Augmented reality as a part of integrated designing and modeling the parameters of reconstruction projects

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The use of augmented reality in architectural projecting is relatively new and commonly unexplored option among the architectural and construction professionals. The augmented reality provides us an immense possibility to facilitate the project work. There a bunch of applications to be used in mobile technologies and various plug-ins for the 3D and 4D CAD software. There is a wide range of use for augmented reality in architectural project starting from visualisation of 3D models, revising the construction process and it also serves as a useful tool to intercommunicate among the construction professionals involved in the process of construction.

Definition and main characteristics of augmented reality

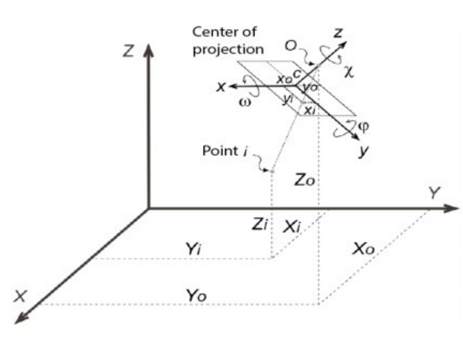
The augmented reality allows us to blend the real and virtual world allowing us to obtain a more complete view of the world around us, making perceptible to humans a series of digital information in the most natural way possible to enhance the interaction between both worlds. The Augmented Reality (AR) as a technology appears in the middle of sixties (1968) in the past century by Ivan Sutherland´s creation of the first virtual reality end augmented reality head mounted display called "The sword of Damocles."

In the 1999 Hirokazu Kato creates an AR computer tracking library named ARToolKit released by University of Washington HIT Lab. Based on video tracking which permits to calculate the camera position in real world and its orientation and distance relative to the square black and white AR marker which allows to position correctly an virtual 3D model, 3D Image or 3D video. This open source project is a base of many contemporaneous AR software and mobile applications.

To definite the AR in the simple way we can use the Azuma´s definition of Augmented Reality [1] which affirms that AR combines the real and the virtual, it's interactive in real-time and that it must register in 3D.

For better understanding the difference between the Virtual Reality (VR) and the Augmented Reality (AR) we can use the Beaudouin-Lafon´s explanation of the world of virtual. As Beaudouin-Lafon states, the Virtual Reality enables us to experience the virtual world, interact with digital objects, but within a totally virtual environment, the AR goes a little further, and enable the virtual objects to be represented in real space, generating a connection of the real world with the virtual, (instead of inserting the user in a computer generated world, the AR covers the real world with the virtual world, or embedded/merges both worlds). [2]

To merge the two worlds is essential to create a relationship between the real and the virtual, for what is needed a usage of a number of sensors able to establish such a relationship (optical sensors, inertial, geo-located), to find such a solution is necessary to calculate six parameters (3 translations and 3 rotations), by which we can define any point in space.



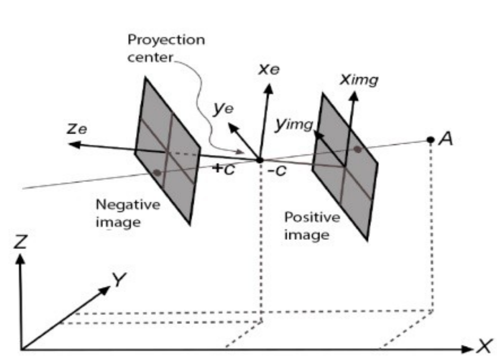


Fig. 1 Scheme of central perspective [5] Fig. 2 Image coordinate system and image space [5] coordinate system

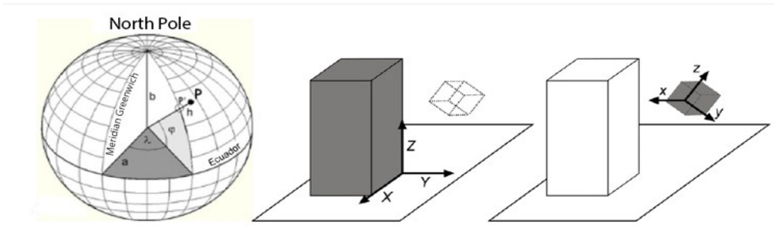


Fig. 3 The coordinate systems: Global-World, Local, Custom – Object [5]

Milgram and Kishino in "A taxonomy of mixed reality visual displays" analyzed the ability of embedding the virtual and the physical, propose a classification of "mixed realities" from the point of view of the real and the virtual, relating to the new possibilities of visualization, of the new hardware and software devices.

