VIRTUALLY REAL

Immersing into the Unbuilt

7th eCAADe Regional International Symposium
Aalborg University

May 2019

Edited by
Nicolai Steinø
Martin Kraus

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Aalborg, Denmark
Department of Architecture, Design
and Media Technology
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Contents

Mixed Reality and lost heritage:

*Reconstituting the Monastery of Santa Cruz of Coimbra through VR-AR convergence**

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To fulfil the specific purposes of a three-year research project we are working on (to reconstitute the Monastery of Santa Cruz of Coimbra in 3D, and its situation in 1834, before the partial demolitions of the late 19th and early 20th centuries took place) we became interested in the possibilities of fusion between Augmented Reality and Virtual Reality - an interactive experience generated by a computer that takes place inside of a simulated environment. These two emergent development fields gave birth to what was recently coined as Mixed Reality and the environments created can be analogous to the real world or they can be based in imaginary environments. We have two basic aims for this initial research: first to create the tools to provide knowledge and wisdom (knowledge with emotions) around lost heritage. The second aim, profoundly related with the first one, is to create a methodology and software capable to surpass a Turing-type Test for Virtual and Augmented Reality, where the observer could be immersed in an environment where virtual outputs and feedback can be greater or, at least, similar to the real world.

Keywords: *Mixed Reality, Virtual Reality, Augmented Reality, Lost Heritage, Monastery of Santa Cruz of Coimbra*

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THE SANTA CRUZ RESEARCH PROJECT

The Santa Cruz monastery, in Coimbra, of the Canons Regular of St. Augustine, founded in 1131, was one of the major religious houses of Portugal before the religious orders were extinguished, by decree of the new liberal government, in 1834. The following abandonment of the building and its application to the most diverse uses led to the progressive loss of important artistic and architectonic heritage. No-

table architectonic features can still be seen today, such as the late-gothic church, the church's chancel (that hosts the tombs of the first two Portuguese Kings), the late gothic cloister and refectory, the renaissance Manga fountain, the mannerist vestry and the baroque sanctuary. However, important parts of the monastery were destroyed during the late 19th and early 20th centuries, such as the monastic façade and entrance cloister (which were substituted by the new Town Hall building of 1876-79), the 110-meter-long renaissance dormitory, the Manga cloister (which surrounded the remaining fountain) and the medieval/baroque bell-tower. This destruction largely affect the overall perception, amongst modern day visitors, of the scale and monumentality of the monastic complex during the later years of its original function.

This is why we thought of setting up a research project that could put together both history of art and history of architecture with the new technologies, particularly in the fields of Virtual and Augmented Reality. Our project proposal was welcomed and selected in a national competition and is now being funded by the Portuguese Research Foundation (*FCT- Fundação para a Ciência e a Tecnologia*, research project code number 30704). The aim of the Santa Cruz research project is to allow for a renewed understanding of the Santa Cruz monastery's erased past through the use of Virtual Reconstructions of its lost architectural heritage that can be perceived through Virtual Reality devices, which will be available for visitors of the modern building and site (personal Smartphones can also be used to download and watch the 3D VR 360 contents on site, matching the architectural remains).

Of course, we will rely on the work, knowledge and expertise of several researchers in several fields, some of them directly connected with the research project, such as archaeologists (Alarcão, 2011), art historians (Dias & Coutinho, 2003; Craveiro, 2011), photography historians (Ramires, 2001) and architects (Lobo, 2006; Couto, 2014) which will account for the physical state of the monastic complex in the mid-19th century, before the main destructive actions took place.In our research project the overlapped geometrical information can assist the existing environment with missed architectural elements that are presented, masking important areas of the existing environment with data from other epoch or context. This new/old information will be faultlessly linked with the real environment in an immersive experience.The primary value of Mixed Reality technologies applied to our research project is that they will bring components of the digital world into a person's perception of the real world, not just as a simple display of data, but through the integration of immersive sensations that are perceived as natural parts of an environment.Main overlaps that we are aiming to build are the elevation of the original cloister surroundings around the remaining Manga fountain (in order to re-insert this magnificent Renaissance architectural piece into its original built environment), the reconstitution of the monastic Renaissance façade beside the remaining church façade, and the insertion of the magnificent human scale sculptural terracotta ensemble of the «Last Supper» (executed by Hodart between 1530 and 1534 and today at the Machado de Castro National Museum) into its original setting, presiding over the monastery's still standing refectory hall.From our work, other developments can be attained in the near future, such as going further back in time, to the original Romanesque church and cloister, which were substituted in the early 16th century by the still standing church and cloister structures.

