DIGITAL RECTIFIED IMAGERY: A SURVEY METHOD FOR DESIGN AND CONSERVATION PROJECTS

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Abstract. Faced with the need for understanding the physical context of the projects that come under their jurisdiction, architects, urban designers, and conservationists strive to secure congruent information. Practicing professionals are not set to carry out the collecting of information themselves. As information "users," they reach out to information "providers," including surveyors, photogrammetrists, and GIS specialists, to secure needed information. Information providers employ a gamut of methods to survey and document design project contexts, including land surveying techniques, stereo-photogrammetry, rectified imagery, laser scanning, and GIS. This study deals with digital rectified imagery (DRI) only and is aimed at creating an awareness of the method characteristics in the minds of the information users toward taking advantage of available DRI documentation opportunities offered by the information providers. As part of the methodology for this study, the authors have selected a subject building, captured a number of images through a digital camera, and processed the images using image processing software. The significance of this study resides in enabling the information users to understand RDI and to tap on its potential for consummating design, planning, and conservation projects.

1. Introduction

Acquiring and analyzing information about the context of design projects remains a hallmark for any environmental design and planning activity. Faced with the need for understanding the context of the projects that come under their jurisdiction, architects, urban designers, and conservationists strive for ways to secure congruent information. This phenomenon arises with any proposed building project on a vacant land, a planning project for a city area, or a rehabilitation project of a historic structure. The purpose and the scale of the project are in all cases dictating factors in characterizing the needed information.

Practicing professionals are generally aware of "what" and "how much" information is needed for the project in hand, but, with some exceptions, are not set to administer the collecting of information themselves. As information "users," design professionals and public agency managers reach out to information "providers," including surveyors, photogrammetrists, and GIS specialists, to secure needed information. Information providers employ a gamut of methods to survey and document design project contexts, including land surveying techniques, stereo-photogrammetry, rectified imagery, laser scanning, and Geographic Information Systems—all with relentlessly changing digital capabilities.

To make the best out of the needed information, it is appropriate for the information users (architects, urban designers, conservationists, and public agency managers) to be conversant with some methods of survey and documentation. Any method considered will, in its own way, add to the user's knowledge in this area. Because of the multiplicity and application versatility of the methods, it was necessary to keep the investigation of this paper within manageable and meaningful scope; in this case, the digital rectified imagery (DRI). Further, the user-friendliness attributes of the DRI compared to, say, stereo-photogrammetry or laser scanning, makes it more approachable for the beginning user and thus germane for the purpose of investigation.

This study is aimed at creating an awareness of the DRI method characteristics in the minds of the information users toward taking advantage of available DRI documentation opportunities offered by the information providers. Digital rectified imagery is a member method of the field of photogrammetry—defined broadly as the art and science of measuring from photographs or images. Like all survey methods, digital rectified imagery goes through data acquisition and data processing functions. As part of the methodology for this study, the authors have selected a subject building, captured a number of images through a digital camera, and processed the images using image processing software.

2. The Study Subject and Data Collection

The subject of the study was Hayes Hall, one of the main buildings on Bowling Green State University campus in Bowling Green, Ohio (Figure 1). Located at the center of the campus, and standing three stories tall, Hayes Hall assumes distinctive visual and historical prominence.

Built in 1931 as the Practical Arts Building and renovated in 1993 to house the Computer Science Department and computer related services, Hayes Hall accommodated a variety of functions in between. The origin of the building is rooted in the exponential expansion of the Bowling Green State College, as the institution was then called, to meet the goals associated with elementary and secondary educator training (Center for Archival Collections, 2005). The changing functions the building assumed since attest to the historical development of the Bowling Green State University as a leading institution in Northwest part of the State. In 1959 the building was officially re-named after Rutherford B. Hayes, the 19th President of the United States, and his wife Lucy Webb Hayes of Fremont, Ohio.

The surface configurations of the main façade lent themselves well to this rectification exercise. For one, the essentially flat surfaces of the building provided a classic subject example for rectification. Additionally, the fact that the façade consists of three segments falling in two vertical planes provided an opportunity for examining the application of rectified imagery for surfaces at different depths—from the camera location. However, this complexity (of multiple façade segments) together with existing tree obstructions to photography on site posed challenges. For the latter, it was necessary to take photographs from multiple positions in front of façade and subsequently to deal with multiple images in the rectification process.

Figure 1. Hayes Hall: main façade looking west

The data collection function consisted of planning and taking a set of fourteen digital color images for the main façade of Hayes Hall. Some considerations were observed in planning and executing digital photography of the subject: first, the camera optical axis was pointing as orthogonal to the façade as possible; second, moving objects in front of the façade were avoided; third, as the capture of the whole façade was presumed, multiple individual pictures were taken in order to get enough texture details; and fourth, image overlaps were guaranteed for building up mosaics.

