

360-Degree Panoramas as a Reality Capturing Technique in Construction Domain: Applications and Limitations

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360-degree panorama is a reality capturing technique for visualizing environments that fully immerses the user in a true-to-reality representation of real-world spaces. 360-degree panoramas create highly realistic and detailed replication of construction sites while giving users a high sense of presence. This paper aims to discuss the applications of 360-degree panoramas and extend the understanding of the current state of this technology in the Construction setting and other affine fields. Additionally, the methodology to develop 360-degree panoramas and the limitations of the technique were examined for the Construction domain. Overall, three major areas were identified that employ 360-degree panoramic technology in Construction: interactive learning, reality backdrop to augmented information, and visualizing safe and unsafe situations. It was found that these applications leverage the realism embedded into 360-degree panoramas to visualize remote, inaccessible, or unsafe places that are common in Construction.

Keywords: 360-Degree Panoramas, Mixed Reality, Reality Capturing

Introduction

360-degree panorama is a reality capturing technique that creates an unbroken view of a whole region surrounding an observer, giving a “sense of presence, of being there” (Bourke 2014). Panoramas were devised by the English artist Robert Baker in 1792 (Ellis 2012), as a method to describe his paintings on the internal face of cylindrical-shaped buildings. The concept present on these paintings was later extended to photography, by combining pictures taken from a static advantage point in a cylindrical fashion and combining them together.

Several domains in the current literature have implemented 360-degree panoramas as a method for immersive visualization of real environments. Large scientific endeavors have implemented 360-degree panoramic technologies in their research. The European Organization for Nuclear Research (CERN) particle accelerator complex uses 360-degree tools to provide panoramic data of their facilities to all users during periods with no access or during shutdowns (Marin et al. 2016). The National Aeronautics and Space Administration (NASA) implemented 360-degree panoramic technology in their Mars Rover InSight missions (Figure 1) to obtain visuals of the landing site and the workspace in which the robot can place the instruments (Golombek 2018). Similarly, Shell Oil and Gas company employed a 360-degree panoramic system in an offshore platform for remote visualization of interest areas and industrial equipment (Berger et al. 2013).

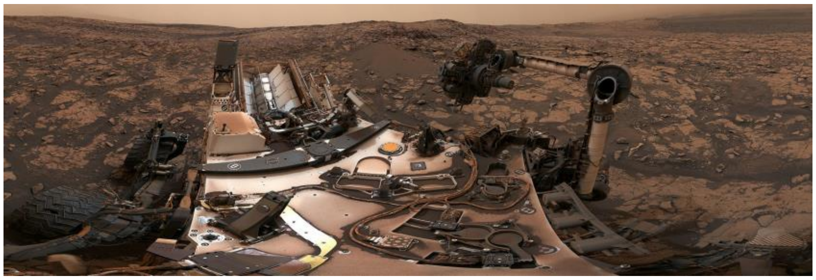

Figure 1. Curiosity Surveys a Mystery Under Dusty Skies (NASA/JPL-Caltech/MSSS)

However, the most common application of 360-degree panoramas across research fields is the creation of virtual tours. Research efforts have used virtual tours to enable the visualization of art and architecture (Byrne et al. 2015), record historical monuments and heritage (Capone and Campi 2014), and provide access to virtual museums (Brumana et al. 2018). Further applications are available in fields such as news reporting, filmmaking, brand advertisement, and live sports (Van den Broeck et al. 2017), remote communication (Tang et al. 2017), virtual team collaboration (Nguyen et al 2017), and photogrammetry point cloud generation (Barazzetti et al. 2017). Most of these application areas are still under research and development, having a very limited implementation in practical situations. This study aims to discuss the current application of 360-degree panoramas in the Construction domain, offer an understanding of the methodology to develop them, and expose the limitations of such a technique.

360-Degree Panoramas in the Construction domain

In the Construction domain, researchers have used 360-degree panoramas to represent real-world remote, inaccessible or unsafe jobsites. Figure 2 displays the timeline of several 360-degree panorama applications in Construction literature – 3 categories where identified: *(1) Interactive Learning, (2) Reality Backdrop to Augmented Information, and (3) Visualize Safe and Unsafe Situations*.

