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VR, Photogrammetry and Drawing Over: Envisioning the City of the Future

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ABSTRACT: This article proposes to discuss a research/design methodology aimed at developing urban visions based on case study analysis of existing urban environments using Virtual Reality technology and Photogrammetry. In order to visualize possible scenarios for the city of the future the method described here is based on “drawing over” existing urban images whether in a 2D format or a 3D environment. As a preliminary to this creative urban design exercise the urban context of a specific street is analyzed both in terms of its physical and material qualities as well as its experiential ones.

This methodology is tied to a pedagogical approach initiated at two different schools of architecture, one located in Nantes, France and the other in Tallahassee, Florida, US.

The idea consists in having a team of students in each school engage in a case study of an existing street and then propose design improvements and scenarios for urban development and growth. The process would involve 3 steps; drawing over in 2D, drawing over on a projected 360° flatten image in immersion and finally sketching in 3D in immersion. This last step would allow a “co-presence” of students from both schools in a shared conceptual and design experience.

Aside from the obvious differences between urban fabrics in Europe and the US, the value of this exercise would lie in comparing design approaches based on similar methodology but rooted in different geographic locations and urban design cultures.

Faced with issues of high density, mobility, low economic growth, inequalities and sustainability, European cities have been under pressure to constantly innovate in terms of urban planning and design whereas the US has only seen such ideas of controlled density an urban environment quality gain traction in the past 20 years with such movements as the New Urbanism.

The methodology described here is aimed at inspiring the creation of urban visions by means of using VR technology, photogrammetry and the idea of “drawing over”. We see the value of this approach by combining the use of specific technologies and a positioning from two different cultural perspectives.

KEYWORDS: Virtual Reality, Urban Design, Photogrammetry, Design process.

INTRODUCTION

Technologies such as virtual reality, though they have been around for a while in various formats have only recently been identified and used as potential design tools in the field of architecture. The initial goal of these technologies was to develop an immersive representational system aimed at creating a realistic and convincing spatial 3D environment. The obvious benefits to architecture and its related fields lie in the ability for designers to create interactive 3D models of their designs in order to experience moving through spaces and therefore better understand a particular design solution. The first iterations of virtual reality technology presented promising opportunities mostly as an improved and enhanced spatial representation system because of its experiential qualities. The idea of using VR as a design tool in architecture is relatively new and follows recent software developments in that field. When the Cave system was invented at EVL (Electronic Visualization Lab) in 1991 it was designed for industrial needs and did not really make its way to the field of professional practice. For a long time VR tools were understood by architects more as rendering tools than design tools. Though in the naval industry for instance, this difference between designing and visualizing does not really exist and VR tools have been embraced since their beginning. Paradoxically some schools of architecture still view 3D tools as “anti-

creative” as opposed to other more “traditional” design tools. In the context of the design methodology discussed here, we are using 2D images, photogrammetry and VR both as analytical and design tools.

The ambitious goal of having students *aiming at developing urban the visions* stated at the beginning of this paper invites an interesting series of questions. First of them, teaching notions of urban design in architecture programs poses a number of challenges. Aside from the fact that students have to grasp the built environment at a different scale they also have to understand concepts such as phenomenology of perception, positive and negative space and think in terms of spatial sequences as well as how building forms are experienced in motion and context. And in order to understand the many concepts associated with urban design, it is crucial for students to physically experience such environments. That is to physically visit urban centers and cities which display successful examples of urban design. Interestingly the current generation of students, and architecture students are no exception, have developed a significant number of meaningful interactions that are not physical in nature but rather digital and virtual. As the millennium generation uses screens in a widespread fashion (phones, tablets) in order to communicate with one another and access information, these tools have played an important part in shaping or reshaping their perception and vision of the world. In fact in the past few years we have observed a generation of students who seem more engaged and seem to place more value at times on a digital world rather than on the physical one. As this current trend poses obvious challenges in education and when it comes to physically engaging students, it also provides new opportunities. Developing a design process based on 2D and 3D images as well as VR environments effectively draws students with tools they are familiar with and may serve as a re-introduction to the real world. Tools such as Google Street view, 3D scanners, photogrammetry and various VR applications have opened new realms of designs by providing large quantities of information about existing urban environments very quickly and accessible anywhere in the world. All that information can then be formatted and analyzed in order to provide valuable input and inform design decisions. For example Google maps and Google Street view can be used effectively to develop reliable 3D urban models most anywhere in the world. This type of access is especially useful for architecture schools where students are geographically isolated from major urban centers.

