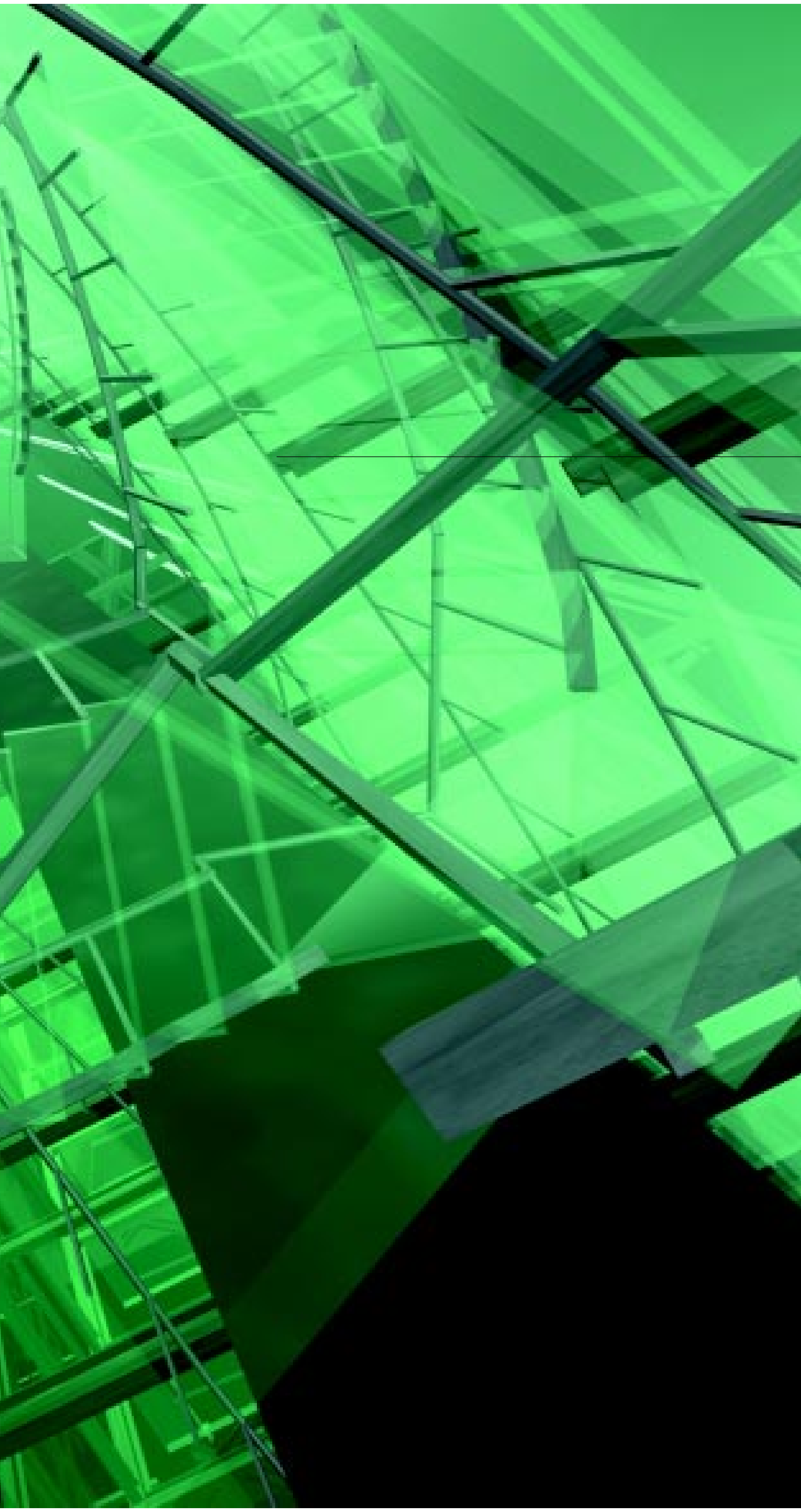

Sambit Datta
University of Adelaide
sdatta@arch.adelaide.edu.au

Robert F. Woodbury
University of Adelaide
rw@arch.adelaide.edu.au

Reducing Semantic Distance in Generative Systems: A Massing Example

Generative design formalisms utilise discrete, constructive steps to encode strategies for formal change. In physical design media, the pervasive metaphor for doing design is the direct and continuous manipulation of the developing form. The goal of our investigation is to develop mixed initiative approaches to design exploration.

