusted to achieve more conformity with the world.

If there is positive augmentation, the looking in the mirror will cause an affirmation of the self-narration and will cause a rise of self-esteem.

If there is frustrating augmentation, the looking in the mirror will cause questions on the augmentation and a shift towards a more autonomous moral position.

From the above we derive the preconditions for our AR game are the following:

- Children will have to be able to see themselves in the game in a kind of mirror
- Augmentation is added
- The augmentation will not cover the eyes and the head of children and will leave open significant areas of the surrounding reality
- The augmentation will be like a task with no positive outcome
- The augmentation will contain a lot of details that are added and taken away over time
- The augmentation will be consistent with the theme of game - the emergent relationship between active and passive data on the one hand and identity on the other

Consistent with the first and second preconditions we will chose ASR as our kind of Augmented Reality. The game will be computer-based and will be played either stand-alone or over the Internet.

In chapter five and six the AR and theme choices will be presented.

Document Glossary

Term	Description
AR	Augmented Reality
ASR	Augmented Self Reality
AWR	Augmented World Reality
CMS	Content Management System
FD	Functional Design
GPS	Global Positioning System
PoI	Point(s) of Interest
QR	Quick Response
SoA	State of the Art
TD	Technical Design
VR	Virtual Reality

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

Our research concerns the development of an augmented reality game in which different sets of data, both active and passive, lead to different outcomes as symbolized by signs. These different signs will be printed by children as an outcome of a stage in the game and will be shown to a computer camera. Then, on their computer screen, the augmented reality translation of the signs will be shown. This translation represents the identity that emerges from the data they have entered in the course of the game. By playing the game children will learn that not providing any data or providing only a small amount of data leads to either a complete lack of representation or a distorted representation while providing of too many validated data will lead to a truthful representation.

Augmented reality is an excellent way to demonstrate the essence of what it means for an identity to be emerging. In a purely visual way - that is a magnet to a child's attention - augmented reality leaps from a sign that is being shown to a camera to an animated 3D image that emerges out of the sign once the sign is being directed at the camera. Since the transformation only occurs on the screen that represents the camera image but not in reality, augmented reality beautifully illustrates the emergent interpretation of data that occurs in a third person's mind although in reality nothing seems to happen.

The document is the outcome from an analysis of current AR applications for learning in terms of technologies, applied methodologies and functionality from a critical viewpoint in terms of their use in children between the ages of 8 and 14. In line with the Work Stream the State of the Art analysis is followed by a needs assessment applied to AR technologies, methodologies and functionalities.

1.1. Purpose of the document

The purposes of the current State of the Art on Augmented Reality document are the following:

- Explore the educational potential of Augmented Reality for children;
- Assess from a critical viewpoint current applications utilising Augmented Reality technologies;
- Promote the use of Augmented Reality for strengthening an educational curriculum;
- AR assessment.

1.2. Document structure

The document is structured as follows:

- Section 2 – State of the Art: Technological and conceptual overview

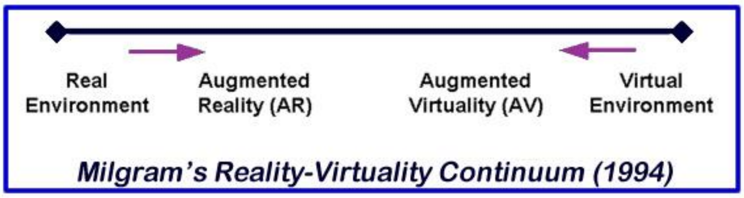
- Section 3 – State of the Art: Concepts and purposes
- Section 4 – State of the Art: Projects in EU and Future Trends
- Section 5 – **Error! Reference source not found.**
- Section 6 – **Error! Reference source not found.**

2. State of the Art: Technological and conceptual overview

In this chapter we'll present an overview of the technological and conceptual State of the Art of Augmented Reality.

2.1. Intro

Augmented Reality (AR) according to Ronald Azuma, Research Leader at Nokia Research Centre, is "an environment that includes both virtual reality and real-world elements[1]. This means that either virtual elements are added to reality or that reality is added to a virtual world. Augmented Reality finds itself in a spectre that ranges from Reality to Virtual Reality[2]:



2-1: Reality - Virtuality Continuum

The difference between adding virtual elements to reality and adding reality to a virtual world will be described in 2.2. In 2.3 we'll go deeper into the differences between Augmented Reality and Virtual Reality.

2.2. Adding virtual elements to reality and adding reality to a virtual world

Augmented Reality takes reality as its starting point. This reality is augmented with virtual elements such as 3D animations, video, image, sound and or other file types. The virtual elements are

[1] http://wik.ed.uiuc.edu/index.php/Augmented_Reality_in_Education

[2] P. Milgram and A. F. Kishino, *Taxonomy of Mixed Reality Visual Displays* IEICE Transactions on Information and Systems, E77-D(12), pp. 1321-1329, 1994

presented within the frame of reality: although reality is changed, it remains our point of reference. The augmentation does not change its essence; it just adds one or more virtual layers[3].

Adding reality to a virtual environment is something different. In this situation the virtual world and its virtual inner logic are the essence. The reality that is added merely functions as a background for the virtual elements to interact with each other. The rules of the real world are not valid any more. Reality is reduced to an augmented layer of the virtual world.

Piclings is an example of a game that uses reality as a background for a virtual environment to evolve in[4].

Following Paul Milgram's distinction we'll call the first type of AR Augmented Reality while the second type is called Augmented Virtuality.

2.3. Augmented Reality and Virtual Reality

As we've noted in 2.2 in Augmented Reality, the reality is the point of reference. In Virtual Reality, on the other hand, the virtual environment with its constructed inner logic constitutes its essence, like in Augmented Virtuality. While in Augmented Virtuality reality still has its place, albeit sometimes marginal, in Virtual Reality the real world has completely disappeared. There are no real elements anymore, just virtual form and logic[5].

Examples of VR are games played on Nintendo or Wii or Xbox or PSP. Arguably also Microsoft's Kinect is a VR where the body movements of the end-user are used as a control – rather than AR. There are no traces of reality left on the screen. Our virtual avatars move around in a completely virtual setting. These avatars are no representations of ourselves. They are virtual elements that react to our movements. The Kinect avatars mimic us obediently but they are no more a representation of us than avatars that we steer by means of a joystick or by a Wii controller. Maybe the fact that we control their visual movements gives us a feeling of closeness, but seeing them as representations would mean that we could see our cars or any other machines that we control as our representations too. Cognitive scientist Douglas Hofstadter comments: "There is something very beguiling about this concept of mapping, projection, identification, empathy – whatever you want to call it. It is a basic human trait, practically irresistible. Yet it can lead us down very strange conceptual pathways."[6]

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[3] An example of the type of AR can be found here: http://augmentedrealityoverview.blogspot.com/2011/05/all-posters-on-wall.html

[4] http://www.gamezebo.com/games/piclings/preview

[5] See f.i. Manovich, 2002

[6] Hoffstaedter in Douglas Hoffsteadter and Daniel Dennett - The Mind's I. 1981.

2.4. Relative or absolute difference

Lev Manovich[7] proposes: "we don't necessarily have to think of immersion in the virtual and augmentation of the physical as opposites." This seems consistent with Milgram's spectre representation of the options ranging from reality to the virtual environment. Manovich proposal though concerns the experience of Augmented Reality and of virtual environments, not the concepts themselves.

We'd like to conceptually distinguish between reality and Augmented Reality on the one hand and Augmented Virtuality and Virtual reality on the other. Their points of reference are radically different and non-reconcilable. Only one set of logic can rule at the same time – either real world logic or virtual logic. At a later stage (chapter 5), we will revisit Manovich' insights on human experience.

2.5. Technological prerequisites

In order to experience Augmented Reality a few prerequisites have to be in place to mix reality and the virtual augmentation. Both reality and augmentation have their own sets of prerequisites.

To start with, we need a camera to register reality in real-time. It does not matter where the camera registers reality: the stream may be locally rendered or imported as a live streaming. If there is a stream from elsewhere, there naturally will be a (small) delay in the image because of the network and hardware involved but conceptually this delay is unimportant. Also noise will be rendered but also this noise is conceptually not relevant. The camera can be a web cam, a smart phone camera, a professional analogue camera or any other cam that is digital or delivers an output signal that can be translated to a digital stream.

