DOI: https://doi.org/10.46354/i3m.2019.vare.001

SYNERGY OF DIGITAL ART, ARCHITECTURE AND DESIGN USING VIDEO-MAPPING IN A COMBINED CLASSROOM

Héctor Nahún Quintero Milián[a], **Nora Argelia Aguilera**[b], **Pablo Guillermo Ramírez Flores**[c], **Samira Hosseini***

Tecnologico de Monterrey, CEDDIE, Vicerrectoría Academica de Innnovacion Educativa, Monterrey 64849, NL, Mexico[a], Escuela de Arquitectura, Arte y Diseño, Tecnologico de Monterrey, Ave. Eugenio Garza Sada 2501, Monterrey 64849, NL, Mexico [b], Escuela de Ingeniería y Ciencias, Tecnologico de Monterrey, Ave. Eugenio Garza Sada 2501, Monterrey 64849, NL, Mexico[c], Tecnologico de Monterrey, Writing Lab, TecLabs, Vicerrectoría de Investigación y Transferencia de Tecnología, Monterrey 64849, NL, Mexico[*].

[a]nahun@tec.mx, [b]naguiler@tec.mx, [c]pramirez@tec.mx
[*]samira.hosseini@tec.mx

ABSTRACT
Technological advances within educational domains permit new teaching systems to emerge. Video-mapping is a technique that involves projecting images on three-dimensional surfaces through motion effects. In the case of architectural projects, there are very few uses of video-mapping that focus on urban planning and even fewer when the mapping is interactive. However, it is crucial to scale new ways of interpreting design using technologies such as video-mapping. In this research work, the themes of virtual environments, spatial representation, and basic design are combined with video-mapping. Students from the Digital Art and Architecture and the Industrial Design programs worked together in this effort, creating an architectural model made with 3D impressions; the users interacted and selected from the options of colors and textures available for the model city, generating different presentations according to the changes in the settings of the video-mapping software. Thus, this project opened the doors to welcome digital artists into the world of architecture and urbanism.

Keywords: Educational innovation, Video-mapping, Interactive models, Interactive surfaces, Spatial representation, Ambient design, Augmented Reality, Higher Education.

1. INTRODUCTION

Students nowadays are interconnected and collaborate with their peers in the classroom using different types of technologies. Video projection is a tool to create interactive spaces and environments for learning that can be continuously updated according to the students' needs. It allows the professor to conduct tasks with fewer constraints than in the conventional methods involving monitors or screens. The interactions between the students and the instructors and among the students themselves are freer than in traditional classrooms. Furthermore, there is a higher level of creativity in teaching and in the delivered content, all of this expanding the potential of classrooms as learning spaces.

We define that video-mapping is a form of art that allows the combination of video and light that when projected onto a surface can transform the most ordinary data into dynamic scenes (Factura, Karsch, Jones, Reyneri, & LaPerche, 2018). This technology goes beyond the creation of animations of emblematic buildings.
Considering this, the objective of this project was to use video-mapping as a focal point to bring together the area of descriptive geometry and the creation of virtual scenarios for educational purposes (Roederer & Revat, 2019). One of the challenges of urban planning and architecture is finding ways to represent people, spaces, roads, and vehicles, etc. dynamically. By combining these elements with video-mapping, students and professionals have a new opportunity to visualize proposed changes and improvements to these new spaces.

Video-mapping and architecture many times go hand in hand due to the fact that most of the time, the work involves buildings, murals, and structures. In this case, the work was done on an architectural model with a different twist to what is customarily shown in a mapping exhibition (Rossi, Petrucci, & Fazzini, 2014). The focus of this project was to present multiple possibilities for buildings that are planned using scale models, whether they are for commercial or residential use, in an urban area. Additionally, what was considered were the textures those models could carry and the location of the buildings with respect to the entry and exit points of the area. This video-mapping project allowed the Architecture and Design students to come together with the Digital Arts students to explore the possibilities that one can imagine within the model.

The purpose of this work was to develop a methodology using video-mapping technology that will be used in classrooms so that future students can use the technology and manipulate the projections on the 3D impressions that they have created and choose how the parts of the structure are divided and observe different textures on the various volumes so they can make design decisions.

