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REALTIME TRACKING IN PROJECTION MAPPING

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Abstract

The projection of a moving image on the surfaces of objects and architectural works can now be viewed as a well-established communicative process within which techniques evolve, even if in essence their form and structure may be regarded as technologically stable. What project context will emerge if, instead of being static, the surfaces that are object of projection vary their form and position in three-dimensional space? This paper investigates the design context of video mapping through a short survey of a series of case studies in which the tracking of the movement of artefacts is recognized thanks to processes of computer vision that give rise to novel elements of interaction between people, objects and the space.

Keywords

Video mapping, realtime, tracking, projection, surfaces, architecture

1. *Present day changes in the screen*

The cinema projection screen has always been one of the invisible elements in a narrative process that has changed the history of man. In its prevailing flat form, originally made of a white cloth, its structure has not changed over the centuries except in its proportions. Today the screen is changing, and the first examples of transformation of this artefact, which is a structural means for visual communication, occurred as a change in its three-dimensional structure, which led to the development of a series of experimentations aimed at improving the immersive experience of projection.

In his book *The Language of New Media*, Lev Manovich seeks to provide a historic and taxonomic classification of screen typologies, (2011, p. 103) by identifying three main macro categories: the *classical screen*, which shows a permanent and unchanging image; the *cinematic screen*, which, in its dynamic nature, displays a moving image; and the *real-time screen*, which shows the present and can be viewed as an actual virtual window representing the real world. This classification, taken up and criticized as simplistic by Erkki Huhtamo in his book *Elements of Screenology: Toward an Archaeology of the Screen* (2014, p. 328), is limited to the context of new media and neglects the physical-structural nature of such a typology of artefact. In its original etymology, the screen begins as a system to protect and shield from the heat and develops over the centuries as a support for projecting the light of the fire, thus becoming, thanks to various techniques, a support for communication.

The evidence that an increase in the scale and a change in the projection surfaces lead to a transformation in the process of shielding the projected light arises gradually, as cinematic images leave the movie theatre and invade public spaces and city with outdoor cinemas. The merger of photographic images and graphic artefacts projected at an architectural scale gives rise to ever more complex and immersive forms of transfiguration of the architecture (Codeluppi, 2012, p. 110; Scodeller, 2017).

The technique of projection mapping, also defined as video mapping, emerges little by little starting in the early 20th century, and becomes a way to transform objects, buildings and environmental spaces into screens upon which contents of various nature can be projected. The principle underlying such a process is the digital mapping made possible by image processing software, capable of controlling multiple projectors and deforming the projection in real time to adapt it to architectural surfaces.

Specifically, when these projection practices are referred to buildings, this field of application is called *architectural mapping*, and the case studies and experimentations conducted in this field over the past few years, emerging mostly from contents available online, are many and heterogeneous in their typology, techniques and communicative objectives.

2. *Video mapping and the identity of places*

In his 2006 paper, Manovich states that "In the longer term, every object may become a screen connected to the Net with the whole of built space eventually becoming a set of display surfaces."[1] Today, more than ten years after this statement, we can acknowledge how the evolution of surfaces involves all scales of a project, and the screen is slowly changing from a limited flat area and a support for communication into an actual luminous material which develops the shape of objects and architectural spaces. This ongoing transformation opens up scenarios in which the surfaces of architectural façades are reconfigured and, thanks to the dynamic nature of moving images in continuous evolution, a precise dynamic identity is developed that makes the places unique and recognizable (Bruno, 2014, p. 107; Caspary, 2009, p. 70). An emblematic case is represented by Piccadilly Circus in London, where enormous LED screens cover and thus transform the surfaces, or the case of Las Vegas which, even earlier, in the 1960s, in the middle of a desert, was one of the first cities to be built on symbolism and communication, as Robert Venturi, Denise Scott Brown, and Steve Izenour taught us in *Learning from Las Vegas*. Their statement, "If you take the signs away, there is no place" (Venturi, Scott Brown, & Izenour, 1972, p. 18) remains a warning that, more than forty years later, still highlights a number of incongruities in our contemporary cities. The transition from the neon signs of the 1970s to present-day LED screens, which display moving images with no compromise, has given these places an even stronger identity to the detriment of their architectural morphology. Moreover, although their overall image is visually ever changing, their recognisability is not questioned.