"The conventionally held view of a Virtual Reality (VR) environment is one in which the participant-observer is totally immersed in, and able to interact with, a completely synthetic world. Such a world may mimic the properties of some real-world environments, either existing or fictional; however, it can also exceed the bounds of physical reality by creating a world in which the physical laws ordinarily governing space, time, mechanics, material properties, etc. no longer hold. What may be overlooked in this view, however, is that the VR label is also frequently used in association with a variety of other environments, to which total immersion and complete synthesis do not necessarily pertain, but which fall somewhere along a virtuality continuum." [2]

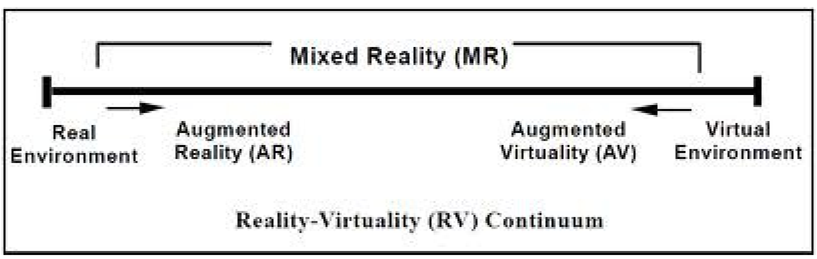


Fig. 4 Milgram kontinuum [6]

Ar application design bases

According to Billinghurst(2013) AR applications have to be designed based on the experience we want users to experience. For a optimum design first thing we should consider is the type of devices that we use. Billingurst compare the experience of economic systems that propose Gilmore and Pine with AR systems. In the economic systems we found that the degree of market value is related to the functionality and emotion , within a pyramidal scale components, products, services and experiences ; lowest step where the components are understood as what is offered to users at the functional level and the highest grade is given to the experience as emotional commitment, which can only be accessed with the right combination of components, products and services.

This economical design scheme given at the enterprise level can be moved to the design of AR products. We find a very similar combination which also operates as a pyramid composed of components, tools, applications and experiences. Where the components would be the way to locate digital elements within the space, the tools would refer to the idea that the author wants to convey (the metaphor), applications related to the interaction that occurs with the user, and experience , that we find at the top of the pyramid would be related to the experience in terms of usability, more usability increases the level of experience of the users. We can use a system where the point is the experience, to understand it better we put a very

simple example: the user wants to take a coffee, which we know that home prices may be about twenty cents , however most people prefer to take in a pub , despite knowing it may cost much more expensive. Just for the experience different of the usual, including music, companionship, comfort or any other factor that we brings into the option of participating in the experience.
When designing user experiences based on science and technology we have to consider various aspects : physical appearance, cognitive or emotional aspect and the most important cultural or social aspect. All these aspects should make the user part of the science and technology. We must not think only of how technology is used, but also in the way people use new technologies in social and cultural contexts. And as this new way of seeing the use of technology can bring the forms to create new experiences, especially in a society where mobile devices have been made available to any consumer, increasing the ability to perceive new experiences through handheld devices.
Billinghurst propose how to make a good experience in Augmented Reality environments from three conditions [3]:

1. Experience "convincing" we have to create a magical world around the users so that increase the desire of users to collaborate.
2. "Intuitive and easy to use" experience using existing skills of the users.
3. "Insertion in the physical world" combining the physical and the virtual in the most natural way possible.

Augmented reality (ar) characteristics

Any AR environment must meet a number of features that enable the combination of real world and the virtual(digital) world. Azuma (1997) offers three features that should always be present in AR systems. Using the right combination of this three features we can get a better performance of the AR application and the user:

Combination of the real and the virtual :

This combination must occur in the most natural way possible , allowing direct contact between the two worlds , mainly it refers to the visual sense, as is the sense that enables us to easier understand the blend between both worlds. This is conditioned to the type of display that we may use :

- Displays connected to the head. (Smart Glasses, Optical see-throught glasses)
- Displays connected to the body. (SmartWatch, Sensors)
- Spatial displays. (Fog and Water Displays, Laser Proyections, Holograms)

Fig. 5 Smart glasses. Vuzix M100

Fig. 6 Spatial display. ION fog display.