To be able to process the digital stream we need hardware. This can be a PC, a smart phone or any other carrier (please refer to section 2.6). Next, the processed stream needs a screen so that we can see the real-time image of reality. This screen can be a computer or smart phone screen but might as well be the surface of special goggles – HMD, head mounted devices - or a car windscreen.

7 Lev Manovich – The poetics of augmented space. 2002, rev. 2004. www.**manovich**.net/nnm%20map/**Augmented_2004**revised.doc

The screen might also be replaced by pre-defined objects as projection based AR uses. Examples of projection based AR are very sophisticated or wild projections on buildings. Rapid prototyping from TU-Delft, Industrial Design Engineering, Jouke Verlinden, uses projection based AR for manipulating appearances of products.

In the 3D Virtual Lab at McHenry County College[8] polarized glasses enable viewers to see a projected image in three dimensions. Then, any model from 3D Studio Max can be converted into a special format that is displayed via two computers and two projectors. The projectors have polarized filters which are perpendicular to each other. The lab was used for the first time in fall of 2005 to show models of the human skeleton, muscle system, and major organs. Wider use in biology, anatomy and physiology, astronomy, and meteorology is planned.

To generate and support the virtual components of Augmented Reality we need relevant hardware and software in place. In Section 2.8 we'll go deeper into these prerequisites when we discuss the development of Augmented Reality applications.

2.6. Carriers

Augmented Reality has started to reach a mainstream audience as a handheld application. AR browsers like Layar or Wikitude are more often than not pre-installed on new smart phones. More recently other carriers such as tablets (especially iPad 2) and game consoles (like Nintendo 3DS) have followed this trend. Augmented Reality on stand-alone computers or on computers over the Internet are rare. Special devices like goggles or car windscreens are very rare, although the teaming up of HMD producers Vuzix with AR specialist Metaio could change that.

[8] www.insidemcc.mchenry.edu/PD/Tutorials/virtuallab2.pdf

2.7. Marker vs markerless Augmented Reality

Currently, many people associate Augmented Reality with black and white squares that trigger augmented reality elements. These black and white squares are called markers.

Popular type of markers is the QR (Quick Response) code or Semacode. A QR code is a two dimensional bar code that allows its content to be decoded at high speed. While a QR code triggers the online opening of pages or files, QR codes are no Augmented Reality markers, not even simple Augmented Reality markers. QR codes do not trigger virtual content that is mixed with reality in real-time; they are merely linking the real world and the virtual world as a kind of real world hyperlink.

2.7.1. Marker Augmented Reality

In marker Augmented Reality a marker typically is a square image that has a black frame around it that is about one-tenth of the image size. Showing the marker to the camera invokes the virtual augmentation of reality, more often than not on the exact place where the marker should have been visible on the screen. Instead of the marker the augmentation appears. But, theoretically, the augmentation triggered by the marker can be projected anywhere on the screen.

Markers function in the same way a 'get'-command functions in code: they trigger an event to happen. Theoretically anything can trigger this 'get'-command: any picture, any sound or even any smell. Faces are sometimes used as triggers ('face recognition') as for instance in a project in the Amsterdam Van Gogh Museum where eyes, nose and mouths set off AR. Non-visual markers are hardly known to be used in Augmented Reality.

2.7.2. Markerless Augmented Reality

Markerless Augmented Reality does not need a marker to trigger augmentation. Here geo-location and direction provide the 'get'-command. This kind of Augmented Reality is mostly used on smart phones that possess GPS, a (gyro) compass, Internet connectivity and optionally tilt sensors (accelerometer).

The process here is as follows: an information provider has some Places of Interest (PoI) stored as if they were on a map (longitude and latitude values for each one of them). The information provider then associates augmentation to these PoI. If the end-user has the relevant software and application downloaded, they will see the augmented content that is associated with the PoI when they are situated at the PoI and point their smart phones to it.

The built-in GPS and the compass enable a smart phone to be aware of the direction the end-user is looking at. The application uses this information as a trigger when relevant. When triggered, the augmentation is displayed on the end-users' smart phone screen as a superimposed layer over reality. For PoI's outside of the field of the user's view arrows may appear pointing to these places.

Although Markerless Augmented Reality is the most commonly used AR, the GPS/compass tracking is suffering from some setbacks that hamper its definitive breakthrough. First of all the tracking system is lacking in accuracy: it might get as much as ten meters off. This means the augmentation is projected close to the intended PoI instead of exactly at it, or even represented as an arrow pointing at a place beyond the camera's view.

Augmentations also have been known to float in the air rather than to be projected on the intended PoI.

Also the stability is an issue because its functionality depends on the GPS-reception of the area it is used.

Other issues concern challenges to get markerless AR working indoors and high battery consumption of markerless AR to render 3D animations.

Overall, though, fast progress is made against all these problematic fields.

Forrester believes that mobile Augmented Reality is not delivering. According to the researcher it is currently more interesting for brands to turn to computer-based stand-alone or Internet-based

AR. Forrester does believe that mobile AR has a great potential for the future to become a disruptive technology but this will not happen anytime soon. It will take years to scale[9].

Geo-location based AR is theoretically not the only kind of markerless AR. Tests are being conducted for instance with markerless tracking algorithms.

2.8. Building blocks of AR: Creating Augmented Reality applications

In this section the typical preparation of an AR application is briefly described. Its aim is to provide some insight into the AR building blocks as well as in some of the creator's choices involved in AR.

Typically an AR project consists of a few standard components:

- At the very beginning there is the Functional Document/ Functional Design (FD). This is the functional translation of the application wish list that has been drawn up by the customer. The FD is like the project bible. Whatever technical decisions the techies will make, they have to obey the FD. In other words, the FD describes the deliverables. The deliverables are monitored throughout the development and they form the core of the testing phase – does the application do what it is supposed to do as described in the FD?
    - Very important is also the description of how many objects need to be displayed and what objects need to be displayed – see below: content production, markers
- The FD should take care of the most common bottlenecks in AR production. Besides laying out the functional requirements it also needs to lay out other relevant specifications like:
    - PC or mobile. In case of PC:
        - PC, MAC or all
        - Stand-alone versus over the Internet
        - Open-air versus indoors
        - Functioning in artificial light versus daylight, or both
        - Specialized cameras or regular built-in cameras
        - Hardware configuration

9 http://www.mobilemarketer.com/cms/news/research/8576.html

- The next step could be a Technical Document/ Technical Design (TD). This is a document where the technical translation of the FD takes places. This is an optional step because AR technology is in a way predefined. There are quite a few prefab AR software environments that function as an AR project basis. Nevertheless, some AR programmers prefer to start from scratch. A TD is obligatory in case there is no trusted AR software base.
- The first step of AR software development is defining the software base. Like we mentioned, some developers start from scratch and have their own brand of AR environment. Others start with a readymade AR software environment like Flair (for PC) or Layar (for mobile).
- The AR software base will always need to be personalized to meet the FD requirements.
- If the personalization is insufficient, new modules are needed. These are additional coding blocks that cannot be derived from existing prefab code (own or readymade). They need to be written freshly to meet the FD requirements. They need to be tested thoroughly but because they connect to a tested base they offer no big risk for the whole of the project.
- Next, there is a graphic environment - often Flash - that functions as an interface between the AR environment and the end-user. The graphic environment does not constitute a major challenge. It needs to be tweaked and installed.
- Then, there is content production. In the FD there is a description of what kind of content is evoked by the application. For any kind of content there are specified file types, be it 3D animation or videos or any content type (pictures f.i.). This content needs to be produced within the specified parameters. Then, it needs to be integrated with the application in a library.
- Next, the content is evoked by either a marker or by a geo-location:
    - Geo-location PoI's are defined in prefab CMSs or in a home grown CMS, and desired effects are added. Optionally, other functionalities are added too, like integration in social media environments.
    - Marker AR means that every individual marker evokes an individual content file (for instance a specific 3D animation). The markers need to be designed within marker frame definitions. The liberty one has to design the markers is dependent on the amount of different content files that need to be evoked within one AR environment. Ideally every marker and every corresponding content file have their own AR environment. An overview page then needs to be created to function as a portal to the different marker/content file combinations. If the amount of markers is limited (what this may be depends on the content file load, but can be estimated as less than thirty to forty) then several markers can be used to evoke multiple content files within one AR environment. The markers and files are stored in a library together with design style sheets and the coding. As a typical additional functionality, an option is created for end-users to view markers as printable PDF files.

