Hybridized Measurement:

Interpreting historical images of Sagrada Família Church in Barcelona using CAD-based digital photogrammetry.

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This paper gives an account of the extrapolated use of digital photogrammetry undertaken by the Spatial Information Architecture Laboratory (SIAL) in the pursuit for new interpretations of historical images at the Sagrada Família Church. The work is an extension of the research activities undertaken as part of the Australian Research Council (ARC) Strategic Partnerships with Industry – Research and Training (SPIRT) project New onto Old : 3D flexible computer modelling to aid heritage building restoration, recycling and extension, where digital photogrammetry was first explored as a measurement tool for non-specialist implementation. The research makes use of the link between Computer Aided Design (CAD) and digital photogrammetry in a reverse manner, using built spatial data to produce orthographic rectified images of what was intended from the historical drawings and models of the architect Antoni Gaudí (1852-1926).

Keywords*: CAD-based digital photogrammetry, spatial information, measurement, interpretation.*

Introduction

This paper presents work in progress of an application of CAD-based digital photogrammetry for the purpose of providing further interpretation of historical images of drawings and models of the original work of the architect Antoni Gaudí (1852-1926). The projects discussed are the Passion and Glory Facades of the Sagrada Família Church in Barcelona. The work contributes to the broader effort of the research team to resolve the intended surfaces from a limited supply of information in order for construction to advance.

Digital photogrammetry, using software to make measurements from images, is now available in comparatively low cost commercial packages. The interdisciplinary combination of the fields of computer vision and photogrammetry has served to enlarge the scope of data acquisition and processing architects are able to deploy on a project. This is by making generally available the ability to generate three dimensional information through processing multiple two dimensional images. This can be accomplished without expensive recording equipment or analytical plotters. Concurrently, architectural description, is undergoing a profound

transformation, one that other design disciplines producing physical objects have generally been through. It is a paradigm shift from the two dimensional plane into three dimensional space. This spatial data, its acquisition, manipulation, visualisation and extraction, present challenges and opportunities across the entire construction industry including architectural practice and education. CAD-based digital photogrammetry refers to the integration of CAD and photogrammetry. A summary of its development and different approaches is discussed by van der Heuvel (2000).

The Spatial Information Architecture Laboratory at RMIT University (SIAL) has been investigating methods of three dimensional measurement and data collection, recording elements of the Sagrada Família using digitizers, laser meters, three dimensional laser and optical scanners and digital photogrammetry. Extracting satisfactory facsimiles of Gaudí's combinations of ruled surfaces has challenged the scanning tools, most of which have their origins in the gaming and film industries. (Burry, Burry, Dunlop & Maher 2001).

Of the Sagrada Família's three facades, the Nativity Façade was the only one to be constructed during Gaudí's lifetime. Its neo Gothic origins were inherited by Gaudí from his predecessor Francesc de Villar and are evident on the bare interior which stands awaiting further carving and statues upon its empty pedestals in striking contrast to the exterior that is covered with decorative finishes Gaudí daubed first with plaster and gradually replaced in stone. The Passion Façade, partially completed in the 1970's, represents the introduction of the geometry developed by Gaudí to construction. The Glory Façade, which is to be the main entrance is yet to begin. Surveys of the existing built work at the Sagrada Família are essential, mainly due to the destruction of the drawings during the Spanish Civil war.

The genesis for this research began during a site visit when amid the ongoing construction activity, direct access for measurement was not available to the interior of the Nativity Façade, being partially obscured by levels of scaffolding and construction platforms. To date detailed photogrammatric surveys for the Passion Façade and the Apse have been carried out by the Topography department of the Universitat Politècnica de Catalunya (UPC). With further survey work not imminently scheduled, CAD-based digital photogrammetry is being explored as a technique for gathering three-dimensional data through the use and adaptation of laser measurement and digital photography, both employed by the technical office at the Sagrada Família (figure 02). It is envisaged the results of the research will both serve to extend the use of such tools and skills on site, and the retrieved spatial data will be used to acquire three dimensional digital models in the form of proxies of the existing building fabric, to then establish the relationships and associations in parametric software between the old and the new. Such methods lie beyond the site measurement skills of most architects but may be highly valuable when contrasted as an intermediary with the more complete and accurate surveys of the UPC.