3. *Real-time Mapping*

The projection of a moving image onto a defined and stationary screen can now be viewed as a well-established communicative process within which techniques evolve. Yet, in their communicative form and structure they do not vary substantially, and may be considered as technologically stable. What would happen if, instead of being static, the surfaces upon which the projection is being screened varied their shape and position in three-dimensional space? Which experimentations are being carried out in this specific design context? This might seem a purely technical issue: with the variation of the position of the surface of the object in three-dimensional space, the real-time projection will be re-modulated by re-adapting it and modifying its trapezoidal projection as rapidly as possible. However, this mostly technicist approach is secondary to the more ample theme that arises in relation to the three-dimensional tracking of the movement of objects and people which the processes of three-dimensional scanning and computer vision can contribute to this particular design field.

There are two main typologies of design approach that we can evaluate which address this change in the traditional techniques of video mapping. In the first scenario, the dynamic behaviour of the projection is determined by the movement of the projector which by rotating around the vertical and horizontal axes, is capable of redefining the projection in different areas of an architectural space. The second scenario is related to the transformation by software of the projected image so as to adjust its geometry to the new configuration of the object.

The first case study related to the remodulation of the image projected through the physical movement of the projector is an installation by Studio Kuma and Studio Visuale housed in the courtyard at Milan's Università Statale[2]. Here the projections were remodulated on a thin organza sheet and on the artificial stone elements laid out in the architectural space. In a time sequence determined by the designers, the projections alternated in different areas of the

[1] See (Manovich, 2006). Retrieved 10/11/2017 from https://doi.org/10.5210/fm.v0i0.1545

[2] See: *Casalgrande Ceramic Cloud: Yin-Yang and projection mapping* by Studio Kuma and Studio Visuale Retrieved 13/11/2017 from http://www.studiovisuale.it/it/casalgrande-ceramic-cloud-yin-yang-fuori-salone_19_43.htm

space thus giving life to the inert elements laid on the grass and to the sheet of organza that divided the rectangular space of the courtyard diagonally.

