G Model
CULHER-3264; No. of Pages 7
ARTICLE IN PRESS
Journal of Cultural Heritage xxx (2017) xxx–xxx
Available online at ScienceDirect www.sciencedirect.com
Elsevier Masson France EM|consulte www.em-consulte.com/en

Original article

Virtual tours and informational modeling for conservation of cultural heritage sites

Rebecca K. Napolitano*, George Scherer, Branko Glisic

Department of Civil and Environmental Engineering, Princeton University, 59, Olden St, 08540 Princeton, NJ, USA[1]

A R T I C L E I N F O

Article history:
Received 16 June 2017
Accepted 21 August 2017
Available online xxx

Keywords:
Documentation
Virtual tours
Informational modeling
Conservation
Heritage structures

A B S T R A C T

Thorough and organized documentation is crucial for conservation of historic structures. While photogrammetry, laser scanning and building information modeling (BIM) have enhanced 3D documentation in conservation, it is imperative that the method of documentation matches the requirements of the project. Present methods are efficient for certain types of projects. However, for projects that need to depict 3D conservation challenges, but do not have the budget or time for a 3D model, a middle ground does not exist. We present an intermediate solution, a workflow for virtual tour environments (VT) and informational modeling (IM) and we test this workflow on a case study. The VT/IM environment we created contains building plans, previous conservation reports, image galleries, databases about past interventions and short descriptions of the conservation issues at Princeton University. In this paper, we compare conservation reports using 2D plans against the VT/IM environment and we compare the time, cost and data management of VT/IM with methods of 3D documentation.

1. Introduction

Currently, a dichotomy exists in the methods for documentation and communication of building conservation data. Conservation challenges on a building are documented and recorded using 2D methods [1], such as digital mapping, or 3D methods, such as photogrammetry, laser scanning and building information modeling (BIM) [2]. Each of these approaches is useful for conveying data relevant to conservation challenges; yet, it is important to understand that the selected method must be appropriate for a project's scope, timeline and budget constraints. If a conservator is conveying information about how two parts of a building connect, a 3D model can prevent misunderstandings or miscommunication. However, if a 3D model is outside the scope, time and/or budget of a project, then an intermediate solution is needed. In this paper, we offer an intermediate approach, VT/IM (defined subsequently) and test this method on a case study.

1.1. *Existing methods for documentation and communication of conservation challenges*

Various programs enable a user to map 2D deterioration patterns on an image of a historic structure [1]. 2D methods of documentation can be useful for a project because of the smaller costs, time requirements and data files. However, 2D visuals can only capture a limited number of details. Moreover, multiple 2D graphics do not always produce a comprehensive and intuitive understanding of a building. For instance, the spalling of an arch could be due to poor drainage on a roof above; this is a 3D conservation challenge since there are problems on multiple faces of the building. The problem of poor drainage might not be recognizable from a 2D image of the damage. By illustrating connections between damage on multiple faces of a building, 3D environments can help conservators and building managers locate, document and treat problems rather than just symptoms.

For this reason, among others, photogrammetry [3,4], laser scanning [5,6] and BIM [2,7–9] have grown common in recent years. Photogrammetry is the process of digitally stitching together overlapping 2D images to generate a 3D model. Laser scanning emits a laser to the surface of a building, tracks the time needed for travel and reflection and then creates a dense 3D cloud of points representing the structure. BIM enables 3D models to have interactive links with relevant data [10]. Utilizing these methods, a user can comprehend the relationship between two different regions of a building in a way that 2D methods cannot easily facilitate. Aside from these methods providing preliminary documentation and routes of communication for conservation challenges, they also generate 3D, digital models that can be recycled and used for tourism, education or structural analysis. While these methods are viable for conservation, there are reasons they have not yet been adopted universally. (1) BIM uses a 3D model and not all

* Corresponding author.
E-mail address: rnapolitano@ymail.com (R.K. Napolitano).
[1] rkn2@princeton.edu.

http://dx.doi.org/10.1016/j.culher.2017.08.007
1296-2074/

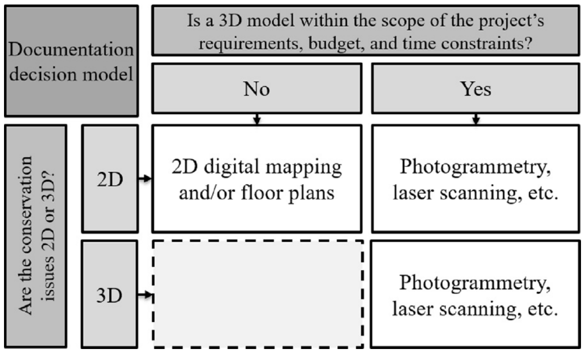

Fig. 1. Gap in current methods for efficient documentation and communication.

existing structures have an accompanying 3D model. There have been studies that outline a method for creating a historic building information model (HBIM) from laser scan point clouds. Yet, (2) due to the high costs of laser scanners and BIM software, this approach is not implemented widely [11]. While photogrammetry can generate point clouds at a lower cost, (3) they still have large data files that require further allocation of time and money for data management.

