

ON RECOVERING THE SURFACE GEOMETRY OF TEMPLE SUPERSTRUCTURES

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Abstract. The application of computational techniques to the analysis of heritage artifacts enables scholars to bring together diverse fragments of surviving evidence, construe “best-fit” strategies and unearth implicit or hidden relationships. This paper reports a hybrid approach for recovering the surface geometry of temples. The approach combines physical measurements, architectural photogrammetry and generative rules to create a parametric model of the surface. The computing of surface geometry is broken into three parts, a global model governing the overall form of the superstructure, local models governing the geometry of individual motifs and finally the global and local models are combined into a single geometry. In this paper, the technique for recovering surface geometry is applied to a tenth century stone superstructure: the temple of Ranakdevi at Wadhwan in Western India. The global model of the superstructure and the local model of one individual motif are presented.

1. Introduction

While the digital reconstruction of cultural heritage is an established area of work, advances in computation provide new ways to explore, analyse and explain the genesis and evolution of historical artifacts. The application of computational techniques enables scholars to bring together fragments of evidence, construe “best-fit” strategies and unearth implicit or hidden relationships.

This paper reports a hybrid technique for recovering and explaining the geometry of temples. The constructive and implicit relationships in the surface geometry are reconstructed based on the literature on temple geometry (Kramrisch, 1946; Chandra, 1975; Meister, 1979) and field studies of temples (Datta, 1993; Datta, 1994). The approach combines architectural photogrammetry and rule-based generation to create parametric models of the surface. The computing of surface geometry is broken into three parts, a global model governing the overall form of the superstructure, local models governing the geometry of individual motifs and finally a parametric model of the surface geometry combining the global and local models. The technique is applied to the reconstruction of surface geometry of a tenth century stone superstructure: the temple of Ranakdevi at Wadhwan in Western India. The resultant

global model of the overall form of the superstructure, local models of individual motifs and the reconstruction of the surface geometry are presented.

2. A hybrid approach

The computing of surface geometry is broken into three parts, a global model governing the overall form of the superstructure, local models governing the geometry of individual motifs and finally a parametric model of the surface geometry combining the global and local models.

The global model of the surface is constructed by using ruled-based generative modeling. Horizontal and vertical control geometries of the surface are derived from textual (canonical) accounts in the temple literature. The global model is then subdivided into four component motifs. Each component motif is modelled as a detailed local model using close-range architectural photogrammetry. Finally, the global surface is tiled with the motif models.

The approach comprises the following steps:

1. A global model of the superstructure using rule-based generation;
2. Local models of motif geometry;
3. Parametric tiling model combining the above.

The computation of each of the above is described in the following sections using the surface geometry of a tenth century stone superstructure: the temple of Ranakdevi at Wadhwan in Western India, built c.960 AD (Figure 1).

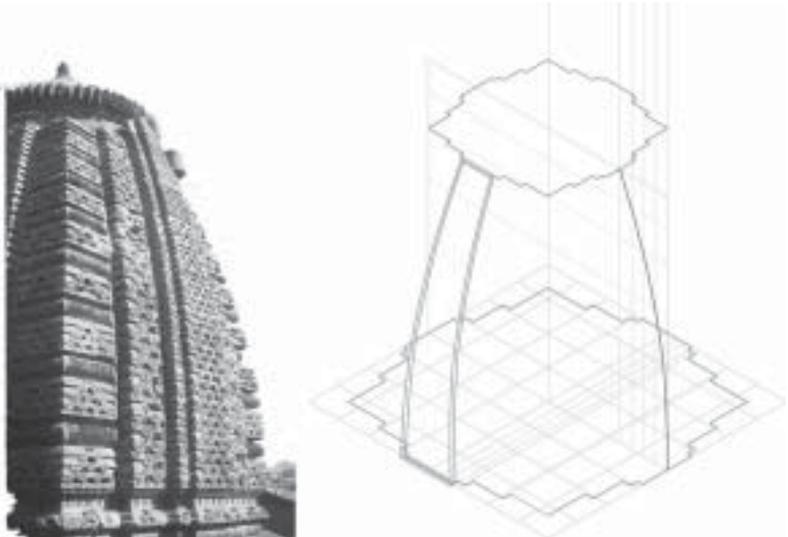


Figure 1. Surface Geometry of the temple of Ranakdevi at Wadhwan. The example develops the tiling geometry of the central spine (left). Surface subdivision of the superstructure is controlled by the control profiles in plan and in section (right).

2.1. RULE-BASED GENERATION

Textual and graphic descriptions of mathematical and geometric constructions governing the form of temple geometry are described in the literature (Kramrisch, 1946; Chandra, 1975; Meister, 1976; Meister, 1979). These descriptions can be codified as rules and constructive methods to generate classes of formal geometry corresponding to the actual monuments. The models generated by encoding these rules can serve as a useful and generic backdrop to the analysis of data from field studies of individual monuments.

