Digital Recipes

A diagrammatic approach to digital design methodologies in undergraduate architecture studios

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This paper is concerned with the development of a digitally-informed teaching methodology for architectural design courses within the context of undergraduate education. Besides situating this methodology within the broader theoretical framework of current architectural discourses, this paper will also discuss the practical implications of its implementation within the context of the second year architectural design course at the University of Edinburgh, which will be examined as an ongoing case study.

Keywords: *Diagram, Generative Design, Fabrication, Recipes, Case Study*

THE DIGITAL IN ARCHITECTURAL DESIGN

The notion that the massive adoption of digital technologies has played a key role in the advent of a radical paradigm shift in architectural production during the last two decades is nowadays a hardly contested fact. However the clarification of what this paradigm shift does exactly amount to -in strictly disciplinary terms- has been the subject of many diverging theoretical approaches.

Perhaps one of the most compelling early visions of the influence of the digital in architecture is Bart Lootsma's idea of architecture presenting itself as a simultaneous, three-fold investigation on topological geometry, robotic material production and generative, kinematic space - all of which could, in his mind, be united transversally under the umbrella of a hybridized notion of space (Lootsma 1999).

These three themes - the articulation of complex, fluid relationships, the possibility of architecture becoming industrially manufactured, and the autopoietic capabilities of digital processes for spatial production - have progressively become well-established fields of contemporary design research, which often overlap one another.

Another approach to the possibilities of the digital is contained in Peter Eisenmann's writings from the early nineties. For Eisenman, the paradigm shift triggered by the digital in architecture revolved mainly around the question of vision or, more specifically, of the dramatic possibilities for the reinvention of projected vision (Eisenman 1992). Eisenman argued that the organizational qualities of architecture were determined by the constrains of its own representational tools, and therefore he explored the notion of folding as an operating framework that - while remaining representational - could potentially overcome the limitations of Cartesian descriptions of space.

John Frazer also signalled two very interesting fields of operation that would, according to his view, characterize the progressive implementation of digital technologies in architectural production. On the one hand, Frazer noted the possibility of architecture becoming an organ of interaction with the global informational environment, therefore rendering visible the intangible qualities of the omnipresent digital networks that are juxtaposed to our physical existence. On the other hand, he also noted how the cultural emphasis in design had progressively transferred from the product to the process (Frazer 1995).

If we collate all these views together, we could summarize that a methodological approach to architectural design that is digital in nature would be based on the articulation of two aspects: On the one hand, a continuous productive environment based on the exploration of relational organizations. On the other hand, the capabilities of such organizations to generatively sculpt spaces that are articulated -and therefore represented- through the tectonic ethos of their associated fabrication processes.

IMPLEMENTATION IN UNDERGRADUATE STUDIO TEACHING

Considered as a whole, the visions outlined above can provide a sufficient general overview of the disciplinary aspects of architectural design that have been most substantially transformed by digital technologies in the last two decades. However, it is still unclear whether the depth and breadth that this radical shift of focus anticipated twenty years ago has been successfully implemented in design education. Whereas an increasing number of graduate and postgraduate programs have been able to articulate a consistent pedagogic framework that incorporates the particularities and capabilities of the digital world, this task has proved to be much more difficult in the case of undergraduate studies.

On the one hand, many younger architecture students struggle to develop their own individual design processes in a manner that guarantees a sufficient degree of spatial and functional sophistication. Hence, they often become frustrated by the shallowness of their own design arguments. On the other hand, undergraduate students also tend to be inexperienced in the use of digital tools, which -to make matters worse- are often understood as simple representational skills to be acquired rather than as design tools. Because of this, the incorporation of digital thinking into the learning experience often has the undesired effect of hampering the already problematic development of the students' design process rather than leveraging it.

One of the reasons for this state of affairs is that instructors often stress the importance of digital skills for architectural production, but rarely outline a methodological model that facilitates a consistent approximation to the design process while being digital in nature.