- The AR environment is typically displayed – on an individual level – as a page in which a frame is dedicated to displaying the camera view and the subsequently evoked content file. This frame may be displayed on any screen. Most often smart phone screens and computer screens are used. The option to record the AR frame stream is one of the optional functionalities that can be added.

2.9. Summary

Augmented Reality is an environment that takes real-time reality as its basis and superimposes virtual augmented elements. The augmentation can be triggered by a marker or by a PoI. AR is typically experienced on a smart phone, a tablet or a game console, but these do not provide for a stable environment. Although this will probably change in the future, currently computer-based AR has a bigger potential.

2.10. Purposes

Most Augmented Reality applications are currently being created for marketing, geo-location based services, amusement and social (media) purposes. Art and culture are rapidly catching up.

The use of Augmented Reality for emancipation or in education on the other hand is rather limited.

Nevertheless, the 2010 and 2011 Horizon Reports, a joint report by The New Media Consortium and Educause predicts that the use of augmented reality in education will be widespread within two to three years.

Chapter 3 is dedicated to AR concepts and purposes. In chapter 3 we also summarize the most important educational AR applications.

3. State of the Art: Concepts and purposes

In this chapter we'll present an overview of how AR applications are used. We'll explore why Augmented Reality is currently used and what its current and future prospects are. Educational purposes will be discussed in detail.

3.1. Intro

Anyone who has ever experienced Augmented Reality has experienced its "wow-factor". No matter how many introductions one has heard or how many videos one has seen, the actual experience of AR is quite something else.

It is this "wow-factor" that makes Augmented Reality so attractive for marketing and communication purposes. To stun the public means that one has the public's attention. That is a rare good and therefore many brands employ Augmented Reality as an important element in their sales strategy. Ranging from fashion (e.g.: fashionista[10] or Rayban[11]) to cars[12] and sneakers[13] AR is used as a means to draw attention.

Children are also targeted by manufacturers ranging from cereals[14] to LEGO[15].

The "wow-factor" seems to be caused by the emergent nature of Augmented Reality: our brains do not seem capable of foreseeing the effect even when it is described to us beforehand in detail. It seems that the brain cannot make sense of the fact that a PoI triggers a virtual augmentation or that a printed marker is replaced on a screen by an augmentation while the rest of reality remains unchanged.

[10] http://augmentedrealityoverview.blogspot.com/2011/05/fashionista.html
[11] www.youtube.com/watch?v=Ag7H4YScqZs
[12] http://augmentedrealityoverview.blogspot.com/2011/05/scirocco-vw-augmented-reality-car-race.html
[13] www.youtube.com/watch?v=rRcognsyqNY
[14] www.youtube.com/watch?v=IZYbHcEmWQg
[15] www.youtube.com/watch?v=PGu0N3eL2D0

The emergent nature of AR is not unique. A similar kind of emergence can be observed in games, even in traditional board games. One can read the rules of the game as many times as one wants, but one cannot foresee how it will be to actually play that game. This experience only becomes evident by playing the game.

The emergent nature of AR triggers our curiosity because we want to understand, but we simply cannot. Over time this effect will wear off as it did with TV, radio, telephone and so many other new technologies. After a certain point they cease to amaze us and become household objects even though we understand nothing. In the words of Manovich they become "domesticated".

3.2. Adding information and objects: Information AR

The most commonly applied purpose beyond the "wow-factor" is to provide information. On smart phones many applications project information layers onto reality to point the end-user to the next hotel, the next tube station (like Presselite's Metro Paris Subway) or nearby houses for sale. These kinds of layers serve mostly commercial purposes.

Layers can also be placed over concrete objects. 3D animations or pictures are added to show how Points of Interest once looked, will look or could have looked:

- SARA[16] by the Rotterdam National Architecture institute (NAi) is an example. By means of AR the NAi presents architectural tours throughout the Netherlands.
- The Amsterdam Stedelijk Museum is working on an ARtour that will replace their audio-tour in the museum.

A very practical purpose is served by the Word Lens application that translates words and phrases on the fly and projects the translation on the place of the original ones. Artist Julien Oliver replaces commercial billboards by creations of his own.

[16] www.visitholland.nl/index.php/Miscellaneous-news/worldwide-sensation-seeing-beyond-reality-with-the-nai-and-3d-augmented-reality-sara.html

Sometimes virtual objects as such are just added to reality:

- The Stedelijk Museum organized a virtual art exhibition on the Museum Square in Amsterdam and has its virtual art rental system by means of which end-users can virtually place virtual pieces of the museum's collection anywhere they want.
- Artist Sander Veenhof created a virtual exhibition in the New York MoMA.
- At University College London's Petrie Museum, an augmented reality display prototype - VEMDis™ (Virtually Enhanced Museum Display)[17] - is being used to add optional 3D images to real-life sculptures, paintings, textiles, archaeological artefacts and other exhibits. It has allowed missing parts of sculpture or paintwork to be restored virtually, showing the piece in original condition, to enhance the museum experience for visitors.

The expected business application for information AR is the local advertising market. The future of this kind of Augmented Reality depends on whether it can attract local advertisers.

3.3. Entertainment

A growing AR market is the entertainment industry. Ranging from a simple football game[18] to an AR version of Nintendo's Mario[19] entertainment applications are hoped to be the services to generate serious revenues. The 2010 mobile AR revenues market amounts to a mere $2 million. But, Juniper "researchers say revenues will rise dramatically after that, as more AR applications are deployed, especially for mobile games with AR features."[20]

3.4. Enterprise AR

The second biggest AR market Juniper expects to take off is Enterprise Augmented Reality. Probably AR applications will be used by staff away from the office, staff requiring data, but not at a desk and customer care, in that order. These applications probably will not involve mobile AR.

[17] www.rcuk.ac.uk/innovation/bpc/vemdis.asp

[18] www.youtube.com/watch?v=JfEoCY4b_X4
[19] www.youtube.com/watch?v=eE82T8QW4CY
[20] www.itworld.com/software/91437/mobile-augmented-reality-market-top-700-million-five-years

Enterprise AR will most probably be triggered by barcodes and rely on an RFID structure[21]. For now, there are no mainstream Enterprise AR environments.

3.5. Commercial break-through

The big commercial question to be asked is: Can Augmented Reality find a commercial purpose that goes beyond the "wow-factor"? If that happens, a commercial break-through can be expected.

3.6. Educational purposes

In this section we'll discuss the most important current educational AR applications.

3.6.1. AR Spot - A Tangible Programming Environment for Children[22]

Table 3-1– AR Spot

Initiative Name	AR Spot - A Tangible Programming Environment for Children
Manufacturer(s)	MIT
Relevant URL	http://www.augmentedenvironments.org/lab/research/children/arscratch/
Brief Description	AR SPOT is the first augmented-reality authoring environment for children. As an extension of MIT's Scratch project, this environment allows children to create experiences that mix real and virtual elements. Children can display virtual objects on a real-world scene observed through a video camera, and they can control the virtual world through interactions between physical objects. This project aims to expand the range of creative experiences for young authors, by presenting AR technology in ways appropriate for this audience.

