Creating Panorama Virtual Tour Systems for the Built Environment: A Practitioner Perspective

Liang Li and Yue Li(✉)

School of Advanced Technology, Xi'an Jiaotong – Liverpool University, Suzhou, China
yue.li@xjltu.edu.cn

Abstract. Virtual tour systems have become an integral aspect of modern technology, revolutionizing the way individuals interact with physical spaces. In the context of the built environment, virtual tour systems offer applications ranging from architectural visualization and urban planning to educational simulations and interactive tourism experiences. The design and development of these systems involve intricate considerations, such as path planning, data collection, tour design, and the integration of multimedia, to create a cohesive and engaging virtual experience of the built environments. In this paper, we present the development of a virtual tour system and discuss the practical constraints. Our work has practical implications for employing digital approaches to present the built environment, shaping the way we interact with and experience physical spaces.

Keywords: panorama · virtual tour · virtual reality · virtual roaming · virtual campus · webvr

1 Introduction

In the evolving landscape of digital representation and exploration of built environments, the creation of panorama virtual tour systems has become a focal point for enhancing our interaction with physical spaces. A panoramic image is a wide-angle view photograph that captures a scene or environment in a broad and panoramic format (see Fig. 1). It can be created using panoramic camera equipment or through the stitching of individual images taken by digital single-lens reflex cameras [1, 2]. While these images are static by themselves, connecting multiple panoramas allows the creation of virtual tour systems. This digital approach has left an indelible mark across diverse fields, including education, tourism, and entertainment [3, 4]. Although panorama virtual tour systems are not as immersive or interactive as a fully reconstructed virtual reality (VR) environment, they preserve a great level of details of the surroundings and are often more accessible than VR applications that require the use of a head-mounted display. Notably, a web-based approach emerges as the commonly adopted way to host panorama systems due to its cross-platform support. Despite the strides made in virtual tour systems, a noticeable gap exists concerning the smoothness and degree of freedom in user movement [5]. Many

J. Han et al. (Eds.): AAB 2024, LNCE 593, pp. 101–109, 2025.
https://doi.org/10.1007/978-981-96-4749-1_12

systems primarily support transitioning between scenes, lacking the nuanced step-by-step movement effect crucial for a heightened sense of presence and spatial awareness [6]. In this paper, we present the design and development of a panorama virtual tour system that allows step-by-step continuous movement in the scene. We also discuss the practical constraints and share the lessons learned from our practices in the four-step procedure encompassing path planning, data collection, tour design, and multimedia embedding. Our work offers valuable insights to guide practitioners, such as VR developers and technical teams of universities and public institutions in the development of panorama virtual tour experiences.

Fig. 1. An example panoramic image. Photo taken by authors at the Xi'an Jiaotong-Liverpool University.

2 Related Work

2.1 Virtual Reality and Panorama

Virtual reality simulates a lifelike environment that users can interact with, often through computer-generated environments or captured real-world scenes [7]. Panoramas are also known as panoramic images. With their ability to encapsulate a complete view of a location, panoramas contribute to the creation of realistic and immersive virtual environments. VR applications can leverage panoramas to create seamless and expansive backgrounds, providing users with a sense of presence within the virtual space. Panoramic images provide a 360-degree perspective of the surrounding environment from a point of view in space, which can also be seen as a node-centred perspective or a node-centred cylindrical plane with a certain height, on which scenes outside the plane are projected. A 720-degree panorama extends further in the vertical direction, providing a broader field of view than a 360-degree panorama. Users can rotate their perspective not only left and right in a complete circle, but also up and down. Two primary methods are commonly employed to capture panoramic images. The first involves using specialized panoramic camera equipment, such as the Insta360[1]. These cameras support the capturing of wide-angle shots in a single sweep. The advantage of this method is that it is simple to use and typically comes with integrated stitching software to obtain panoramic images. However, the images captured using this approach may have limited level of details due to the camera resolution. The second method is to use a standard digital camera to capture overlapping images and then use specialized software to stitch them together [2]. This method allows the production of panorama with high resolutions. Given that standard digital cameras are affordable and widely available, this method is cost-effective and remains the most popular method, despite being comparatively complex in editing.