Real time interactivity :

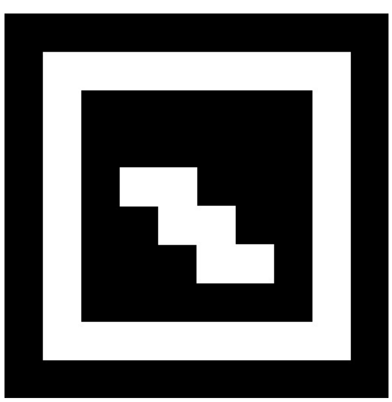
This interactivity not possible in real time or with minimal latency almost imperceptible to humans. It causes the user's sensation of immersion within applications, so it is directly related to the user interaction and the type of input device and output data used . As input devices can be included:

- Tangible Objects.
- Pressure (Touch HHD).
- Gestural inetfaces.
- Multimodal interfaces.

3D Environment operation: This registration usually occurs when we can associate real and virtual objects with each other . This is related to the type of technology we use. There are several techniques that make possible the association, let's name the key features:

AR based on tracking technologies

1. Sensors : mechanical, magnetic , ultrasound .
2. Monitoring in relation to: GPS coordinates, Wireless Sensor Network, phone location.
3. Tracking based on: accelerometer data, digital compasses data, gyroscopes data.
4. Flat patterns " Markers " tracking: black and white images. (by detecting edges , lines and points within them) .
5. Tracking based on two-dimensional color images. (by detecting edges, lines, dots and textures) .
6. Tracking - 3-dimensional objects ,detection of simple shapes (cubes, cylinders, spheres) .
7. Tracking based on CAD data, edge model.
8. Detection of texts can associate a particular text as if it were an AR marke .
9. Tracking natural features, allowing to detect natural features associated with users (facial or body gestures), or associated with it space (corners or fixed forms that maintain high color contrasts) .
10. Multimodal tracking (Any combination of the above monitoring techniques).



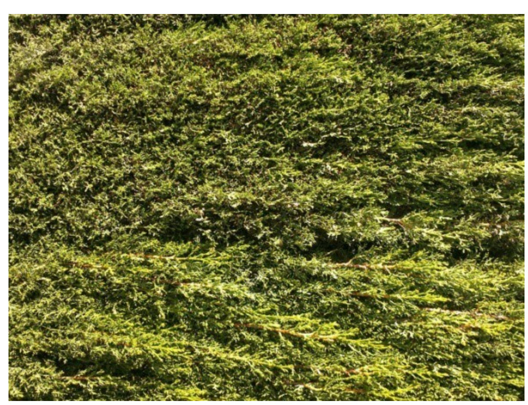


Fig. 7 Flat pattern Marker

Fig. 8 Two-dimensional color image Marker

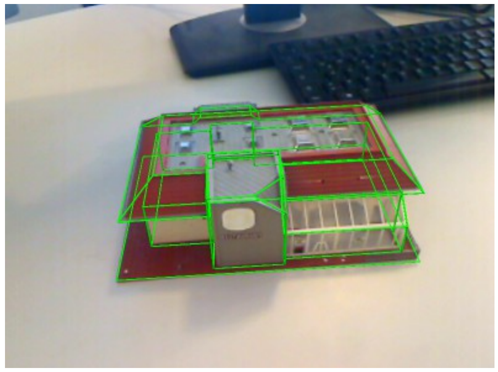


Fig. 9 Tracking based on CAD data, edge model. Metaio SDK

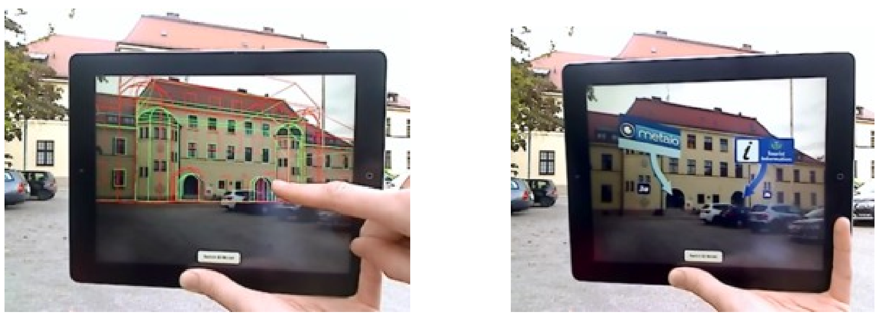


Fig. 10 Tracking based on CAD data, edge model. augmentation in geo-referenced scenario . Metaio SDK

How does the augmented reality work?

