Usability

Opportunities and Obstacles for Augmented Reality in the Practice of Architecture

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Abstract

This study aims to explore the possibilities of augmented reality being the next major technological advancement which could change the architectural profession, and explores the opportunities and obstacles in the application of augmented reality in architecture.

Augmented reality has been a fascinating and exciting topic to discuss. Certainly the technology has come a long way from its roots in virtual reality. Architectural design is changing fast due to its availability to apply the latest technological advancements. Architects are open for new technologies, being always among the first ones to try new solutions. Now it has become apparent that there are new opportunities, as the rapid technological development of smart phones and tablets enabled these devices to compete with desktop computers. Their capabilities can fully exploited now on construction site, meetings, doing presentations away from the office. New evaluation methods are also required for the development and evaluation of AR technology. The source of usability problems might be rooted in not having full understanding of the architectural workflow.

This paper discusses the potential of AR applications in the field of architecture. Also some light will be shed on how to assess the usability of AR systems on mobile devices. A new type of usability testing procedures need to be applied for this new type of applications, as the user interface perceived as three dimensional. There are some new guidelines being developed and implemented for such systems already.

Keywords:

Usability, Testing, Augmented Reality, AR, Mobile Apps, Architecture, 3D Models, Buildings, Virtual Reality, Architectural Design, Urban Planning, Simulation, CAD

1. Introduction

Not too long ago architects were using mainly sketch pads, scale rulers and knife sharpened pencils to sketch up their designs. Perspectives of buildings or interiors were carefully drawn, then coloured with pencils or watercolour. Mastering various skill sets were required to communicate clearly design ideas via paper. These skills are still highly valued today, but the latest advancements in technologies made them less essential. Developments in computer technologies were always quickly applied in architecture, as it is a very competitive sector. First the computer aided design (CAD) systems arrived and working in a 3D virtual reality became part of their everyday life. Then building information modelling (BIM) took everything to the next level. Computer systems finally are able to assist efficiently in the design progress too, with photorealistic visualisations. Maybe mobile augmented reality (MAR) systems will be the next game changer. The augmented reality (AR) application's potential in the field of Architecture can be huge. These can overlay (or augment) the real world with digital information, in a way that it seemingly co-exists. The nature of the (mobile) augmented reality requires that the user holds or wears a display, and moves, rotates in the real world in order to experience the augmented reality. As more and more head mounted display (HMD) solutions released, it is projected that the number of users of AR devices will reach 1 billion people by 2020. Abbound, Rana (2014)

There were several successful experiments made by enthusiastic researchers in the field of architecture. Although this technology is new, the commercial success of a widely used and popular architectural AR application can be guaranteed. There are already few augmented reality applications developed for architects, but they are not that commonly used yet. Still, only few application reached full majority and have been introduced to the market. These have received very little attention yet, compared to the virtual reality (VR) applications. Wang, X., Aurel, M. (2009)

2. Augmented Reality

The concept of the augmented reality dates back to the early 1900's. This concept was not possible to execute until the rise of computer technology. Nowadays cameras, high resolution screens and more than sufficient computing power enables users to experience, explore and even play within AR scenes. The advancement of mobile technologies further personalised this possibilities. Now is the time when AR applications can take the lead, after many decades of laboratory testing the technology is ready for everyday use.