Besides, an attempt was made to have all images taken under uniform day lighting conditions. This reduced the possibility for the captured images to have wide variations in their color and radiometric characteristics and, in turn, reduced the need for color and radiometric corrections forthcoming at a later stage of the rectification process. Such corrections help in maintaining color homogeneity throughout the composition.

3. Rectification Technique and Mosaic

Rectified imagery is based on the concept of bringing the surface of an object, say a building façade, and the plane of the image (photograph) into a parallelism condition. Rectification is the process that creates such condition so that the resulting image is measurable. Thus, this method is most appropriate when the building surface is geometrically flat. However, buildings having multiple surfaces positioned in different vertical planes can be rectified separately and, subsequently, all brought to collapse in one reference plane through digital manipulation.

The image rectification procedure can be carried out either with or without surveying control points on the objects. The former procedure requires the knowledge of a minimum of four feature positions (x and y co-ordinates) in object space. The two projective transformation (Wolf and Dewitt, 2000; Lerma, 2002) is the ideal geometric transformation applied in order to geometrically correct the photography into a planar object space. This is true with no regard to lens distortion. We assume here working with either cameras with negligible lens distortion or calibrated cameras with known set of additional radial and tangential parameters.

The latter procedure, without surveying control points, also requires the application of a two projective transformation to correct the tilt inherent in the original imagery. This procedure can be carried out either interactively and visually with digital image processing software, or through correcting the image shape geometrically, i.e. transforming a quadrilateral into a rectangle.

Figure 2 shows an image and its rectified version after rectification using the Image Processing Toolbox in Matlab v. 7.0.

(a)

(b)

Figure 2. Imagery of the façade upper left part: (a) original; (b) rectified

The obtained rectified image is correct in proportion but is not to scale because the effects of the non-linear parameters were considered with the calibration dataset or were negligible. Thus, Figure 2b needs to be made scalable in both axes. For this process, it is necessary to know at least two dimensions (preferably one horizontal and one vertical) on the monument in order to be able to measure accurately from the output (rectified) imagery.

There are occasions where the rectification procedure must be repeated for multiple images. This situation is typical when a) the monument is larger than the capturing image frame, b) the composition deals with several monuments and/or features, c) the need for accuracy mapping as well as the degree of detail is maximized and, d) when some outer features are placed in front of the target (for example, a tree or a streetlamp). Thus, a mosaic (or assembly of photographs forming a composite picture) is the result of multiple images. Applied to our subject, multiple image rectification resulted in a mosaic of rectified imagery.

Rectification becomes more challenging when the survey subject contains planar surfaces falling in more than one vertical plane. One vertical plane will be the "reference" surface, a surface where accurate measurements are meant to be taken. Features on surfaces in front of the reference surface and features on surfaces behind the reference surface will not be properly geometrically referenced. Hays Hall main façade contains planar surfaces falling in two vertical planes, one having the central part of the façade with the main entrance portal, and the second having two similar lateral segments flanking the entrance portal part. The second vertical plane was taken as the reference plane. The façade rectification procedure, at this juncture, continued as follows: a) completing rectification and mosaic for each of the three façade parts separately, and b) bringing the set of the three mosaics to form a collage by collapsing these mosaics into the reference vertical plane.

Figure 3 shows Hayes Hall's façade imagery as a collage of the three sets of mosaic imagery. The total number of images used to this point was eight.

Figure 3. The façade after rectifying eight images

The image (Figure 3) so far produced through rectification, mosaic, and collage has some distractions arising from partial concealment of façade surfaces by trees and from heterogeneity (diversity) of the image colors. These distractions were corrected as described below (Figure 4). The façade areas concealed by trees in front of the building were cleared by taking four additional images from different locations and rectifying these images over the established image mosaics. The color correction of the twelve final rectified images was manually conducted through stretching and adapting the color image histograms to one neutral pre-selected image.

Figure 4. The façade after rectifying twelve images

A final step has completed the rectification effort. The mosaic of the central part of the façade was rescaled to come into a fit with the surrounding rectified mosaic sets (Fig. 5).

Figure 5. The façade's final rectified imagery subsequent to rescaling of the central part mosaic

The final rectified imagery obtained in Figure 5 can be considered a textured elevation plan, enriched with all the image texture provided by the different digital photographs.

4. Applications, Advantages, and Use of Digital Rectified Imagery

Characteristics of DRI underlie the method's applications and advantages. Capitalizing on the potential of the method's use, however, begins with understanding the nature and relationship between information users and providers.

Digital rectified imagery has several applications in the context of architectural, urban design, and conservation projects. These include: a) providing dimensional measurements of essentially flat surfaces, including interior elevations and ceiling surfaces; b) aiding in surface material condition evaluation, including color distinction; c) providing synchronized imagery of extended surfaces such as street corridor elevations that can be used in urban studies or strip conservation; and d) aiding in generating 3D modeling of building masses.

Similarly, rectified imagery has several advantages. It can be an economic and relatively quick method of producing a record of sufficient accuracy for most purposes (Andrews et al, 2003). Furthermore, it involves a limited number of images for the documentation task compared with other techniques, such as stereo photogrammetry. Additionally, it requires the use of common, not necessarily high-end, computer hardware; and, it benefits from the availability of commercial software with digital image processing capability.