AR technologies today's employ a lot of platforms to display the results. The most common way to visualise the 3D virtual content is using a computer and a web camera connected to it. In the last years also the mobile platforms like smart-phones and tablets are gaining the important role in this field. Another way for the visualisation purpose is to use the special devices for so called head mounted displays.

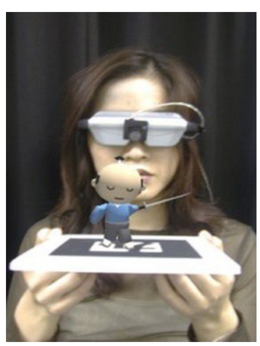


Fig. 11 Head Mounted Display example [7]

The visualisation devices can be generally divided in two groups: live-video referenced and the see-through. The first ones are the base of almost all AR systems known today, used by computer and mobiles,

this technology employs the computer´s web camera or the mobile´s integrated camera for tracking and marker recognition. The second one is relatively new technology which finds itself in development progress such as Google Glass, Vuzix SmartGlasses, and Nissan 3E...This way of visualisation allows the users to see directly the real world through the special glass and superimposes only the virtual computer-generated information over the user´s real world view.
For mobile devices there are two different types of operation, one based on the recognition of flat patterns and other geo–based using a GPS sensor. The pattern recognition method is based on the software´s ability to distinguish different types of patterns made in 2D, such as flat black and white markers or image patterns. It is necessary to print this recognition patterns. Once loaded the AR software on the computer or AR application on a mobile device, it’s necessary to point the terminal´s camera to the marker or an image pattern, which has been previously linked to a virtual content stored in internal or external database (3D model, video, picture, sound). When the optical sensor (camera) detects the marker, it is searching for the image´s landmarks that allow calculating the position of marker in real space. Once obtained the scale, rotation and distance data, the software inserts the virtual content in physical space. Regarding to the marker, until recently, it had to be a relatively simple geometric figure embedded within a black and white square detected as easy as possible through the contrast based tracking method. Today we can use any image as a marker, but that it has to be previously encoded in the manner that the software is able to detect it. The geo-location method is based on the GPS coordinates and Wi-Fi triangulation technology, which permit to localise the user in the real world, and load the virtual content within our real world based on the GPS coordinates. The same way as for the flat patterns it is possible to use any type of virtual content that stored in a database. This technology not only uses GPS data, which would be incomplete to reconstruct the virtual object. The orientation matrix is also needed. To retrieve this information are used sensors of our device (digital compass, accelerometer and gyroscope).

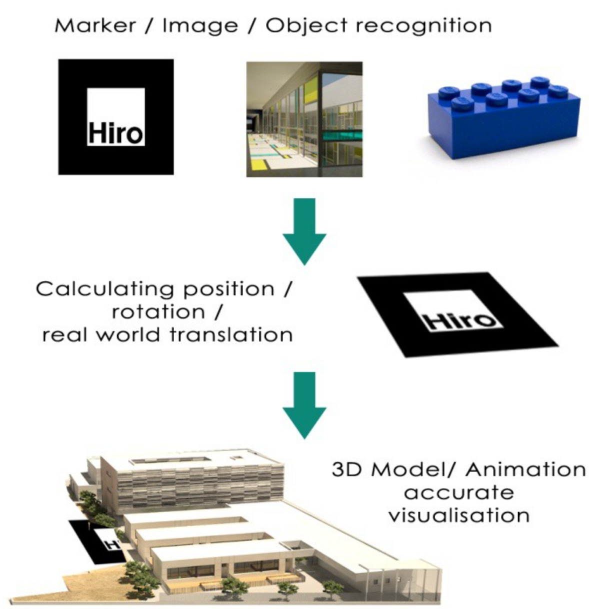


Fig. 12 Scheme. Capturing the AR marker

Augmented reality as a part of architectural and construction process

During the developement process of an architectural project there are many possibilities to employ the AR tecnoligies. The more common use of AR is the visualising of the 3D models intended for the presentation to the client or for the development purpose within the project team. There are several plug-ins for the