2.2 Virtual Tour Systems

The transformation of a panorama into a virtual tour system involves leveraging technology to create an interactive and immersive experience for users. While a panorama is a static representation of a wide-angle view, a virtual tour system extends this concept by allowing users to navigate and explore the environment in a dynamic and interactive manner [8]. Virtual tour systems embody a fusion of various information technologies such as computer graphics, image processing, multimedia technologies, and interaction design. These systems can realistically simulate navigations within digitally reproduced scenes and have been widely applied in commercial uses, such as indoor house tours in real estates [9], online museum tours [4], and virtual campus tours [10]. By incorporating features such as hotspots, panning, zooming, and tilting to simulate a real-world roaming experience, users can move around and feel a sense of ‘being there’ in the virtual environment. Multimedia content such as images, videos and links can also be added as interactive elements in the virtual roaming systems. Many development toolkits are available on the market, such as A-Frame, Pannellum, and Google VR. These toolkits are often compatible with web development and have built-in support for viewing in VR. However, the navigation in virtual tour systems is not as smooth and free as in a fully reconstructed VR environment. As panoramas are essentially stationary images taken at fixed locations, users’ movements are often simulated as transitions between scenes through fade-in and fade-out effects. Simulating continuous step-by-step movements is a challenge for virtual tour systems.

2.3 Existing Practical Constraints

While the technologies used to create panorama virtual tour systems are relatively mature, there are several practical constraints that impact the overall design and implementation of such systems [11]. To begin with, the size of the environment poses logistical considerations for seamless navigation during path planning. In addition, the data collection introduces complexities related to unpredictable factors such as weather conditions, variations in lighting, and the presence of people within the scene. Tour design, particularly the tasks of image stitching and modelling on the panoramas, can be time-consuming and resource-intensive, requiring careful consideration and adjustment for an optimal user experience. Multimedia embedding faces challenges related to device

[1] https://store.insta360.com.

compatibility and web response time, influencing the accessibility and responsiveness of the virtual tour. Subjective factors, including the expertise required for content creation and system maintenance, contribute to the overall feasibility of the project. Additionally, ethical considerations must be carefully addressed, reflecting concerns related to user privacy, data usage, and the responsible deployment of virtual tour systems. Navigating through these practical constraints is essential for the successful development and deployment of panorama virtual tour systems, ensuring a balance between technical requirements, user experience, and ethical considerations.

3 Methodology

Creating a virtual tour system requires a series of planning and data collection work before the system development. In this section, we summarize a four-step procedure that details the design and development of a virtual tour system (see Fig. 2). For the data collection, we used a Nikon D7500 DSLR camera with a 14 mm f/2.8 ultra-ultrawide lens that can cover a wide 114° angle of view. The camera was mounted to a tripod for stability. Using the north campus of the Xi'an Jiaotong-Liverpool University (XJTLU) as an example environment, we captured over 700 images (4096 x 2160) in RAW and JPEG file formats. These image data were used to create 65 panoramic images (6528 x 3264), with a total size of 2.61 GB. Adobe Photoshop and PTGui[2] were used for image processing and stitching. We used the krpano[3] and everpano[4] to design the virtual tour and embed multimedia information. These tools are used because they are the mainstream approaches in the construction of web-based virtual tours and have rich plugin support for extended features.

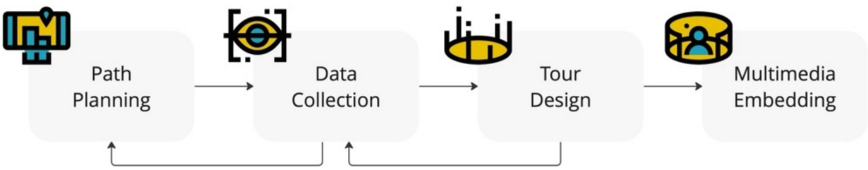

Fig. 2. Virtual tour system design and development procedure. Source: Created by authors.

3.1 Path Planning

At the beginning of the system design, we planned a travelling path on the satellite map to cover the main buildings and areas of the campus. The north campus of XJTLU covers an area of around 150,000 square meters. Along the planned path, we set a point every 3–5 m to ensure smooth transitions for step-by-step walking simulation, leading to 65 points in total.

[2] https://ptgui.com.
[3] https://krpano.com.
[4] https://everpano.com.

3.2 Data Collection

After the path planning, we started our field study to collect the image data. To ensure sufficient overlapping between images for panorama creation, we captured 6–8 images of the built environment and two images of the sky and the ground. The camera settings such as the exposure and white balance should remain consistent across all images to avoid variations that may affect the image stitching results. To improve the viewing experience, the collected images were batch processed into a unified style in Adobe Photoshop. Some manual adjustments were also needed for better image stitching results. The image stitching was based on the recognition of feature points between the overlapping areas of two images (see Fig. 3a).

