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Liang-Yee Cheng *Editor*

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Rendering 360° Images in a 360° Theater

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Abstract. This paper describes a workflow to realize a Virtual tour with a 360° camera to be enjoyed with a new device, a 360° immersive theater. Since their inception, 360° cameras have been subjected to many applications that surpassed initial expectations: not only Virtual tours obtained by image stitching of panoramic photographs as a novel form of visualization but also photogrammetric projects for the creation of 3D Virtual environments too. In this paper we test a new immersive situation of a Virtual tour obtained by stitching of images, not only enjoyed through web application for a desktop or smartphone but through its projection inside an immersive theater of 7 m in diameter also. The use of equirectangular images in an immersive theater is a process already tested; the use of a Virtual tour is the implementation offered. To obtain it the geometry of the equirectangular images projected on the screen of the theater and the implementation of the activities related to its fruition have been investigated and made available through specific app carried out through Unity software.

Keywords: 360 cameras · Virtual tours · Immersive theater

1 Introduction

In recent years Culture-related communication has been profoundly transformed by emerging technologies, growing with products and services; many virtualization activities were implemented during the pandemic event also and being able to explore routes and locations even remotely has become routine.

The historical moment that marked the expansion of Virtual tours was the technical development of a research project sponsored by Google at Stanford University whose evolution gave birth to Google Street View project [1]. The first application of this project covered virtual tour in Denver, Las Vegas, Miami, New York, and San Francisco. From that experience Virtual tour have become a possible visit option.

Google has exploited its position of advantage by establishing a platform based on virtual visits such as "Google Arts & Culture" but now international museums (e.g. London British Museum) [2], cultural institutions (e.g. Palazzo del Quirinale) [3], main events (e.g. Strehler at Il Teatro alla Scala) [4] and Cultural Heritage in general (e.g. Palazzo Schifanoia) [5] use the Virtual visit as a tool to increase the attractiveness of a possible real visit.

In the cultural domain 360° panoramic images are still the most extensive use for virtual environments [6]: in the Virtual tour generally some icons link to informative text

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and new images while the visit is accompanied by introductive information referred to a site map of the panoramic stations to guide the users during the navigation.

Virtual tours have opened a season of promise with respect to the customer journey by offering users the possibility to have a preview of the experience, to be engaged with several information. Even if until now there has been a limited attention to the different Virtual reality platforms, devices and software related, nevertheless the approach to content creation is evolving suggesting new interactions between tools and cultural products.

One opportunity has motivated and reinforced the experience of Virtual tours and Virtual Reality in general [7]: the diffusion of more affordable devices [8]. Low costs devices together with smartphones or immersive glasses have above all suggested a boomerang effect on the demand for Virtuality; in the meanwhile, the release of new cameras with completely renewed focal lengths has broadened the range of users and consequently producers of new immersive modes.

Before 360° cameras diffusion other techniques such as image stitching using flat images were practiced generating panoramic views [9]. These techniques were supported by software developing, demonstrating the possibility of obtaining spherical images merging plain images, partially overlapped, when taken from the same point of view. This technique from the 90's took strength owing to the opportunity to have a lower-cost equipment and a zero distortion, not requiring the traditional internal orientation that is incorporated in the process of stitching of a 360° camera; in a photogrammetric project it had the disadvantages due to alignment errors between images that can affect the results of the final product, especially if considered for survey measurement. At present spherical panoramas, produced by 360° cameras and image stitching, can have good metric quality too when stitching is controlled and calibrated, resulting in a good quality both for photogrammetry projects than for Virtual enjoyment.

The use of 360° cameras [10] because of the ease of use and the production of some cheap models, has mainly focused attention on the possibility of creating Virtual tours with the opportunity to offer simple added content through simple software: from images to videos to the digital 3D models so that the world of culture has approached the hybridization between the real world and intangible content with considerable interest.