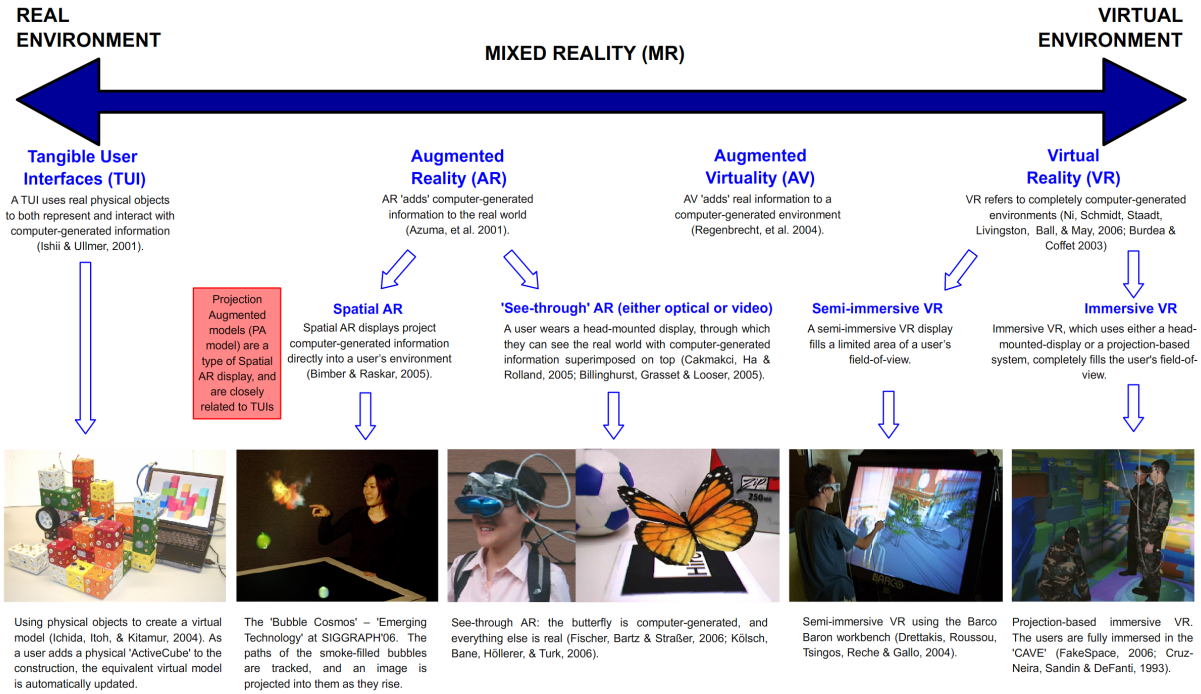
2.1 What Is Augmented Reality?

Augmented Reality (AR) is a term which has been applied to any view of a real scene that is modified, enhanced, or augmented by a computer generated sensory input. Novak-Marcincin, J., Janak, M., Barna, J. (2012). It is a medium in between the real environment and virtual reality. It is actually embedding virtual objects in real life scene. The virtual 3D objects can rotate and scale to fit into the real world environment.. The possibilities are endless, how the real world is enhanced with the augmented virtual objects.

The architectural use of such visualisation effect is stronger and the augmentation is more effective when the input forms almost seamless part of the scene. The most effective augmented scene give enough visual clues for the viewer to understand and perceive distance, perspective and size. Augmented reality applications will be very beneficial for architecture within 1-3 years, removing boundaries of place, time and material, a real unification of information. Lehman, Maria Lorena, (2012)

2.2 Reality-Virtuality Continuum

Virtual reality (VR) is a creation of a virtual world that the user can interact, and this world is isolated from the real world. A virtual rendering can be very detailed, up the the level where details are so close to reality, that the image or video looks like reality.



Continuum of advanced computer interfaces, based on Milgram and Kishino (1994)

Meanwhile the augmented reality's virtual world is blend in with the real world, allowing users interact with the real world. This is usually can be achieved by using wearable computing assets, headsets or mobile devices. McKalin, Vamien, (2015) Some AR gaming platforms can take virtual 3D objects and superimpose them onto the real world. Users can interact with these objects like they were part of the real world, just as it was seen in the movie 'Minority Report', or 'Avatar'.

Augmented virtuality (AV) adds real information to a computer generated environment, but this paper does not go into details on this object. AV is, for example, when a news correspondence 'sits' in a fully virtual news studio.

2.3 Limitations of AR

During the more than two decades long development of the augmented reality devices, the technology allows consumers to access this technology by the use of smart phones, tablets or head mounted devices. There are still a lot of challenges and limitations to overcome. Augmented reality faces technological, financial, privacy issues and social acceptance.

The mobile devices have limited processing power to calculate render perspective views in real time. Such devices have usually small storage space, and complex 3D models can be huge in size.