THE GLOBAL CONTEXT

Cultural and Creative industries are globally recognized, nowadays, as one of the most relevant economic factors of growth and job creation. In Europe particularly, where these industries represent around 5% of the European Union's GDP (Forum D'Avignon & TERA consultants, 2014), it is vital to study and promote the uniqueness of its cultural heritage sites. UNESCO World Heritage sites compromise 40% of global tourism revenues from cultural products re-

lated with the local monuments, arts and crafts. The Santa Cruz monastery is not a World Heritage Site in itself but belongs to the Property Area of the University of Coimbra which was recently granted with the UNESCO World Heritage classification in 2013 (url: worldheritage.uc.pt). Approximately 10% of the European Union's GDP comes from International Tourism activities.The rapid arrival of digitization and the associated shift in the way people apprehend reality is forcing the Creative Cultural Industries (OECD designation) to develop new growth strategies to improve this almost trillionaire industry. The CCI's boast €558 billion in value added to national GDP's in 2011 (Forum D'Avignon & TERA consultants, 2014)To accomplish the specific purposes of a Creative Cultural Industries related project, we became interested in the fusion of Virtual Reality and Augmented Reality, two emergent development fields that gave birth to what was coined as Mixed Reality (Milgram & Kishino, 1994).

MIXED REALITY ERA

Contemporary authors/artists such as Maurice Conti and Zenka (Jenny Carden) suggest that we are at the dawn of a new age of human history defined by the way we apprehend knowledge.This last revolution - the Information Age - is connecting us to realities far beyond our natural senses, giving birth to Augmented Reality, characterized by cognitive augmentations anchored in our basic sensory system, providing an interactive experience of a real environment where the elements of reality are nurtured with digital information, across several senses, to empathize certain aspects of reality. Augmented Reality allows computational systems to help us to observe and think, based on the way our nervous system was developed and pre-wired, as well as allowing us to communicate symbolically in several cultural contexts (nature and nurture).To fulfill the specific purposes of the three-year Santa Cruz research project we are working on, we became interested in the possibilities of fusion between Augmented Reality and Virtual Reality - an interactive experience generated by a computer that takes place inside of a simulated environment. These two emergent development fields gave birth to what was recently coined as Mixed Reality (Milgram & Kishino, 1994) and the environments created can be analogous to the real world or they can be based in imaginary environments. Unlike AR or indirect AR, Mixed Reality is not based on the simple superimposition of layers of information to create enriched contents. Mixed reality works mainly with tridimensional maps of the surroundings (figure 1) to interconnect the real and the virtual elements inside a physical paradigm that leads us to a better understanding of the reality or, if we pretend to, can lead us to a better illusion. Nevertheless, other sensory feedback like and auditory and the haptic (as defined by Gibson, 1968) have been also explored.