In this paper, we address how constrained manipulation in generative systems can support both discrete and continuous modes of interaction. Massing is a common strategy for processing conceptual notions about three dimensional form. We use massing models of tenth century temple cellas as an example to illustrate an environment for constrained manipulation.

Reduction de la distance sémantique dans les systèmes génératifs: un exemple d'étude d'aspects massifs

Les formalismes en design génératif utilisent des étapes discrètes et constructives pour encoder des changements de forme stratégiques. Dans les médias physiques de design, le métaphore répandu pour effectuer du design est la manipulation directe et continue de la forme développante. Le but de notre investigation est de développer des approches d'initiatives mixtes à l'exploration en design.

Dans ce papier nous étudions la façon dont la manipulation à contraîntes de systémes génératifs peut supporter des modes d'interaction continues aussi bien que discrètes. L'étude des masses ('massing') est une stratégie commune pour mieux comprendre des notions conceptuelles relatives à la forme trois-dimensionnelle. Comme exemple illustratif d'un environnement pour la manipulation à contraîntes, nous utitisons des modèles de masses des 'cellas' d'un temple du dixième siècle .

introduction

Generative design systems (Heisserman 1991, 1994; Woodbury 1995a, 1995b) are useful formalisms for encoding design knowledge. However, they enforce a separation between the encoding of design knowledge and the exploration of their design spaces (Carlson 1994). The skill and expertise required to interact with such formalisms has restricted their usage to a few specialists, with bridging skills in both design and computation.

Users interacting with a generative system encounter semantic distance, a qualitative measure of the degree of engagement afforded by an interactive system (Abowd 1993). To reduce semantic distance between the formalism and its users, we explore techniques for constrained manipulation. Specifically, we describe how interaction with a generative system can benefit from discrete and continuous modes of interaction during model construction.

massing: generating cellas

Massing is a conceptual design tool that designers use to develop functional or compositional forms in three dimensions. Formal strategies for developing massing models constitute a significant body of knowledge that designers acquire through their use of manual and computational media. In both cases, the aquisition of expertise in massing consists of developing ever more refined versions of schemata through discrimination and generalization using a repetoire of form-making strategies ranging from principled formal knowledge to plain opportunism.

These strategies are relevant to an entire class of design problems that deal with abstract volumetric composition. We describe massing operations in a generative system that uses formal principles to develop models of tenth century temple cellas from Western India.

The basic massing scheme of a typical cella comprises the Pitha, or base, the Prasada consisting of the Garbagriha, a cuboidal inner sanctum, the Mandovara, or wall which encloses the sanctum and the Sikhara, a curvilinear solid of distinctive form that sits on top of the sanctum. The significant constructive principles dealt with in this paper, comprise a sacred grid of 64 squares, the mandala and proportional (Figure 1) subdivision of the mandala to derive the angas or offsets. We restrict our scope to exploring the elaboration of the Angas, using an operation for wall subdivsion. Each of these formal operations is based on a body of constructive knowledge described in (Datta1992,197).

Briefly, a cella massing is distinguished by its profile, which in turn depends on the number of offsets or angas and the proportion of each anga. We focus on the massing operations (Figure 3) involved in elaborating a cella from a simple square, by adding angas to its sides and assigning proportions to each of the offsets. The grid diagram of 8 x 8 = 64 squares, is used to generate the ground plan and control measure in the configuration of stone temples (Datta 1992). The anga offsets are based on the subdivision of the mandala of sixty-four squares. We classify the cella types as ekanga, dvianga, trianga, caturanga and panchanga having one, two, three, four and five offsets respectively (Figure 2).