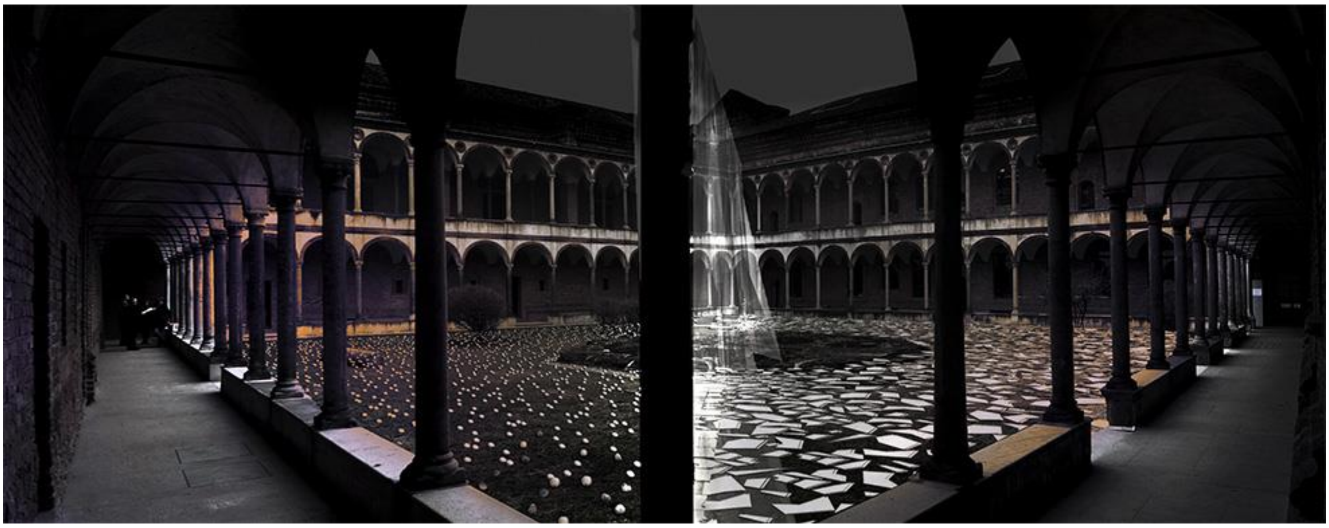

Fig. 1: *Casalgrande Ceramic Cloud: Yin-Yang and projection mapping*
by studio Kuma & Associati and Studio Visuale. Communication project Alfonso Acocella (2010)

A similar intervention, although on a different architectural scale, is represented by the project *Gallery Invasion*[3] by Filip Sterckx and Antoon Verbeeck developed with the technology of the Austrian company, Dynamic Projection Institute Medientechnik, that devised a proprietary projection system based on a motorized mirror. The work by the two designers inside an art gallery creates a small monkey who invades the exhibition space and moves freely across its four walls.

Fig. 2: *Gallery Invasion*
by Filip Sterckx and Antoon Verbeeck (2016)

The projection area is never large, yet the possibility of moving it dynamically by means of the motorized mirror head positioned close to the projector lenses, transforms any surface of the gallery into an area that can be useful for the projection.

Similar, although with a substantially different approach, is the short film "Box" made by the company Bot & Dolly's[4]. This video product features a live performance halfway between choreography and a magic show, highlighting the encounter between contemporary art and a range of technologies: robotics, video mapping, and software engineering.

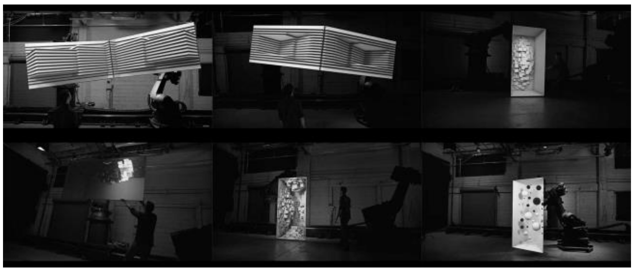

Fig. 3: The short film *BOX* by Bot & Dolly's (2014)

A person within a space interacts with two flat surfaces upon which a series of videos are projected, which are focused in a perfect perspective thanks to the synchronization of the robots that operate them. These machines,

[3] See: *Skull Mapping*. Retrieved 14/11/2017 from http://www.skullmapping.com

[4] See: *BOX* by Bot & Dolly's in The Creator project https://creators.vice.com/en_us/article/53wzz3/video-exclusive-bot--dollys-the-box-unpacks-a-radically-new-design-concept

originally designed for "camera control" on movie sets, manage the performance, which consists of millimetrically precise movements, coordinated by a computer that elaborates in real time the robots' actions and the three-dimensional transformations of the images projected on the surfaces.

With reference to the second scenario, where the control of the adaptability of the projected image relies on the three-dimensional reconstruction of the space and on the use of software to modify any deformation, a first interesting case study for analysis is the project for the German Pavilion at EXPO Milan 2015.

The communication agency Milla & Partner, which was responsible for the concept, installation, and multimedia exhibits, conceived an interesting immersive experience in which the projection on simple pieces of cardboard was deformed in real time through a system based on an infrared camera.