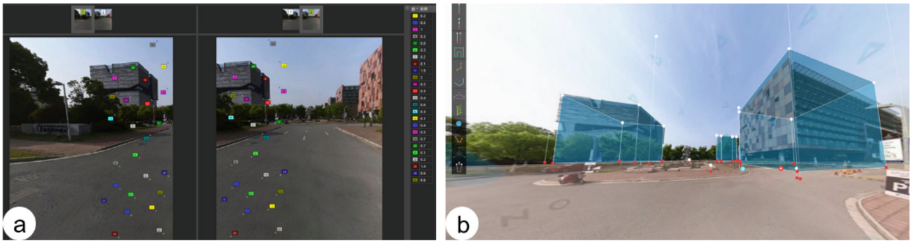

Fig. 3. (a) Two images with shared features in image stitching; (b) panorama modelling showing geometry outlines of the buildings. Photo taken by authors at the Xi'an Jiaotong-Liverpool University.

3.3 Tour Design

After the panoramic images were generated, they were imported to the krpano to create a basic tour system that contains folder of all images and an XML file. This step includes several design considerations: 1) the default viewing angle of each panorama, 2) the navigation order, and 3) the transition effects. These are defined by the tags in the XML file. For example, the <view > tag defines the direction and field of view of a panorama; the <autorotate > tag allows to enable automatic rotation of the user's view; the <hotspot > tag defines specific panoramas that are clickable on the map, so that users can quickly teleport to a different location. Interactive hotspots play a key role in facilitating navigation in the virtual tour. In addition, we modelled the 3D environment over panoramic images in everpano to create realistic transitioning effects between two adjacent points (see Fig. 3b). Compared to the basic fade-in and fade-out effects used in hotspot transitions, this approach presents additional depth information within the environment that facilitates users' sense of moving along the path, thus supporting a greater sense of presence in virtual tours.

3.4 Multimedia Embedding

Once the tour design is completed, users can take a basic virtual tour as planned and see the build environment. To enrich the user experience, we also embedded multimedia to the virtual tour (see Fig. 4). For example, we included a campus map and added background music to the tour system. In addition, image, text, and hyperlink information can be enabled if users click on the floating tags on top of some panorama.

Fig. 4. A screenshot showing the embedded multimedia in the virtual tour system. Users can click on the floating tag above the boat to access more information. Photo taken by authors at the Xi'an Jiaotong-Liverpool University.

4 Analysis and Results

We invited 12 participants (9 males, 3 females, aged M = 25.5, SD = 7.8) to use the virtual tour system and evaluate the usability using the System Usability Scale [12]. Overall, the system had a usability score of 72.71 (SD = 15.94), indicating an acceptable (>68) system usability. Detailed results are shown in Table 1.

Table 1. Detailed evaluation results of the virtual tour system usability.

Question	Mean	SD
I would like to use the virtual tour system frequently	3.92	0.90
I think the virtual tour system is too complicated	2.67	1.15
I think the virtual tour system is easy to use	4.50	0.52
I need professional help to use the virtual tour system	2.33	1.37
I think the multiple functions of the virtual tour system are well integrated	3.92	1.08
I think the virtual guide system has too many unconnected places	2.50	1.00

(*continued*)

Table 1. (*continued*)

Question	Mean	SD
I think most people can quickly learn to use a virtual tour system	4.42	0.51
I find the virtual guide system troublesome to use	2.08	1.08
I felt confident using the virtual tour system	4.25	0.75
I had to learn a lot to use the virtual tour system	2.33	1.67

Overall, participants had a high acceptance of the virtual tour system. They found the system easy to use (M = 4.5, SD = 0.52) and agreed that the system was easy to learn (M = 4.42, SD = 0.51). They also felt confident using the system (M = 4.25, SD = 0.75) and were willing to use it frequently (M = 3.92, SD = 0.9). The evaluation also pointed out some areas of improvements. For example, some participants found the system complicated and had unconnected places. Future improvements can be made to address these issues to improve the usability and user experience of the system, such as shortening the distance between hotspots and supporting automated touring.