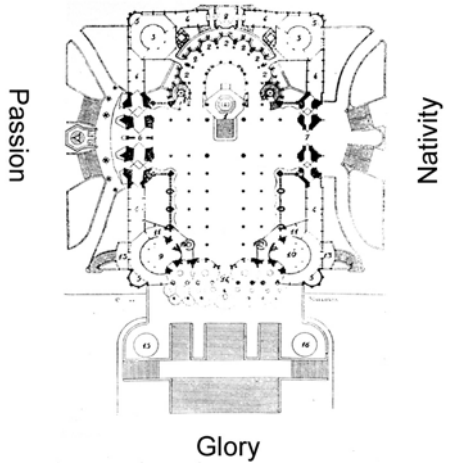


Figure 01. The three facades of the Sagrada Família church.

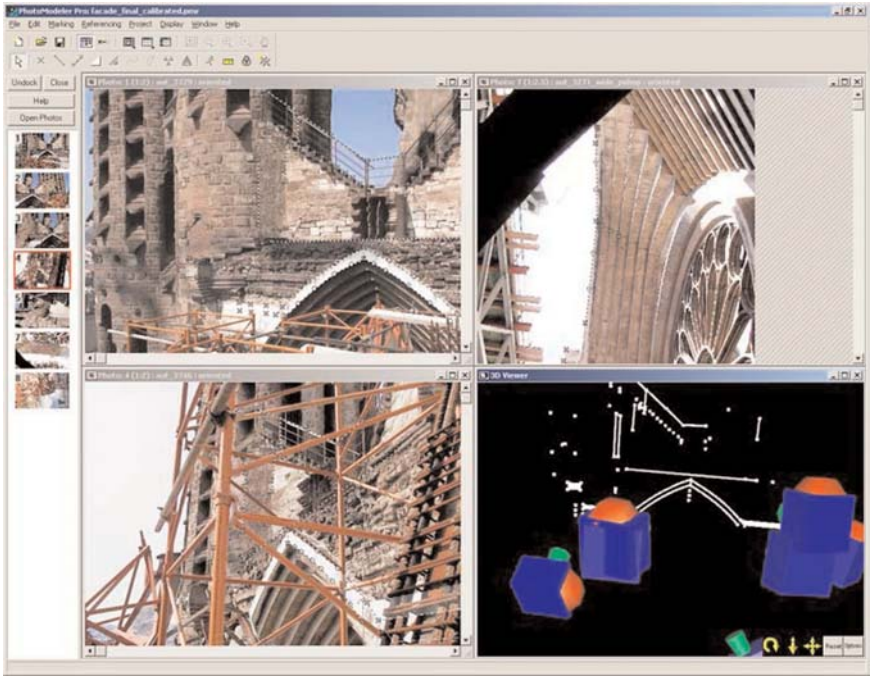


Figure 02. The Nativity Façade Photomodelor Pro project.

The development of CAD-based digital photogrammetry as an interpretive tool discussed in this paper differs from our research on the Nativity Façade and other similar approaches such as Bae *etal* (2002). It was undertaken with the partial absence of measurable built structure. The Passion Façade, is a 'mixed media projection' of the image of Gaudí's drawing of the Passion Façade using survey data, while the Glory Façade is attempted through various means including reconciling original images with a present-day plaster model.

