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Procedural Parametric Modeling of Balinese Architecture

Abstract
Traditional Balinese architecture is based on ancient Bali-Hindu philosophy. The underlying architectural principles are complex, containing intrinsic "parametric rules" based on both a philosophical and a building tradition. The parameters are in relation to the religious belief system as well as being derived from the bodily dimensions of the "head" of a building. These parametric rules were based on literature and additional assumptions, and then implemented in a digital simulation using a shape grammar. In this project, we aim at a procedural parametric model of traditional Balinese architecture that includes the following aspects: a) verification with photogrammetry b) comparison of Balinese design rules with other related cultures, and c) adaptation for contemporary architectural design needs.

Keywords: Procedural modeling; parametric modeling; traditional Balinese architecture; intangible heritage; photogrammetry

1. TRADITIONAL BALINESE ARCHITECTURE

Ancient Balinese knowledge and traditions have been conserved in palm leaf manuscripts, so-called lontar. Contents on the lontar do not solely cover architecture, but a huge variety of aspects of human life including religion, healing, arts, history, and so on. The parts covering building principles are referred to as Asta Kosala-Kosali (Bidja 2000). Traditional Balinese architecture is known for its extensive rules ranging from the design of architectural elements to the layout of entire villages. It is based on ancient Bali-Hindu philosophy which can be observed in traditional built environments on Bali (Bidja 2000; Budihardjo 1995; Gelebet et al. 1981; Davison 2003).

Preservation of architectural traditional knowledge by contemporary means could go beyond mere digitization and be made more useful by applying a formalized approach. Ideally, this formalization should incorporate the design intent as well, which represents the intangible aspect of a building tradition. Current formalization of architectural heritage as in (Müller et al. 2006), put their main focus on capturing the appearance rather than the underlying philosophy and design principles.

The underlying philosophy of Balinese architecture is reflected in seven building principles (Budihardjo 1995):

1. Hierarchy of space,
2. Cosmological orientation,
3. Balanced cosmology,
4. Human scale and proportion,
5. Open air "court" concept,
6. Clarity of structure,
7. Truth of materials.

2. DIGITAL SIMULATION OF BALINESE DESIGN RULES

We took a closer look at a single housing compound, a rumah, and the shape grammar (Özkar & Stiny 2009) rule set for constructing it. It starts with the creation of a suitable floor plan according to the orientation scheme and the distance rules. With this, the traditional building principles in general, and the requirements for a house compound in particular were incorporated. Parameters have been introduced for the rules as means to take into account some context of their application. Examples for parameters (of a pavilion) were: roof construction, number of enclosing walls, number of supporting columns, door, windows, roof tiling.

Aside from reconstructing a single building exactly, one of the great advantages of procedural modeling lies in the ease of generating a vast number of similar buildings, thereby producing "hypothetical" rumah in the same historical tradition according to their building principles.

A new aspect of our approach within procedural modeling was in preserving the design intention as well as the appearance, thus including both, tangible and intangible aspects of architectural heritage. Balinese traditional architecture has a rich base of intangible aspects. These are reflected in the orientation and dimensioning of buildings, for example.

3. ANALYSIS, VERIFICATION AND EXTENSION OF THE DESIGN RULES

Our project idea is to analyze traditional design rules of Balinese architecture to protect this intangible heritage with modern digital means.

Figure 1

Figure 2

Fig. 1 & 2
Traditional Balinese house compound (rumah) in Batuan. (Photo: Ferschin & Di Angelo)