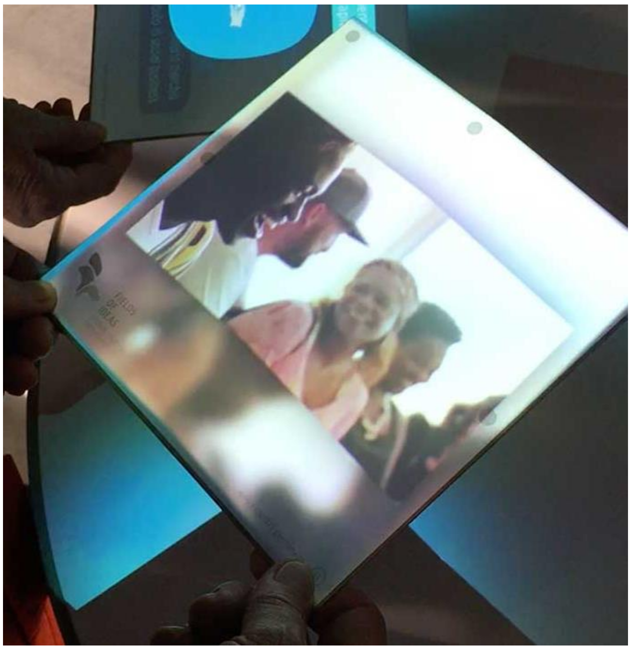

Fig. 4: The projection of the video on the cardboard. German Pavilion at EXPO Milan (2015)

The process was, in essence, very simple. Each support contained three small circles printed with a refractive paint 3mm in size near the corners. These elements were lit by infrared LEDs that made it possible to relocate the surface in three-dimensional space and, consequently, the system could deform the projection in order to adapt it to the new position of the object.

Fig. 5: The projection and the computer vision system. German Pavilion at EXPO Milan (2015)

This mode of managing the projections within the exhibition space gave rise to a completely new experience. The public was totally involved, the surfaces, simple inert – non-technological – artefacts, suddenly came to life with a reflected light, thus becoming the core of the narration within the space. The technology employed for this kind of projection system is very inexpensive and reliable. This solution allowed the designers to map almost the entire exhibition itinerary within the pavilion with this type of interactive experience.

Fig. 6: The projection of the video on the cardboard on a table. German Pavilion at EXPO Milan (2015)

Another interesting project that tackles the theme of dynamic mapping is the research work conducted by Gaku Narita, Yoshihiro Watanabe, and Masatoshi Ishikawa[5] from the Ishikawa Watanabe Laboratory in Tokyo. This prototype is capable of recognizing the deformation of a surface thanks to a system of three-dimensional reconstruction, and of adapting the deformation of the image to the projected surface in a highly accurate manner. The experimentations carried out by the Japanese researchers show examples of projections on t-shirts and deformed sheets of paper.

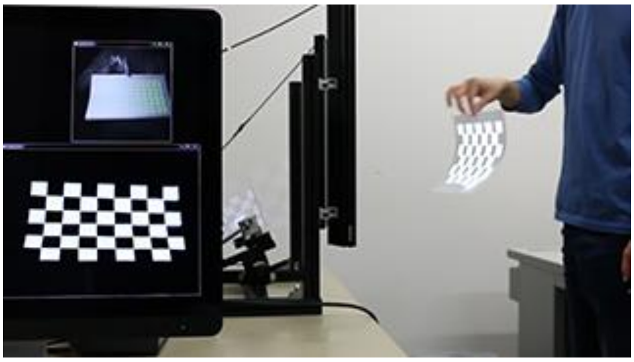

Fig. 7: Dynamic projection mapping onto deforming non-rigid surface using a high-speed projector by Gaku Narita, Yoshihiro Watanabe, and Masatoshi Ishikaw from Ishikawa Watanabe Laboratory, Tokyo (2015)

As a final example of this review of design applications involving real-time projection mapping, I will describe in this paper a project that I personally developed in collaboration with Pietro Costa for the Museo della Filanda, Salzano, in 2016. This design project dealt similarly, although with different requests on the part of the clients, with the main theme of dynamic projection on rigid supports handed out to visitors inside the exhibition space. The hardware available for the project was limited and the lighting conditions were not the best due to an installation project that had already been defined.

