$f(x_n)$: Explicit and Recursive Definitions of Architectural Typology

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Abstract

The notion of a generative description of architectural typology is discussed. Two different approaches are identified and contrasted in terms of their expressive power in design. The building type of the courthouse is selected to showcase and test the approach. One case study is briefly presented to pictorially illustrate the findings.

Keywords: Computation; Typology; Shape grammars; Courthouse design; Variation.

Introduction

Semper's algebraic formulation of style as a function $f(x_n)$ modified by a series of variables x_1, x_2, …x_n, still remains one of the most enduring theoretical expositions of a constructive understanding of architectural style (Semper, 2003). Semper's definition of style considers the variables x_i in the widest possible sense denoting any physical, programmatic, technological, engineering, social, cultural, environmental, economic, aesthetic, symbolic and other factors as desired.

Implicit in this definition of style is the definition of type – the latter a reduced version of style with fewer sets of variables. Semper himself set the difference between style and type in the characteristics of the variables: objects with common formal properties performing similar functions are of the same type while different environmental, cultural or material properties distinguish these objects stylistically. Despite the limitations of this specific interpretation the fundamental formulations of style and type as functions $f(x_n)$ modified by nested series of variables is still useful and underlies contemporary definitions of both. For a succinct account of the various construals of type in architecture discourse and its similarities to affine concepts in computational design and design cognition, see Mitchell (1990).

A fundamental motivation in research focusing in typological forms is the identification and enumeration of a finite number of forms that can be used as blueprints for the generation of a potential large number of variations. The quest for such a set of underlying set of configurations that can be used as schemas to generate design solutions to given problems is a prevalent mode of inquiry in design research. Alexander's indefatigable but ill-fated approach to identify the underlying patterns that can be used as scaffoldings for the creation of architectural form is perhaps to most systematic endeavor in this trajectory (Alexander, 1980).

The problem with this and similar approaches is not about how the pattern or the type can be transformed in a spatial configuration, but whether the available patterns can capture what is of interest and potentiality in a design setting. A way out of this conundrum is to think of these diagrams and patterns in a recursive way that allows them to recombine freely in any imaginable way allowing novel and useful representations of patterns in a design setting. The computational framework for such visual computations with shape rules and rule schemas is captured nicely by the shape grammar formalism (Stiny, 2006; Knight 1997; Grasl and Economou, 2013).

The work here presents the findings of a series of structured design exercises that are designed to tackle studies in architectural typology in a generative (recursive) way. These studies have been set within an architectural design and research studio linking shape grammars, a computational tool that uses visual recursion for the generation of designs, to architectural design studio discourse (Economou, 2001). The proposed design domain is the courthouse design that exhibits one of the most complex contemporary building programs (for recent accounts see, Phillips et al, 2003; Gruzen et al 2006; USCDG, 2007; Resnik et al, 2011). Two case studies are briefly presented to pictorially illustrate the findings of the studio research.

Three Approaches

The identification and enumeration of a finite number of forms that can be used as blueprints for the generation of a potential large number of variations has been a central inquiry in architectural design. One approach is to present and exhibit all the types in the form of a catalogue. This approach is impractical for all inquiries except for small sets of types. Better they can be described constructively – that is, they can be described by an initial schema and a rule or set of rules to operate upon it. This very informal description of types is intuitively appreciated when we think of sequences in mathematics and their descriptions in terms of enumerations and/or their calculations in terms of *explicit* and *recursive* formulas. An explicit or closed formula is

used to calculate directly the value of any term in the sequence. A recursive formula is used to calculate the value of any term in the sequence in terms of the term preceding. For example, to compute the fiftieth member of the Fibonacci sequence using an explicit or closed formula, the only thing that is needed is a substitution of the corresponding numbers in the formula. The corresponding computation of the fiftieth member of the Fibonacci sequence using the recursive formula requires fifty calculations starting from the first member and proceeding to the last. It is important to understand that both definitions are constructive – that is, they require an initial input and a rule to operate upon it (Stiny, 1978)..

The analogy is straightforward. An explicit representation of a type consists of a schema along with a set of variables and/or combinations of sets of variables. These variables are used to define a type representation when values are assigned to them to satisfy given conditions and constraints. A recursive representation of a type consists of a set of rules that can apply repeatedly for the construction of the schema. In both cases, a systematic construction of a hierarchy of subtypes within subtypes, either by explicit or recursive means, often provides a comprehensive classification scheme to describe, interpret and evaluate elements in a discourse that the typology applies to.