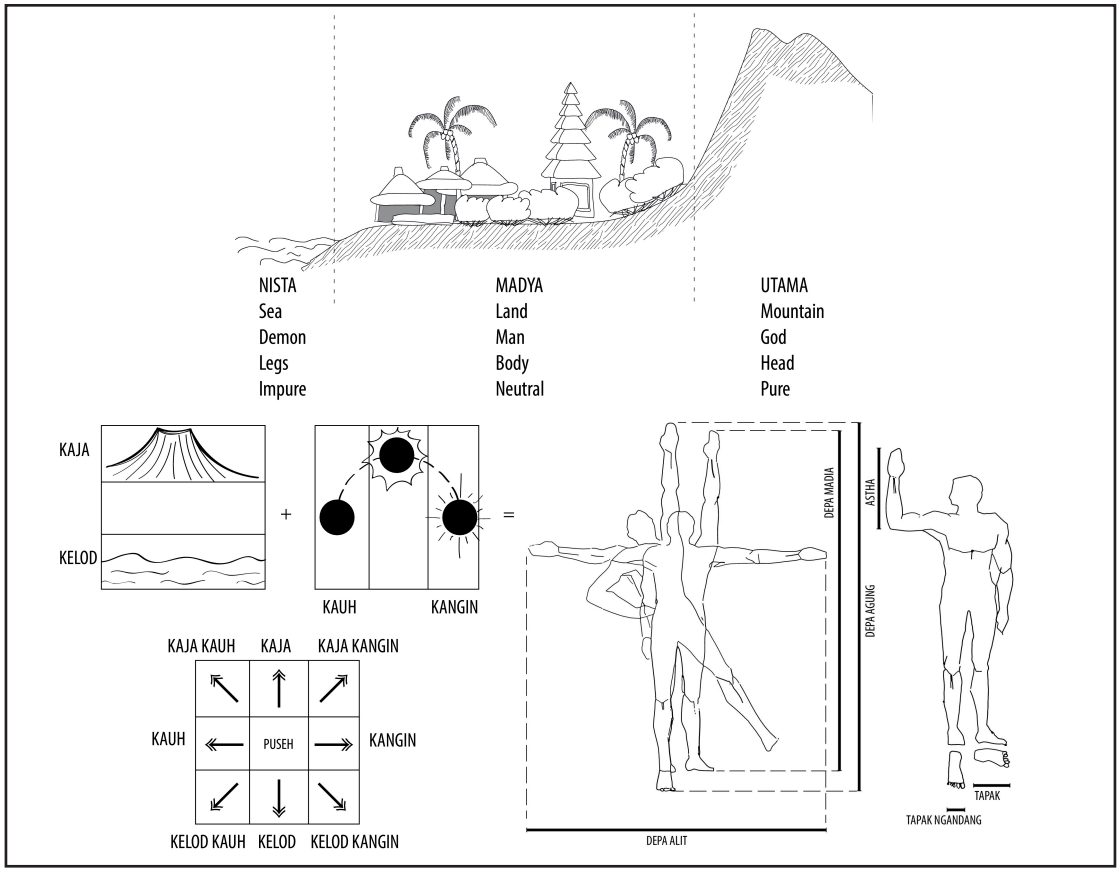

Figure 3

Furthermore, we aim at extending these rules to make them applicable for contemporary needs.

3.1. Understanding the past

The aim of the project is to analyse traditional Balinese architecture in greater detail, in order to preserve the knowledge of building traditions as a precious cultural background. The analysis includes spatial arrangement as well as dimensioning and proportioning of residential buildings and particular building elements. The design rules of Balinese architecture are based on the proportions of the human body and Hindu cosmology. Highlighting exceptions, differences and contradictions of the various sources aims at understanding the design philosophy in its practical application. The investigations should provide a comprehensive overview of the existing design rules and construction principles.

As traditional Balinese architecture can be seen as an important holistic and sustainable system it is important to embed it in a larger context of architectural theory. Therefore a comparison of the Balinese system with other design systems and measurement rules is of great importance. The analysis will focus on similar cultures, mainly on other Hindu building tradition from Sulawesi, Sumatra and India, such as the Vastu Shastra. Additionally it will incorporate European architectural history with commensurable measurement rules using human proportions as basis of a design system, such as Vitruv (2006) and Leonardo da Vinci.

Photogrammetric surveys on Bali will be used to generate a collection of elements and materials of existing traditional Balinese buildings. We intend to survey reference buildings from literature if possible. Photogrammetric methods should provide a segmentation of building elements with semantic attributes. This aspect represents an interface to the integrated information platform TJOA. Moreover, this relates to the cartography GARTNER project.

The rules that can be derived from the literature analysis will be transformed into a procedural parametric model of traditional Balinese architecture in a suitable digital design framework. This model should be conformed to the Bali-Hindu philosophy and semantically annotated in both, traditional and contemporary architectural terminology. This aspect represents an interface to the integrated information platform TJOA.

The developed procedural parametric model of traditional Balinese architecture will be verified by the application of photogrammetric methods. The data sources for the verification process will be either historical photographs or contemporary photogrammetric surveys. This should indicate if and what kind of design rules were actually used. Additionally, we should be able to extract parameters from the photogrammetric analysis for the rules. Finally, this should generate an iterative process of model creation and verification, leading to a refined methodology and model.