[21] www.broadstuff.com/archives/1885-Enterprise-Augmented-Reality-First-Thoughts.html
[22] www.augmentedenvironments.org/lab/research/children/arscratch/

Target Groups	Children
Educational Objectives	The tool mainly aspires to enhance the creativity of children by allowing them to mix real world objects (captured through camera) and virtual objects which they author themselves.
Establishes interaction?	Interaction is a key component of the specific tool since once children proceed to author their virtual environment, they can control the virtual world through interactions between physical objects
Can be used in classroom?	AR Spot is an extension of MIT's Scratch project which has been reported as being appropriate for classroom usage[23]
Marker or Markerless?	The AR Spot uses typical black & white markers for enabling the AR projections
Location-Based?	No location-based information is used
Hardware Requirements	The application requires a web camera (or a camera that can be used with a computer) and a personal computer

3.6.2. Letters Alive

Table 3-2 – Letters Alive

Initiative Name	Letters Alive
Manufacturer(s)	Logical Choice Technologies
Relevant URL	www.logicalchoice.com/products/letters-alive-curriculum/teachers-cheer-letters-alive/

[23] http://web.media.mit.edu/~kbrennan/conference/Scratch@MIT-DRAFT.pdf

Brief Description	Letters Alive is an augmented curriculum application which is created by Logical Choice Technologies and demonstrates the use of AR in the classroom. According to the 2010 Horizon Report, this unique way to teach children how to read is expected to become main-stream within the next four to five years. Parents, teachers and children that use the new app will see an amazing virtual giraffe interacting with students. The curriculum is guaranteed to be effective because it reaches children on so many sensory and emotional levels. This AR application allows for a "two-way interaction" between students and seemingly-real virtual characters. Unlike simple animated characters, Logical Choice's virtual animals can respond to the actions of the student.
Target Groups	Children
Educational Objectives	The goal of Letters Alive is to teach children to read. It allows students to interact with a kingdom of 26 entertaining, intelligent animals — each representing a letter in the alphabet — who virtually come alive in the hands of students.
Establishes interaction?	Yes. Letters alive applies research-based, best practices of phonics curriculum, but in a way that has never been so engaging or so interactive for early learners.
Can be used in classroom?	Letters Alive is designed in a way that it can be efficiently integrated to classroom activities
Marker or Markerless?	Although not explicitly mentioned, the product seems to be based on marker technology since the trigger that sets off AR are specifically designed cards that help children learn the alphabet through interaction with virtual animals
Location-Based?	No location-based information is used
Hardware Requirements	According to the product specifications, the following equipment is needed: • Teacher's laptop (PC or Mac) • Compatible USB document camera • Classroom audio system • Digital projector and screen or an interactive whiteboard

3.6.3. LearnAR[24]

Table 3-3 - LearnAR – eLearning with Augmented Reality

Initiative Name	LearnAR – eLearning with Augmented Reality
Manufacturer(s)	Augmatic Ltd
Relevant URL	http://learnar.org/
Brief Description	LearnAR is a new learning tool that brings investigative, interactive and independent learning to life using Augmented Reality. It is a pack of ten curriculum resources for teachers and students to explore by combining the real world with virtual content using a web cam. The resource pack consists of interactive learning activities across English, maths, science, RE, physical education and languages that bring a wow-factor to the curriculum.
Target Groups	Students / Pupils (age not explicitly specified)
Educational Objectives	Help students learn more intuitively the topics incorporated in the relevant suite (maths, science, RE, physical education and languages)
Establishes interaction?	All learning activities in LearnAR are interactive
Can be used in classroom?	Yes, the specific product targets schools as well
Marker or Markerless?	The product is based on the usage of markers as explicitly stated in its specifications
Location-Based?	No location-based information is used
Hardware Requirements	According to the specifications, the hardware requirements are the following: • Correct printed markers • A good quality webcam • A reasonably fast machine • (2.4 Ghz, DuoCore, 4GB RAM) Furthermore, Flash player 10 needs to be installed

3.6.4. Training

24 http://jamesalliban.wordpress.com/2010/03/16/learnar-elearning-with-augmented-reality/

The ability to provide visual and time-lapse examples allows for rich examples of complex phenomena (engineering, earth sciences, medicine, environmental applications to name a few) while engaging many styles of learners.

Augmented reality can provide rich contextual learning for individuals learning a skill. Currently virtual reality and augmented reality applications are used for training in fields as diverse as trades, military and medicine.

Karen E. Hamilton writes on AR and training: The Military has long been a leader in the use of augmented reality especially in the area of training. Virtual displays layered over the field of vision of the user to enhance scenes using wearable head gear have become common. In 2009 Sarnoff Corporation demonstrated the first augmented reality training system for US War fighters in what the military calls its Future Immersive Training Environment (FITE) Joint Capability Technology Demonstration (JCTD).The 36 Million dollar experiment allows soldiers to train at home to prepare for small, urban and borderless conflicts around the world. Sarnoff's head-mounted visualization training system combines real world views, computer generated images and avatars. Soldiers interact in a realistic training environment with their own weapon, while interacting with computer-generated avatars. The avatar responds realistically to the soldier's actions by talking, avoiding contact or returning fire. The soldier is able to record and replay training sessions. The Military has also used AR to train users in maintenance and repair.

See a video example Maintenance and Repair. According to Daniel Long of PC Lifestyle, the military are also, *"developing an Android phone app that overlays engines with schematics, potentially turning anybody into a mechanic."*

Table 3-4 – Augmented Reality for Maintenance and Repair

Initiative Name	Augmented Reality for Maintenance & Repair (ARMAR)
Manufacturer(s)	Columbia University Computer Graphics & User Interfaces Lab
Relevant URL	http://graphics.cs.columbia.edu/projects/armar/index.htm
Brief Description	Augmented Reality for Maintenance and Repair (ARMAR) explores the use of augmented reality to aid in the execution of procedural tasks in the maintenance and repair domain. The principal research objective of this project is to determine how real time computer graphics, overlaid on and registered with the actual repaired equipment, can improve the productivity, accuracy, and safety of maintenance personnel. Head-worn, motion-tracked displays augment the user's physical view of the system with information such as sub-component labelling, guided maintenance steps, real time diagnostic data, and safety warnings. The virtualization of the user and maintenance environment allows off-site collaborators to

	monitor and assist with repairs. Additionally, the integration of real-world knowledge bases with detailed 3D models provides opportunities to use the system as a maintenance simulator/training tool. This project features the design and implementation of prototypes integrating the very latest in motion tracking, mobile computing, wireless networking, 3D modelling, and human-machine interface technologies.
Target Groups	US Army Mechanics
Educational Objectives	Aid in the execution of procedural tasks in the maintenance and repair domain
Establishes interaction?	Yes, the overall concept is to use interaction between the mechanics and the system
Can be used in classroom?	No, the system is deployed inside the vehicle to undergo maintenance and repair
Marker or Markerless?	The product is based on the usage of markers
Location-Based?	No location-based information is used
Hardware Requirements	The framework requires specialized software, such as specifically designed tracking cameras.

In March 2010, the US Army put out a request for information on "Augmented Reality (AR) Systems Technology Roadmap Survey Dismounted Soldier Applications." Their objective is to explore, "methods of presenting 2D/3D virtual objects (representing various types of targets, fire and effects, friendly forces and opposition forces, civilians on the battlefield (COB), vehicles, etc.) to the dismounted soldier while operating both indoors and outdoors, on various types of live training environments. Additionally, the trainee would be capable of interacting with virtual targets, personnel, vehicles, etc. as though real. The objective is to create an interactive, multi-sensory, non-linear environment that provides the War fighter with training that is unparalleled in flexibility and realism."

For an excellent example of how augmented reality will be used by BMW for auto mechanics, click to see the movie on this website BMW Augmented Reality: Introduction.

Fire Departments are using a mobile Augmented Reality Training Unit made by Resolve Fire & Hazard Response, Inc. to train participants to fight fires. Participants learn everything from the basics of fighting a small structure fire to how to handle a major HAZMAT incident. See a video here FDNN TV Augmented Reality Training.

Table 3-5 – Augmented Reality Training Unit

Initiative Name	Augmented Reality Training Unit,

Manufacturer(s)	Resolve Fire & Hazard Response, Inc.
Relevant URL	http://www.fdnntv.com/review.asp_Q_reviewID_E_6_A_title_E_Augmented_Reality_Training_Unit
Brief Description	A mobile training unit, manufactured by Resolve Fire & Hazard Response, Inc., travels to departments throughout the United States assisting Training Officers as they teach their fire fighters everything from the basics of fighting a structure fire to handling a major HAZMAT incident or a the fallout of a Weapons of Mass Destruction attack. Powered by a multi-million dollar computer program, this unit is becoming a popular training tool, as it reduces the liability, mess and downtime usually associated with live burn training.
Target Groups	Fire fighters
Educational Objectives	Teaching fire fighters a variety of training objectives such as fighting fires to industrial and residential places, non-fire emergencies (gas leaks, spills etc).
Establishes interaction?	Yes, the system engages learners in a fully interactive training process
Can be used in classroom?	No, specialized facilities are needed.
Marker or Markerless?	N/A
Location-Based?	No location based functionality mentioned
Hardware Requirements	The AR-based training takes place inside a mobile unit equipped with specialized hardware

3.6.5. Authentic learning

AR provides a form of situated learning. For example, AR can tremendously enhance vocational studies for those wishing to enter the trades: auto and aviation mechanics, electricians, carpenters, etc. The ability to annotate real elements and the ability to add to reality by superimposing virtual aids, will aid in instruction and learning for those disciplines where a specific spatial configuration of elements must be learned and remembered (auto mechanics, medicine, chemistry)[25].