2. PREVIOUS WORK

Portman et al. (2015) stated that virtual reality is ultimately a type of "visualization," a technique which has experienced a recent boom in professional and academic literature (pp. 376–377). Andreani et al. (2019) in their article, "Reframing technologically enhanced urban scenarios: A design research model towards human-centered smart cities," claim that "over the last few decades, technology has played a major role in the envisioning of urban scenarios as well as in affecting actual urban operations." The authors believe that future designs of urban developments based on technology would place the human experience as only "a side effect of the intervention of a smart city" (Portman, 2015). So, we can establish that video-mapping gives objects or buildings new forms by changing the perspectives of solid objects and by giving the impression of movement with the projection of light. Such technology generates enthusiasm in spectators because, on the same surface, different features can be simultaneously displayed.

Nofal et al. (2018) described that video-mapping could be used in different areas, as follows:

- Commercial – In interactive publicity for its use at public spaces.
- Artistic – Synchronized animations to trigger emotions and to entertain the audiences.
- Cultural – On-site projections (e.g. historical sites or museums).
- Social – Mapping of socio-demographic data to design the facade of a house.
- Politics – Demonstration of solidarity and sympathy by projecting patriotic symbols onto the country's representative buildings.
- Educational - Projection of synchronized images over tridimensional structures for full comprehension of content.

Projection mapping has been widely used to visualize real-world objects efficiently in various areas such as exhibitions, advertisements, and theatrical performances. To represent the projected content in a realistic manner, the user must consider the appearance of an object. Although there have been various attempts in computer graphics to use digital modeling realistically to show the appearance of materials, it is difficult to combine this with projection mapping because it takes a tremendous amount of time and requires ample space for the measurement. Junho Choi (2016) developed a realistic 3D projection mapping system using the reconstruction of the projector view based on the projector-camera correspondences and polynomial texture maps that can provide effective visualization.

The concept of video installation has emerged with the addition of video technology to combine so that space and art objects are exhibited together (Kaye, 2007). Installation, film, video, video-mapping, animation, Internet and networks, and art software are all new media technologies that do not have a very long history; the production of digital art from these digital platforms results in art that is interactive and dynamic (Tardieu et al., 2010). While digital art forms use technology as an "environment," this environment's possibilities and features reflect new techniques to be used for artistic purposes (Saglamtimur, 2010).

Geometry is needed for the construction of any object or building because the finished work has to be very precise. Teaching geometry is not easy at all, and every new generation has more problems with spatial understanding. With the new digital technologies, the young people are increasingly losing the sense between real, three-dimensional space and the two-dimensional one due to the fact that they are immersed long periods of time on flat screens of two dimensions. Howard Gardner (Gardner H., 1999) writes about this sense, calling it, "Spatial intelligence." Previous works of Patricia Salinas (P. Salinas, 2015) (Salinas Martinez Norma, 2017), and Pablo Ramirez (Pablo Ramirez, 2013) remark about the importance that spatial intelligence has in education. Therefore, the system of learning spatial representation must change to answer to the interest in the use of these new technologies (Aguilera González, 2015).

Augmented Reality (AR) and 3D Printing are the technologies that offer significant advances in the production of prototypes with respect to a spatial representation. A great advantage of applying such techniques is identifying and avoiding possible errors in the early design stages of a production process. This, in turn, results in reducing the number of physical prototypes, thus saving time and resources for companies. These techniques are valuable tools that improve and accelerate many processes (Aguilera González, Suarez-Warden, Quintero Milian, & Hosseini, 2018).

3. METHODOLOGY AND DESIGN PROPOSAL

In the course of "Descriptive Geometry," the objectives are the spatial visualization for the 3D representation, the modular conception for the reproduction of volumes in space, and the application of a project oriented to architecture. In the course of “Virtual Environments Design,” what is sought is for students to show their acquired knowledge in virtual spaces and applications throughout the Digital Arts major. This is achieved by assigning them projects with various professors and clients from different areas of knowledge and specialties. In this case, the Digital Art students were assigned to collaborate with the students of Descriptive Geometry in the Architecture and Industrial Design curricula.