Another aspect, which could limit the popularity of MAR applications is financial. The development of such complex systems come at huge cost. There must be ways to make money on these applications, apart from their price. One of the most obvious solution could be the use of advertisements. The extent of the use of advertisement in an extra, added dimension raises concerns. Digital data will be tagged and categorised, and can overload the senses. As Keiichi Matsuda put it in his video clip project in 2013, which was about a futuristic augmented mash-up of architecture and advertisement, overloading the senses of bombardments of advertisements and information:

> *" The latter half of the 20th century saw the built environment merged with media space, and architecture taking on new roles related to branding, image and consumerism. Augmented reality may recontextualise the functions of consumerism and architecture, and change in the way in which we operate within it."*

Video clip screen shot from Keiichi Matsuda's project

Another concern in AR is privacy. A person can be tagged and information attached to, without the consent of that person. Facial recognition systems work successful on the internet, at certain airports. A face could be quickly linked social networking, and more information could be collected about people, like date of birth, sexual and political preferences, height, allergies, marital and employment status, history. It is possible, that people will just point their mobile devices in the direction of people, just to know them.

2.4 AR (VR) Devices on the Market

In general, almost all AR devices currently on the market suffer from at least one of the following issues: The lack of processing power causing serious latency, and the controls are not ergonomically placed, inconvenient to use them.

- **Google Glasses**
  With the arrival of the Google Glasses, a wearable AR device was announced for the wider public. While it is powerful, it still has its flaws and needs to be perfected. Its information Glass is not related to the real world, hence it is not a real AR device without an AR application. Still, this is the fore runner of the AR devices currently on the market. Several companies manufacture AR glasses, which are available on the market already.

- **Oculus Rift / VR**
  http://www.popsci.com/oculus-rift-will-make-vr-reality-2016
  Oculus VR has been developed for more than a decade now, its projected arrival is Q1 2016. This device is mostly focusing on VR based applications and gaming, it has built in speakers and a tracking device. By adding a small camera, the device could actually used as an AR device.

- **Samsung Gear VR**
  Samsung has introduced its own, peculiar virtual reality headset, which is actually just a head mounted case for smartphones. The user just slides in the smartphone into the headset, and then uses it as the actual screen. This device, just as the Oculus, could be modified for AR uses.

- **Drones with AR Capabilities**
  AR applications could hugely benefit from some innovative combinations of other gadgets too. Drones & quadcopters are often equipped with cameras, the high end ones are usually with GO Pro's. Larger construction sites and building processes could be easily overviewed and monitored through AR drones.

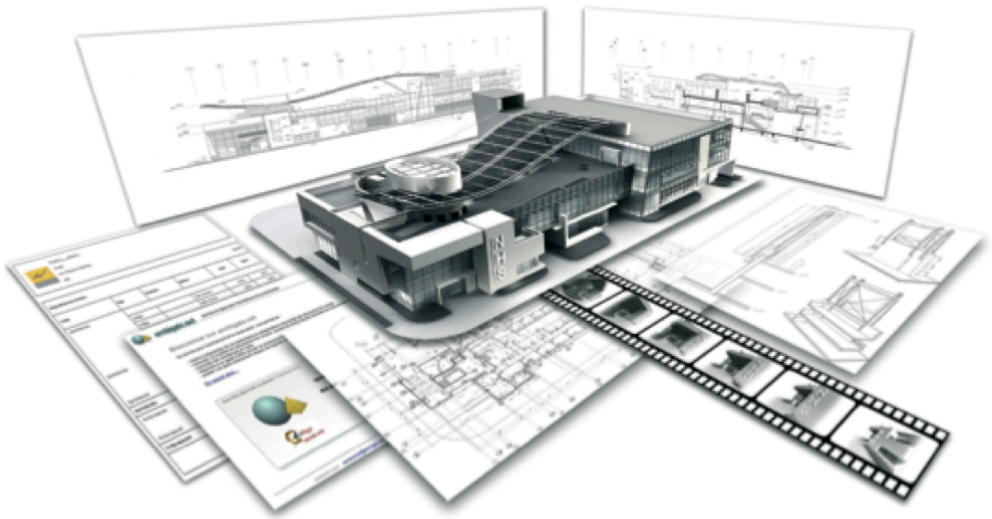
- **AR HUD Helmets**
  Few companies are entering the market with helmets with built in HUD, like Skully (for bikes) and Daqri. These helmets provide information on speed, location, fuel consumption, etc. Also the work as rear view mirrors too, as both have built in 360 degree camera.