[25] http://augmentedrealityoverview.blogspot.com/2011/05/realtime-reflections.html

3.6.6. Realistic models

For students in K-12, AR provides a means of "seeing" phenomena in 3D, thereby bringing the contextual three dimensional nature of the real world to their learning. Textual and pictorial information in the typical 2 dimensional print-based resources loses much of the richness of the "real" world elements, and involves an element of interpretation that is difficult for some students.

3.6.7. Engagement

Illustrations in books can come to life with AR technology and can captivate readers of all ages.

3.6.8. Discovery based learning

Karen E. Hamilton writes on AR and discovery based learning: The term Discovery Learning is used to describe inquiry-based learning. Jerome Bruner, who furthered the notions of discovery learning in the 1960s, believes that *"Practice in discovering for oneself teaches one to acquire information in a way that makes that information more readily viable in problem solving,"* (Bruner, 1961, p.26).

Many early versions of portable AR illustrate the ability to enhance a live experience through discovery based learning. A visitor to an art gallery, museum or historic site can access AR applications that enable additional information, maps, audio content, or videos.

Colleges and Universities are now providing campus tours that include AR content. One application for the iPhone called uTourX comes with tours of Yale, Stanford, MIT and Harvard. While on campus, potential students just point their iPhone or iPod Touch at buildings or areas and campus details pop-up: Campus Tour. In the fall of 2010, Champlain College will begin offering an MFA in Emergent Media.

According to Jeff Rutenbeck, Dean of the Communication & Creative Media Division the program "*is not only about the knowledge we possess, it's about the processes we use to create new knowledge. All knowledge has a built-in expiration date."* The program will focus not only on ways to shape the future but also define what that future means for society. To market the new program and to illustrate one of the emerging technologies, graduates and professors of the school worked with Tag New Media to create an interactive augmented reality website. Potential students received a postcard in the mail. They were directed to the website and asked to hold up the eye on the postcard to their webcams. An on-screen image would then appear with streaming information about the program. Other effects occurred when the card was tilted or moved.

Other applications allow the viewer to point a mobile device at an historical location, and a picture of how that location looked like in different time periods appears.

To encourage cultural tourism, iTacticus explored ways to enhance visitors' experiences in cultural locations through AR by overlaying 3D objects onto a scene, annotating the landscape with information or videos, and overlaying spatial acoustics to relay the sites original ambiance[26] [17].

Table 3-6 - iTacitus

Initiative Name	iTacitus
Manufacturer(s)	Multinational Consortium from EU
Relevant URL	www.itacitus.org
Brief Description	iTacticus application is the outcome of a EU FP6 research program under the same name, that provides ways to enhance visitors' experiences in cultural locations through AR by overlaying 3D objects onto a scene, annotating the landscape with information or videos, and overlaying spatial acoustics to relay the sites original ambiance
Target Groups	All museum visitors
Educational Objectives	Enhance the cultural experience during visits to museums / cultural locations
Establishes interaction?	No interaction mentioned in project description
Can be used in classroom?	No, the application is functional only on the cultural points of interests (e.g. museums)
Marker or Markerless?	The technology behind iTacitus seems to be based on a Markerless approach given that the used points his/her mobile device towards cultural sites (exhibits, places etc)
Location-Based?	iTacitus uses location identification to superimpose augmented reality over cultural points of interest
Hardware Requirements	Visitors use mobile devices for displaying AR cultural information

CultureClic is another recently released augmented reality application for the iPhone and other smart devices. Visitors to France can use their devices and the CultureClic app to access high definition information on 1300 museums- including 500 paintings, photos and sculptures, as well as information about cultural events[27].

[26] http://itacitus.org/

[27] http://wik.ed.uiuc.edu/index.php/Augmented_Reality_in_Education

Table 3-7 – CultureClic

Initiative Name	CultureClic
Manufacturer(s)	ProximaMobile
Relevant URL	www.cultureclic.fr
Brief Description	CultureClic is a recently released augmented reality application for the iPhone and other smart devices. Visitors to France can use their devices and the CultureClic app to access high definition information on 1300 museums- including 500 paintings, photos and sculptures, as well as information about cultural events.
Target Groups	All people visiting France
Educational Objectives	Enhance the cultural experience of visiting / touring France
Establishes interaction?	No interaction mentioned in product description
Can be used in classroom?	No, the application must be pointed at specific locations / points of interest so that relevant cultural information is superimposed
Marker or Markerless?	The technology behind CultureClic seems to be based on a markerless approach given that the used points his/her mobile device towards cultural sites (exhibits, places etc)
Location-Based?	CultureClic uses location identification to superimpose augmented reality over cultural points of interest
Hardware Requirements	Visitors use mobile devices for displaying AR cultural information

At MIT, students are using handheld devices to participate in activities that combine real-world experiences with simulated events and data[28]. In one activity, students interview virtual people, travel the campus taking measurements, and analyze data to determine the source of a toxic spill (simulated, of course). In another set in Boston's Museum of Science, students use wifi-enabled handheld devices to gather clues to solve a murder mystery. The projects are collaboration between the MIT Teacher Education Program and the Education Arcade.

[28] education.mit.edu/ar/

Table 3-8 – MITAR Games

Initiative Name	MITAR Games
Manufacturer(s)	MIT
Relevant URL	http://education.mit.edu/projects/mitar-games
Brief Description	The MIT Teacher Education Program, in conjunction with The Education Arcade, has been working on creating "Augmented Reality" simulations to engage people in simulation games that combine real world experiences with additional information supplied to them by handheld computers. The first of these games, Environmental Detectives (ED), is an outdoor game in which players using GPS guided handheld computers try to uncover the source of a toxic spill by interviewing virtual characters and conducting large scale simulated environmental measurements and analyzing data. This game has been run at three sites, including MIT, a nearby nature centre, and a local high school. Early research has shown that this mode of learning is successful in engaging university and secondary school students in large scale environmental engineering studies, and providing an authentic mode of scientific investigation.
Target Groups	University and secondary school students
Educational Objectives	Environmental engineering studies
Establishes interaction?	Yes
Can be used in classroom?	No
Marker or Markerless?	No markers are used
Location-Based?	Yes
Hardware Requirements	Handheld device

3.6.9. Gaming

AR gaming has a place within education as well. Karen E. Hamilton writes: Games based in the real world environment and augmented by digital information have the power to engage learners in authentic ways. While interacting with an augmented game, the learner is able to make connections and understand relationships in a more meaningful way. In 2006 Karen Schrier designed a game “Reliving the Revolution” to evaluate AR games in education. The game takes place at the Battle of Lexington in Massachusetts. Players of the game are assigned various roles and sides in the battle and are able to interact with virtual historic characters. The game uses GPS data that triggers events on the players hand held device. Players use the experience to understand the battle. Through her study, Schrier found that, "AR games, when properly designed for pedagogical purposes, can motivate the authentic practice of 21st century skills". More specifically, she sees AR games potential in teaching interpretation, multimodal thinking, problem solving, teamwork, and diverse perspectives. In her article "Student Post-mortem: Reliving the Revolution," Schrier says, "So, throughout the experience, the participants practiced essential skills like bias identification, decision making, delegation, and problem solving—skills they might not normally encounter in classroom activities. Not only that, but the participants reignited their waning interest in history, and even began to see why it’s important to be historical thinkers in an increasingly global digital economy[29]”.

3.6.10. Entertainment: Dennō Coil

An important educational initiative comes from Japan and is called “Dennō Coil”. It is a Japanese science fiction anime television series depicting a near future where semi-immersive augmented reality technology has just begun to enter the mainstream. The series takes place in the fictional city of Daikoku, a hotbed of AR development with an emerging city-wide virtual infrastructure. It follows a group of children as they use AR glasses to unravel the mysteries of the half real, half Internet city, using a variety of illegal software tools, techniques, and virtual pets to manipulate the digital landscape. The children access the virtual world through Internet-connected visors called dennō eyeglasses. This allows them to see virtual reality superimposed on objective reality. To visually confirm something as virtual, the children often lift their glasses from their eyes. The visors also work in conjunction with futuristic ear monitors placed behind the ear, which allow the wearer to hear sounds from the virtual environment.