In this study, applying video-mapping in the teaching of spatial representation was targeted. As part of this challenge, students of the first semester of Architecture and Industrial Design were assigned together with students in the seventh semester of Animation and Digital Art. The Architecture and Industrial Design students made a modular representation of a residential and commercial sector while the Digital Art students produced a series of visual elements to project over the same buildings and layout within that sector. Therefore, the project was divided into two phases: (i) spatial representation of the buildings in physical form, and (ii) video-mapping of the proposed physical structures and buildings. In the second phase, the students comprehend how they work with this technique and commence to apply it through the learning of a video game in which the objective is to learn the basic concepts of Gestalt (Figure/Ground, Similarity, Proximity, Closure, Common Region, Continuity, Symmetry, Focal Point) and visual communication. The importance of this phase is to comprehend the basic principles of design applied through the functioning of a digital tool. Comprehending the principles of design and the representation of space are objectives to be achieved in the production of 3D models of urban areas in order to elaborate these features further in video-mapping.

The proposed space for this project is presented in Figure 1; it is a mix of multi-purpose buildings in an architectural space that consists of office buildings, departments, and public and commercial areas - the kinds of spaces that are current architectural trends in Mexico.

In the two groups of students, what was sought was for them to develop better the concepts of scale, space, dimension, and spatial visualization of an estate. That is why we started with the 3D modeling of the buildings made in the Descriptive Geometry class, then materialized them with the help of 3D printing, and used the models as a frame of reference for the proposal of the video-mapping project with the Digital Art students.

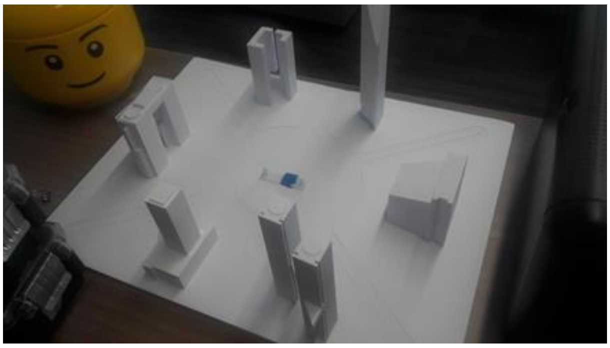

Figure 1: 3D-Printed architectonic model proposal

3.1. Modeling software tools

The 3D modeling software used was SketchUp, which is easy to use and has a fast learning curve, so there was little distraction from the learning of Descriptive Geometry. The students of Descriptive Geometry were in their first semester and therefore were ignorant about other digital tools similar to SketchUp. Thus, the students were motivated to develop their spatial intelligence at an early stage of their professional development by using software facilitating the production of 3D building models (Figure 2). This is in line with Howard Gartner’s recommendations (Gartner, 1999).

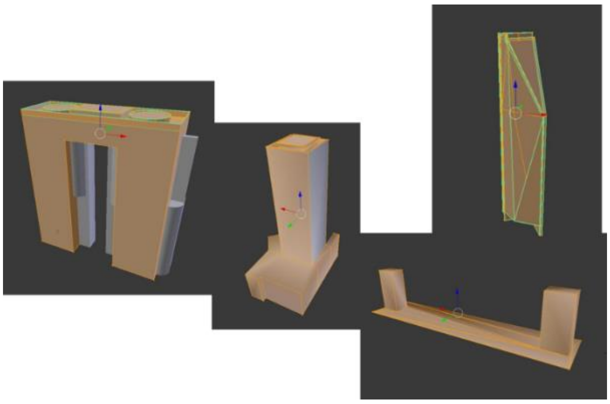

Figure 2: 3D model representation of buildings by Descriptive Geometry students.

3.2. 3D Printing software

For the 3D printing process, it was required to export to a .stl format, which needs to be processed into Solid Inspector, a plugin from SketchUp that allows a figure composed of different polygons to be converted into a solid object to ensure that the 3D printing process will be useful and will not cause a problem. In the Cura software for 3D printing, when importing the models, they are visualized, and their consistency is seen whether the figures are solid or hollow, so the printing time, the external quality of the model, and its scale can be calculated.

To understand the process to follow, the students did practice exercises of their designs to be able to ensure that the final models would come out with correct proportions and adequate quality (Figure 3).

Figure 3: 3D Printed buildings.