Clearly both representations of types can be intertwined to generate interesting possibilities; for example, types that have been generated in a recursive way can be used in an explicit way to structure the generation of variations of designs as parametric versions upon these schemas. And schemas that have been cast in an explicit manner can be used in a recursive way to structure the generation of variations of designs as recursive versions upon these schemas. But among the two, the recursive form is privileged here for two reasons: firstly because of its pedagogical purposes – it clearly brings to the foreground the rules and conventions used to make the schema that comprises the type, and secondly because, it shifts the interest from a search for a comprehensive, finite, immutable, and metaphysical series of schemas to a reconfigurable, emergent, and ultimately ironic series of schemas that can constantly draw attention to diverse aspects of the representations they capture.

Two Formal Studies

The notion of a recursive representation as applied to a given building typology is briefly illustrated in this section. The proposed design domain is the courthouse design that exhibits one of the most complex contemporary building programs (for recent accounts see, Phillips et al, 2003; Gruzen et al 2006; USCDG, 2007; Resnik et al, 2011).

Contemporary courthouses in US pose unique design challenges. They have complex functional requirements and vary extensively in their size, volume, configuration, form and style. The tell-the-tale characteristic of the courthouses is their division in three distinct, independent zones and networks that all meet at the courtrooms of the courthouse. These three zones are: a) the public zone intended for the circulation and accommodation of the general public including attorneys, clients, witnesses and jurors; b) the restricted zone, intended for the circulation and accommodation of judges, court clerks, court employees and jurors; and c) the secure zone intended for the circulation and accommodation of the defendants in custody. The functional requirements of these three zones can be quite complex. For example, the public zone includes central public halls and waiting areas, as well as circulation corridors, staircases, elevators, restrooms etc. The restricted zone includes jury facilities, judges' chambers suites, court libraries, clerk's offices, probation and pre-trial offices, court units, as well as circulation corridors, staircases, elevators, restrooms, mechanical areas, maintenance areas, storage areas, and so forth. Finally the secure zone includes holding areas and circulation corridors, staircases, elevators and so forth. All zones include and terminate into the various courtrooms, that become thus, literally and figuratively, the core of the courthouse.

The formal inquiry on the architectural typology of these building forms is set here along a series of formal studies cast within the core of architectural pedagogy linking directly architectural design studio discourse with computational design and especially shape grammars, the par excellence recursive system for visual design. More specifically, the formal exercises are set along two main directions: In the first mode the design inquiry starts from a set of spatial relations found or observed in the corpus to satisfy functional relations, and the new designs are produced as formal variations (productions) upon these relations. In the second mode, the design inquiry starts from a set of spatial relations devised to satisfy functional relations - and the new designs are produced as formal variations (productions) upon these relations.

Both of these trajectories can be cast in a variety of ways to accommodate the intuitions and idiosyncrasies of diverse design team and clearly design actions can be cast in a variety of ways including bottom-up and/or top-down approaches, or inside-out add and /or outside-in approaches, and so forth. Two case studies are briefly presented below to pictorially illustrate the findings of the studio research. These case studies are selected from two advanced graduate design and research studios run at the School of Architecture at Georgia Institute of Technology during the academic year of 2012-2013. Both exemplify examples of recursive definitions of architectural form; the first starts from given formal/functional pairs and the second inquiries from scratch. A brief description follows below.

Rewind: Deriving schemas

The inquiry starts from the identification of schemas or schema relations that satisfy given functional relations in existing designs. In this case existing designs (precedents) and existing spatial and functional pairs in these designs are used as the departure points

for the generation of new ones. The conventions of the representation of the identified functional/spatial pair is entirely upon to the discretion of the author of the grammar. The steps in this inquiry include: a) the definition of a corpus; b) the recast of specific two-dimensional or three-dimensional representations of the parts of the corpus in terms of schemas or abstracted representations; c) the extraction of a set of spatial relations from the schemas that are deemed significant; d) the extraction of shape rules from these spatial relations to form the generative mechanism (shape grammar); e) the redescription of the chosen designs in terms of the rules as a means of validating the theory (shape grammar); and f) recalculations of rule sequences to produce new schemas in the corpus.