most common CAD programs which are used for the architectural visualisation, such as Autodesk 3D Max, Maya, SketchUp, Cinema 4D, Vectorworks, and Scia Engineer.
The software that is operating within all of these platforms is called AR-media plug-in. This software permits not only the marker based visualisation of the 3D model but also real- time lightning and switch mode between soft and hard shadow rendering. It also poses a very useful tool which performs a real-time sectioning along any axis and a multiple mode sectioning. It is compatible with short animation and also, what is very interesting at the point of view for the client presentation; it permits to show the 3D model of the building, floor by floor, in a real time manner, which simulates the real constructed model in that we can take off the roof of the house.

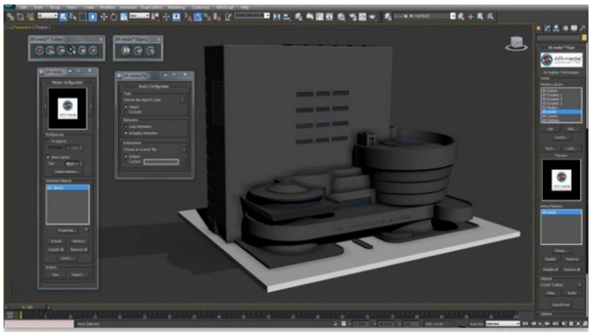


Fig. 13 AR- media plug-in. User´s interface within Autodesk 3D max [7]
Fig. 14 AR- media plug-in. Visualisation of 3D model in real-world environment

To share these 3D models with other team members or clients AR-media offers a Player, which allows the user to visualise the geometries created with this plug-in. There is an iOS an Windows option but also exists the option for the Android platform, which allows the user to use this application outdoors and visualise the 3D virtual content in the real-world environment.

Fig. 15 AR- media Player. Visualisation of 3D model in real-world environment [7]

The augmented reality technology could be also employed not only to visualise the future projects but also serves to a various uses like building maintenance or visualization of the missing parts of the ancient historical monuments. The plug-in called 3D Tracker which uses is object based tracking is able to recognize even a complex objects independently of its scale like a building. For example it can be employed to visualise the real position of a building´s infrastructure, based on a project documentation, to allow a further maintenance of the buildings. Due to the angle and distance from the tracked object it superimposes the virtual layer with the desired information.

Fig. 16 AR Tracker. Building manteinance example [8]

Another utilization of recognizing the complex object is a Rome Coliseum Application example. This reconstructs virtually the parts of this ancient construction which has been destroyed in the pass of a time. This application is for outdoor use and can be executed on mobile devices.

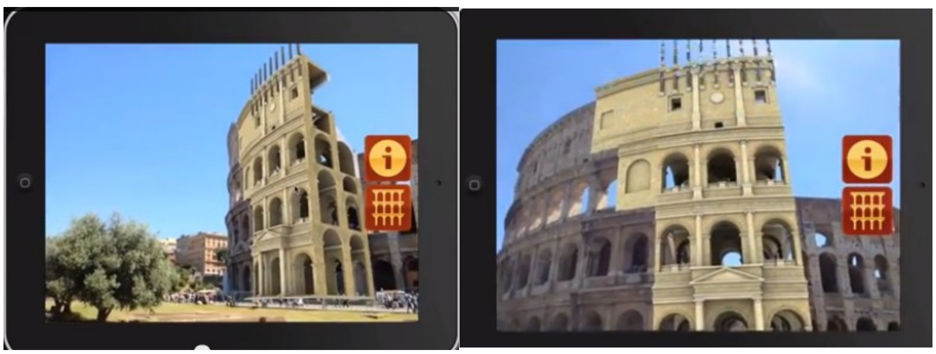


Fig. 17 AR Tracker. Ancient building virtual reconstruction example [8]