SketchUp digital files were exported in .dae and .obj format so that Digital Art students could start working with them in their practice sessions and texture simulations. For this, Autodesk Maya 2018 software was used to generate the UV's (texture maps) that are used in the Adobe Photoshop CC software, where the texture maps for the buildings were generated. Figure 4 presents a sample of textures and the corresponding UV maps of some buildings. The models had to be redone because the normal maps were flipped, and the UV maps could not be obtained due to the fact that there were some errors in the modeling process. So the students from Digital Arts had to recreate some of the pieces so that they could be appreciated in the projection and the textures could be displayed.

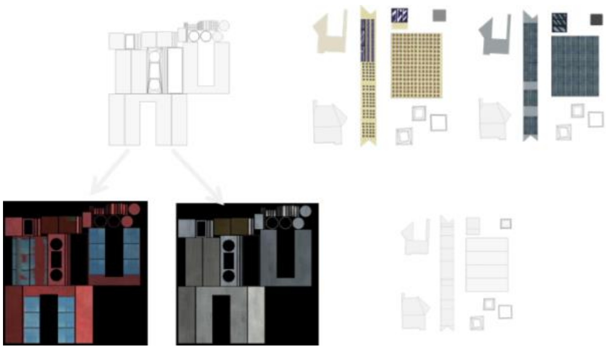

Figure 4: Samples of UV maps and textures for buildings.

3.3. Virtual space integration and user interface

Unity3d was used to integrate the virtual space, define the user interactions, and generate the projection layers for the video-mapping software. The user interface has a main window and four sub-windows, one for each building projection and the other for ground-plane point-of-view.

For video-mapping projection, we used VPT8 software because it is free, and to connect Unity3D with VPT8, we selected KlakSpout plugin (or Syphon for Mac) because it allows connection in a simple way and with excellent response time. We tried other software such as Millenium for Unity3D, but unfortunately, the performance was not usable for the purpose. VPT8 has a limitation up to 4 spout channels; for this reason, we limited the projection to three buildings and the ground plane. Each projection channel has its own layer, and VPT8 allows aligning the projection with the real object and prioritizing layers for correct overlapping projection. In Unity3D, four virtual cameras were projected, and each one was linked to a layer in VPT8 and was arranged and matched with the projection in the physical model.

Figures 5, 6, and 7 present the final results of mapping textures over the buildings and the ground plane.

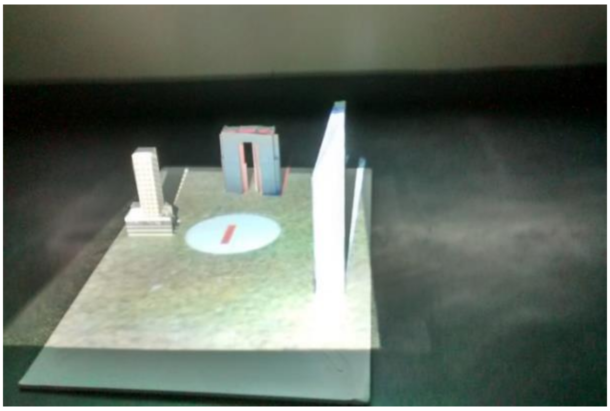

Figure 5: Sample 1 of projection mapping in buildings.