DIAGRAMS AND THE DIGITAL WORKFLOW

Therefore, this paper intends to address this pedagogic challenge by putting forward a series of digitally informed teaching strategies for the design studio. These strategies are primarily based on the development and dissemination of a series of digital procedures for generating rigorous geometric organizations, whose spatial qualities possess a high degree of architectural potential. Furthermore, this paper argues that these geometric procedures can be read as diagrammatic processes, and therefore can be articulated by tapping into the rich theoretical sources that have addressed the notion of the diagram -both from outside and from within the disciplinary framework of architecture-.

In terms of architectural design, a diagram is simply a visual, non-representational device that is used as an organizational tool. In essence, diagrams constitute tools for compressing and assembling information in the form of techniques, tactics, situations and functions. As such assemblages of information can support a multiplicity of readings a diagram can potentially give rise to a very large number of different organizational effects (Van Berkel & Bos 2010).

Diagrams are often confused with maps, which

establish a codified relationship of correspondence between two systems -one being the initial source, the other being the map itself- and therefore are purely representational. As opposed to this, diagrams are generative in the sense that they can reverse the operation produced by mapping by becoming the starting point for generating a real condition (Solomon 2007).

This understanding of diagrams as generative systems is strongly connected to Deleuze and Guattari's work (1987) on the distinction between topologic and metric spaces. For Deleuze and Guattari, metric systems are characterised by notions such as 'length' and 'area', which remain unaltered throughout any geometric operations taking place within them, whereas in topologic systems the aspects that remain invariant are the number of dimensions and their degrees of connectivity (Deleuze & Guattari 1987). Therefore, topologic systems have no scale as such, but are rather organised around a network of connections and relations between points. Hence any architectural diagram with generative properties is necessarily a topologic system which, rather than producing a single, specific form, determines an abstract organizational structure that can be materialised through a potentially infinite number of instances (Umemoto & Reiser 2006).

Once diagrams are conceptualised as holding both topologic and generative qualities, three additional characteristics emerge:

Firstly, the development of diagrams is necessarily deployed over time, in a context in which matter is considered as an animated, dynamic flux which is permanently activated (Kwinter 2002). The temporal dimension of diagrams is, precisely, what allows them to be generative. Once animated by this temporal flux, a diagram can trigger formal processes of progressive differentiation. In such processes, topologic and relational invariants remain but are assembled with different sets of metric properties, therefore generating multiple material instances of the original topologic diagram (Umemoto & Reiser 2006). Thus, diagrams simultaneously belong to the realms of the real and the virtual. Their products are generated as material actualisations of their abstract, formative principles, and emerge through interlinked processes of progressive differentiation (De Landa 2010).

Secondly, the generative process that can potentially be deployed by a given diagram only acquires metric qualities -such as scale and size- once it is applied to specific material assemblages. However, this process is regulated by non-metric qualities such as differences of intensity between points, which define the topologic form of the diagram (Umemoto & Reiser 2006). Therefore, diagrams can be understood as abstract, vector-based organizations that, rather than numerical data, contain relational information that is qualified by differences of potential between points.

Finally, being animated by both material and temporal fluxes, and organised by differences of potential, generative diagrams are in a continuous state of production. As a consequence of this, they give rise to a multiplicity of progressively differentiated outputs. Such outputs reflect not only the topological distribution of their originating diagram, but also our intervention as designers through the selective introduction of mutations, folds and local connections. This combinatory productivity fosters a progressive formal synthesis that is defined within the framework of what could be defined as a 'reproductive community' (Umemoto & Reiser 2006). Hence, the roles or the topologic designer are related to the choice of a material substrate for the deployment of the diagram, the intentional filtering of the dynamically generated instances, and the selective modulation of local mutations and relational connections into the original diagram.

DIGITAL DIAGRAMMATIC PROCESSES IN THE DESIGN STUDIO

At this point, it is clearly possible to consider the qualities and capabilities of a diagrammatic design practice -outlined in the previous paragraphs- as particularly well attuned to the mechanisms and pro-

cesses of a digital approach to architectural production. This is reflected in aspects like the primacy of an abstract, topologic organization over the form of Cartesian metric space, the emphasis on generative, time-driven processes of progressive formal exploration, and the understanding of design outputs as parts of a larger continuum of production and manufacturing. Therefore, it can be argued that any design practice that is digital in nature (at least considering the way in which such practice has been outlined at the beginning of this paper) can be articulated as a diagrammatic process.