DAQRI helmet, (http://hardware.daqri.com/smarthelmet/)

3. The Technological Landscape of Architectural Profession

Mastering the latest computer technology can give an architect the edge over the competition. There is a usual process, how architects get employed by clients to design and develop a project, guiding their clients through the building process. RIAI (2014) Clients can contact directly an architect or send out requests for proposals (RFP), which gives a brief detail of the project. Architectural offices then respond to such RFP if they are interested, and represent their design ideas to win the project. The quality of deliverables will distinguish good practices, so a good presentation is very important to secure a contract. Clients usually don't have as good visualisation skills as architects, so few 2D sketches won't be sufficient to convey the design. It is the architects duty to represent it in the a format which is easy to understand and the client can experience the size, space and the site intervention.

Architects, who are experts of the latest available technologies and systems, can produce almost photo realistic visualisations. There are a wide range of softwares available, but a handful stand out as the most efficient and commonly used ones. These are SketchUp for quick 3D sketching. The most experienced ones can use Building Information Modelling systems, like AutoCad, VectorWorks, Revit and the most advanced one, ArchiCad. BIM systems can generate computer generated images (CGI), which then can be enhanced and graphics softwares, like to most commonly used Adobe Creative Suite. There is one common in the aforementioned softwares, these are used in an office or at home. The computing power requirement is so huge, that they simply can't run on tablets or smart phones. Laptop users have to have very strong GPU and CPU to work with these applications. Laptops and desktop computers can't be used in a standing position, nor walking around on site. The BIM applications are second only to video editing applications in respect of computing power. Mobile devices can display only a a very simplified 3D shell, stripped of almost all additional BIM related information. These exported 3D objects are a cul-de-sac, as stripped information can not get back to the full BIM model. For the time being portable devices, tablets and smartphones, are simply not powerful enough to run full BIM applications.



Architects don't have technological tools at the moments which would enable them to visualise their design on site. They are limited on site to taking photographs, hand sketches or site measurements. They still have to rely on their desktop computers to complete the visualisation process in their offices. This where the new range of AR enabled portable devices with AR applications have great opportunities. Practices usually provide more than plans, sections, elevations and visualisations. Firms, which will be willing to engage to master AR visualisation on site, will have a huge opportunity to help their potential clients to truly experience their design. The design over laid the site, an AR walk-through can give the client the full understanding of the project. The importance of the application of the mobile augmented reality in architecture can not be underestimated. Domingo, AAron G (2013)

Architects rarely use pencils to do some hand sketches, nowadays everything is done through BIM systems. BIM is actually CAD (Computer Aided Design) + a huge amount of information on the building elements. It is the original, three dimensional computer aided design (CAD), on a completely different, multi dimensional level. BIM has currently six, officially accepted dimension. Three spacial, the forth is the scheduled time (or programming) , the fifth is the cost related information, the sixth describes the whole life cycle of the building, including management. Storer (2012).

Architects after the first sketches immediately start to develop a virtual reality world for the project. This VR is an extremely detailed BIM environment. Collaboration with other parties are through 2D plans or 3D models, depending on the complexity of the project. These files are sent via emails, or stored in a cloud. BIM work instead of the top-down or the bottom-up model, like a follower-ship, where leading from the middle becomes the model. Deutsch, R. (2012)

The architectural workflow is very complex, integrates the design process with the client, liaison with authorities, working with consultants, coordination on site with contractors, etc. Design meetings often involve a large number of participants of other professions. Presentations are usually done as quickly and as efficiently as possible, due to the time pressure of the fast paced programmes. AR applications have to be very easy, intuitive and fast to use.

4. Existing AR Applications for Architects

The augmented reality applications have developed a lot in the last couple of years. This opportunities of adding an extra dimension to our 4 dimensional space-time, is endless. Technology is catching up and ideas can be developed to working applications.

There are few architectural augmented reality application for mobile devices, like UrbaSee and Augment. UrbaSee app can present future projects in their actual environment, as if they were already completed. The app can add shadows and integrate the model into its real life landscape. Augment is a user friendly app which has advanced user gesture tracking, this enables users to place their VR model correctly in the augmented reality. Its rendering engine can also make the 3D objects to blend in more to their real life environment.