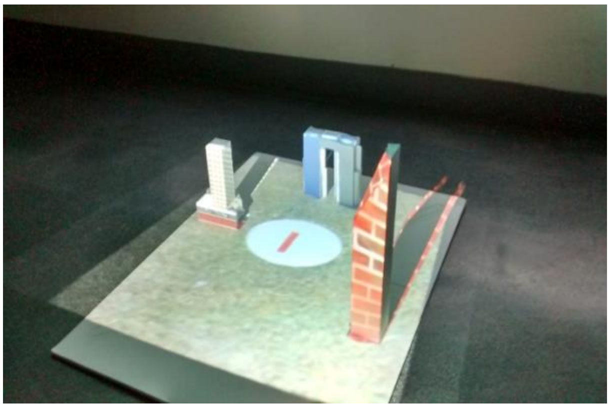

Figure 6: Sample 2 of projection mapping in buildings

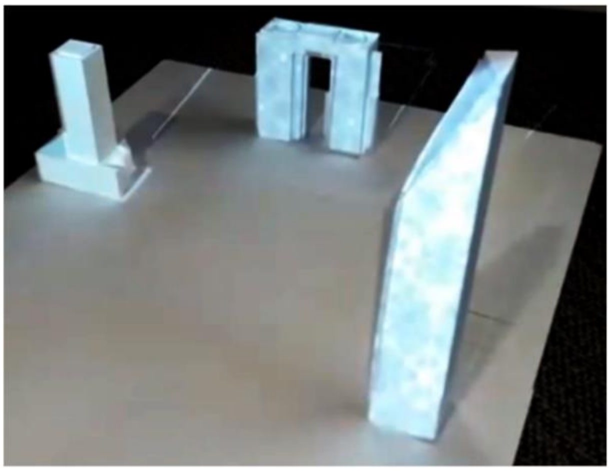

Figure 7: Sample 3 of projection mapping in buildings

Figure 8: Disproportionate tile textures in buildings

4. CONCLUSIONS AND RESULTS

In recent years, computer construction has increased, using digital systems to build constructs. In this project, we achieved a synergy between students in the fields of Architecture and Industrial Design and Digital Art to train successfully two different sets of students via video-mapping. Students actively interacted in this joint program to improve their understanding of both the design of the urban constructs and the production of visual features that further developed into a video game. The program was assessed as highly engaging and informative by the students, and the surveys which were distributed among the participants reported a high level of satisfaction with the training.

Some limitations were identified in the project:

- By using only one projector for video-mapping, we identified a limited coverage of the physical mock-up space; also, the lack of impact projection resulted in the appearance of some undesirable shadows.
- VPT8 only allows 4 layers for Spout/Syphon projection, which limited us from using more buildings in the mock-up space. We need to consider extra projectors for video-mapping.

Reflecting on the collaborative work among students, we identified the following elements:

- Digital arts students need to reinforce their spatial intelligence knowledge. They lack the notions of scale and proportion of real buildings when projecting the textures onto the models. Some of these textures were not in the correct size and proportion (Figure 8).
- The use of 3D printed models motivated the students of Architecture and Industrial Design to leave the established and traditional methods of learning and to focus more on reality through digital systems.
- The concept of video-mapping was liked by Digital Art students because they realized that their digital work could be reflected in real three-dimensional spaces and not be limited only to the restrictions of a two-dimensional screen.
- As we commented, the students worked in two different teams (Architecture and Design students and Digital Art students). On the one hand, this separation allowed them to focus on the part of the project they had to deliver, but on the other hand, a lack of communication and synergy were detected. Students had to do extra work to correct 3d models of buildings for correct UVs and texture mapping.

5. FUTURE WORK

There is always room for usability and workflow improvements in video projection, especially when it comes to supporting different or new file formats that have the potential for live generative content, leveraging software to enhance the visual effects . The combination of projection mapping and moving objects is definitely a development on the horizon. It is a great way to create visual experiences that can be enjoyed by large audiences. The person viewing does not need augmented reality glasses or virtual reality headsets to enjoy an excellent projection-mapping experience.

There is enormous potential that this work can have for urban planning, alternative materials, and finishes in a proposal, not to mention the settings of spaces, including alternative roads, recreational areas, simulations of the weather, behaviors of sunlight reflections at different times of the day, and seasons. Projection mapping can be used for different cases, such as simulations of maintenance processes, repairs, and industrial planning.

"Storytelling" in projections is a step forward in terms of content beyond the simple projection of images and shapes. There is opportunity to engage people in stories that look beyond buildings and delve into history by using the format with a little more narrative.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial and the technical support of Writing Lab, TecLabs, Tecnologico de Monterrey, Mexico, in the production of this work. We also want to thank the following students who participated in the development of this project: Isaías González, Cristian Tza, Rebeca Fuentes, María de la Luz Nava Rdz., Manolo Zárate Oteiza, Ivanna Campos González, Ithatí Alejandra Lagos Chávez, Debanhi Michell Villanueva, Andrea Chávez Soto, Brandon Eloy Martínez M., Raúl Eduardo Balderrama, Arantxa Alfaro Hernández, Román Nacianceno Treviño, María Fernanda Guerra C., Mauricio De la Peña Cueva, Daniela Renata Nolasco M., Sofía Contreras Sánchez, Mariana Álvarez Castañeda, Brenda Díaz Sánchez;