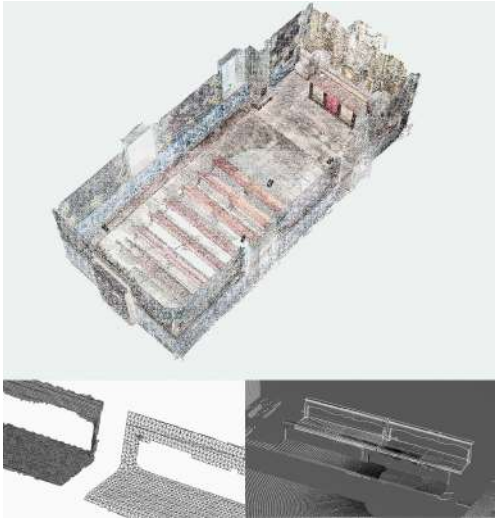

Figure 1
Our first tests were done inside a Jesuit chapel that belongs to Coimbra University Department of Architecture (cloud-point survey). First rehearsals of modelling environments by automatic methods in order to generate 3D faces based on point clouds provided by laser scans: 3D faces of the Jesuit chapel benches.

To enhance the sensory and intellectual experience, our project also combines explicit and tacit knowledge. For instance, the public can read or hear of descriptions of Hodart's «Last Supper», or visit the human scale sculptural figures at the museum room (set in a much larger space, according to a relatively random disposition), but they will also be able to look

around and experience the sculptural ensemble in a more correct assemblage and placed in other, more constricted, settings such as the original one was - a small room over the Santa Cruz monastery refectory top wall.

Figure 2
Human scale figures of the terracotta ensemble of the «Last Supper» by Hodart, of 1530-34, at the Machado de Castro National Museum, Coimbra (Christ, St. Peter and an apostle).

This idea, to make the biblical «Last Supper» experience as real as possible, was in fact attempted by Hodart himself with his original sculptural recreation (figure 2). With the technology and knowledge of his time, and alike the immersive big paints drawn in perspective views during the Renaissance (such as Leonardo's own «Last Supper» at *Santa Maria delle Grazie* monastery in Milan), the intention was there to experience this biblical primordial context with the maximum of fidelity.

ABOUT THE "VR TURING TEST"

In 2016, Renshaw, Sonnenfeld and Meyers proposed at the Human Factors and Ergonomics Society Annual Meeting the ground rules for a future development of a Turing type test for Virtual Reality in order to pursue the objectives of the imitation game created by Alan Turing in 1950 (Renshaw, Sonnenfeld & Meyers, 2016). This challenge, initially focused on aspects related with Artificial Intelligence, also promotes studies of how humans construct a judgment about the veracity and tangibility of their routine observations. Accordingly, a "Virtual Reality Turing Test" is shaped and used as a reference for the accomplishment of created immersive environments.The observers submitted to the "VR Turing Test" are, firstly, the visitors of a prototype display where digital versions of some human scale sculptures of Hodart's «Last Supper» (figure 3) are taken from its actual and well known environment - the museum room previously referred to - and abruptly inserted into other architectural spaces with scarce relation with the actual (or even the original) context.

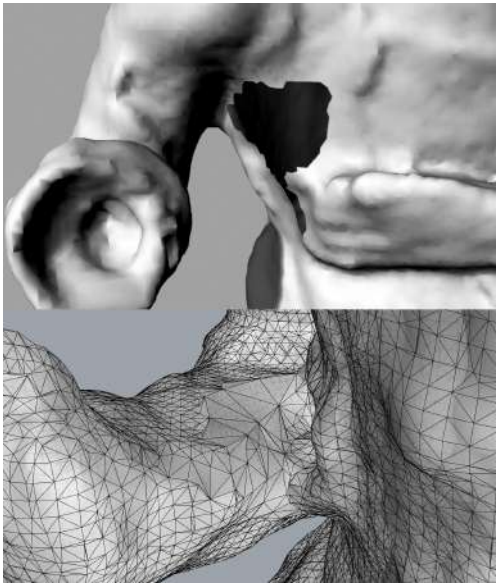

Figure 3
3D face (rendered and wireframe) reconstruction of missed parts of sculptural elements based on edge analysis applied to figures of the «Last Supper» by Hodart.