Augmented reality realised construction projects examples worldwide

Although the AR technology is not yet widely known and uses for the architectural and constructing purpose there are some interesting examples of how this technology can enrich the existent architecture or even be a part of a real physic environment. For now there is a unique example of integrating the AR technology in the architecture itself, which allows us to perceive the architecture in a never experienced way until now. The N Building architecture project by TERADADESIGN ARCHITECTS (Terada Naoki, Hirate Kenichi) and Media architecture project by Qosmo, Inc. (Alexander Reeder, Tokui Nao, Sawai Taeji) in Tokyo presents an interactive facade. This commercial building rather than billboard and announcement on it facade present a huge QR (Quick Response) code. On it´s opening in December 2009 an iPhone application was released, which permits the user to interact with the building and other users which find themselves in the building. By pointing a mobile phone to focus the building a virtual superimposed layer appears. The users can visualise the comments of other users which want to be seen, also the shop information and short animation can be visualised.

Fig. 18 The N Building facade. Tokyo [9]
Fig. 19 The Augmented layer of N Building. Tokyo [9]

Another interesting project is what was denominated as a largest AR project. In 2010 in Brazil a Rossi Construction Company presented the world´s biggest AR marker to potentiate the visualisation of the skyscraper building project. To present the project to the investors and potential clients in the buildings site there was placed a 10 x 10m AR marker. By overflying the site in helicopter the virtual 3D model was visualized in the place of its future construction. By this way of presentation could be fully evaluated the visual and aesthetic impact of this construction to the surrounding environment.

Fig. 20, 21 The world´s larges AR project. Rossi Construction Company [10, 11]

„Timetravellerscabanyal“ – augmented reality project

The original AR Project, which was realised in 2011 by Ferrer-Hernandez and Mesárošová, tasked by Esfera Azul Association and was aimed to support the citizen´s initiative against the city urban plan that destroyed street line structure in the Cabanyal, Valencia at Spain. Cabanyal is the city district that is considered as an area of tourist and cultural interest by UNESCO. The AR Project "TimetravellersCabanyal" enables not only the virtual reconstruction of demolished buildings on their original place, in three-dimensional representation, but also expands the knowledge concerning plats, actual plans, and information of various kinds of the same buildings. We have employed own original method which using old photos, as well as life street view of Google Earths to create the virtual 3D model of the original buildings. The application was programmed by scripting for GPS recognition. Abovementioned application was made within the project "The Cabanyal Living Archive (Virtual Drifts)", which won the Europa Nostra award in 2012 under section of the „Education, Training and awareness-raising."

Aims of TimeTravellersCabanyal project:

- Promote the artistic and cultural heritage of Barrio del Cabanyal.
- Introduce new ways of interacting with the public space.
- Approach to an unspecialized audience.
- Report constant destruction of cultural property by the government.
- Expand users' knowledge of cultural heritage.

To select the space where the intervention would take place, we considered several factors:

- Deterioration of the zone.
- Duration and distance of the route necessary to visualise all of virtual content.
- Viability and exploitation of chosen augmented reality application.
- Spatial requirements of GPS to perform in correct order.
- Buildings affected by urban plan "PEPRI".
- Buildings emotive value to local residents.
- The possibility of mayor number of virtual content placed in less physical space.

For the purpose of 3D model creation we have collected the original images and photographs from the inhabitants of Cabanyal district. We also retrieved the additional information from the Google street view, which served as blueprint for the 3d model creation. The modelling was performed in the open source 3D software Blender.