For the communication and explanation of our procedural parametric model, a reconstruction of a surveyed building with photogrammetrically extracted building parts will be provided. Additionally, we will create a visualization of the underlying rule set and its parameters.

3.2. Designing the future

The project aims not solely at understanding the past but also at contributing to a possible future. Within the framework of preserving and protecting cultural heritage the traditional design rules

Fig. 3
Building principles: hierarchy of space (upper), cosmological orientation (left), human scale and proportion (right). (Graphic: Ferschin & Di Angelo)

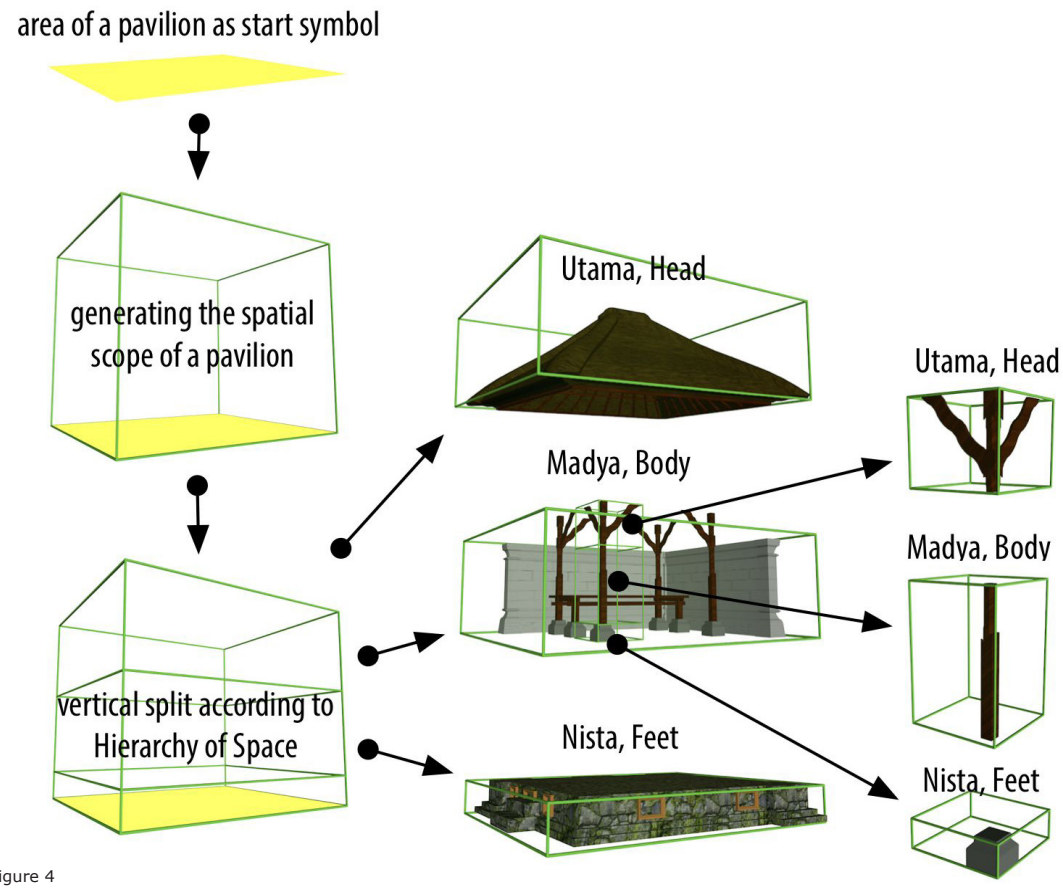

Figure 4

and construction principles can be extended for contemporary architecture and modern comfort. Based on the evaluation of today's needs and values classical knowledge shall be adapted for new purposes.

Based on the analysis of contemporary architectural needs, we will extend the procedural parametric model for contemporary Balinese architecture in an evolutionary fashion while maintaining the traditional design philosophy.

Furthermore, it would be desirable to have a map of buildings, materials, construction methods. This aspect relates to the cartography project.

As a design support for contemporary architects we will develop a concept for the implementation of generative design aids. This summarizes our approach towards the overall goal of transforming traditional architecture to contemporary needs.

4. APPLIED METHODS FOR THE PROJECT

Deepened research based on written sources and oral tradition will be combined with fieldwork, building surveys and the analysis of historical photo material. The extensive studies of Balinese building tradition are complemented by the research of similar systems with related cultural background.