Figure 4
Raw image of the insertion of three «Last Supper» figures into a totally different context. Both the statues and the observer are inserted in the artistic installation.

In fact, we have essayed placing three central figures of the sculptural ensemble (Christ, the assumed St. Peter, and St. John) in the former Jesuit chapel of the University of Coimbra's Department of Architecture (figures 4 and 5). Reactions from observers could be video-recorded in order to verify the momentarily accomplishment of the "VR Turing Test". Instinct reactions such as surprise or distress, as well as other more complex responses such as the verification of the physicality of the sculptures, could also be verified. A similar experience will be attempted here in Denmark, in a workshop we are organizing for the 7th eCAADe Regional International Symposium, in which we will place some of the «Last Supper» figures at the table of the CREATE building refectory in Aalborg («Dinner at the Table: VR/AR Convergence applied to the 'Last Supper'»).

We are aware that all the efforts made nowadays to implement a real-like environment will be improved by the refinement of techniques and by Moore's law effect (Moore, 1965), which can be observed in several emergent technological fields. All these problems will be solved in a near future by the acceleration of the information processing capacity. The "brute-force" applied to creating anticipated interactions between real and virtual elements, as well as the infamous apparatus needed for the immersive experiments can be, in a matter of time, substituted by disruptive technologies capable to providing direct visual brain encoding, similar to what we already have for sound reading with cochlear implants. Meanwhile, the methodologies applied in this project can be improved in order to persecute the "VR Turing Test" in all the knowledge contents of the Santa Cruz project.

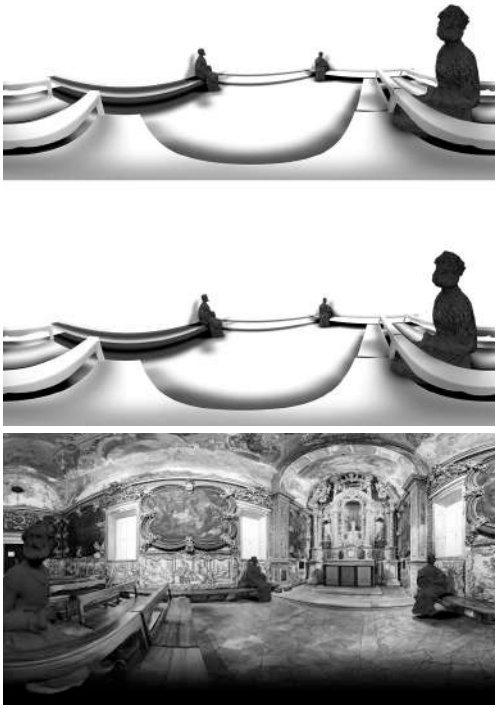

Figure 5
Part of a raw 360 by 180 degrees 4k stereoscopic image simulating the intercalation of the «Last Supper» sculptures placed between real chapel benches previously 3D scanned and photographed.

MIXED REALITY CONTEMPORARY EDGES

Commercial contemporary VR glasses, and contents provided to them, are normally limited to three degrees of movement (rotation around x, y and z axis). Other can be simulated but are not coherent with the user's movement. Every day, new technologies are being launched into the market. Nevertheless, the majority of hardware and software providers are not evolving in the direction of new interaction capabilities. Interaction tools are still largely in the joystick era and don't give us any particular motivation to explore these rudimentary game-like interfaces.On the other hand, the state of the art technologies in Augmented Reality are based in glasses where low qual-

ity 3D digital images are mixed with the real world. In short, 3D computer-generated imagery is superimposed over reality using one or several layers of transparent screens where a digital light field is projected. Despite the accelerated technological advances, there are several limitations in these current tools for Augmented Reality. The limited field of view on which digital images are projected, the image resolution itself and the real-time rendering limitations are some of the contemporary main restrictions to an immersive experience.Ideally, this type of Augmented Reality technologies should map the world, placing virtual objects into reality. For example, walls, floors and tables should be detected to coexist with the digital 3D contents created or translated from other contexts. Both structural and geometrical understanding of reality, as well as some semantic understanding of the way in which we interpret reality is needed to produce the immersive effect.