Taking these considerations as a starting point and in my role as a Course Organiser for the second year undergraduate architectural design studio at the University of Edinburgh, I have attempted to articulate a pedagogical strategy that relies on the capabilities of three-dimensional modelling software to control generative, diagrammatic design processes. In doing so, it is expected that students will see the development of their individual approaches to design facilitated and articulated within a framework that is rigorous, transferable and consistent while simultaneously allowing for ambitious spatial and organizational explorations. The following is a description of the particularities of this pedagogical strategy as it is currently being implemented.

The second year studio in which this experimental approach to architectural design pedagogy is being undertaken in entitled 'Any Place' and runs during the second semester of the academic year. Following the general guidelines set by the four-year BA/MA Architecture degree it is part of, 'Any Place' is aimed at exploring how architecture can be indebted to things beyond its own vocabulary. In doing so, and whereas previous studios within the degree explore the ways in which immediate contextual inputs could inform the design process, 'Any Place' specifically deals with the exploration of architectural design conditions that extend beyond the level of the local. The course handbook - compiled by me- lists function, programme, spatial experience or insertion within a broader socio-cultural context as some of these conditions. In clear resonance with John Frazer's ideas previously mentioned in this paper, the course handbook also emphasizes the need for architecture to be approached as an instrument of mediation between the scale of the individual and the scale of collective culture.

DIGITAL RECIPES AS PROCEDURAL DIAGRAMS

As a vehicle for channelling this set of interests and ambitions, the course proposes the development of a mid-sized library project in the city of Madrid as its central theme. Considering that the cohort size for the 'Any Place' studio is relatively large (120 students), young and culturally diverse, the main challenge of the course is that of articulating a digitally informed, diagrammatic approach to design in a way that was both extremely clear and easy to disseminate.

Therefore, the first half of the course was structured around the development of a series of spatial and organizational explorations for a site-less library program, which were elaborated by students using a set of seven open procedural diagrams as points of departure. These diagrammatic instructions were intentionally referred to as 'digital recipes' in order to clarify the methodological approach that they were embedding.

Hence, and using the metaphor of cooking recipes, 'digital recipes' were introduced to students as procedural diagrams for the transformation and assemblage of matter. As in cooking books, these recipes are articulated as a series of interconnected steps or actions that orchestrate the interaction between diverse components. Variations in the parameters that inform such interactions have the potential to significantly alter the final outcome of the process. Moreover, there is a certain expectation that, once the basic interactions of a given recipe are understood, the cook (or, in our case, the designer) can introduce substantial modifications in the process that will yield alternative outputs.