This paper focuses on the geometry of the superstructure and develops its form based on encoding two control profiles. The horizontal profile is based on the extrusion of the profile of the ground plan in the vertical direction. A grid diagram of $8 \times 8 = 64$ squares, is used to generate the ground plan and control measure in the configuration of stone temples. Meister (1979) shows how the horizontal profile depends on the number of offsets and the proportional relationships between each offset based on the subdivision of the sixty-four square grid. The extrusion in the vertical direction is controlled by a curved profile. This profile establishes the degree of curvature of the superstructure. Following Kramrisch (1946), Datta (2001) shows how the control curve can be generated based on textual descriptions.

The global geometry of the superstructure can thus be characterised by a combination of its horizontal and vertical profiles (Figure 1). Since the profiles are governed by rules, a large class of profiles, and by extension, superstructure forms, can be explored.

2.2. MOTIF GEOMETRY

Many hybrid approaches have been proposed in the literature for recovery and reconstruction of model geometry from photographs. DIPAD (Streilein and Niederöst, 1998) combine digital photogrammetric methods with CAD models in an a priori and a posteriori mode. The Facade (Debevec and Malik, 1996) system combines model-based geometry with image-based rendering to reconstruct architectural scenes from photographs. Facade combines photogrammetric modelling with a model-based stereo algorithm to develop architectural scenes and renders these scenes with view-dependent texture mapping. In our approach, the 2D and 3D information is extracted from photographs using close range architectural photogrammetry. One drawback is that object information is recovered on a low, unstructured level, a collection of points (point cloud), edge information and as an aggregation polyhedral primitives. To recover elemental, structural and constructive geometry information, it is necessary to convert the vector data acquired from photographic analysis into profiles, surfaces and solid objects. To accomplish this, the metric information of the motif geometry are then imported into a modelling environment and to create a 3D model (Figure 2).

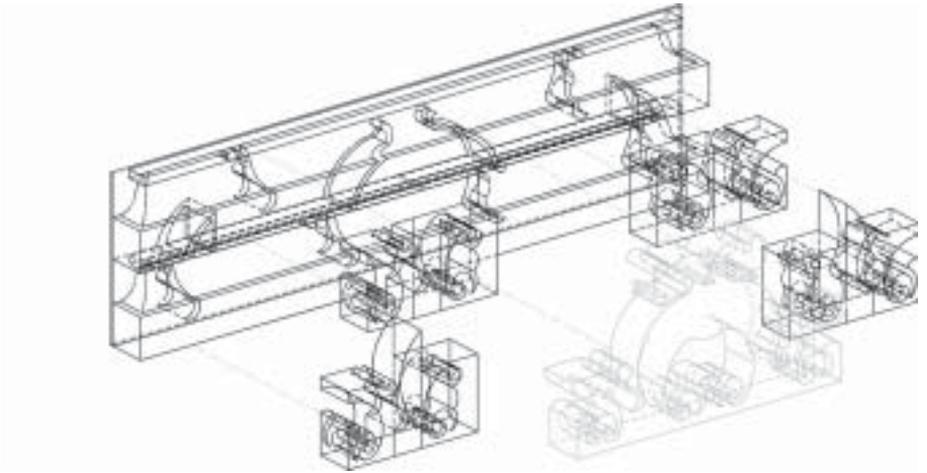


Figure 2. The motif geometry of the central spine is recovered into a three-dimensional tile made of two interlaced segments, a backplate and units composed of carved patterns.

2.3. COMBINED PARAMETRIC MODEL

In the final stage, the models obtained from rule-based generation of the global model and photogrammetric reconstruction of motif geometry are combined. The parametric surface is developed using the global model as a skeletal surface and this skeletal surface is tiled with a sequence of scaled units using the local geometry of the motif (Figure 3). The shape and appearance of model entities are derived by parameterization, and generative modelling to support multiple variations from the same model geometry. The recovered tile geometry is then combined into a single



Figure 3. Parameterised model of surface geometry of the superstructure. The recovered tile geometry is then combined into a single model. This forms the basis for the repetitive tiling of the surface using a scaling function based on the curve profile shown in Figure 1.

model. This forms the basis for the repetitive tiling of the surface using a scaling function based on the curve profile shown in Figure 1. A parametric model of the three-dimensional surface is developed based on geometric sequences measured from the example shown in Figure 2.

3. Discussion

The paper describes a computational technique for reconstructing the surface geometry of stone temple superstructures. The reconstruction presents new possibilities for interpreting the formal and geometric basis of temple form. The combination of techniques described here in our hybrid approach, shows a dramatic improvement from past results. The example demonstrates the principles in the context of one type of tenth century superstructure, one that follows the profile of the offset in plan, and a curve in section. The advantage of this process is that changes in any stage due to revision of assumptions or testing of alternatives can be easily propagated between the models. Further, since the models of the surface geometry are based on generic constructions, they can easily be transferred to other, similar classes of form (e.g. a related but different school of temple building). Finally, the use of constructive geometry as a generator allows researchers to study the evolution of temple architecture form over time, as a series of related instances of arising out of similar techniques.

The digital models of the tiles are manually created, and motif geometry is particularly tedious and time consuming to reconstruct due to the complexity of the shapes. There is scope to further automate this process by using laser scanning techniques. To derive the surface geometry of more complex superstructures based on tiling motifs, further work is necessary in this domain. Tools that combine interactive manual modelling (direct manipulation) with formal methods for solving tiling problems (solvers) offer one possible direction to extend the work described in this paper.

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