This inquiry is illustrated here by a case study that took on four contemporary courtroom and courtroom aggregations designed by eponymous architectural firms including Morphosis Architects; Safdie architects; Richard Meier Architects; and Scoggins and Elam Architects. Details about the secure network of all these courtrooms are conjectured as long as the actual data regarding these parts of the courthouses are not generally available to public. All the courtrooms are represented in an identical manner using similar conventions of wall configuration, programmatic adjacencies, entry sequences, lighting conditions and so forth. Each courtroom is captured by a grammar that can produce more courtrooms in the same language too and all grammars can be combined in a variety of ways to produce new and interesting examples of hybrid designs. Similarly all grammars are extended to capture the ways courtrooms combine to produce courtroom aggregations, the core of courthouses, and significantly, all these grammars combine too. One of these grammars, the grammar for the Morphosis courtroom is shown in Figure 1. Two productions of the grammar– one to reproduce the original one (and verify the theory – the grammar) and another to produce a new diagrammatic representation are shown in Figure 2. The derivation of all designs is fully executed in an automated way in a shape grammar interpreter (Grasl and Economou, 2013).

Forward: Devising schemas

The inquiry starts from the design of schemas or schema relations to test whether they satisfy given functional relations. In this case existing designs or systems from other domains (metaphors) or entirely new constructs are used as the departure points for the generation of the new ones. The steps in this trajectory include: a) the definition of a (metaphorical) corpus; b) the cast of specific two-dimensional or three-dimensional representations of the corpus in terms of schemas; c) the extraction of a set of spatial relations from the schemas that satisfy the functional constraints; d) the extraction of shape rules from these spatial relations to form the generative mechanism (shape grammar); f) calculations of rule sequences to produce schemas in the corpus that satisfy the given functional relations.

The case study illustrated here provides a generative grammar to produce courtroom configurations that capture existing ones but more significantly expand the known configurations. The single element that is foregrounded here is the notion of circulation space diagrammed as a single bar with a range of parametric modules that are mapped to spatial and metric constraints.

The key idea of the grammar lies on the exploration and formalization of the opportunities of interaction that emerge between the user groups that use the distinct networks of the courthouse, and mainly the public and the restricted ones. . These interactions are classified in relations of adjacency, proximity, visibility, and other characteristics and result in a proposed vocabulary of five intersecting and asymptote circulation paths. These five nodes become then the L-shape, the T-shape, and three parametric X-shapes, one keeping the complete symmetry of the node and two more in asymmetric relations.

The fives parametric schemas, the Ls, Ts, and the three Xs define the possible interactions between the networks and the possible ways the networks can grow. Among all possible interactions between these schemas a specific subset of eight spatial relations is selected because of their particular ability to provide a continuous boundary either of a triangular or a quadrilateral topology. It is this way that the spaces of the courthouse, specifically the courtrooms and the empty spaces rendered as atria emerge from the circulation grammar system.

The five parametric schemas and the eight spatial relations between these schemas are used here for the design of a network shape grammar for courthouse design. Te grammar consists of fourteen schema rules that capture the basic configurations of quadrilateral and triangular spaces. The triangular spaces (and the corresponding X-joints are used for asymptote relations and overpasses of one network over the other. All spatial relations and the rules derived by them are parametric as well in the sense that each node acts as a hinge point and renders the grammar and the resulting designs kinetic, adding yet another layer of variation in the overall design of the circulation and ultimately the building design.

The parametric designs produced by the grammar can be described by grid-like configurations that can be as normative as desired, capturing for example the typical front-and-back ring circulations around the courtrooms with the public zone in front and the restricted zone in the back; but more significantly, they can extend these configurations producing emergent figure-8 patterns that interchange with ramps both public and restricted networks and make the users of each aware and cognizant of the other. The design specification of one of these designs is shown in Figures 3 and 4.