[29] http://wik.ed.uiuc.edu/index.php/Augmented_Reality_in_Education

3.6.11. *Entertainment: Free All Monsters*[30]

Table 3-9 – Mobile Radicals

Initiative Name	Free All Monsters
Manufacturer(s)	Mobile Radicals
Relevant URL	www.freeallmonsters.com
Brief Description	Free All Monsters is an Augmented Reality geo-caching game for children. The creators re-invented geo-caching as a game for families and children, creating a new mobile game called "Free All Monsters". Children can use their creativity to draw monsters, these monsters then get transplanted into the real world, where they and their friends can then use a "Magical Monstervision Machine" (a Nokia N95 running special software) to detect and find monsters in the real world. The display overlays the sensor information and monster pictures onto the real world similar to Layar. The game reinvents geo-caching in a creative, understandable way. For example, the strength of the GPS fix is represented as a "Captoplasm" gauge – you can't capture monsters if you haven't got enough. The game reinforces creativity throughout. Children's monster creations are added to a "Liber Monstorum" (book of monsters), which is used to populate the game world – personalizing the game to the players
Target Groups	Children
Educational Objectives	The game enforces creativity of children and also their collaborative skills, since in certain aspects of the application collaboration between players is required to accomplish the relevant objectives.
Establishes interaction?	Yes, the application is interactive
Can be used in classroom?	The game requires open space for full deployment
Marker or Markerless?	The application does not use marker technology
Location-Based?	The game uses location based information when prompting children to seek monsters in their neighbourhood
Hardware Requirements	Web access and iPhone are required for the specific game

[30] http://fisharepeopletoo.blogs.com/1/2009/10/free-all-monsters.html

3.7. Educational value of AR

Quite a bit of research has been done on the field of AR for educational purposes.

3.7.1. ARducation

Table 3-10 - ARducation

Initiative Name	ARducation
Manufacturer(s)	Kay de Roos
Relevant URL	www.kayderoos.nl/ARducation-Augmented-Reality-in-education
Brief Description	The main goal of the “ARducation” project by Kay de Roos is to examine the possibilities of Augmented Reality in an educational context. In this case the student group created two scenarios (prototypes) that could be part of a history lesson. In order to use the full potential of Augmented Reality and make the concept more useful, more interaction and features should be added. But even without “more features” or “more interaction” this work is a great student project. And as we have learned from a previous post about AR in education, the technology has great potential in this domain due to its fascinating and intuitive information design. Exploring goes nicely with learning.
Target Groups	Children, Students
Educational Objectives	General purpose AR-based learning tool mainly addressed to teachers. The prototype has been mainly validated using content from history lessons.
Establishes interaction?	Yes, the application is interactive
Can be used in classroom?	Yes, it has been designed for use in classrooms
Marker or Markerless?	The AR Toolkit of the ARducation project is based on markers
Location-Based?	No
Hardware Requirements	PC

3.7.2. Implementing Augmented Reality in Education[31]

This initiative demonstrates how augmented reality can enhance math education; specifically, geometry classes.

3.7.3. The Envision Center, Purdue University[32]

Purdue University's "Envision Center" project focuses on research and design in computer-based visualization, with the aim of enhancing teaching and learning across disciplines. The center combines computer science, engineering, perception, technology, and art to process and display information. Current projects range from GIS applications to creating human avatars to assist in sign language education.

3.7.4. Transparent Reality Simulation Engine[33]

Table 3-11 - Transparent Reality Simulation Engine

Initiative Name	Transparent Reality Simulation Engine
Manufacturer(s)	University of Florida
Relevant URL	http://vam.anest.ufl.edu/wip.html
Brief Description	The University of Florida has used a 2-dimensional web-based Transparent Reality Simulation Engine to teach students how to operate medical machinery for several years. Recently, the addition of a GPS-enabled tablet device has allowed learners who are spatially challenged to experience the transparent reality visualization overlaid directly onto the real machine, enabling them to use the machine's controls rather than a mouse as input to the simulation. Geolocation is used to track the tablet and align the physical machine with the visualization on the tablet

[31] www.k12mobilelearning.com/?p=1764
[32] www.envision.purdue.edu/

[33] vam.anest.ufl.edu/wip.html

Target Groups	Students of Medicine and Engineering
Educational Objectives	Teach basic principles of medicine and education to students
Establishes interaction?	Yes, learners may establish interaction with the application
Can be used in classroom?	Yes
Marker or Markerless?	No markers are used by the application
Location-Based?	Yes
Hardware Requirements	PC

3.8. Research results

The increasing demand for AR-based educational applications has made the research community intensify its efforts in terms of coming up with more sophisticated AR tools and algorithms for delivering courses and content both remotely and on site. This chapter reviews some of the most prominent research works in the specific area.

In the work presented in **Error! Reference source not found.** the authors investigate how an AR system called Studierstube improved spatial abilities and transfer of learning of math and geometric objects. They suggest that the system encouraged experimentation and improved spatial skills. In **Error! Reference source not found.** Maier, Klinker and Tonnis studied how an AR tool they developed called Augmented Chemical Reactions could aid students learning and understanding chemistry. They found that the system allowed students to inspect molecules from multiple viewpoints, and also allowed students to control the interaction of molecules. They believe that the system could increase the understanding of chemistry and decrease a student's fears. In **Error! Reference source not found.**, **Error! Reference source not found.** the authors describe a pioneer (for its era) wearable computer which orchestrates an audiovisual narration as a function of the visitor's interests gathered from his/her physical path in the museum and length of stops. The wearable is made by a lightweight small computer that people carry inside a shoulder pack. It offers an audiovisual augmentation of the surrounding environment using a small, lightweight eye-piece display (often called private-eye) attached to conventional headphones. In the work described in **Error! Reference source not found.** the researchers present a mobile outdoor mixed reality game for exploring the history of a city in the spatial and the temporal dimension. They introduce the design and concept of the game and present a universal mechanism to define and setup multi-modal user interfaces for the game challenges. A similar work is presented in **Error! Reference source not found.** where Herbst et. al present a pervasive outdoor mixed reality edutainment game for exploring the history of a city in the spatial and the temporal dimension, which will closely couple the real environment with the virtual content. The game provides a new and unique user experience, which links rich interactive content to time and places. They also introduce the development of such a game, including a universal mechanism to define and setup multi-modal user interfaces for game challenges. The issue of AR interfaces is thoroughly explored in the works of **Error! Reference source not found.** and **Error! Reference source not found.** where the authors dig deeper into the issue of customizing AR interfaces for enhancing usability and user engagement. Finally, some prominent research works in the area of AR-based e-Learning are presented in **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.**. A comprehensive list of prominent works in the AR-based education is presented in the following table.

Table 3-12 - Prominent Works on AR for Educational Purposes

Related Work Description	References
AR in cultural heritage and education	**Error! Reference source not found.,Error! Reference source not found.,Error! Reference source not found.,Error! Reference source not found.,Error! Reference source not found., Error! Reference source not found.**
AR in Mobile Learning Environments	**Error! Reference source not found.,Error! Reference source not found.,Error! Reference source not found.,Error! Reference source not found.,Error! Reference source not found.,Error! Reference source not found.** **Error! Reference source not found.,Error! Reference source not found., Error! Reference source not found.**
AR-based Learning Frameworks	**Error! Reference source not found.,Error! Reference source not found., Error! Reference source not found.**
Handheld AR learning / interactive environments	**Error! Reference source not found., Error! Reference source not found., Error! Reference source not found.**

3.8.1. Research on AR games

Karen E. Hamilton writes on handheld AR games: In 2009 researchers Morrison, Oulasvirta, Peltonen, Lemmela, Jacucci, Reitmayr, Nasanen & Juustila in Helsinki investigated the differences between playing a location-based game using either a 2D map or an augmented reality application called MapLens. Their research showed that the augmented reality application allowed users to find common ground, ignited discussion, negotiation and improved problem solving. Players of the game are required to collaborate and negotiate multi-level tasks. The researchers collected multiple types of data: video recordings, field notes, log notes, interviews and questionnaires. The main difference they found between the 2D map and the AR system was that the 2D map seemed to result in more solitary problem-solving; whereas, the AR MapLens system resulted in more collaborative problem solving[34].