TECHNOLOGICAL DETAILS OF OUR RESEARCH

Like Eduard T. Hall mentioned in his book The Hidden Dimension (Hall, 1966), there are several different ways which our brain uses to interpret the space that surrounds us. In our research project we are focused in the following aspects of space interpretation:

- Dropped shadows (coherence and hierarchy);
- Illumination (intensity and colour);
- Focal distance (the focal point can be part of the story telling technic like we are used to practice in photography or cinema. The elements that we want the observer to be focused on are the ones we will, literally, focus on at the final cut);
- Parallax (slicing several spherical views and remaking them through a programmed process);
- Fog or atmosphere density;
- Interaction between the sound heard in real space and the introduced sound environment (eco and noise reduction);
- Coherent sound directions (binaural).

Instead of leaving to the glasses the effort of reading the 3D environment in real time, our methodolgy is being tuned to a state of the art technology, where 3D laser scanning and 360º images are combined to provide both stereo images and 3D vector information. These techniques and technologies give us the opportunity to make several geometrical and image refinements that can be given to the final observer as a high quality stereoscopic 360º immersive experience. To create 360º parallax environments, firstly we have to take several Ultra High Definition (UHD) spherical photos according to the directions and spots where we want to intensify the observer's experience of immersive parallax perspectives. Secondly, all the photos are subjected to a programmed process where each spherical photo is combined/remixed with other several photos in order to obtain parallax views keeping, at the same time, the notion of continuity between the several sliced pieces needed to obtain the parallax effect. Another process that is made in parallel is the 3D laser scanning of the spaces where we want to introduce new information. In this case, the raw scan is processed with Artificial Intelligence (A.I.) in order to rationalize geometries presented in the point cloud. In the great majority of the architectural cases, human hand is needed in order to reduce drastically the quantity of information presented after a A.I. shape rationalization. After the geometrical validation of the 3D faces, UHD renders are done based on the spots and lens used to photograph the 4K 360º parallax environments. Finally, both environments are creatively mixed in video.

RESEARCH PROJECT SITUATION POINT

At the moment, in our research project, we are developing two main VR-AR convergences which will be able to be experienced by future visitors to the Monastery of Santa Cruz and to its surrounding area. The first we have already partially unveiled and has to do with the reinsertion of the terracotta "Last Supper" ensemble in its original setting - a former elevated space that existed on the top wall of the monas-

tic refectory. Although the late-gothic refectory still stands, the space where the "Last Super" was originally placed has been destroyed and the Renaissance opening, through which the composition could be seen, has been walled. We have already surveyed, with cloud-point technology, the eleven figures of Christ and the Apostles, one torso and one head that are kept and exhibited at the Machado de Castro National Museum, in Coimbra.

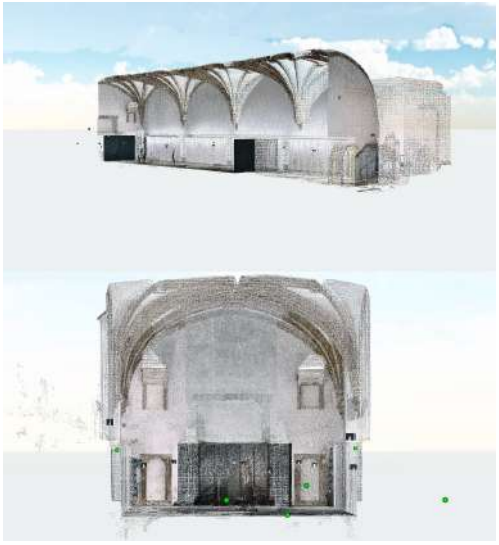

Figure 6
Cloud-point surveys of the Santa Cruz Monastery refectory.