The Passion Façade and the original 1917 drawing

The Passion façade as it is today (figure 03) was constructed between 1954 and 1977. Current work has been for the near complete rose window (Burry, Burry and Fauli, 2001), and investigations for the colonnade, consisting of a column and gable assembly above the cornice, of which only a single photograph of a drawing for the façade exists. This drawing is by Gaudí, dated 1917 (figure 04) and indicates the use of forms derived from the combination of ruled surfaces which were in the process of development during the last twelve years before his death in 1926. It is the primary source for the entire façade.

During the 1970's a 1:25 plaster model of one side of the colonnade was interpreted and completed under the direction of one of Gaudí's former collaborators Puig i Boada and completed by Cardoner and assistants during the 1980s (figure 05). This model has been topologically digitized by the SIAL and the columns are currently undergoing a process of generative development (Burry, Burry, Dunlop, Maher 2001). The half model introduces a

Figure 03. Passion Façade in 2001

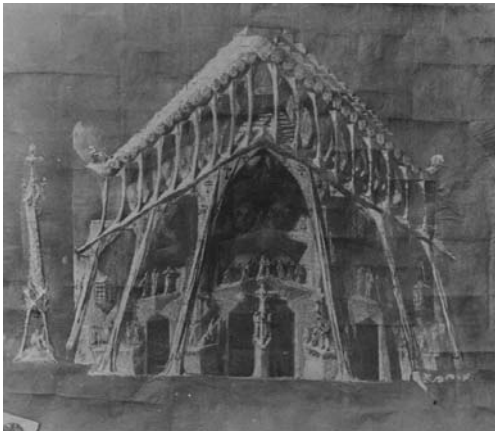


Figure 04. 1917drawing by Gaudí of the Passion Façade

Figure 05. 1:25 Plaster model of the Passion Façade colonnade

degree of ambiguity to the question of the symmetry of the entire composition.

The original photo, approximately eighty years old, clearly shows an architectural elevation almost perpendicular to the projection plane. It is assumed to be taken with a bellows camera, although little information about its purpose or exact date are known. Of particular interest is to understand the relationship of the camera to the photo of the drawing. If survey data from the 3D model could be used to orient the drawing further interpretation could be made of its apparent asymmetry. Was it intentional or a result of the camera angle? Did the drawing take into account the fall of the site and what is the difference between the drawing and what has been built?

Interpretation

The aim of the project was to create an orthographic image of the original Gaudí drawing – an architectural elevation. Where it is impossible to

regain information, assumptions have been made and their declarations serve to weigh the importance of the work in relation to current body of knowledge and state of construction. The hybrid nature of the rectification locates three dimensional coordinates from the actual building and then projects through the drawing to the object itself. The cornice in the drawing is treated as though it were a photo of the actual built work. Figure 06 shows a comparison of an orthographic image of the existing Passion Façade by the UPC, with Gaudí's original drawing.

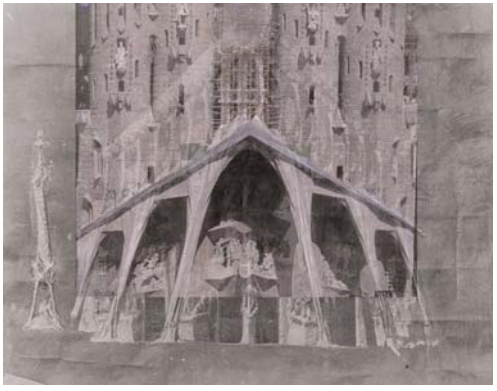
PhotoModeler Pro by EOS Systems Inc. was used for this research. A single photo project was established and control points, three-dimensional points of known location, were imported from the existing features in the UPC survey (figure. 07). Corresponding points along the edges of the cornice, the doorway and the cornice columns were identified.

The absence of the fidicual properties of the original camera used were solved by processing the project as an inverse camera operation. Such an operation establishes parameters for the unknown camera using the imported control points as constraints. In this situation the camera is located as though it were photographing the actual building. It is unknown whether the drawing was on an angled wall or within a frame. To eliminate distinguishing between perspective within the object itself and the perspective within any 'out of plane' relationships of the drawing it was assumed the drawing was hanging planar. The position of the camera was identified as rolling 1.35 degrees about its direction vector and being 2.80 degrees from centre vertically and 0.83 degrees from centre horizontally.