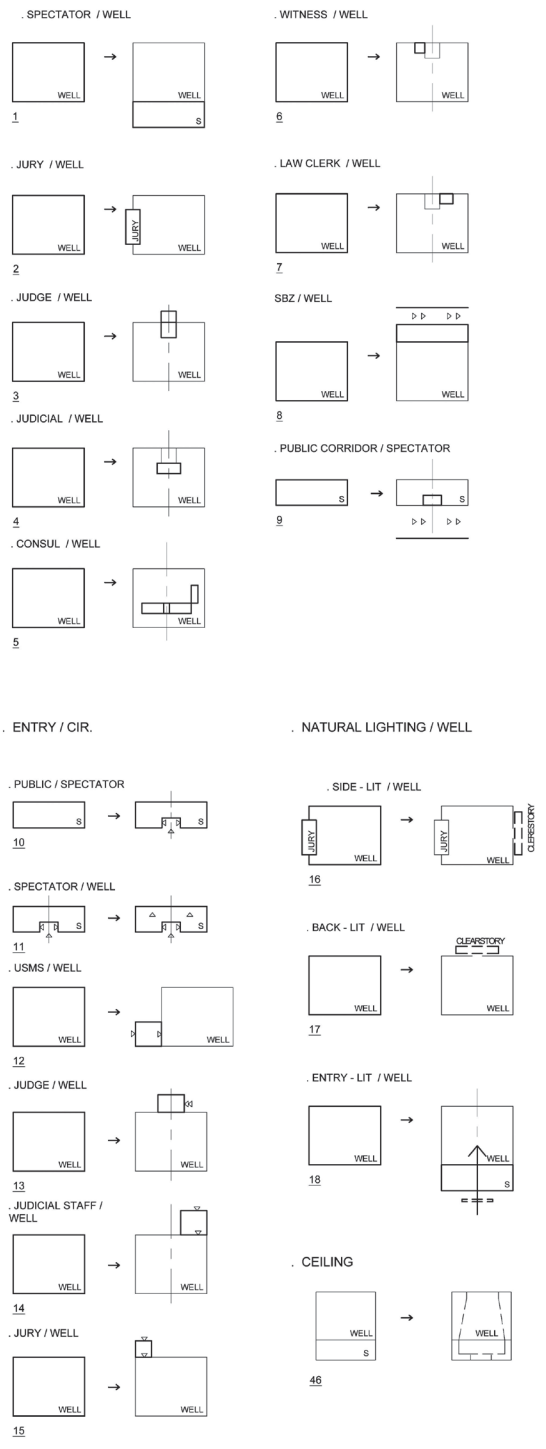


Figure 1: A grammar for a Morphosis courtroom (Yi, He).