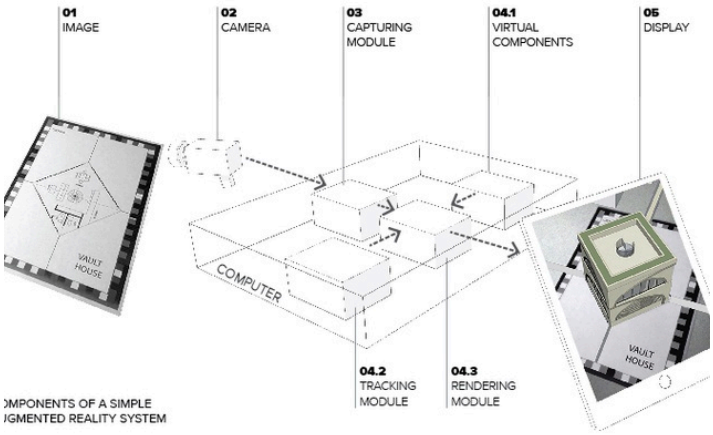
A small group of students carried out the usability evaluation of four different types of AR applications in the Department of Computer Science of University of Helsinki in 2014. Schaeffer, Satu Elisa; editor, (2014) They combined their report into one study to share their findings and provide guidelines for usability testing for IT professionals and other researchers around the world. These AR applications were for overlaying 3D models, for navigation, one app was developed as an AR interface of a museum, and the last one was for a device, which sensed directions of human movements.

The most challenging aspect of their studies was to build a system through users can interaction with the AR application. The system output of an AR application is a form of stimuli of the senses of the user. There is no need pressing buttons. Researchers were convinced - not without any ground - that in the future less and less button pressing will be required to interact with our portable devices. Already there are several devices which can read our gestures, eye movements, postures, understand our verbal commands. The wearable gadgets nowadays are still far from their full potential and the technological developments may render most of them useless within a few years.

They papers focused on the usability testing of AR applications. They determined the adaptability of their application through the ease of use of AR applications. Each of the four student groups had to select an existing AR application or develop from scratch one for testing. First usability evaluation techniques were applied, then modifications were made as required to enhance the usability of the applications. They focused on how informative the results were, which were obtained by user interaction with the AR application. Schaeffer, Satu Elisa; editor, (2014)

Usability evaluation of an AR application for overlaying 3D models

Heuristic evaluation principles were used to evaluate the execution of structured and unstructured tasks by potential users, who were nor developers nor designers. A Cognitive walk through and a Heuristic evaluation method were used, and a usability inspection in laboratory. Also, the users filled in questionnaires after the usability testing. The cognitive walk through included operating VR objects within the AR environment. Problems were categorised into three categories, critical, serious and cosmetic problems. The results of the Heuristic evaluation were compiled into a table with the id numbers of problems. Time for completing each task was recorded and shown in a chart. Results from the questionnaire were plotted in a frequency table.



Out of the four usability evaluation methods (cognitive walk through, Heuristic evaluation, inspection in laboratory and questionnaires), the questionnaire was the one which identified the lowest number of reported problems. A combination of methods were the best practice to report as many problems as possible. Moreover, using more than one evaluator in the heuristic evaluation increased the number of identified problems significantly.

Design and user evaluation of an AR interface for museums

This research explored the aspects interactions between visitors and museum artefacts. This AR application was built from scratch by the researchers. Apart from text, audio and video streamline, users were provided with a QR code and AR marker around the artefacts as well. The usability evaluation provided feedback on handling of the application. Preferences of the favoured media type were recorded. Results were very encouraging the use os QR codes and AR markers. Users gave several practical advice to further improve the application. The results were quite significant to provide the best user experience in museums.