2 The Optical Device and the Round

2.1 The Camera

An Insta 360 Pro camera was used for this tour, which offers the opportunity for different geometric considerations in relation to the capture it gives of the entire field of view from a single point of view. The characteristic of 360° cameras is precisely that they have a representation without outline, but with a single point of view. Spherical cameras can capture a spherical image with a single shoot, dividing it into two hemispherical images as if each were captured with a fisheye lens. Both views are then mirrored together in such a way as to acquire them on a single flat image. The result is a single equirectangular projection of panoramic proportion 2×1.

An initial calibration process takes place inside the camera so that the calibration control points can cover the whole of each fisheye and calibrate it to the spherical camera

model. Normal mode, optical flow algorithm takes time to stitch a 360° Pano or 360° 3D in real time, simultaneously preserving 6-lens original images. The whole real-time stitching process takes certain time (camera status is "Processing") and then enters the next shoot after stitching completed. Alongside this possibility it is possible to use a post-stitching process since the camera is equipped with 6 × F2.4 fisheye lenses; the simultaneous process developed by the camera is less satisfactory in the used model than a following processing by laptop, where it is possible to place a series of consistent control points, manually, on the parts of higher distortion. In the laptop workflow all the materials may be previewed, which is helpful to add contents quickly also. Most of the material files are larger in volume, plus a camera's performance of downloading and playing is relatively weak, so the use of a computer to view and manage added contents is recommended [11] (Fig. 1).

Fig. 1. An Instant 360° Pro image obtained with automatic stitching inside camera.

2.2 The Round

The new device where to test the virtual tour is an immersive theater: it is formed by a cylindrical structure of 350 m in diameter that provides 360° projections on the wall and floor. The projection height considered sufficient for the immersive experience is 2.50 m, being all the technical equipment contained in a limited space from 2.50 m to 3.40 m; a higher technical space allows the housing of other equipment. The round is equipped with 6 projectors that ensure the projection on the wall and on the floor with an overlapping as in the drawing. The floor is also covered with a material suitable for projection. The technology used provides Laser projectors of high quality and resolution (1920 × 1200, 4K compatible) projecting content as they are or allowing interaction among the browser and the server facilitating real time applications through Unity developments.

The technology of the projectors is Panasonic and Canon, both with Laser technology and with the use of ultrawide optics (0.28:1 for the Panasonic provided for the floor and

0.56:1 for the 4 Canon of the round). The management of the projections is entrusted to a Media processor server with 4 out 1920 × 1200 on active mini-DP (with m-space functionality for warping) + 1 IN 4K + 1 IN full HD capacity 240 Gb. The floor is served by a Media processor server with 2 OUT 1920 × 1200 on active mini-DP (with m-space functionality for warping 240 Gb capacity) 1 in 4K. The round has been equipped with an integration software, useful for interfacing with the server on which the Unity rendering engine is located to be able to select the different projects to be shown in the round (Fig. 2).

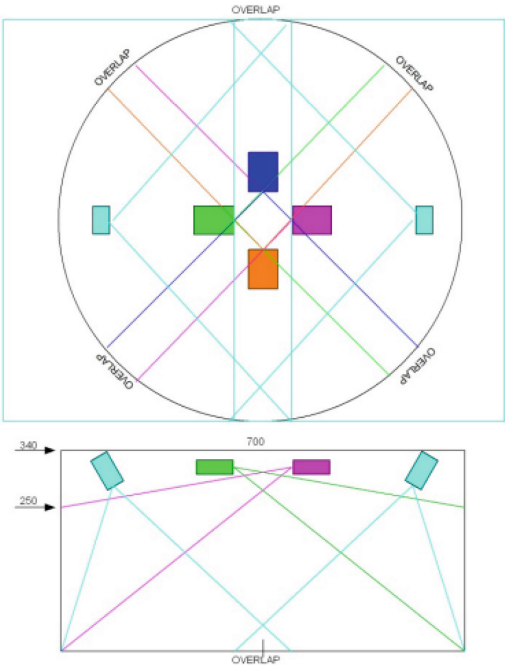

Fig. 2. Plan and elevation of the theater with overlapping of projectors.