In addition to being tied two specific tools (i.e. 3D models, immersive technology) the methodology we are describing here is also defined by having teams of students from two different schools, one in Nantes, France and the other in Tallahassee, Florida US complete the work. Each team would develop a case study of an existing street in their urban location using a variety of digital tools and then create a design proposal for urban development and growth. Each school will then share the materials gathered during the case study with the other school so that ultimately each team of students at each school would develop a design proposal for their local site as well as for a remote site. Based on the information provided, i.e. Google Street views, photogrammetry and VR, on a specific environment they are not necessarily familiar with, each team of students would have to apply their own set of analytical tools specific to their pedagogical environment and cultural background. Ultimately the urban design proposal of the offsite teams when compared to the local teams may be influenced by a difference of cultural perspective but also by the fact that they did not have physical access to the site. In our attempt to try to identify the factors driving design decisions, each team would fill out an exhaustive questionnaire (in the form of a table) describing design goals and how they were translated in urban forms. This process would attempt to decipher which design decisions were driven by a particular pedagogical environment, cultural urban context, case study format or other unforeseen factor. Teams at each school would present their design proposals in a similar format composed of mostly graphic materials such as urban maps, street plans, street sections, diagrams, 2D perspectives, and VR immersive environments. Some of the anticipated outcomes would be to identify how trends in urban design proposal, both successful and less successful, are tied to specific curricula and cultural context. These two issues would be especially interesting to investigate as they touch on the place of urban design in architecture education and would provide clues of a European versus American perspective.

European cities have historically been very engaged with the notion of constantly improving the urban environment and addressing growth as well as cultural and social issues. Faced with issues of high density, mobility and transportation, low economic growth, inequalities and sustainability, European urban centers have been under pressure to innovate and propose concrete solutions to these ongoing challenges. Current strategies include increases in urban density by means of adding stories to existing buildings, feeling empty lots, developing zoning regulations discouraging sprawl and shared vehicles to name a few. On the other hand the US has only seen such ideas of control density and urban environment quality gain traction in the past 20 years with such movements as the new urbanism. Similarly to their European counterparts American cities are facing acute challenges. Urban sprawl alone is omnipresent and is responsible for the destruction of valuable natural environments, increased commute time,

pollution, loss of productivity, stress and infrastructure cost increase. Structurally the making of most American cities was driven by short-term economical goals and by zoning laws associated with the development of the automobile. Therefore the suburban nature of the American urban landscape and our relationship to space in that context is very different from that of European citizens. Therefore it is interesting to evaluate to what extent urban and spatial environments affect the way we can conceive urban spaces especially for a generation of students immersed in digital media and an imagery full of global references. Based on the identification of potential cultural driving factors, urban design proposals by students would in turn shed some light on the place of education and of a particular curriculum on an urban design process. Aside from the quality of the urban design work itself the benefits of this approach would also inform us on the appropriateness of relatively new visual tools and determine the values of being placed in a drastically different cultural design environment.

METHODOLOGY

The design methodology of this urban design project is organized in 2 distinct phases. The first phase is analytical in nature and consists in gathering data on the project site, an existing street, using Google Street view as a 2D photographic tool. The second phase involves the use of 3D scanning and photogrammetry to bring streets in a 3D immersive environment for an experiential and phenomenological analysis. Flatten photos of the 3D photogrammetry models will be created to analyze content, typologies, surfaces and determine the level of complexity of the street. Following the information gathering phase, the second phase will consist in developing urban design proposals using the same techniques introduced in the initial phase. Therefore students will first draw over existing 2D street view images in perspective using the Procreate application on an iPad to represent their urban design ideas. They will then sketch in 3D in immersion (Gravity Sketch) and finally draw over on a projected 360° flatten image. This last step would allow a co-presence from students from both schools in a shared design experience.

PROJECT DESCRIPTION: CASE STUDIES AND URBAN DESIGN EXERCISES

Google Street View

The first step of the analytical phase of the project consists in using Google Street View as a two dimensional photographic tool. This graphic media provides an introductory approach to the spaces and surfaces of an existing street. Students initially create a scaled map of the urban space to be studied in order to get a sense of the context and understand the nature of the urban fabric. The map will also be used to reference the locations of the different perspective views. Though the 2D perspective views extracted from Google Street View



Figure 1 - Sketch over Google Streetview, by Olivier Chamel

are not at eye level and the point of view is located on a road, the overall format of the representation system presented is similar to that of a person walking along a Street. The analysis would be composed of two series of street views in perspective, one in each direction. The photos would then be displayed adjacent to a street map referencing the points of view of all the photographs. This method is consistent with a traditional and sequential photographic analysis of a space. It provides a description of a space along a dynamic axis by means of still photographs to evoke a spatial experience through movement.

This approach would inform students about the physical characteristics of an urban space, its scale, proportions, materials and would also provide clues about the qualities of the overall spatial experience. This would also allow students to observe patterns in terms of building massing, surfaces and façade details and start to identify how these typologies may affect the human experience. Students will ultimately produce a graphic analysis of the street by means of annotated photographs and conceptual diagrams.