Usability testing and heuristic evaluation of the Wikitude navigational application

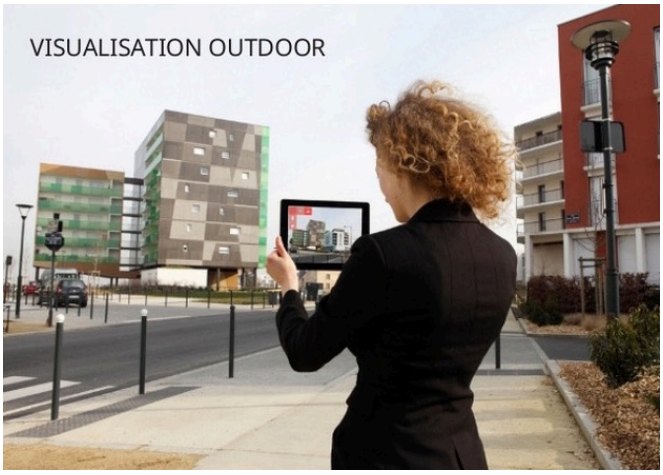
Wikitude is an AR navigational for Android platform. Navigational tasks were executed by users. Heuristic evaluation was used and testing scenarios were constructed as well. This experiment was overshadowed by unusually high number of system crashes, and the other significant problem was that the application was able to show only a limited, small number of interest. The test results were inconclusive.

Tactile navigation belt: Wearable device for sensing the direction

The last test was a prototype test of a portable, a hand free tactile device, which gives users feedback on direction, its users can actually feel the direction. The tactile belt informed the user which direction to travel to, following a pre-set route, guided by GPS. The idea is that such device could guide a person without the need of holding a navigational device. AR can include not just images, but smells, sounds and touch as well, the latest was used here. The two tasks included finding a conference, and a car rental company. Time to complete these were recorded, the number of user reacted or did not react to the belt's vibration, number of times the user traveled in the wrong direction. At the end users filled in a questionnaire.

5. Opportunities

The uses of mobile augmented reality (MAR) with mobile devices is full of opportunities. As augmented reality overlays objects the real world from a virtual reality, so its potential in architecture is exceptionally huge. Virtual models can be overlaid existing rooms for example, with the help of AR systems furnishing layouts, sizes can be checked. Walls can be made see-through for maintenance people and engineers, so ducts and cable trays can be seen and easily located. AR can show the past of urban areas by overlaying virtual data.



AR has been used in the gaming industry and media entertainment for much longer than in architecture. Now it is more available for the Architects are experts of virtual reality too, only game developers have more complex VR environments. A fully rotatable AR can show the building in such ways, which are conveying the message the architect wants to deliver. Also, clients can be distracted by an AR model, loosing their focus on the understanding of the building.

6.1 Opportunities in Architectural Design

Architect, with the help of MAR systems, would be able to release the full potential of BIM projects. The design process could take place on site. Client's instructions could be immediately modelled up and visualised. Architects could provide engineers and contractors on site a better understanding of the design and details by overlaying their BIM model the real environment. AR would allow full scale modelling and review of complex building details on site. Key technical issues could be addressed with high precision, without the need of building mock-ups.

Clash detection is a feature already included in BIM applications, but it works only in the VR. When a building is being built, and e.g. one column was not built at the right location, with the help of an AR application spacial consequences could be analysed on site.

Site notices could have and ID Marker and a link to the model, which would allow anyone to have a look at the proposed development through an AR application. Interior design and fit-out jobs can benefit hugely as the environment is well defined for AR projections. Connection to online BIM object warehouses (e.g. IKEA furnitures, etc...) has to form integrated part of such app.

Landscape architecture could hugely benefit, as an AR application can overlay the proposed park over the existing landscaping. Plants can be shown at different seasons, how the garden would look like several years later. Such use of AR would lead better decision making during the design process, like selection of trees, shrubs and flowers, selection of their final location.

AR can be used to aid the public to be familiar with future developments in their areas. A study was done by two professors and a Ph.D. candidate in Sao Paolo, which focused on the user perception and recognition of 3D model in relation to the way the AR model was presented. A smart-phone application showed the proposed architectural development in an AR visualisation, on top of the real world, existing architecture. The test with these scaled urban environments were highly successful among members of the public and proved that the participation of future developments can be done through AR applications. The discussion of the results were summarised as a preliminary guidelines, to help developers of mobile AR applications. The researchers made some interesting connections between the placement of the 3D model and its ID/paper marker and the perception of the architectural design. Cuperschmid, Ana Regina Mizrahy; Ruschel, Regina C; Monteiro, Ana Maria R. de G.; (2012)

6.2 Opportunities in Construction

The construction industry would hugely benefit from the combination of MAR, BIM and high accuracy tracking systems. It would be very easy to visualise which is not yet built, to show which is hidden, or which can not be seen as it has been already demolished. Site inspections for architects and engineers would be simplified, like dimensional and photographic surveys. The construction process could be more controlled, location of building materials could be tagged, safety zones around equipments highlighted and projected. Communication through meta tags would make different professions to work together more efficiently through space and time.