We chose to design installations that could work by means of consumer-type cameras whose purchase price was relatively low so as to guarantee a reasonable economic management of the installations as well as the longevity of the project.

Fig. 8: The Museo della Filanda, Salzano (2016).

A fiducial marker 5cm long was placed on the projection supports. When the camera framed a marker within its visual field and it fell within a precise active area, its position in the space was recognized. Once the marker was recognized by the optical system, a simple process of geometric interpolation made it possible to identify the surface that could be used for the projection and to deform it in real time.

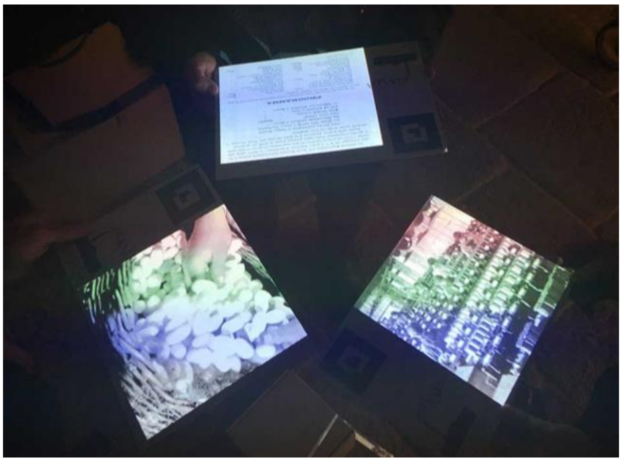

Fig. 9: The cardboard panels and the fiducial markers.

[5] See: *Dynamic projection mapping onto deforming non-rigid surface using a high-speed projector*. Retrieved 15/11/2017 from http://www.k2.t.u-tokyo.ac.jp/vision/DPM/ or *Lumipen 2: Robust Tracking for Dynamic Projection Mapping.* Retrieved 15/11/2017 from http://www.k2.t.u-tokyo.ac.jp/mvf/LumipenRetroReflection/index-e.html