Based on the photographs collected during the initial phase of the analytical study, i.e., the Google Street View analysis, students will be given the opportunity to draw over or sketch over the street view photographs. The process is simple and consists in sketching in layers over the original image in order to create new building masses and possibly modify the existing urban fabric. A number of drawing

Software or applications are currently adapted to this exercise and we have chosen the Procreate application with an iPad Pro and i-pencil. Typically students would use one layer to create a line drawing in order to delineated new urban patterns and massing while using two or more layers to apply color either as new built surfaces or to cover or modify existing buildings.

One purpose of this exercise is to provide a pre-existing environment, the street view photograph, as a way for students to be mindful of the existing urban context as they are exploring design ideas in their drawings. Using an existing urban space in perspective also helps them construct a correct perspective drawing and brings the design and ideation process into focus rather than the drawing technique. This process involves freehand sketching but because it is digital it allows students to continuously edit their work until they are satisfied. They can create new layers, delete existing one and move layers to the foreground or background of the drawing. We have found this method to be conducive to developing numerous an interesting urban design ideas as it is flexible and provides drawing guidelines, which the current generation of students appreciates as their freehand drawing skills may be limited.

Drawing on a 220 degree screen in co-presence

Immersive environments have now a long history if we consider panoramas as the first immersive devices. The first panorama was invented by Barker in 1787 and received many improvements associated with technological advances such as photography, electric light, automated machines and even movies. One can find examples of immersive images at a large scale in movies, an early example being the Napoleon feature film from Abel Gance in 1927. More recent applications include theme parks such as Disney World or Universal. Nowadays digital technology has made considerable improvements and it is relatively easy to create convincing immersive environments by using several video projectors (*Lescop-2017-2019*).

For three or four hundred dollars, it is now possible to buy a fairly good 360° camera. These types of camera are equipped with two 220° lens ,which instantly create a 360° image at a resolution of 4k for the most standard models. Controlled with a smartphone the camera creates an equirectangular image, meaning that the sphere is mapped on a 2.1 rectangle. It is then possible to redraw this image in two different ways. The first one consists in drawing directly on the flat image, though it typically involves geometric deformations from the sphere being flattened on a flat rectangle. Software such as Panopainting , which allows a real 360 VR painting constitute an improvement from the original set up. The equirectangular image is then remapped on a spherified cube that eases the redrawing.



Figure 2 - Drawing at 220° in the Naexus (photos Laurent Lescop)

Since 2012 we have used panoramic immersive devices to work in co-presence. It means that students together or students and professors can have a 360° drawing or photo projected around them and work on it. The first immersive device we used was the Naexus. The Naexus was a 220° cylinder screen of 15m long and 2m height. Any software could run on this device and it was very easy to project an image around the students and design with a regular tablet or even a mouse.

The Naexus screen is similar to a huge computer desktop. Sitting together, students and their professors can experiment shapes and spaces drawn in 2D but projected on the curved screen with a huge feeling of immersion. The Neaxus is a straight forward device, which does not need additional software to work. Sketchup, AutoCad, Photoshop can easily be used one just need to put a tablet, a mouse and a keyboard in the center of the device. We have been using the Naexus screen as a very effective collaborative design tool at ENSA Nantes for four years now.

Photogrammetry: flattened 3D images

Drawing on a panoramic screen allows designers to create in a real-time interactive environment. The relationship between professor and student is modified because the design work is created side by side as opposed to a pin-up where the work is evaluated after completion. Pedagogical improvements are significant and have been measured by the John Gero research team at UNC Charlotte and by Julie Milovanovic in her PHD defended in 2019. (Milovanovic 2019)



Figure 3 - Drawing on a 3D photogrammetry with Tomas Dorta's Hive-3D in Nantes (photo Laurent Lescop)

After the Naexus experiments, two major improvements have been possible : one, the increasing power of the graphic cards to have an actual “real-time” experience with a complex 3D model, second the possibility to survey any kind of environment at no cost. This has been made possible with photogrammetry. Photogrammetry consists in using the parallax between two images to retrieve the 3rd dimension. One of the first statement of the technique can be found in 1893 with the creation of “metric archives”. Scheimpflug (1865-1911) was the first to articulate the grounding rules of photogrammetry: “The identification of three points in a couple of photographs is enough to determine the absolute position of the couple”. Photogrammetry has long belong to the field of land planners and aerial cartography. The development of photogrammetry is strongly linked to advances in computer science and online calculation services brought about by the spread of the Internet. Nowadays photogrammetry is progressively getting integrated to BIM models. According to H.Marcher¹, further scanning systems will involve the fusion of photogrammetry and lasergrammetry. Cloudpoints will be made out of the correlation of thousands of photographs, or from several sensors or from Light Detection and Ranging (LIDARs - « light detection and ranging », a surveying system that measures distance to a target by illuminating the target with laser light and measuring the reflected light with a sensor.)