Planar control points were identified and used to create and export an orthographically rectified image (Figure 10) or elevation.

The orthographic image and its possible interpretations

This research indicates that through this unorthodox use of photogrammetry another interpretation is possible. The resultant image opens several avenues of interpretation of the colonnade. Most notably is the effect of symmetry and alignment. The drawing which appears at first to be more suggestive of a symmetrical relationship of columns is now indicating a more pronounced 'stagger'. With Gaudí's interest in forms derived from nature and the human body, the similarity could be described as to a rib cage. The difference in height evident in the columns will inform the development of the SIAL's parametric modelling design for the columns.



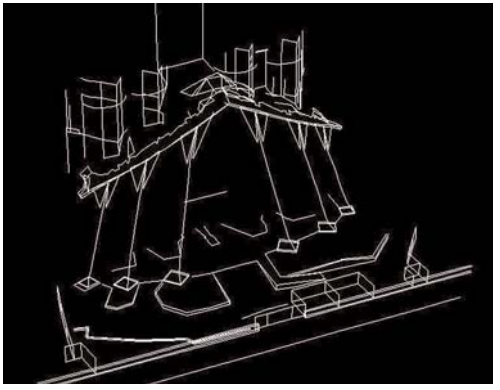


Figure 06. Comparison of 1917drawing by Gaudí with the UPC orthographic image of the Passion Faćade

Figure 07. Wireframe model from the UPC survey used as control points for the project

Figure 08. Camera station location relative to the image.

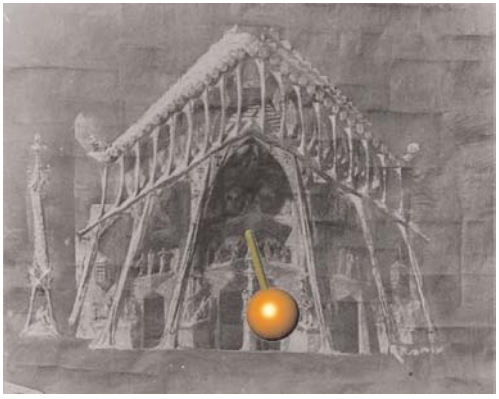


Figure 09. Front view of camera position relative to the image

The Glory Façade and the original model

The Glory Façade, celebrating the resurrection, is the main entrance to the church. It is also the least documented of the facades with only two photographs of an original model by Gaudí in existence (Figures 11 & 12). The model shows an arrangement of sixteen spires of hyperboloids of revolution surrounding four bell towers, whose proportions have been identified with those throughout the church. The project follows that of the Passion Façade and the primary investigation was to compare the photos in isolation and generate an orthographic image of the original model. However the absence of possible processing constraints (photos, axes or control points) inherent in such geometrical forms pose significant hurdles to retrieving spatial data. In isolation there is little prospect of extracting any information from the images alone, due to the lack of camera information and the resultant perspective of the forms.

The physical location of the original model can be discerned by the architectural elements in the photograph. These were re-established as control