As has been established, the rectification procedure can be used for correcting tilt and scale in photographs and, accordingly, it fits flat objects or objects that can be easily decomposed into planar segments. Would rectification be of benefit in cases where object surfaces depart from flat or planar surfaces, such as undulating surfaces? It would in an extended process called differential rectification; this process makes the backbone of "orthoimagery," another method of recording. Produced from digital photographs, orthoimagery eliminates image displacement not only due to tilt but also to object relief. Therefore, this method, through the embedded differential rectification process, assures that all the image patches are rectified to a common scale.

As an extension to rectified imagery, orthoimagery is a demanding method, however. Producing measurable orthoimages requires the knowledge of both camera interior and exterior orientation parameters as well as a digital surface model of the whole object. Its operation involves specialized equipment, software, and personnel. Such stringent requirements render orthoimagery appropriate for tasks that digital rectified imagery cannot perform adequately.

What categories of information users and providers are there? An architectural firm and a city planning department are instances of users. Each has interest in obtaining information regarding the existing physical contexts in which their projects take place. The architectural firm receives commissions to renovate and add to extant buildings in its jurisdiction of practice. The city planning department deals with area planning and design on regular basis. Both organizations have reoccurring need for dimensional, condition, and polychromatic information on individual structures, urban cores, and historic areas.

Information providers hail from different documentation specialties. An interesting citation of these specialties comes to us from what becomes known as Recording, Documentation, and Information Management (RecorDIM) Initiative (a partnership between Getty Conservation Institute (GCI), International Council on Monuments and Sites (ICOMOS), and CIPA—joint Documentation Committee of ICOMOS and the International Society of Photogrammetry and Remote Sensing). Although addressing information needs primarily in the conservation field, the RecorDIM Initiative (GCI-ICOMOS-CIPA, 2002) identified a number of survey and documentation specialties that also apply to surveying of environment and objects in general: photography; photogrammetry (of which DRI is a constituent); surveying and GPS; 3D laser scanning; 3D modeling; geophysical prospection, etc.

As entities, information providers assume a number of organizational structures:

1. Documentation specialist groups: typically private enterprises that deal with survey and production of drawings and models of historic structures and sites using advanced digital technologies
2. Multi-purpose firms: design businesses that incorporate documentation and conservation studies together with other functions associated with architecture, interior design, landscape architecture, planning, and engineering
3. Conservation architects: professional architectural practices that specialize in historic architecture where survey and documentation are fundamental activities
4. Conservation–related public programs: typically large public programs with a mission to further documentation and conservation of historic resources (examples: the Historic American Building Survey of the U.S. Department of the Interior and the English Heritage sponsored by the Department of Culture, Media, and Sports)
5. University units: associated mostly with surveying or photogrammetry departments at engineering or technical schools

To cast a light on the nature of documentation information exchange, three projects involving the same information parties are summarized in Table 1. The provider party is the Department of Cartographic Engineering, Geodesy and Photogrammetry at the PolytechnicUniversity of Valencia,

Valencia, Spain; the user party is the Valencian Cultural Council. Rectification had been used in the three projects.

TABLE 1. Rectified imagery projects with project outcomes

Project description	Place and year	Project Outcome	Documentation method used
1. Documentation of two Neoclassic monastery inner-yards	City of Valencia, 1997	Scale drawings over rectified images; AutoCad hard copy drawings	Digital rectified imagery
2. Documentation of a Roman period floor mosaic	City of Enova, 2004	Scale drawings over rectified images; AutoCad hard copy drawings	Digital rectified imagery
3. Documentation of interior walls and ceiling of a train station space	City of Valencia, 2004	Scale drawings over rectified images; AutoCad hard copy drawings	Digital rectified imagery plus reflector-less total station

5. Conclusions

The objective of this study was to create an awareness of the DRI method characteristics in the minds of the information users toward taking advantage of available DRI documentation opportunities offered by the information providers. The principles, steps, and outcome of digital rectified imagery as discussed in the context of Hayes Hall documentation project provide a means of knowledge for architects, urban designers, conservationists, and agency managers—as information users. Not less important in this regard is the discussion's clarification of the applications and advantages of this method, and more pointedly, the categories of users and providers and the interaction between them.

The added knowledge to the design professionals' expertise will help not only in carrying out successful projects, but also in developing a decision making ability as to the appropriateness of using the method in the first place. Further, simple in structure but sufficiently telling, the DRI method, as discussed, is bound to turn the addressed audience's attention to the availability of other documentation approaches that can offer opportunities in their unique ways.

It is not unconceivable for certain user organizations, such as governmental conservation agencies or large architecture and engineering firms, to deliberate the introduction of DRI or, for that matter, other survey method as an in-house documentation practice feature. The results of this study are bound to feed right into this kind of deliberation.

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