The adaptation of traditional design rules, construction principles, handcraft, and use of materials for under today's conditions builds on the abundant knowledge of the past and opens up new horizons.

On the technical level, we will apply the following methods:

- Analysis of traditional construction methods and applied rule systems with regard to their derivation from the measurements of the human body
- Cultural comparison of the procedural parametric model with related traditions
- Digital collection of an algorithmic rule set for the calculation of proportional reference systems
- Implementation of a procedural parametric model of Balinese architecture (traditional and contemporary) in a suitable digital design framework
- Model verification and adaptation (photogrammetric aspects)
- On-site building survey by photogrammetry
- Photogrammetric collection of building elements
- Segmentation (automatic interpretation) of relevant elements (walls, pillars, roofs, base, etc.), e.g. on geometric criteria, texture (materials: wood, stone, palm leafs)
- Extraction of parameters from the building surveys utilizing the procedural parametric model
- Comparison of parameters obtained by photogrammetry with those from literature analysis
- Extending and learning design rules from data
- Documentation and visualization of formal design rules

Peter Ferschin

Ass.Prof. Dipl.-Ing. Dr.techn. Dr. Peter Ferschin is assistant professor of Digital Architecture and Planning at the Technische Universität Wien (TU Wien) in Vienna, Austria. He graduated in computer science (computer graphics). 1991 he worked at PreDoc researcher at light simulation on a supercomputer. 1994 he became university assistant at the Institute of Architectural Sciences - Digital Architecture and Planning. He wrote his Ph.D. thesis on the subject of light simulation and received his Ph.D. 1996 from TU Wien. At 2007 he became assistant professor at the Institute of Architectural Sciences - Digital Architecture and Planning. Since 2014 he became member of the interdisciplinary centre for geometry and computational design, where he leads the digital architecture group.

His research interests are in parametric procedural design, 3D reconstructions of architectural heritage, augmented architecture, spatial- temporal information systems and digital exhibitions. Peter Ferschin thus frequently works in interdisciplinary manner together with experts from geometry, computer science, architecture, civil engineering, archaeology and art.

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Monika di Angelo

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She spent research visits in Sydney (UWS, 2004/2005), Melbourne (RMIT, 1996/97), Tokyo (CRLabs, 1992/93), and new Haven (Yale, 1989). Recent research interests include Digital Heritage, with a special focus on architectural heritage documentation, visualization, and communication.

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Fig. 4
Spatial composition according to hierarchy of space. (Graphic: Ferschin, Di Angelo & Paskaleva)

Fig. 5
Typical house compound, generated with a digital rule set. (Graphic: Ferschin, Di Angelo & Paskaleva)

Ingrid Erb

Dipl. Arch. ETH Dr. techn. Ingrid Erb is born in Basel, Switzerland. Her studies included Design at the School of Visual Arts in Bern, Art History at the University of Basel and Architecture at the ETH Zürich, where she received her degree in architecture in 1992. An internship in the Atelier 5 in Bern followed, as well as freelance work in different project in the fields of architecture and stage design. Ingrid Erb was the winner of the Swiss Design Award for Stage Design in the years 1996, 1998 and 2001.

Her professional work includes architecture and interior design as well as set design for l theatres in Switzerland, Austria, Germany, Italy and Russia. In 2016 she finished her PhD with the title Venice in Vienna, the staging of the ephemeral as a playground of modernity, at the Institute of Architectural Sciences at the Technische Universität Wien, Austria (TU Wien). Since 2015 she is a lecturer at the TU Wien, Department Digital Architecture and Planning. Her research interests are in temporary structures, scripted space concepts and staging in architecture.

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His research interests are in photogrammetry and laser scanning, reaching from modeling the measurement process, via calibration and orientation of sensors (cameras, laser scanners), to 3D mapping and modeling. Especially modeling for environmental sciences, archaeology, and architecture are in the focus of his research. Norbert Pfeifer thus frequently works in interdisciplinary manner together with experts from geomorphology, forestry, archaeology, and architecture.

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Figure 5

Our project could be useful for architects who are interested in extending traditional building principles towards contemporary use and people in history of architecture, building archaeology, and restoration. On the one hand, it would aid the adaptation of building traditions for contemporary needs (e.g. tourism). On the other hand it could facilitate a wider comprehension and appreciation of traditional knowledge within the research community as well as the parties involved.

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