2.3 The Case Study

The occasion for the development of this application grows from the need to integrate within the website of the Politecnico di Milano University an inspirational tour for students living abroad to give them a cue and a desire to move to the Campus not only for the quality of teaching and research but also for a sense of belonging to a place; a tour to reveal the attractiveness of a place of culture. The campus is the seat of a technical university and, like other Italian and foreign universities, has made its architectural image a source of pride and identity, further developed with recent interventions by architects such as Renzo Piano whose new architecture has been able to compare itself with that of other illustrious masters such as Giò Ponti or Piero Portaluppi [12] who previously

worked on the architecture of the buildings. The seat is divided into two poles in the city, but the virtual tour has provided a single screen access from the headquarters of the Dean, then divided into the fruition of places also distant one from the other. Each of the campuses was surveyed with spherical images taken with Insta 360, then processed with a commercial software to prepare the virtual tour augmented with cultural content of the location, which will be lived from the website (Fig. 3).

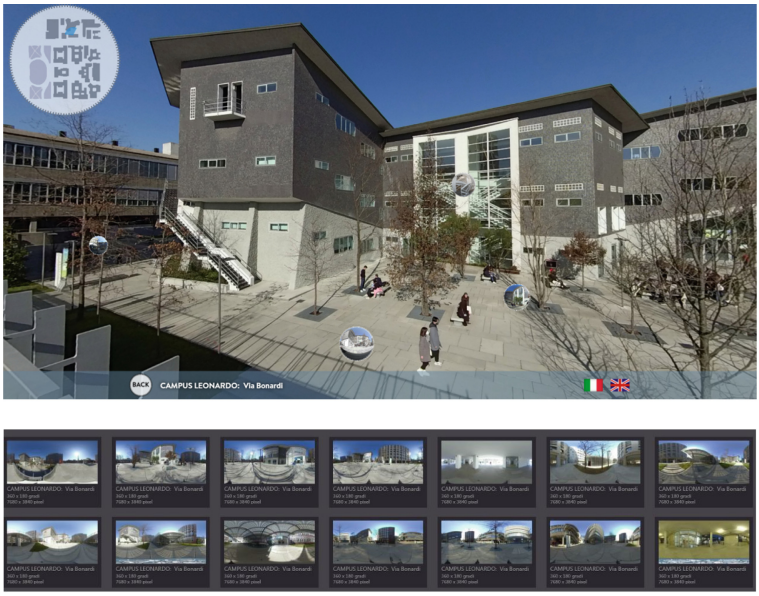

Fig. 3. Trifoglio's view from the tour with map and bubble-gates to other spaces. Below the software interface with the panoramic view.

The tour contains about 200 images or video of immediate enjoyment with access through spherical bubbles or by scrolling, with 80 added textual or iconic content. It is currently in the testing phase in the website to be visited by laptops or portable devices and is scheduled for official release within summer 2022. The software utilized for the tour is a commercial one still an authoring software. The following focus has been directed to the fruition of the same tour in the immersive theater.

3 The Workflow

The workflow includes the creation of 360 images from Insta 360 with a desktop stitching process with the camera's proprietary software 3D Vista; the production of an immersive tour with added content of the various campuses of the university, with the production of points of interest, added with videos, models, documents, interview with avatar. The projection inside the theater has been developed to test the possibility of immersive use of the tour in the theater, including the fruition of documents, with a Unity development (Fig. 4).

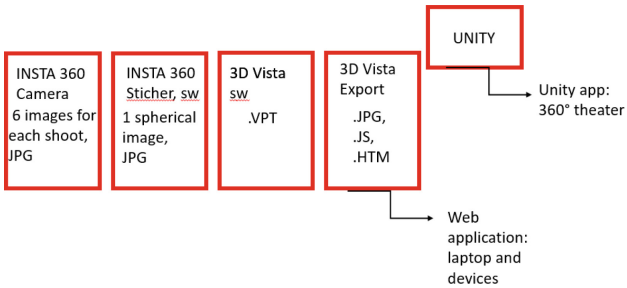

Fig. 4. The two workflows

3DVista currently produces 3D tours for desktop, and mobile. The immersive theater setup isn't currently supported, a way to convert 3DVista tours to a Unity environment responsible for rendering the scene onto our theatre [13] has been here developed (Fig. 5).