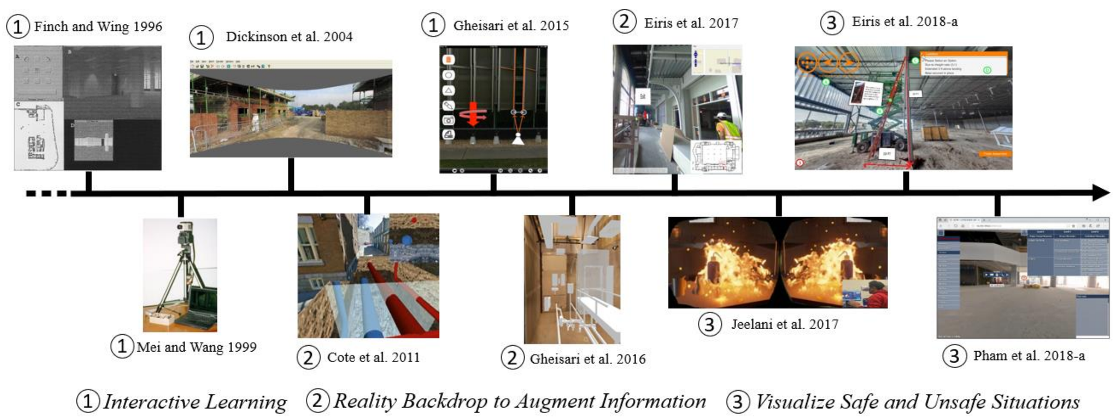

Figure 2. 360-degree Panoramas and 3D Models in Construction

(1) 360-Degree Panoramas of Construction Sites for Interactive Learning: Initial stages of research concentrated on identifying the methods of creation, capturing, and navigation of panoramic images for interactive learning. Early techniques of 360-degree images used cylindrical projections instead of spherical projects because they required fewer images to be created. Finch and Wing (1996) created a computer-based system that employed images to

produce a navigable simulation of construction and architectural locations for student learning, engagement, and exploration. The produced navigable platform with interconnected site images and floor plans, provided students with interactive means of visualizing in real jobsites. Mei and Wing (1999) developed an automated robot-camera to obtain images that once stitched (joined together) would enable the users to explore the location through an interface. This platform was mainly to enable students to visit virtual construction sites. Dickinson et al. (2004) employed cylindrical panoramas to introduce interactive links to movies, sketches, drawings, and animations within the images. These methods of interaction had the objective of transporting construction students into the jobsite within the confines of the traditional classroom, encouraging learning about the tasks and processes involved in the construction industry. More recently, Gheisari et al. (2015) utilized 360-degree interactive panoramas as a viable and location-independent solution to display the whole structure of a building in a specific location and illustrate free-body-diagrams of the structural elements of the building to students. This way the students, without physically going to a jobsite, could experience standing in front of a building structure, interacting with its different structural elements, and viewing associated free-body-diagrams.

(2) 360-Degree Panoramas of Construction Sites as a Reality Backdrop to Augment Information: Construction domain research efforts have focused on using 360-degree panoramas as a reality backdrop to augment information in them (e.g., 3D models, 2D images, audio, text). Cote et al. (2011) used 360-degree panoramas to display the surface of a street, where augmentations (e.g., 3D models, images, annotations) show a virtual excavation and illustrated underground utilities on it. In another example, Gheisari et al. (2016) employed 360-degree panoramic spaces of a construction renovation project to superimpose the BIM models on it to provide construction personnel with a location-independent way to access their required information in an immersive interactive environment. In this renovation project, the interior furniture as well as some parts of the plumbing and HVAC system, were superimposed on the 360-degree captures of the construction renovation project to better visualize and communicate the finish work to sub-contractors. 360-degree panoramas have also been used as a method to record and document the building processes in the jobsite. Eiris et al. (2017) described the process of employing 360-degree panoramas for the creation of a virtual tour within complex construction projects for asset management and documentation. Augmentations used in the 360-degree panoramas provided a simple method for locating and visualizing different building components and documenting potential issues in the construction processes for later remote communication between stakeholders.