6.3 Post-completion Opportunities

After practical completion the virtual BIM model of the building could be overlaid the real building. The attached information on maintenance, spare parts, product details, manufacturers' contact details, etc, can be visually and in audio format attached to building elements. As a building is a very complex object, maintenance could be simplified. Maintenance personals don't have to be fully trained to operate the building and make repairs, they just have to be familiar with the use of the MAR system. Walls can be see-through, meta data would be loaded from the building information model (BIM)

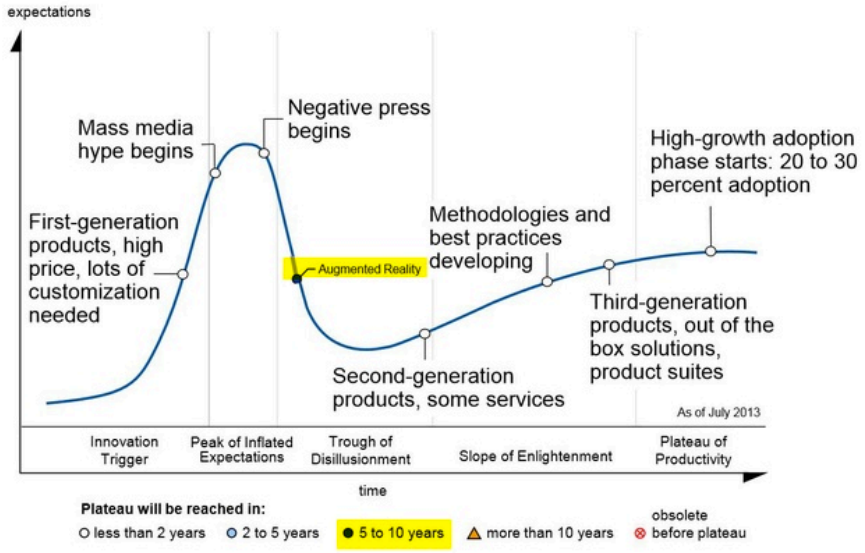
The property business could benefit from the AR applications too. Potential buyers could have a look of alternative furnishing layouts, which could help selling the property. Virtual tours could be arranged, and AR could provide different point of views of the building, can be viewed at any angle, sections can be taken.

Building acceptance at the end of the planning application process can be simplified, as a self supported AR device could aid planners to facilitate a comparison by overlaying the 3D model on top of a video recording of what was actually built. The suitability of such application of AR was assessed by two researchers of Graz University of Technology in a real factory. They furthermore analysed the the usability of their AR system to other AR systems. Their free standing device seemed to be suitable for extended use in complex industrial environments. Their findings revealed some ergonomics related issues and underlined the validity of the use of such AR devices on the field.

The tedious task of snagging a building regularly on site can be aided by AR applications. The value of this would be that it allows a quick dimensional comparison of the 3D model and what was actually built. Notes could be taken promptly of any inconsistency, with images explaining the issues. Such successful real life experiment has been conducted in Graz, in a factory. The AR device was precisely calibrated, and was able to detect differences within a range of few millimetres, depending on the distance. Schoenfelder, R., Schmalstieg, D., (2008)

7. Obstacles

The hype about augmented reality peaked around 2011, according to Rana Abbout's article from 2010. There are more and more questions about the practical application and even usefulness of such systems. The current commercial adaptations of AR are not stable enough yet. Some user will probably wait for the second or maybe third generation of AR products, before investing money in a MAR device. It is very similar, which happened to the LED technology, as its first end second generation products were causing disappointment among users, but the third generation proved to be superior to any, previously invented lighting technology.