If “a” is the side of a single square in the grid, the 3D form of a cella is assigned a cuboidal geometry based on a value of “a”. Each side of the cella is then elaborated into three faces with the middle face extruded by an offset value, the edge faces are equal (Figure 2). The recursive application of this offset rule to each matched side, results in the progressive instantiation of a new angaface.

A mechanism for varying the proportions between the matched face and the instantiated face, assigns to the matched-instantiated face pair, a proportional relation chosen from a finite domain of integers (Figure 2), the proportion set. Complex fractional ratios in cella proportion are not handled.

This unfolding of a cella massing imposes a complex interaction on the exploration machinery. Firstly, the recursive application of the offset operation is controlled by the built in logic interpreter. A greater control may be achieved by allowing the user to participate in the resolution process. Secondly, in order to traverse the proportional relationships in a smooth manner, direct manipulation under continuous constraints is more feasible than the discrete state change mechanism we currently use. We discuss two techniques for developing smoother interaction in a generative system, direct manipulation of discrete moves, and continuous change during exploration.

reducing semantic distance

Direct manipulation techniques (Shneiderman 1983) have been successful for many interaction tasks. Users can control and manipulate the objects of interest by interactively grabbing and pulling them. The rationale for this is that there is a quality of directness between the task that the user has in mind, the way it is represented and the way the task is accomplished by the system. This directness translates to an immediacy in the designer's involvement with a world under change. Direct manipulation interfaces recover this qualia of immediacy. They emphasize continuous object representations, physical actions and the use of rapid, incremental and reversible operations (Shneiderman 1983).

In a generative system, a finite set of operations that define valid changes are employed in exploring a design space. These operations are discrete and modular and can be sequenced by using a control strategy. We cast such generative moves in the guise of direct manipulation operations by using a graphical representation of the operation as a first class object within the model under construction. The operation object is then constrained to trigger a discrete operation (Figure 3), depending upon user manipulation. Thus potential discrete moves in the exploration are graphically "glued" to the substructures they refine. The user then determines which paths are elaborated by using a pointing device to select the operation.

While this strategy is promising and general enough to enable seamless interaction with a set of generative operations, it is insufficient to maintain continuity of change. Discrete subspaces (Figure 3)in our current model, however explosive their combinatorial search space, need to be enumerable. For continuous proportional relationships, movement by state change is unwieldy and a notion of continuity in the navigable space is necessary to complement the manipulation of operations. This dilemma is illustrated in our massing example,

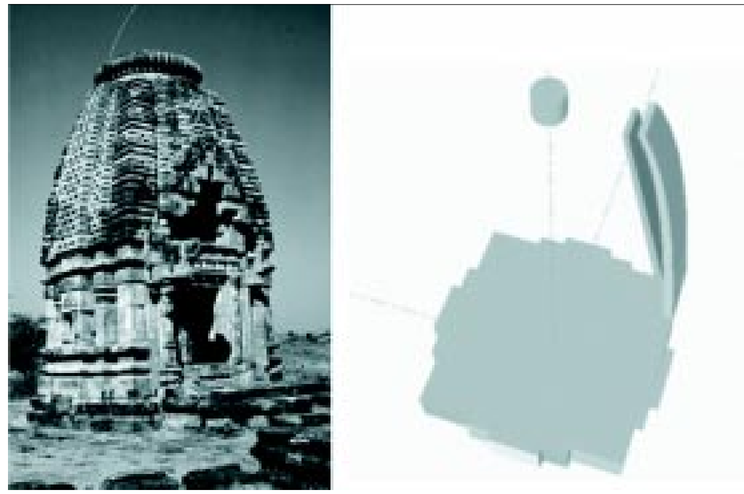

Figure 1. A cella and its abstract massing elements.