An intermediate documentation typology where a user can convey 3D information without a 3D model is crucial so that the scope and methods for documentation can appropriately match the needs and capabilities of the project as outlined by Letellier, 2007 [12]. Fig. 1 illustrates the gap in modern methods for documentation and communication of 3D conservation information. Methods exist for documenting:

- 2D problems if a 3D model is not appropriate for a project's constraints and needs;
- 2D problems if a 3D model is appropriate for a project's constraints and needs;
- 3D problems if a 3D model is appropriate for a project's constraints and needs.

Therefore, the question addressed in this paper is in what efficient ways can we convey 3D, structural conservation data and challenges without a 3D model?

2. Virtual tours and informational modeling (VT/IM)

Previous studies in construction management and building documentation outline approaches that combine virtual reality (VR) and information modeling (IM) [13–17]. In those studies, two main types of VR exist:

- those made of polygonal, 3D models;
- those made with spherical panoramas (also called virtual tours, VT).

VR environments made of polygonal, 3D models can be costly in terms of time and ability. These environments need a user to generate the polygons that make up the digital, 3D building, which is time consuming; as an example, the 3D model of a physical bridge in Fig. 2A took 12 hours to produce.

VT environments, however, are made of spherical panoramas, not 3D polygonal models. Created on consumer devices, planar panoramas (Fig. 2B) capture 360° around a user perpendicular to the camera lens. When a user views a planar panorama in virtual reality, the panorama is projected onto a cylinder with the user at the center; there is nothing above or below the user. Spherical panoramas, besides capturing 360° around a user, captures what is above and below the camera providing a more immersive environment (Fig. 2C). When a user views a spherical panorama in virtual reality, the panorama is projected onto a sphere with the user at the center; here the floor is below the user and the ceiling is above. The ability to capture what is above and below the camera is key in documenting cultural heritage structures since damage and underlying causes can be connected to faults on the roof or the floor. Multiple spherical panoramas can be brought together into a VT program that allows a user to virtually walk from one view of a room or building to another. For example, a user can be virtually looking at a room with a door (spherical panorama 1). If they click on the door in the VT environment, they can be brought to a new view (spherical panorama 2). The spherical panorama has advantage that it can be quickly made; as an example, the spherical panorama in Fig. 2C took less than 5 seconds to capture.

A tradeoff for this increased acquisition speed (several orders of magnitude) is that 3D models contain much more detailed information about the scale and more viewing flexibility than the VT environment. If a user scales a 3D model to the proper dimensions, a user can take accurate measurements digitally on the 3D model, without having to be on site. Additionally, in a 3D model, a user can choose their own perspective of the building. In a VT environment, since it is made of panoramic images, a user can only view the building through the selected perspectives where the images were taken. Considering the advantages and disadvantages of each approach, for projects where a 3D model is out of the budget and time constraints, only initial levels of documentation are needed and it is necessary to convey information about 3D space, VT environments could provide an efficient and practical method.

Having available relevant data, such as digital mapping of damage, reports and maintenance logs, is crucial for facilitating communication, developing informed diagnoses on cultural heritage projects, and augmenting the conservation. For this reason, a user should join a VT with some form or information presentation. Informational modelling (IM) is an approach that involves managing and visualizing digital representations of data; this approach can be facilitated through user interactions within the VT. For example, if a user in the VT clicks on an icon, they can view the latest conservation report. This inclusion of relevant data within the immersive VT environment can aid communication between a conservator and a building manager and facilitate informed diagnoses. Presently, no VT/IM workflow exists for building conservation. In this initial study, we provide a workflow for future implementation of VT/IM and test it on a case study. This workflow is appropriate for conservation projects where initial documentation of 3D conservation issues is essential, but a 3D model is outside the current budget and time constraints.

3. Levels of detail for documentation

It is important to recognize that VT/IM falls under the category of "initial recording" level and should not be used for detailed recording. As stated in recording documentation and information management for the conservation of heritage places, a publication compiled by a group of experts in the field of cultural heritage documentation in conjunction with The Getty Conservation Institute, there are three main levels of detail for heritage documentation:

- initial/reconnaissance recording;
- preliminary recording;
- detailed recording [12,18].