5 Discussion and Conclusion

In this paper, we present the design and development of a panorama virtual tour system that supports step-by-step continuous movement in the scene. Instead of delving into the algorithms and techniques, we focus on the practitioner's perspective and reflect on the development process. In addressing the practical constraints and challenges encountered during the development of our panorama virtual tour system, we implemented a series of strategic solutions and gained valuable lessons in the process. For the challenge of path planning and the size of the environment, we first collected data from a small area of the scene (i.e., the entrance), planned the distance between two panoramas, and estimated the number of images needed. This involved multiple iterations between path planning and data collection. Through experimentation, we discovered that choosing cloudy days and leveraging holiday or weekend time yielded optimal results for data collection. This helped avoid having bright reflections, sharp shadows and too many people in the scene. To mitigate challenges related to data collection complexities, we checked weather reports and conducted all data collection during similar times of the day to maintain consistency. Additionally, we iterated between the data collection and image processing, adopting an agile approach with short loops so that we could refine image stitching and modelling tasks. It was learned that having objects with recognisable features in the overlapping areas will increase the efficiency in image stitching. For example, buildings usually have more recognisable features than trees and roads. The embedding of multimedia requires a careful balance between visual effects and web response time. While high image quality enhances visual effects, it comes at the cost of longer times needed for loading and rendering. Subjective factors, such as expertise for content creation and system maintenance, are also important constraints. Our project experience demonstrated that a motivated individual with some technical background, such as a master's student, can self-learn the necessary techniques within a reasonable timeframe (~30 h). Finally, it is often inevitable to include passengers when capturing panoramas in public open areas. It is important to implement transparent and ethical practices, ensuring that user concerns are addressed and respecting privacy throughout the virtual tour system's development and deployment.

Acknowledgement. We sincerely thank our participants for their time and valuable comments. This work is supported by the National Natural Science Foundation of China (62207022), Natural Science Foundation of the Jiangsu Higher Education Institutions of China (22KJB520038), and Suzhou Municipal Key Laboratory for Intelligent Virtual Engineering (SZS2022004).

References

1. Brown, M., Lowe, D.G.: Automatic panoramic image stitching using invariant features. Int. J. Comput. Vision **74**, 59–73 (2007)
2. Adel, E., Elmogy, M., Elbakry, H.: Image stitching based on feature extraction techniques: a survey. Int. J. Comput. Appl. **99**(6), 1–8 (2014)
3. Hookham, G., Nesbitt, K., Cooper, J., Rasiah, R.: Developing a virtual tour of a community pharmacy for use in education. Inform. Technol. Industry **2**(1) (2014)
4. Li, J., Nie, J.W., Ye, J.: Evaluation of virtual tour in an online museum: exhibition of architecture of the forbidden city. PLoS ONE **17**(1), e0261607 (2022)
5. Dai, F., Zhu, C., Ma, Y., Cao, J., Zhao, Q., Zhang, Y.: Freely explore the scene with 360 field of view. In: 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), pp. 888–889. IEEE (2019)
6. Zhao, Z., Li, Y., Yu, L., Liang, H.N.: TeleSteer: combining discrete and continuous locomotion techniques in virtual reality. In: 2023 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), pp. 755–756. IEEE (2023)
7. Sutherland, I.E.: The ultimate display. In: Proceedings of the IFIP Congress, vol. 2, No. 506–508, pp. 506–508 (1965)
8. Pan, Z., Fang, X., Shi, J., Xu, D.: Easy tour: a new image-based virtual tour system. In: Proceedings of the 2004 ACM SIGGRAPH International Conference on Virtual Reality Continuum and its Applications in Industry, pp. 467–471 (2004)
9. Chhikara, P., Kuhar, H., Goyal, A., Sharma, C.: DIGITOUR: automatic digital tours for real-estate properties. In: Proceedings of the 6th Joint International Conference on Data Science & Management of Data, pp. 223–227 (2023)
10. Osman, A., Iskak, N.I., Wahab, N.A., Ibrahim, N.: Interactive virtual campus tour using panoramic video: a heuristic evaluation. J. Comput. Res. Innov. **5**(4), 1–7 (2020)
11. Shinde, Y., Lee, K., Kiper, B., Hasanzadeh, S.: A systematic literature review on 360° panoramic applications in architecture, engineering, and construction (AEC) industry. J. Inform. Technol. Construct. **28**(21), 405–437 (2023)
12. Brook, J.: SUS: a "quick and dirty" usability scale. Usability Evaluation in Industry (1996)