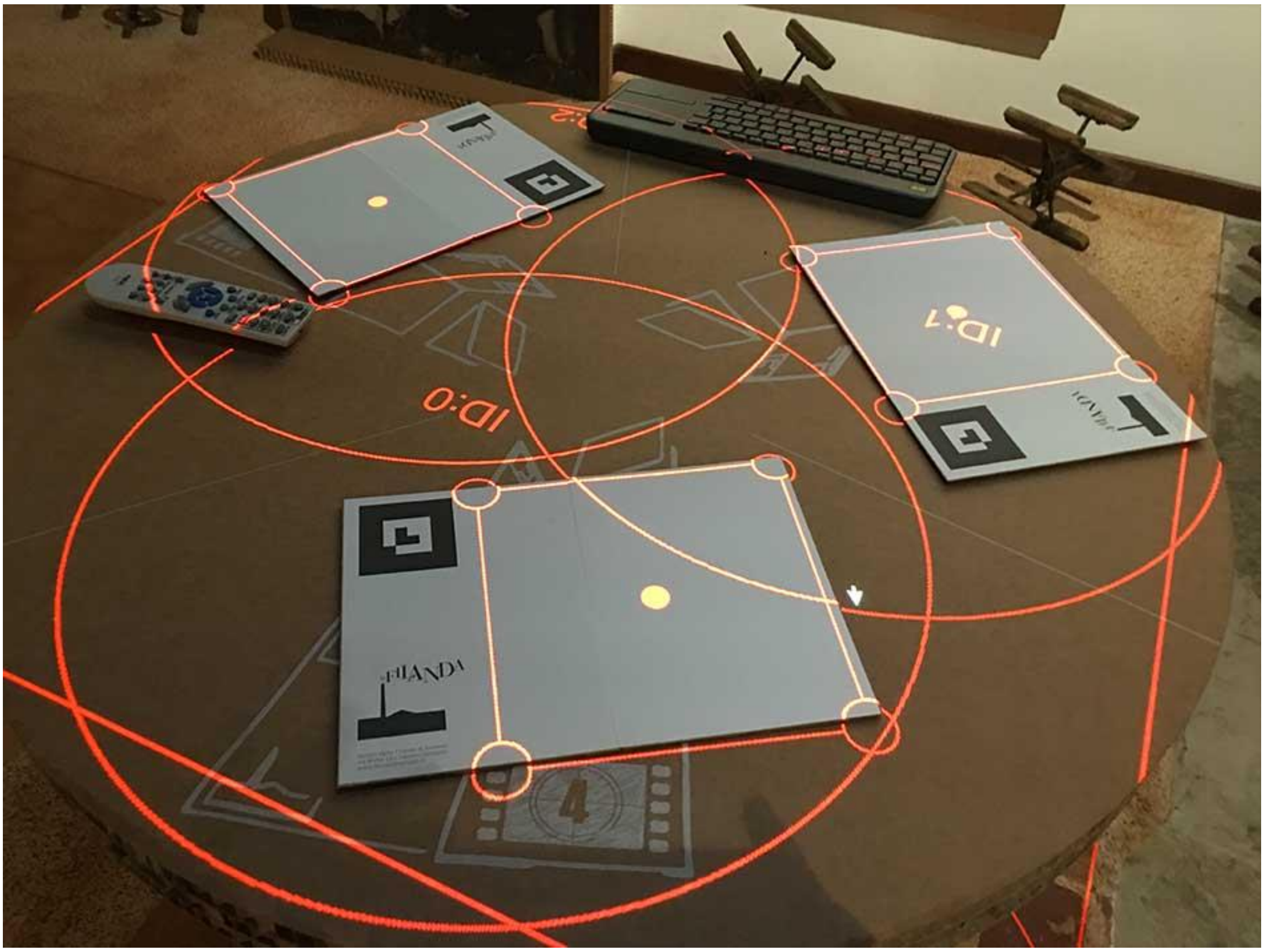

Fig. 10: The server program and the recognition of fiducial markers in the setup mode.

The applications were developed with *Processing* by using *BoofCV*[6] open source library for the recognition of fiducial markers, as well as *VMAP*, a development of the *SurfaceMapper* library by Ixagon.

The system consists of two types of software, a client and a server that communicate with each other through the OSC protocol. The server handles the recognition of fiducial markers, whereas the client manages the three-dimensional transformations for real-time projection.

The system can be operated either from one single computer station, or from a configuration of several on-line computers so as to better handle the computation loads required for the elaboration of the camera images.

Fig. 11: The position of the projector and the camera.

[6] See: BoofCV. An open source JAVA library for real-time computer vision and robotics applications. Retrieved 15/11/2017 from https://boofcv.org/