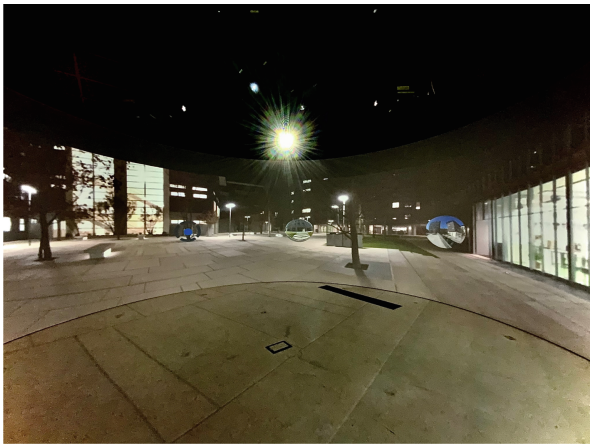

Fig. 5. Plan and elevation of the 360 Image from Insta 360 with implementation spaces reachable by placeholder lenses

The first need has been to export everything to Unity, as this is the environment supported by the theater for any development.

Our tool has been fully implemented into the Unity game engine with the use of C# as the programming language of choice.

All the photos and media needed for the recreation of the virtual tour are fetched by our code from the Web package that can be created by 3DVista. Once the tool is pointed toward the folder containing the web version of the tour, all information regarding the tour is rebuilt by parsing a JSON file present in the Web package.

In its current state, our importer does not have any limitations regarding picture resolution when using panoramic photos and it is also capable of dynamically fetch and load the highest resolution photo provided in the tour. The same cannot be said for importing panoramic videos, as the high demand in memory bandwidth results in

3DVista exporting panoramic videos to HLS format for higher resolutions. This format is not easily supported by Unity obliging us to use only the panoramic videos in mp4 format, which demonstrate to have limited resolution (Fig. 6).

Fig. 6. Plan and elevation of the 360 Image from Insta 360 in the theater

The Unity game engine is quite flexible and has already proven itself to be a good tool to create 360 virtual tours with, as such it did not present any major limitations that slowed down our work. The only real obstacle present has been the proprietary nature of the data that we have been working with. Given that the packages produced by a 3DVista projects are self-contained and are not designed for usage and modification by a third party, the format of all the information regarding the tour has had to be reversed and converted in a format that was usable by Unity itself. This has been an issue especially given the fact that C# currently does not support dynamic typing when it comes to reading JSON files and a special class needed to be specified which worked as a dynamic container for everything found in the web package.

What we ultimately finalized is an importer which can convert 3DVista tours into Unity tours that can be projected onto our 360° immersive theatre which allow the user to switch among all the scenes present in the tour while preserving the topology and order of the tour panoramas.

At present, to convert the tour into a format that's usable by our theatre, Unity must be launched into edit mode and the tour must be selected through the editor prior to build the executable responsible for projecting the tour onto the 360° degrees screen. Moreover, tour information such as captions that pop up when hovered over with the mouse are not yet present in the tour ported to Unity.

The current aim of this project is thus to fix the current shortcomings of the importer, by implementing both a way to launch the theatre ready tour without opening Unity

Editor as well as add all tour information that 3DVista allows the user to insert, to produce a more complete version of the tool.

4 Conclusion

This paper describes a process of further enhancing 360° Virtual tours by setting up a fruition in an immersive environment, the theater. Immersive theaters have not yet been implemented in the normal workflows of fruition of the tours, so special software implementations have been created to support the geometric projection on the screen, in motion. While remaining in a two-dimensional environment and therefore without recreating a 3D modeling of space, while preserving the topology and order of the tour panoramas, the immersive space has proven to have excellent potential but also performance limitations mainly due to the quality of importing panoramic videos.

Although the immersive visit of 3D modeled environments is moving rapidly in our research, the ease of use of virtual tours to be enjoyed in immersive theater encourages us to continue on this track; the implementation of the app is expected to grow by resolving issues related both to the rendering of images, and the allocation of content in the various scenes to be used in the same circular screen; currently all content added can only be used on the flat floor.

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