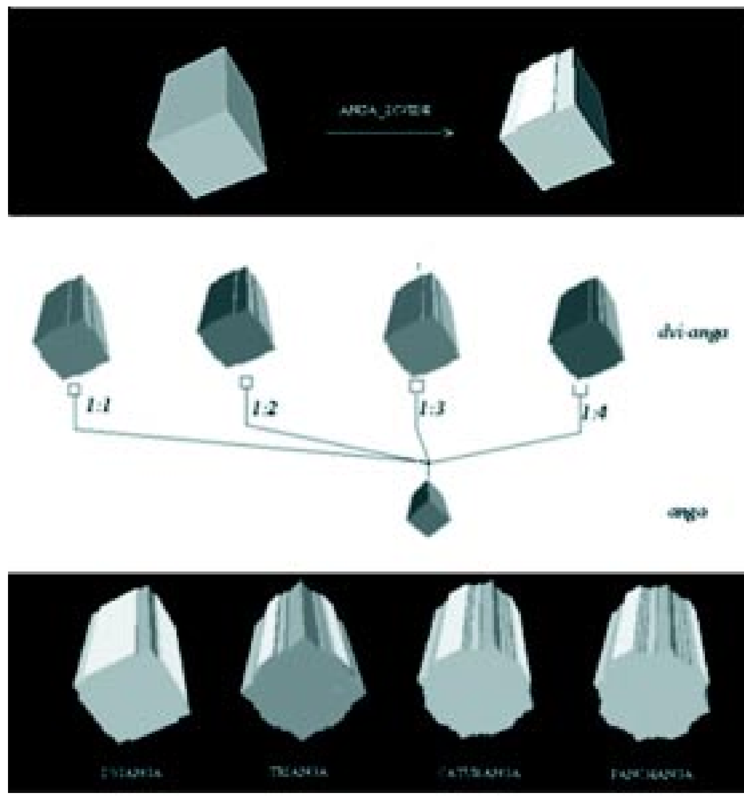

Figure 2. Offset rule, branching and discrete variations.

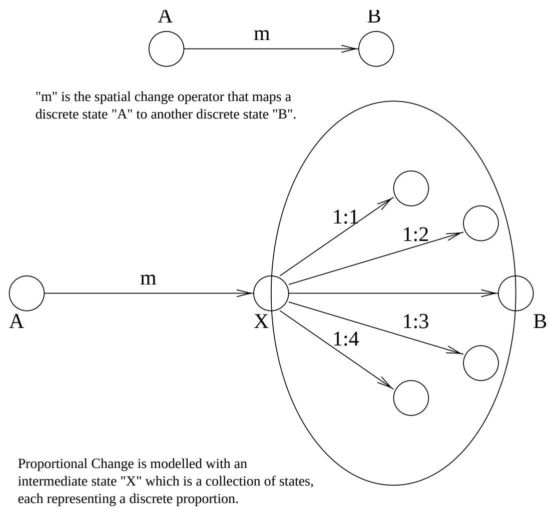

Figure 3. Offset rule and proportioning strategy.

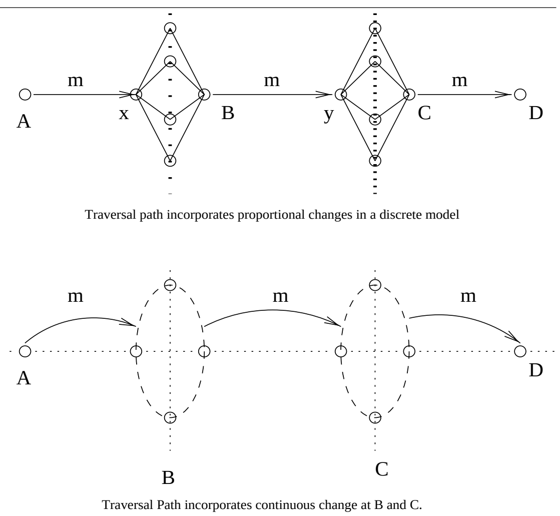

Figure 4. Traversal models of the exploration space.

in the choice of proportionate ratios (Figure 2) for the wall offset operation. The choice of subdivision, a seemingly trivial operation engenders an infinite set of possiblities in the choice of proportional relationships, unless both are modelled with discrete variables over countable domains (Figure 3). The structure of the design space is then a hybrid combination of discrete jumps with smooth motion.

This entails integrating the discrete operations of form generation with continuous exploration of proportional constraints (Figure 3).

constrained manipulation of cellas

Design space exploration presents the problem of embedding continuous constraints in a discrete world. We describe a direct manipulation approach to performing the generative operation of anga subdivision (Figure 5) and extending the proportional relationships between facets from discrete integer values to a continuous domain within constraints.