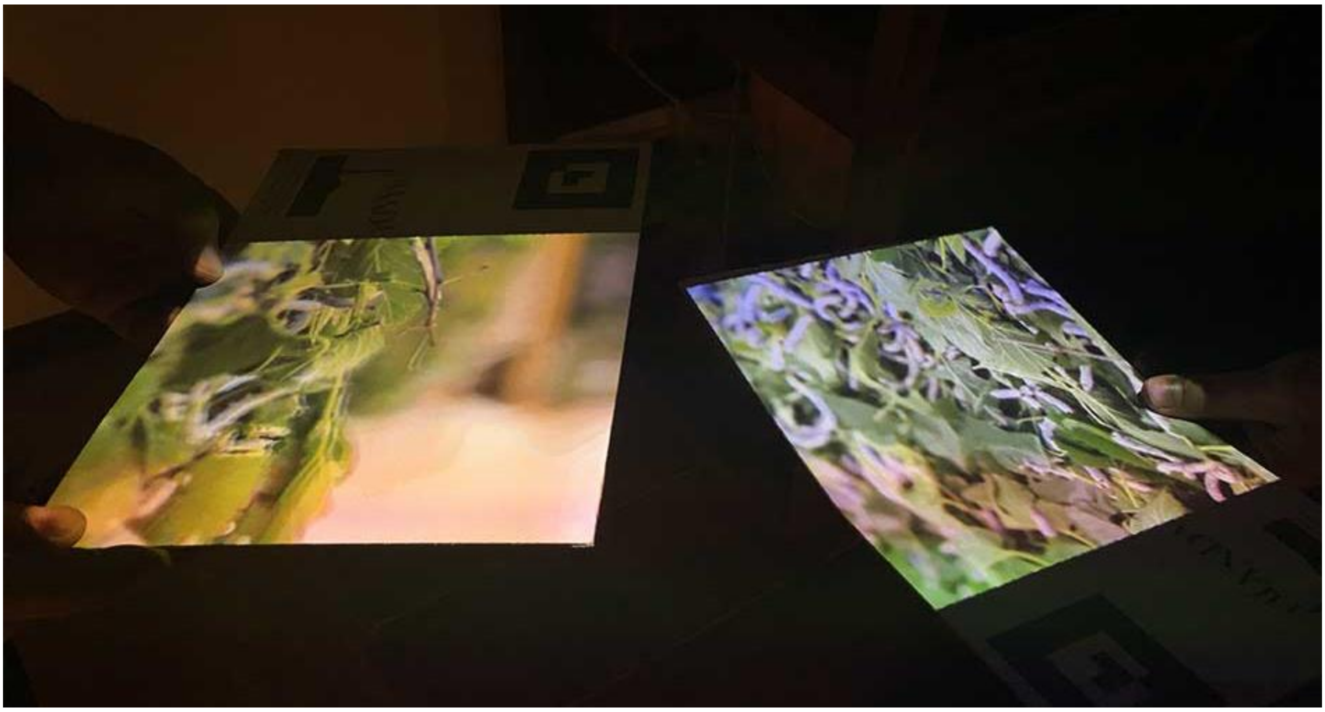

Fig. 12: The client program and the three-dimensional transformations for real-time projection.

4. Conclusion

With increased computational power and the development of ever more affordable solutions for the three-dimensional scanning of objects, the hardware and software development platforms for the creation of real-time projection mapping systems are becoming increasingly accessible. These technologies, although in an embryonic phase of research, seem to be mature products ready to develop project solutions, as in the case of the German pavilion at EXPO 2015. This type of solution is characterized by the capacity to increase the realism of the experience of multimedia contents within an exhibition space, since the interaction with the material or the support on which an image is projected does not change.

At present, based on the technologies and depending on the quality of the hardware that are employed, the result will be more or less reactive and the deformation more or less precise by virtue of the coherence of the model of projection and recognition of the surfaces in the space.

All the projects illustrated in the first scenario, which rely on mechanical systems to manage the projection instruments, are still affected by high costs for the equipment and by a the exceptional complexity of the design process that requires multidisciplinary expertise in robotics, in software application development, as well as in the creation of the actual contents of the projection.

It may be possible that in a short-term scenario, an improvement in the optical systems of three-dimensional reconstruction may lead to the increased integration of these instruments with current professional video-mapping software, thus making the process of recognition and projection of surfaces an easier one.

At the moment the more stable systems with the highest performance are all based on the use of infrared light sources and parts of surfaces pre-treated to reflect the light.

This predefined configuration excludes all those generic situations in which objects or persons come into contact with a system that is not capable of recognizing them because they have not been prepared to reflect the infrared light. The evolution towards a better-performing recognition of the geometry of surfaces will undoubtedly lead to a generalized increase in this kind of project and further research into the communicative capacities of an information system based on real-time projections.

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