With the help or art historians and specialists in Renaissance perspective, and by working upon the 3D models, we will try to reconstitute their original disposition, since no photographs remain of the time before the sculptures were taken away from the monastery, in the mid-19th century. In this way we will have to reconstitute the classical opening, the space behind it and the scene itself by means of a virtual 3D model, which will then be associated and mixed with a 360º parallax photomontage environment of the refectory hall or with raw scan optimizations of cloud-point surveys of the same space (figure 6). The terracotta sculptural ensemble can then be perceived as belonging to its original place through the use of *Oculus-Go* or VR headsets for current use smartphones.

A second exercise, almost opposite to the first we have just described, will be to recreate in 3D and through the visualization of old photographs, the built structures that surrounded the Renaissance Manga fountain *tempietto* and thus constituted the Manga cloister. These surrounding structures have been totally destroyed since the late 19th century and the remaining fountain *tempietto* is set today in the middle of a public urban garden with direct physical and visual access from the street (figure 7).In this way a fountain *tempietto* that was idealized for a quiet and contemplative enclosure is now exposed to the hustle of city life, a situation which totally alters both the architect's and the patron's original intention.

Figure 7
Photograph of the Manga cloister and baroque bell-tower, Santa Cruz Monastery, Coimbra, cª 1880, and Manga fountain /tempietto/ today.

Hence, we are now developing a 3D model of all sur-

rounding structures which also include the baroque bell-tower (demolished in 1935) which could be seen from inside the cloister towards the North. We will then merge the 3D model of the surroundings with a raw scan optimization of a cloud-point survey of this outstanding architectural piece (figure 8) or with 360º parallax photomontage of the existing fountain *tempietto* (figure 9).

A third convergence we are also considering to develop, in the near future, will be the "substitution" of the actual Town Hall, built in 1876-79, by the 16th century monastic façade that stood beside the imposing late-gothic monastic church of Santa Cruz. On the opposite side of the monastic church we will also proceed with the replacement of the actual façade of the Santa Cruz Café by the former elevation of the parochial church of St. John. The former elevations can be tracked down in a 1796 drawing and in mid-19th century well-known photographs (Ramires, 2001; Dias & Coutinho, 2003).

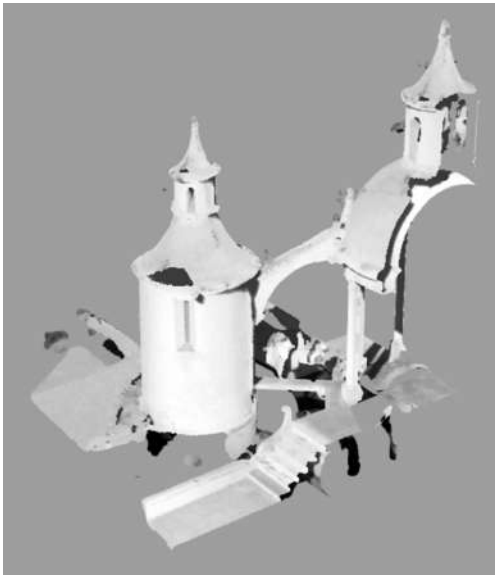

Figure 8
Raw scan optimization of cloud-point survey and automatic 3d modelation: sector of the Manga fountain tempietto.

CONCLUSION

Concluding, there are two basic aims of this initial research: first to create the tools to provide knowledge and wisdom (knowledge with emotions) around lost heritage. The second aim, profoundly related with the first one, is to create a methodology and software capable to surpass a Turing-type Test for Virtual and Augmented Reality, where the observer could be immersed in an environment where virtual outputs and feedback can be greater or, at least, similar to the real world.

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Figure 9
3D model of the former Manga cloister and bell tower with photomontage of the existing fountain /tempietto/ in the center.

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