REFERENCES

1. Aguilera González, N. A. (2015). How to Include Augmented Reality in Descriptive Geometry Teaching. *2015 International Conference on Virtual and Augmented Reality in Education. 75*, pp. 250-256. Monterrey: Procedia Computer Science.
2. Aguilera González, N. A., Suarez-Warden, F., Quintero Milian, H. N., & Hosseini, S. (2018).The impact of new technologies in design education. *Proceedings of the International Conference of the Virtual and Augmented Reality in Education*, (pp. 38-45). Budapest.
3. Andreani, S., Kalchschmid, M., Pinto, R., Sayegh, A. 2019. Reframing technologically enhanced urban scenarios: A design research model towards human-centered smart cities. Technological Forecasting & Social Change (142) 15-25. https://doi.org/10.1016/j.techfore.2018.09.028
4. Bhatt, M., Borrmann, A., Amor, R., Beetz, J. 2013. Architecture, computing, and design assistance. Automation in Construction (32) 161-164. https://doi.org/10.1016/j.autcon.2013.01.001
5. Eslam Nofal, E., Stevensa, R., Coomansc, T., Vande Moerea, A. 2018. Communicating the spatiotemporal transformation of architectural heritage via an in-situ projection mapping installation. Digital Applications in Archaeology and Cultural Heritage (11) e0083. https://doi.org/10.1016/j.daach.2018.e00083
6. Factura, B., Karsch, K., Jones, B., Reyneri, P., & LaPerche, L. (2018). Lightform: procedural effects for projected AR. *Proceeding SIGGRAPH '18 ACM SIGGRAPH 2018 Studio* (p. 2). Vancouver: ACM New York.
7. Gardner, H. (1999). Intelligence reframed: Multiple intelligences for the 21st century. New York, NY, US: Basic Books.
8. Kaye, N. (2007). Multi-media: Video - installation - performance. Multi-media: Video - Installation - Performance. https://doi.org/10.4324/9780203964897
9. Kim, G., Kim, A., Kim, Y. 2019. Computers, Environment, and Urban Systems: A new 3D space syntax metric based on 3D isovist capture in urban space using remote sensing technology (74), 74 – 87. https://doi.org/10.1016/j.compenvurbsys.2018.11.009
10. Ramirez Flores, Pablo & Ramírez, Hector & Díaz Infante, Luis & Manuel López, Jose & Rosquillas, Jordi & Lucia Villegas, Ana & Santana, Diana & de la Vega, Diego. (2013). Explora México: A Mobile Application to Learn Mexico's Geography. Procedia Computer Science. 25. 194–200. 10.1016/j.procs.2013.11.024.
11. Portman, M.E., Natapov, A., Fisher-Gewirtzman, 2015. To go where no man has gone before: Virtual reality in architecture, landscape architecture, and environmental planning. Computers, Environment, and Urban Systems (54), 376–384. http://dx.doi.org/10.1016/j.compenvurbsys.2015.05.001
12. Roederer, C., & Revat, R. (2019). Experiential Staging in the Urban Space: Video-mapping of Places and Non-places. *International Journal of Arts Management.*, *21*(2), 15-26.
13. Rossi, D., Petrucci, E., & Fazzini, S. (2014). A framework to increase the video-mapping accuracy of an architectural heritage mock-up. *Proceedings of the 2014 Virtual Reality International Conference (VRIC '14)* (p. 4). Laval: ACM New York.
14. Saglamtimur, O.Z. (2010). Dijital Sanat. Anadolu University Journal of Social Sciences, 10(3), 213-238.
15. Salinas Martínez, Norma. (2017). Augmented Reality: Opportunity for Developing Spatial Visualization and Learning Calculus.
16. Tardieu, D., Siebert, X., Dupont, S., Mazzarino, B., & Blumenthal, B. (2010). An interactive installation for browsing a dance video database. In 2010 IEEE International Conference on Multimedia and Expo, ICME 2010 (pp. 1624-1628). https://doi. org/10.1109/ICME.2010.5583260