The Peak of Inflated Expectations, Abbound, Rana (2010)

One of the most obvious one is tracking. The virtual models have to be placed precisely into AR and kept in position, relative to the real world. This constant identification of position and orientation requires tracking systems. The most commonly used outdoor tracking is GPS based. GPS system works with huge tolerance, depending on weather condition, number of satellites in view providing measurements. The building industry requires a precision of few millimetres, which can be achieved by the use localised tracking system, installed on site. Such system can be sensitive as well, to resonation, dust, obstruction of signal on a chaotic construction site. Solving the technical issue of high precision tracking will have a milestone along the development path of the MAR applications.

Although AR applications have intuitive interaction mechanisms, they still can not provide more than rotating and scaling a 3D object, using a live camera feed from the device's camera as backdrop. The AR applications available now lack any Building Information Model (BIM) connectivity. BIM becoming industry standards in many sectors of the construction industry, in 2015 in the UK and in 2016 in Ireland. An AR based collaboration is yet to be clarified, how it would happen, a common industry standard file format is to be developed, as videos or screenshots are barely satisfactory for such design communication.

8. Conclusion

Augmented reality has developed a lot since it was born. Portable devices (smart phones, tablets and head mounted displays) with decent graphical processing capabilities allow more use of mobile augmented reality. Developments of such applications can take place more often, there are useful AR application on the market already. It is far from being a fully developed technology either, there are several challenges to overcome. These challenges are technological, financial, there are some privacy issues and social acceptance. Usability testing of AR applications require slightly different approach, as users interact with the portable device and the real world at the same time.

The architectural use of AR on mobile devices on site has huge advantages. Architects can communicate their design ideas much more successfully towards clients, authorities and the public. Building information modelling systems contain a massive amount of information, which could be displayed with the help of MAR on site. Managing the construction process can be more controlled and clearer for all parties. After practical completion, the results of final measurements and checks, interactive photographic surveys can be connected back the BIM system. Later, maintenance of complex buildings will be simple task, information on all building elements can be reached on site through MAR and BIM.

Augmented reality is a fascinating technology, which has entered a new, more realistic phase with the arrival of more powerful mobile devices. This technology will change not just the architectural profession in the future, but the our world, buy adding a new dimension to it.

References

Abboud, R. (2013) Architecture in an Age of Augmented Reality: Opportunities and Obstacles for Mobile AR in Design, Construction, and Post-Completion. 2014 Venice Architecture Biennale http://www.codessi.net/sites/codessi/files/IWDS2013%20AR%20PAPER%20-%20R%20ABBOUD%20-%20MARCH.pdf

Cuperschmid, Ana Regina Mizrahy; Ruschel, Regina C; Monteiro, Ana Maria R. de G.; (2012)

Deutsch, R. (2012) “BIM beyond Boundaries” http://www.di.net/articles/bim_beyond_boundaries/ [Accessed 18 February 2012]

Domingo, AAron G (2013), A Whole New Perspective, University of California. Davis, Landscape Architecture Program

Lehman, Maria Lorena, (2012) The Future of Architecture as Impacted by Augmented Reality

Matsuda, Keiichi (2013) Augmented (hyperReallity: Domestic Robocop, http://thesuperslice.com/2013/12/18/augmented-hyperreality-domestic-robocop-keiichi-matsuda/

McKalin, Vamien, (2015) Augmented Reality vs. Virtual Reality: What are the differences and similarities?, Tech Times

Novak-Marcincin, J., Janak, M., Barna, J. (2012). Augmented Reality Technology Applications. Proceedings in Manufacturing Systems, Volume 7, Issue 2, 2012. 1-4

Abbound, Rana (2014), Architecture in an age of Augmented Reality, ArchitectureAU, http://architectureau.com/articles/architecture-in-an-age-of-augmented-reality/#img=4

RIAI (2014), Working with an Architect, http://www.riai.ie/consumer_services/working_with_an_architect/

Schaeffer, Satu Elisa; editor, (2014) Usability Evaluation for Augmented Reality, Department of Computer Science, University of Helsinki

Schoenfelder, R., Schmalstieg, D., (2008), Augmented Reality for Industrial Building Acceptance, Virtual Reality Conference, 2008. VR '08. IEEEE Vaulation of 3D Models of Leisure Equipment Recognition in Augmented Reality

Storer, Doug, (2012), Six Dimensional Building Information Modeling, Wang, X., Aurel, M. (2009) Mixed Reality In Architecture, Design, And Construction