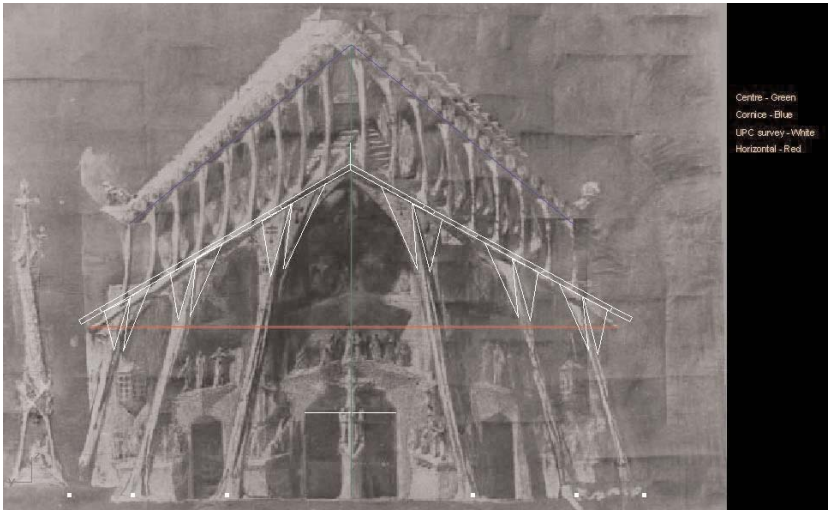
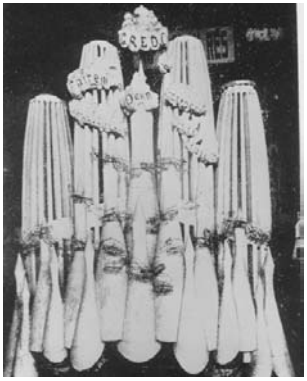


Figure 10. Orthographic rectification of the image



Figures 11.& 12. Images of the original model of the Glory Facade.

points through the creation of a simulated model of the scene, but failed to produce a result. In the future actual identification of the space may allow information to be gathered on the possible location of the camera and the model and their relationship to one another.

Another hybridized method of referencing external data is now in development. There is a present-day plaster reconstruction of part of the Glory Façade model that has been made by the Sagrada Família workshop (Figure 13). Measurements have been clearly taken from the photographs as the markings are still visible. Using CAD-based digital photogrammetry a three-dimensional digital model was generated by the SIAL of the plaster model to check the validity of deriving the surfaces in such a manner. Combined with a prior geometrical the digital model was found to be dimensionally accurate by comparison.

Several iterations of the project were carried out initially with only the two photographs. To enhance the level of constraint, later iterations of the project included the addition of the locality data and finally three dimensional control points from the present day model. PhotoModeler would in fact only process once camera information was given, and the results of the Passion Façade were used. This is not a true representation of the unknown camera though, as the camera used was most likely a camera which would not have repeatable settings.

The project as reported is still a work in progress. A new variation to the methodology, in order to build a more comprehensive database of the model and its environment is proposed. Scanning and digitizing tools will be used to capture highly accurate and detailed information of the present day plaster model generating control data to orient the original photos. Initial research has indicated the possibility of processing a successful project. Such a method would introduce a second abstraction, using a present day model – itself an interpretation to generate a further interpretation of the original. Such a method though, would embody the transmitted knowledge of Gaudi's collaborators with the skills of the technicians in Sagrada Família workshop; approaching a digital craft through the combination of the original intention with the experience of the hands that make the objects.

Conclusions

The research shows an interpretive approach through the development of the link between low cost commercial digital photogrammetry software and CAD. It may broaden the use and the way architects deal with computers and design, in this case by furthering engagement with the object for the purpose of a hybridized measurement.

Figure 13. Present day model of part of the Glory Facade.

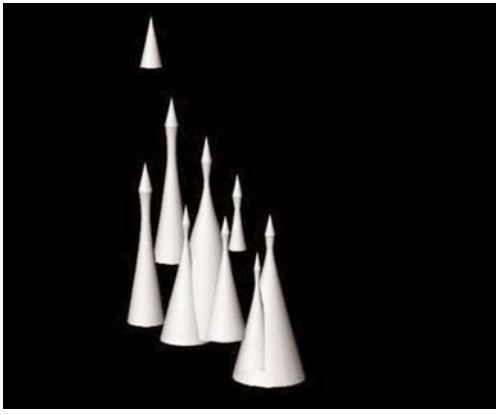


Figure 14. Three dimensional model retrieved from the plaster model.

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