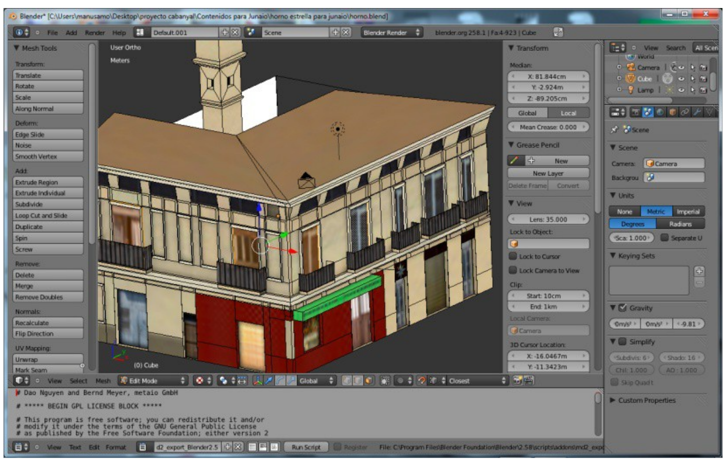


Fig. 22 3D model creation in Blender software

The Augmented Reality Junaio software, which allows use of the Internet, was chosen for the realization of this project. This software possesses the capacity to retrieve and interpret the GPS coordinates and the information from the inertial sensors built into the device (mobile phone or tablet pc). This allows performing a correct positioning of virtual content within the physical space in real-time. This way the application does not depend on any physical element located "in situ", allowing the application to be super temporal and could be accessed by users at any time. In this application we correct errors from the GPS by LLA Marker. This allows us to change the position of the GPS in our terminal, so that whenever we scan the LLA Marker with our device, it places us in a predetermined GPS coordinates. Thus making possible the correction of the position, in which we find ourselves, as well as the position of the 3D virtual objects located in space. Reducing the error, which normally oscillates between 15 and 75 meters, to a few centimetres and allowing better control for adjusting the virtual elements to the real space where they are located. We have programmed the specific application by using PHP scripting in open source software Eclipse. This application can be executed by Junaio software on any mobile device. The user interaction is produced by their free movement in the real environment, following the route of AR application. The immersion is performed through mobile devices, transforming it into a kind of window in time, which permits to visualize the real and virtual content synchronously.

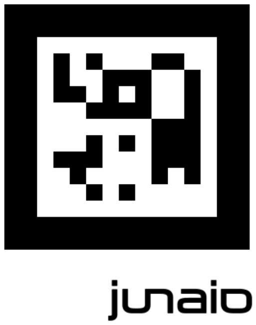


Fig. 23 LLA Marker

Fig. 24 “TimeTravellersCabanyal” users

The detailed information concerning the specific technical parameters and content sources:

- TimeTravellersCabanyal documentation used in the project:
  - Photography: Live Archive Cabanyal from Google Maps.
  - Textures: Manuel Ferrer and Alena Mesárošová photographs.
  - Images: Blender Render, Manuel Ferrer and Alena Mesárošová.
  - Measurements: Cadastre Cabanyal, GPS: Compass 2.1.1.
- Supported Systems:
  From iPhone 3G, iPad, iPod (3rd Generation +) and Android devices from version 2.1 with ARMv7 processor. It runs on devices from iPhone 3G, iPad, iPod (3rd Generation +) and Android devices from version 2.1 with ARMv7 processor.

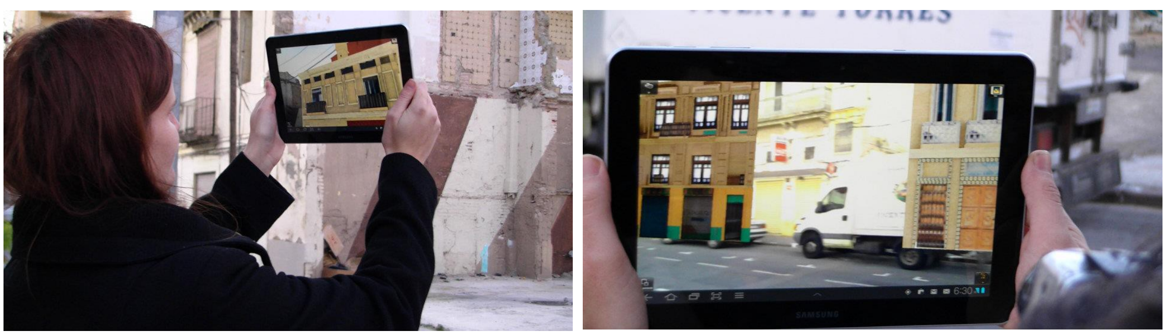


Fig. 24 “TimetravellersCabanyal” Application

Conclusion

Authors described the augmented reality as a useful tool of integrated designing and modelling the parameters of construction projects. The main traits of augmented reality were characterised, as well as the augmented reality realised projects, including their own AR Project “TimetravellersCabanyal”. The implementation of augmented reality in the construction projecting could facilitate the communication between project teams and clients.

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