(3) 360-Degree Panoramas of Construction Sites to Visualize Safe and Unsafe Situations: Researchers have used 360-degree panoramas to provide visualization means in the context of hazard awareness and identification in the construction domain. Jeelani et al. (2017) used 360-degree panoramic images to explore the development of a personalized training experience. In that 360-degree panoramic platform, simulation of accidents would enable workers to visualize hazardous events. A pilot study concluded that this simulation provided a sense of presence to the users. Similarly, Eiris et al. (2018-a) created a platform for safety training using augmented panoramas of reality. This system allowed users to actively navigate construction sites, visualizing highly realistic environments with augmented interactions. In a subsequent study, Eiris et al. (2018-b) evaluated the fall hazard identification index of trainees using the previously

created platform. It was found that study participants identified 52% of fall hazards in such environment. Moreover, a usability platform was conducted, revealing several improvements were required in the platform to provide a better overall experience. Similarly, Pham et al. (2018-a) and Pham et al. (2018-b) developed a learning platform for improving the safety education using 360-degree panoramas. The created platform allowed students to look at a digital site visit to recognize hazards using 360-degree panoramas. The platform enabled the assessment of safety knowledge learned from the exploration using gamified testing mechanisms. This set of studies compared safety hazard identification on students that used the 360-degree panoramas to students that visited the construction jobsite to perform the same tasks, findings no statistical differences of the scores of groups.

360-Degree Panoramas: Technical Development Process and Challenges

Technical Development Process: 360-degree panorama is a reality capture technique that provides omnidirectional views of the complete environment encircling the observer, creating a virtual space that replicates the viewpoints surrounding the user. 360-degree panoramas enable look-around visualization by leveraging photographic technologies. To produce these complex interactive representations, a 360-degree panorama must be captured from the real locations or places and translated into the virtual space for visualization (see Figure 3). The capture of a 360-degree panorama entails the construction of an equirectangular projection in a two-dimensional plane. Comparable to a map projection, the process requires software algorithms for the systematic transformation from a 2D plane into a sphere, cylinder, or cube and vice versa**.**

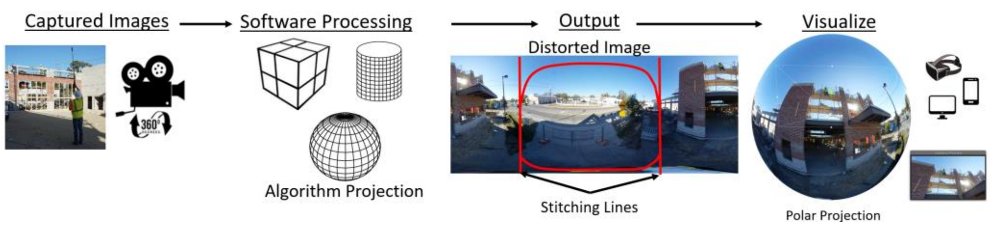

Figure 3. 360-Degree Panoramic Development Process.

Two common methods are used to create such equirectangular projection – using a traditional camera with a narrow-angle lens (e.g., DSLR or Point-and-Shoot) or using a camera with multiple ultra-wide-angle lenses (e.g., Ricoh Theta or Samsung Gear 360) to document spherical 360-degree images (Nayar 1997). The first technique can be achieved by taking multiple rows of photos shots with a single rotating camera from a pivot point or using multiple cameras setups, in a spherical or partial cylindrical fashion (from a static point) to recreate a full 360-degree panorama. The second technique for data capturing employs fish-eye lens or catadioptric lens systems on a stationary location to produce strong visually distorted images due to the wide-angle of the camera. In both approaches, the equirectangular projection requires the use of computer software to stitch each image into a single picture. The primary purpose of the software is resolving the distortions produced in the capturing process and mapping the 360-degree image spherical, cylindrical, or cubical coordinates into planar coordinates.