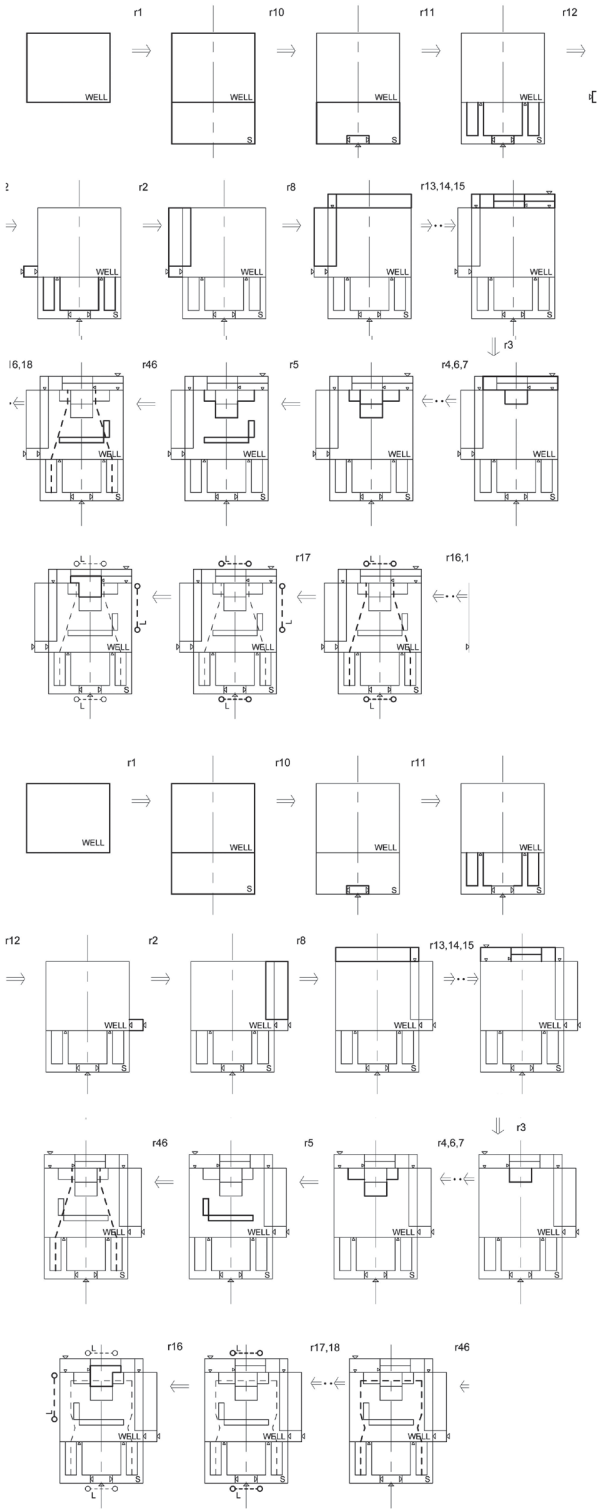
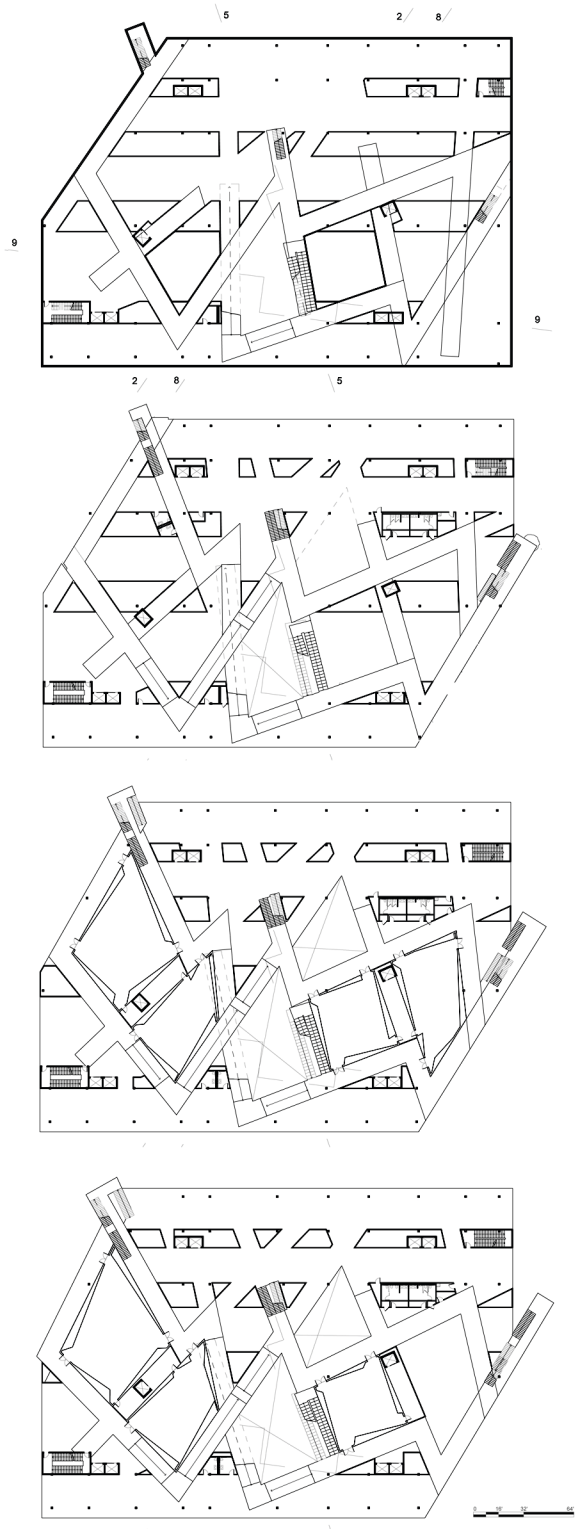


Figure 2: Two courtroom productions. a) Morphosis courtroom; b) a new Morphosis courtroom (Yi, He).