[34] http://wik.ed.uiuc.edu/index.php/Augmented_Reality_in_Education

3.9. Summary

Commercially, AR is at an early stage. Information AR depends on attracting local advertisers while Enterprise AR is at a very early stage. The biggest chances are for entertainment AR. AR has to find a commercial purpose beyond the wow-factor to be economically viable.

Educational AR shows that AR visualization engages end-users in the things they are doing, be it learning or training or reading a book. Besides facilitating cognitive processes AR can stimulate social and decision-making skills.

4. State of the Art: Projects in EU and Future Trends

This chapter will provide an overview of some of the most relevant European research projects on Augmented Reality as also a brief look into what the future of AR holds for stakeholders.

4.1. European Research Projects related to Augmented Reality

Currently, in the context of both FP7 and FP6 there are several European projects that have been running and working on the subject of Augmented Reality. The application areas span several sectors, such as:

- Service Oriented Infrastructures and Multimedia Applications: The FP7 project **IRMOS** (Interactive real-time multimedia applications on service oriented infrastructures) focuses on the design, development and validation of Service Oriented Infrastructures that enable a broad range of interactive real-time applications. Although the project is principally oriented towards the provisioning of next generation Service Oriented Infrastructures it does so by basing to a great extend its methodology on the incorporation of Augmented Reality practices in order to enhance current infrastructures that fail to deliver satisfactory levels of Quality of Service assurances and they consequently become insufficient for the rapid construction and provision of many interactive real-time applications, lacking also dependability and resilience.

- Culture: The FP7 project **ARTSENSE** aspires to bridge the gap between the digital and physical worlds in a highly flexible way in order to enable novel, adaptive cultural experiences. The concept behind ARTSENSE lies on: a) the incorporation of novel wearable technologies for sensing continuously and non-intrusively the user's context (visual eye-tracking, audio, physiological bio-sensing) in order to determine the user's current interest (mental engagement); b) the usage of highly sophisticated Augmented Reality tools that enable overlaying reality with digital information transparently, including gaze-and gesture-controlled interaction, so that visitors to cultural points of interest have the feeling that physical objects are directly responding to them. In that way artworks become active artefacts that react on users' attention and emotions and provide more information about them. This approach followed within ARTSENSE has led to a whole new approach to the idea of using Augmented Reality for enhancing cultural experiences. The concept had been dubbed by the project consortium “Adaptive Augmented Reality (A2R)”

- Automation and Industry: The goal of the FP7 project **VERITAS** is to bring both Augmented and Virtual Reality in to the industry, by enabling the incorporation of those technologies in various stages of production, testing and quality assurance. The application scenarios of the project include among others the automotive industry, design and development of personal healthcare systems, smart living spaces and infotainment. All outcomes of the project will be based on the large scale usage of Augmented and Virtual reality in various application areas. Such outcomes include for example: a) an Open Simulation Platform (OSP) for testing at all development stages that will provide automatic simulation feedback and reporting for guideline/methodologies compliance and quality of service b) virtual simulation environments for ICT and non-ICT products offering tools for testing and verification mainly at the design stage but also during the development stages when links to ICT technologies are implemented c) a simulation environment that will support multimodal interface virtual testing in realistic scenarios that will offer the opportunity to fine tune and adapt these technologies to the specific application.

- Healthcare: The project **VAALID** is oriented towards the usage of Augmented Reality technologies in the area of Ambient Assisted Living (AAL). It aspires to create new tools and methods that facilitate and streamline the process of creation, design, construction and deployment of technological solutions in the context of AAL assuring that they are accessible and usable for senior citizens. The **VAALID** system will be a simulation environment that will be composed by software and hardware components that constitute a physical ensemble that in conjunction allows the ICT designer to implement actual Virtual Reality and Augmented Reality scenarios of AAL. It will be used to verify interaction designs and validate the accessibility of the AAL products by means of immersing the users in 3D virtual spaces. The ICT designer will be able to evaluate the suitability of the proposed solutions with a significant reduction of the global design and development cost. The project **IMPPACT** will use Augmenter Reality techniques for simulating interventions that will also account for patient specific physiological factors. The study will try to reveal the inner workings of Radiofrequency Ablation (RFA) of malignant liver tumors and to address gaps in the understanding of particular aspects of the RFA treatment using multi-scale studies on cells and animals. Validation will be performed at multiple levels. Images from ongoing patient treatment will be used to cross check validity for human physiology. The final project deliverables will be the patient specific intervention planning system and an augmented reality training simulator for the RFA intervention.

A thorough list of European projects exploiting the potential of Augmented Reality techniques can be found in the Appendix of this deliverable

4.2. Research Trends in Augmented Reality

In this section we take a brief look into the future of Augmented Reality and we see a few examples of how it is evolving with respect to some specific application areas that have recently benefited from the particular technology.

Collaboration Support

A relatively new application field for Augmented Reality is the collaboration support. A characteristic example can be found in **Error! Reference source not found.**; in the particular work, a study is presented 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. In the relevant experiments an AR system was utilized for supporting joint planning tasks by providing organization specific views of a shared map. The study involved a simulated emergency event conducted in close to real settings with representatives from the organizations for which the system is developed. The results showed that the users were positive toward the AR system and would like to use it in real work. Another recent similar approach in terms of exploiting AR for enhancing collaboration between groups is presented in **Error! Reference source not found.** which describes a virtual environment intended to support a range of collaborative activities, especially those that involve sense making, deliberation, and decision making; in the specific publication several case studies demonstrate how virtual / augmented interaction spaces can be used for enhancing the aforementioned processes.

Robotics

The technology of augmented reality has also been recently applied with great success in the area of robotics as well. The authors of **Error! Reference source not found.** demonstrate the application of Augmented Reality in simulating, designing, projecting and validating robotic work-cells in industrial environments that are not equipped with real manipulators. In another similar work presented in **Error! Reference source not found.**, a semiautomatic tele-operation concept is presented which allows robots to execute highly dynamic tasks in dangerous or remote environments. The particular concept relies on a modular software architecture, which allows intuitive control over the robot and compensates latency-based risks by using Augmented Reality techniques together with path prediction and collision avoidance to provide the remote user with visual feedback about the tasks and skills that will be executed.

Industry / Industrial Design

There are several research works that emphasize the great potential behind the incorporation of Augmented Reality in industrial processes. In a paper about using augmented reality in the process of industrial appliance design **Error! Reference source not found.** the authors make a thorough presentation of the Spatial Augmented Reality, which is a set of technologies that allow physical objects to be augmented with prospectively

correct computer generated images; they proceed with the description of a demo they set up in order to validate the effectiveness of Spatial Augmented Reality in the design of electro domestic appliances. A very fundamental work on the usage of Spatial Augmented Reality is the one developed in **Error! Reference source not found.** where a new methodology for User Interfaces' design is introduced based on a set of physical tools that are overloaded with logical functions and which, through visual feedback enable the setup of a prototype application that implements a two handed technique allowing an industrial designer to digitally airbrush onto an augmented physical model, masking the paint using a virtualized stencil.

Medicine

The medical science has significantly benefited from the latest developments in the area of Augmented Reality. The most common application in this field is the simulation of operations using mixtures of real and virtual models, the AR/VR – assisted operations and the training of student doctors. The positive effects of adopting practices in medicine that rely on Augmented Reality has been substantiated by a recent study **Error! Reference source not found.**. The study focused on determining whether augmented reality image overlay, that allows surgeons to view underlying anatomical structures directly on the patient surface, and laser guidance systems can assist medical trainees in learning the correct placement of a needle for percutaneous facet joint injection. The results revealed that participants that received training sessions using image overlay had significantly better results compared to people that followed traditional training practices; it is therefore concluded by the authors that "*an augmented reality overlay guidance system can assist medical trainees in acquiring technical competence in a percutaneous needle insertion procedure.*" The image overlay – based AR technique is also examined in another recent work **Error! Reference source not found.** which focuses more on the challenges associated with the design and development of such tools that improve intuitiveness of computer-aided surgery by removing the need for sight diversion between the patient and a display screen and have been reported to assist in 3-D understanding of anatomical structures and the identification of target and critical structures; challenges that are examined in the particular work include among others the projection setup, calibration, patient registration, view direction, and projection obstruction

Entertainment

Finally, an area that has traditionally benefited from Augmented-Reality based application is of course the field of entertainment. Augmented Reality has been used as a means of enhancing users' entertaining experiences in applications such as games based on Augmented/Alternate Reality **Error! Reference source not found.** that are based on the mixing of the players' actual and virtual lives and "augment" their everyday activities with game-related tasks and challenges and with rich digital content that is communicated to the players through a variety of devices, usually augmenting their mobile-device views. Another recently emerged concept in the application of Augmented Reality in entertainment is the shopping-assistance: the authors of **Error! Reference source not found.** & **Error! Reference source not found.** study and present prototypes that use mobile devices for projecting augmented information to consumers and helping them throughout their shopping.