To visualize the equirectangular projection in an immersive experience, the planar coordinates must be reconverted into spherical, cubical, or cylindrical coordinates. This process remaps the equirectangular images into proper volumetric coordinates using mathematical relationships for coordinate system transformations. In the produced virtual spherical, cubical, or cylindrical space, users can explore the images to observe focus areas in detail. Ultimately, the 360-degree panoramas can be distributed between devices for visualization, providing pronounced immersion and feeling of physical presence (Lee et al. 2016). This process delivers access to the 360-degree panoramic imaging in laptops, PCs, handheld devices (e.g. smartphones or tables), and head-mounted displays (HMD).

Commercially available software utilizes these 360-degree panoramic techniques to enable construction professionals to traverse the jobsite remotely. HoloBuilder® and StructionSite® utilize a web-based implementation of 360-degree panoramas for jobsite documentation, simplifying the capture and visualization of as-built conditions by spatially linking the images to existing 2D plans. The software also allows for progress motoring as images of the construction site can be captured across time, enabling the tracking of work tasks as the project advances. Finally, facility managers can leverage the captured data to better understand the conditions of a given building, efficiently evaluating and assessing their work within the represented space. These web-based solutions enable all stakeholders to communicate by using annotations and documentation attachments augmented within the 360 images. Both platforms support integration with other commonly used software tools for documentation such as Procore®, Autodesk BIM360®, and Bluebeam®, simplifying the information exchange for construction professionals. Live streaming solutions are becoming available within this technology to enable telepresence and remote immersive communication for project managers, providing means of prompt problem resolution with globally distributed teams.

Challenges of 360-Degree Panoramic Technology: Although 360-degree panoramas have many applications within Construction and other domains, several limitations have been found regarding image quality, static vantage point, and stitching parallax. The image quality of the currently available cameras is not comparable to that of traditional photography or videography, as the final image observed is an amplified portion of the overall picture. Due to the nature of being a photographic technology, 360-degree panoramas are inherently static. The vantage point limits the exploration of the data exclusively to a visual rotation. Furthermore, the current stitching algorithms produce parallax issues on the images in certain conditions. Such issues can be often observed when objects are near the focal point of the camera or sometimes at the intersection of the stitching lines. These issues can be managed with pre-planning of the captures (Saarieen et al. 2017).

SUMMARY AND FUTURE WORK

360-degree panoramas are omnidirectional views of the environment allow users to actively explore remote, inaccessible or unsafe places in an immersive and interactive way. Traditional and fish-eye lens cameras are capable of capturing these images and then visualize them in various devices (e.g., HMD, Computer Screens, Mobile Devices). Although some major organizations utilize 360-degree panoramas for advanced visualization applications, most publications employ 360-degree panoramas for virtual tours only.

In the construction industry, applications of 360-degree panoramas were found in three categories: *Interactive Learning, Reality Backdrop to Augmented Information, and Visualize Safe* *and Unsafe Situations*. Student learning has been achieved by capturing remote, inaccessible or unsafe construction locations for interactive navigation and exploration of jobsites. Layers of information in the form of 3D models, 2D images, audio, and text, have been augmented into the backdrop produced by 360-degree panoramas to enhance the capabilities of this technique to communicate knowledge to the users. More recently, 360-degree panoramas have been used as a method to educate students about safe and unsafe situations, enhancing their awareness of potential hazards. Although 360-panoramas have inherent challenges due to capturing techniques utilized, improvements are continually being studied and implemented for many applications.

Future application of 360-degree panoramas within the construction industry lies within the fields of collaboration in the virtual space and photogrammetry. Telepresence interactions within 360-degree panoramas remain unexplored as a method that can simplify highly realistic remote interaction. Moreover, 360-degree panoramas have the capability of simplifying the photogrammetry capture process at it collects large data sets in each image. As the applications for 360-degree panoramas continue to be investigated in the Construction domain, researchers need to address the effectiveness, cost, and ease of adopting this technology for a variety of traditional construction-related applications such as progress monitoring, planning, and documentation.

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