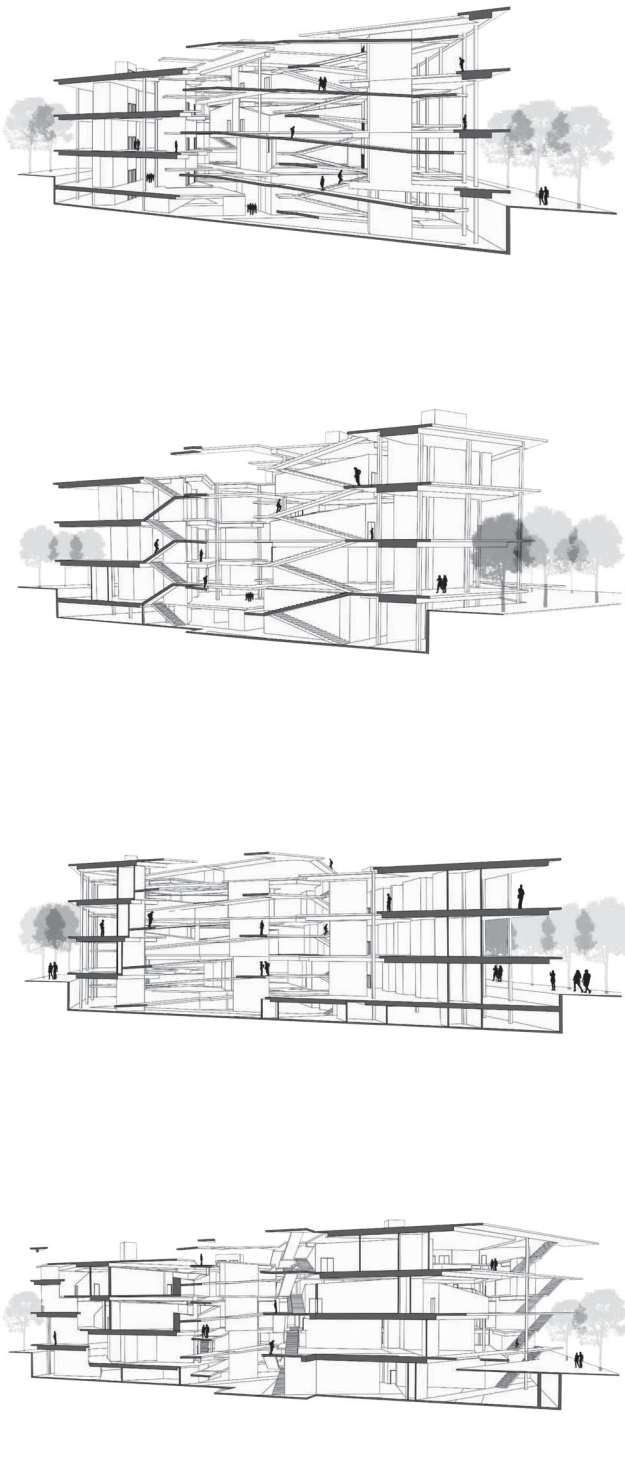


Figure 3: Project for a federal courthouse in Mobile, AL. a) Basement; b) Ground floor; c) Second floor; d) Third floor. (Kelly Heyer; Woody. Woodhurst).

Figure 4: Project for a federal courthouse in Mobile, AL. a) Seciton AA; b) Section BB; Section CC; Seciton DD. (Kelly Heyer; Woody. Woodhurst).

Discussion

The work here presented a small sample of the findings of a series of structured design exercises that were designed to tackle studies in architectural typology in a generative and visual way. These studies were set within an architectural design and research studio linking shape grammars, a computational tool that uses visual recursion for the generation of designs, to architectural design studio discourse. The premise of the work was that formal inquiry in design research - and specifically here on the constructive description of the typology of a complex building domain, can indeed be implemented in a studio setting. Significantly, the studio project was couched within a larger research project on the analysis and generative description of federal courthouses (Economou end Grasl, 2012). This study includes a formal description of the federal courthouses that have been built under the aegis of the GSA Design Excellence Program and an associated database and ontology to support the model. Current work looks at the design of a shape grammar application that will formalize the current practices of courtroom layouts in three-dimensional representations and significantly extend them with a language of open spaces (courtyards, atria, gardens, etc) to produce highly expressive and original specifications of courthouse schematic designs.

Acknowledgments

I want to thank my graduate students in the advanced architectural design and research studios at Georgia Institute of Technology, USA, for their commitment, energy and engagement and especially Woody Woodhurst, Kelly Heyer, and Yi He for their extra effort, sensitivity and criticality in all our discussions and the work produced. A detailed account of their work and the rest of the students in these studios is overdue).

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