The primary element of variation in most constructed cellas was a combination of the number of offsets on the cella wall, the anga and their proportional relationships (Figure 2). Currently, the space of valid models that can be explored in this way is limited to varying the choice of anga, anga proportions, rekha and the number of units in each lata. The nature of branching in the design space lies in the choice of anga and the proportional variation of the resulting offsets. Once the anga space is explored, the prasada or superstructure can be refined using recursive techniques as explained in (Datta 1992,1997). The range of experimentation that was possible in practice can be effectively extended by enabling continuous variation of the proportional parameters.

The refinement of the cella wall is performed by the offset rule. This operation, at the user level, refines the sides of the cella into three parts, with the central portion being offset outwards. The recursive application of this operation to the central face results in a design space of valid models that is controlled by direct manipulation. We now consider the continuous manipulation of wall offsets (Figure 6) in a temple cella. The basic idea is to

Figure 5. Recursive application of the offset rule.

constrain a set of standard manipulations and limit the degrees of freedom of the offset of the cella based on semantic issues of possible or legal changes in the cella. The complete range of geometric operations we can possibly perform on the cella can be covered as non-standard manipulations. The geometric representation of the cella is endowed with a semantics or structure of constrained forces that dictates the behavoiur of its parts under direct manipulation. We express this behaviour as a collection of constraints, derived from the formal and physical structure of wall subdivision.

The control of the offset operation resides in the pointing device of the user. This operator places visible markers on the substructures that can be further subdivided. The user can grab the visible marker and perform the operation. This operation defines a recursive language of designs that traces a discrete design space (Figure 5), given by the number of times the marker is pulled by the user.

The control of continuous manipulation also resides in the pointing device of the user. This class of proportional problems can be effectively separated from the creation of the offset. The constrained space of movement enables the user to vary the offset size in a continuous fashion.

Summarising, constrained manipulation is a promising technique for reducing semantic distance in a generative system. As an example, we show the generation of wall-subdivision (Figure 5) and the constrained motion of a generated offset (Figure 6) by direct manipulation.

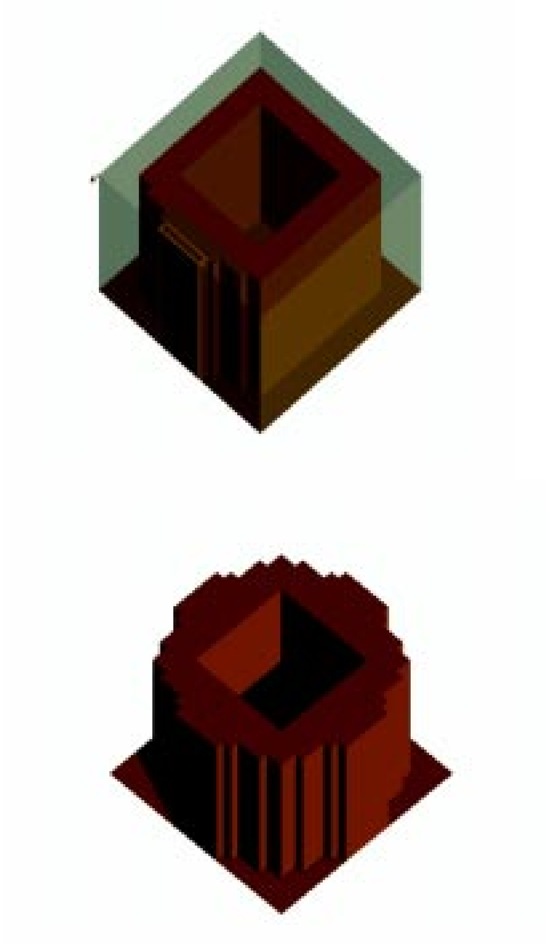

Figure 6: Continuous manipulation of offset proportions.

related research

Physically-based modelling research provides direct, interactive manipulation interfaces for constrained models, based on physical simulation. In these systems, users interact with the model by exerting virtual forces. The system responds to the applied forces, subject to constraints (Witkin 1987). Physically-based techniques are in extensive usein the interactive manipulation of complex non-linear constraint systems in interactive graphics (Witkin 1990; Welch 1992; Gleicher 1992). The framework of interactive physics based manipulation for design exploration (Harada 1995, 1997) is a relevant model that integrates discrete and continuous constraints.

conclusion

Model construction in a digital medium is quasi physical in character. It embraces both discrete and continuous notions. Thus any formulation for supporting such a process must entail a smooth integration of discrete operations with continuous manipulation.