The acquisition process can be described in three steps. Initially the photo shoot is conducted with 60% overlay and as far as possible perpendicular to the target surface. When photographing a building, it is better to have a pole, as high as possible to take details that might be out of range. Secondly the collection of photographs is aligned in a 3D space, using a specific software such as MetaMesh or Autodesk Recap. The position of each shot is determined by the camera alignment. From these positions every single pixel

¹ invented at EVL in 1991

is located on an xyz axis creating a dense colored cloud point. This cloud point is then transformed into a mesh thus creating a polygonal colored model. The final step consists in extracting the color information to create a texture map. It is then possible to work from this textured model. The mesh is imported into a 3D software like Blender or 3DsMax to be simplified and then to be reworked, transformed and augmented. It is then possible to add some geometries on the existing structure. It is easy to draw shapes and volumes on top of the mesh given by the photogrammetry. This 3D sketching allows to test the first raw ideas before diving in a more precise and complex design.

Drawing over a 3D environment built with photogrammetry requires a specific device to be fully effective. The best one we have been working with is the Hive-3D invented by Tomas Dorta at the University of Montreal - Hybridlab (<http://hybridlab.umontreal.ca>). The Hive-3D is a 180° portable screen that allows sketching in 3 dimensions. With a single iPad using the tablet's gyroscope to be correctly oriented in space, the student can perform a freehand drawing, add objects, copy and paste. When finished, the sketch can be exported and reworked. The Hive-3D is able to display in real time very large or complex models such as those we can get from a laser or photogrammetric survey.

Immersive VR environment

The next step we are currently testing is the full immersed sketching experience. In that regards the recently released HTC Vive is offering impressive new capabilities. The HTC Vive is a headset for virtual reality, which allows the user to move, walk and twitch. The device is sold with TiltBrush, a software that allows to paint and draw in a 3D space. With TiltBrush the user does not paint on a canvas anymore but literally in the air so it is then possible to walk through the painting. Following TiltBrush came Gravity Sketch, which is more dedicated to platonic shapes, 3D models and lights. With Gravity Sketch it is now possible to import a 3D model, (our simplified photogrammetry for instance) and work at full scale to create virtual 3D spaces, additions, shapes and so on. Before Gravity Sketch, building in 3D was made possible with a special addition of the Unreal Engine. A virtual library of shapes and objects was available to create in real time. Gravity Sketch is only one of the softwares capable of doing this. Even Sketchup has a virtual component that can be manipulated in real time either at the scale of a model or by moving inside a building.

We started to experiment two things with our students. First sketching on a 3D model using TiltBrush. With this app it is literally possible to sketch in 3D on an imported model (which shall be light) and have the possibility to walk around, and freely draw details, additions, comments in real time. With Gravity Sketch, the user manipulates real geometry and is able to process a real technical design with shapes, curves, lines, imported models and much more. The very innovative way to work is given by the possibility to modify the model's scale on the fly and have a scaled model in the hand and then expand it and walk in a real scaled model. We know that we are at the very beginning of VR/AR developments and we are awaiting the opportunity to have more collaborative tools to be in a real process of sharing the design and knowledge.



Figure 4 - VR design in a real built neutral environment, this neutral environment is than virtually augmented.

CONCLUDING THOUGHTS

Project visualization at full scale and in real time can considerably impact the design process of an architectural project. It is widely accepted that sketching is a quick and efficient exploratory design method because of the direct hand/brain connection and has proven to facilitate creative thoughts. Though sketching does not necessarily have to involve paper as a medium. Some of the latest VR goggles offer sketching tools, which are at least as fast, flexible and accurate as traditional pencils. The paradigm change consists in the fact that sketching does not occur on a 2D surface anymore but rather directly in 3D. Therefore this implies that students have to familiarize themselves with a new form of perspective drawing at full or reduced scale in a real space. Because of our perceptual stereotypes associated with 2D representation, 3D sketching can produce distorted creations, which may take some learning and adapting.

One can wonder if we should go beyond the question of parametric design and start to include real world data in the design process. This is especially pertinent as architecture and design is viewed more and more as an integrated process including such notions as sustainability, spatial quality and systems along with the development of meaningful concepts. The ability to move around freely in the virtual space of a full-scale building or in a 3D model under construction should not be perceived as a limitation but rather as an opportunity to empower architects. This would equip them with powerful tools and ultimately help them make meaningful decisions in an increasingly complex design environment. We see value in the tools and processes discussed here because we believe they can positively contribute to the definition of a contemporary design process.

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