Appendix – European Projects Related to AR

Table A-1- European Project Related to AR

Project	Description
IRMOS Interactive real-time multimedia applications on service oriented infrastructures	IRMOS will design, develop, integrate and validate a Service Oriented Infrastructure that enables a broad range of interactive real-time applications. It will support the development and deployment of real time applications in a distributed, managed, secure and cost effective way. The infrastructure will be demonstrated in sectors with major economic and social importance by focusing on film production, virtual and augmented reality, and interactive collaborative learning. The infrastructure will be accompanied by specification languages, toolkits and standards compliant interfaces to ensure the widest possible take-up in applications involving complex value chains and real time needs, for example in security, safety and emergency response scenarios.
ARTSENSE Augmented RealiTy Supported adaptive and personalized Experience in a museum based oN processing real-time Sensor Events	ARtSENSE tackles a very important problem in the modern usage of ICT in cultural heritage domain: bridging the gap between the digital world with the physical in a highly flexible way in order to enable a novel, adaptive cultural experience. ARtSENSE aims to develop an active assistants which looks over the user's shoulder (physical world) and react on any change in a visitor's state of interests (user's world) by adapting the guide (digital world) accordingly.
VERITAS Virtual and Augmented Environments and Realistic User Interactions To achieve Embedded Accessibility DesignS	VERITAS aims to develop, validate and assess an open framework for built-in accessibility support at all stages of ICT and non-ICT product development, including specification, design, development and testing. The goal is to introduce simulation-based and VR testing at all stages of product design and development into the automotive, smart living spaces, workplace, infotainment and personal healthcare applications areas. The goal is to ensure that future products and services are being systematically designed for all people including those with disabilities and functional limitations.
VALID Accessibility and usability validation framework for AAL interaction design process	VAALID project aims at creating new tools and methods that facilitate and streamline the process of creation, design, construction and deployment of technological solutions in the context of AAL assuring that they are accessible and usable for senior citizens. The main objective of the project is to develop a 3D-Immersive Simulation Platform for computer aided design and validation of User-Interaction subsystems

	that improve and optimise the accessibility features of Ambient Assisted Living services for the social inclusion and independent living.
IMPPACT Image-based multi-scale physiological planning for ablation cancer treatment	IMPPACT will develop an intervention planning and monitoring application for Radiofrequency Ablation (RFA) of malignant liver tumours. RFA is a minimally invasive form to treat cancer without open surgery, by placing a needle inside the malignancy and destroying it through intensive heating. Though the advantages of this approach are obvious, the intervention is currently hard to plan, almost impossible to monitor or assess, and therefore is not the first choice for treatment.
LISTEN "Augmenting everyday environments through interactive soundscapes"	LISTEN was a European funded project aiming at creating a new medium: the immersive audio-augmented environment. The concept consisted in superimposing a virtual soundscape to the real environment users are exploring. Wireless tracking technology, 3D audio rendering and interactive scenario design allowed composing new relationships between sound, body and space. LISTEN developed the concepts and technology necessary to approach this vision and produced audio augmented reality applications dedicated to media art, museum pedagogy and product marketing
ARCHEOGUIDE Augmented Reality-Based Cultural Heritage On-site Guide	The ARCHEOGUIDE project provided access to information in cultural heritage sites in a compelling, user-friendly way through the development of a system based on advanced IT techniques including augmented reality, 3D- visualization, mobile computing, and multi-modal interaction. Visitors were provided with a see-through Head-Mounted Display (HMD), earphone, and mobile computing equipment.
LIFEPLUS Innovative revival of LIFE in ancient frescoS and creation of immerse narrative sPaces, featuring reaL scenes with behavioUr fauna and flora	LIFEPLUS proposed new developments for the innovative revival of life in ancient frescos and creation of narrative spaces. The revival was based on real scenes captured on live video sequences augmented with real-time behaviour groups of 3D virtual fauna and flora. The metaphor was oriented to make the "transportation in fictional and historical spaces", as uniquely depicted by frescos, as realistic, immerse and interactive as possible. The whole experience was presented to the user on-site during his/her visit, through an immerse, mobile Augmented Reality-based Guide featuring wearable computing and multi-modal interaction.
EXPLOAR	The EXPLOAR project demonstrated an innovative approach that involved visitors of science museums and science centres in extended episodes of playful learning. The EXPLOAR approach looked upon

Design the classroom of tomorrow by using advanced technologies to connect formal and informal learning environments.	informal education as an opportunity to transcend from traditional museum visits, to a "feel and interact" user experience, allowing for learning "anytime, anywhere", open to societal changes and at the same time feeling culturally conscious. These pedagogical concepts and learning practices would address implementing a set of demonstrators (learning scenarios), employing advanced and highly interactive visualization technologies and also personalised ubiquitous learning paradigms in order to enhance the effectiveness and quality of the learning process. In this way the proposed service demonstrated the potential of the Augmented Reality (AR) technology to cover the emerging need of continuous update, innovate and development of new exhibits, new exhibitions, new educational materials, new programmes and methods to approach the visitors
INSCAPE Interactive storytelling for creative people	INSCAPE generated and developed the knowledge in the emerging domain of Interactive Storytelling by researching, implementing, demonstrating and disseminating a complete suite of innovative concepts, tools and working methods tightly integrated in a homogeneous web-based framework and offering a full chain to people with no particular computer skills, from content acquisition and creation, organizing, processing, sharing, and using all the way to publishing, from creators to "viewers". INSCAPE also addressed issues such as the acquisition, the creation, the management and the sharing of interactive stories or their real-time multi-sensorial rendering combined with natural agent behaviours and multimodal interfaces. It also provided innovative natural interfaces and devices for intuitively creating or living interactive stories within multi-dimensional virtual, augmented and mixed realities. By addressing this domain, INSCAPE went beyond "standard" content creation research and technology development projects and addressed scientific and industrial simulation, training, education, poetry, art, emotions, cultural and human context and diversity.

ARISER Augmented reality in surgery, research training network for minimally invasive therapy technologies	The project aimed at providing training for young researchers through a structured training and knowledge transfer program that provided Europe with human resources with knowledge that will lead to better healthcare to citizens in Europe. The particular focus of the research training and joint project was software that is user-friendly, fast and reliable for the practitioners of minimal invasive therapy (MIT). MI T is a compound of minimally invasive surgery, image guided surgery and interventional radiology. MIT makes use of numerous sources of information including multi-modal images and patient information systems. Intelligent processing of this information comprises a vast pool of knowledge that can aid the operator in his decisions. The ultimate goal of the joint project, which gave the recruited researcher training-by-doing, was to create an Augmented Reality system for interactive image guided therapy providing the clinical user with a new generation of decision support tools. This system will integrate intra-operative and pre-operative image-information and enable the user to see beyond the organ surface to inner structures and pathology. An intuitive human computer interface consisting of 3D display systems, haptics and robotics hided the underpinning complexity of the decision supports tools. Demonstrators were made aiming at providing a seamless workflow for the clinical user conducting image-guided therapy.
ARISE Augmented reality in school environments	ARiSE developed a new technology, the Augmented-Reality-Teaching platform by adapting existing augmented reality (AR) technology for museums to the needs of students in basic, middle, or high school classes. Building on existing open platforms, the new technology promoted team work, collaboration between classes in the same school or even remote collaboration between schools in different countries in a learner-centred approach. Using 3 dimensional presentations and student suited interaction techniques better understanding of scientific and cultural content, the project enhanced student motivation.. The platform and example scenarios were implemented country independent and therefore excel in applicability across Europe. Two representative schools from two different countries in Europe provided excellent opportunities for testing the platform in realistic pedagogical scenarios and validation of the research results using sound research methodologies from the areas of pedagogy, didactics, and human computer interaction.