Generative systems provide the formal machinery for discrete changes while direct manipulation interfaces handle continuity. A mixed initiative environment that integrates the two is a powerful mechanism for modelling spatial change in a digital medium.

Massing design provides an example of how this may be done. The discrete operations that elaborate a form are visualised graphically and their actions are directly manipulated by the user. The user can simultaneously perceive continuous change in the substructures of the developing form and trigger discrete changes within it.

This quasi-physical formulation paves the way for thinking about generative design in an interactive setting, in which user manipulations play a direct role in the exploration of design spaces, not unlike physical media. This interplay between formal generative machinery for discrete operations and the discriminatory power of the human user to discern structure in continuous domains forms the core of our future research.

references

Abowd, G., A. Dix, J. Finlay and R. Beale, 1993. *Human-Computer Interaction*. Prentice Hall.

Carlson, Cristopher, 1994. “Design space description formalisms,” *in Formal Design Methods for CAD IFIP WG5.2* , J. S. Gero and E. Tyugu (eds), B(18):121-131, Elsevier Science B.V. North Holland.

Datta, Sambit, 1992. *Geometric Delineation in Indian Temple Architecture : A study of the temple of Ranakdevi in Wadhwan*. VastuShipa Foundation & CEPT Ahmedabad, India.

Datta , S. , T. Chang and R. Woodbury, 1997. “Describing temple cellas in SEED-Config,” volume 2:367-376, Taipei, Taiwan, April 1997. CAADRIA, Hu’s Publisher Inc.

Witkin, A., K. Fleischer and A. Barr, 1987. “Energy constraints on parameterized models,” *Computer Graphics*.

Witkin, A., M. Gleicher and W. Welch, 1990. “Interactive dynamics,” *Computer Graphics*, 24(2):11-21, *Proceedings*, 1990 Symposium on 3D Interactive Graphics.

Gleicher, Michael, 1992. “Integrating constraints and direct manipulation.” *Proc. Symposium on Interactive 3D graphics.*

Harada M., A. Witkin and D. Baraff, 1995. “Physically based manipulation of discrete / continuous models,”, *Computer Graphics*, in *Proceedings*, SIGGRAPH’95.

Harada, Mikako, 1997. *Discrete / Continuous Design Exploration by Direct Manipulation*. PhD Dissertation, Department of Architecture, Carnegie-Mellon University.

Heisserman, Jeff, 1991. *Generative Geometric Design and Boundary Solid Grammars*. PhD Dissertation, Department of Architecture, Carnegie Mellon University.

Heisserman, J., and R. Woodbury, 1994. “Geometric design with boundary solid grammars,” in *Formal Design Methods for CAD IFIP WG5.2* J.S. Gero and E. Tyugu (eds), B(18):79-100. Elsevier Science B.V. North Holland.

Shneiderman, Ben, 1983. “Direct manipulation: a step beyond programming languages,” *IEEE Computer*.

Welch, W. and A. Witkin, 1992. “Variational surface modeling," in *Computer Graphics*, 26, Proceedings, SIGGRAPH'92.

Woodbury, R. and T. Chang, 1995a. "Building enclosures in SEED-Config," in M. Tan (ed), *The Global Design Studio*, International Conference on Computer-Aided Architectural Design, Singapore, 24-26 September 1995. CAAD Futures'95 Conference, pages 1-10.

Woodbury, R. and T. Chang, 1995b. "Massing and enclosure design with SEED-Config," *ASCE Journal of Architectural Engineering*, 1(4):170-178.