Consequently, 'digital recipes' outline general

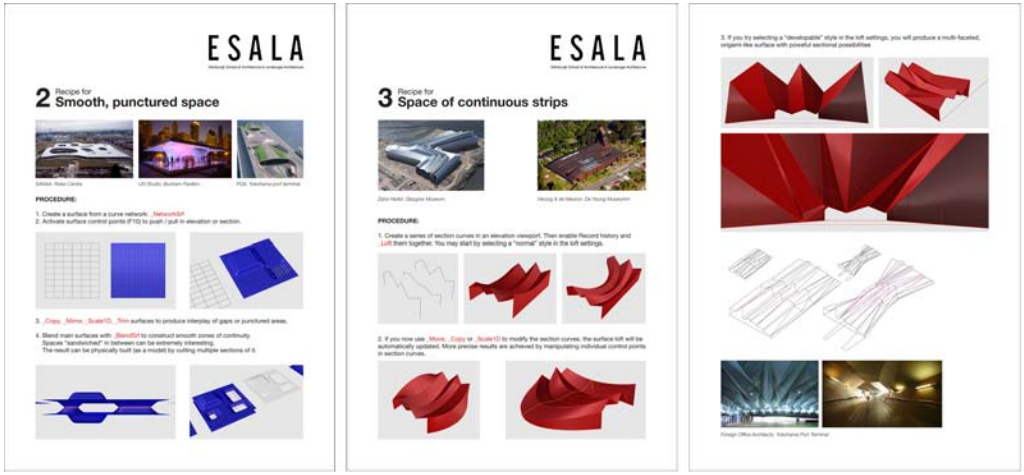


Figure 1
Digital Recipes 2 (Smooth, Punctured Space) and 3 (Space of Continuous Strips)

design procedures for generating certain spatial and organizational assemblages, whereas it is up to the students to propose their own versions, modifications and alterations of such protocols in ways that fulfil both the requirements of the design brief and their own design inclinations.

The seven 'digital recipes' (figure 1, 2) used in the Any Place course are based on the Rhinoceros modelling software due to its combination of accessibility, data processing power and geometric rigorousness. Each recipe was presented under a name that summarised the spatial properties it could potentially generate, therefore giving rise to the following set of diagrammatic abstractions, listed in order of increasing complexity:

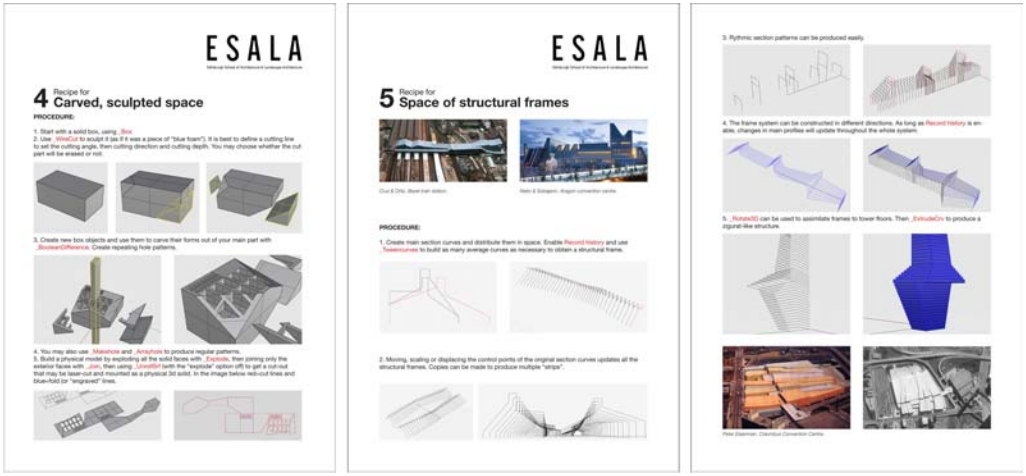


Figure 2
Digital Recipes 4 (Carved, Sculpted Space) and 5 (Space of Structural Frames)

1. Recipe for a flowing, repetitive space
2. Recipe for a smooth, punctured space
3. Recipe for a space of continuous strips
4. Recipe for a carved, sculpted space
5. Recipe for a space of structural frames
6. Recipe for a connective tiling space
7. Recipe for a folded, tiling space

From a formal point of view, 'digital recipes' were presented to students as detailed, step-by-step illustrated guides to generate each particular spatial effect using Rhinoceros commands. Each recipe was also associated to at least one contemporary built precedent that exemplified these spatial effects. From a methodological point of view, the 'digital recipes' implemented a set of geometric operations that contained exclusively topologic relationships or, in other words, connective relationships between components. No considerations of dimensions or scale were introduced, and hence the procedures described did not contain any metric constrains. By demonstrating or testing the recipes, students introduced such metric constrains into their diagrammatic structure, together with additional sets of connective relationships that complemented those of the original topologic assemblage.

STAGE 1 - INITIAL EXPLORATIONS

Recipes were distributed and demonstrated during the first three weeks of the course, and by the fourth week students were asked to serially develop and present at least two different spatial studies for a siteless library building using two 'digital recipes' of their choice as points of departure.

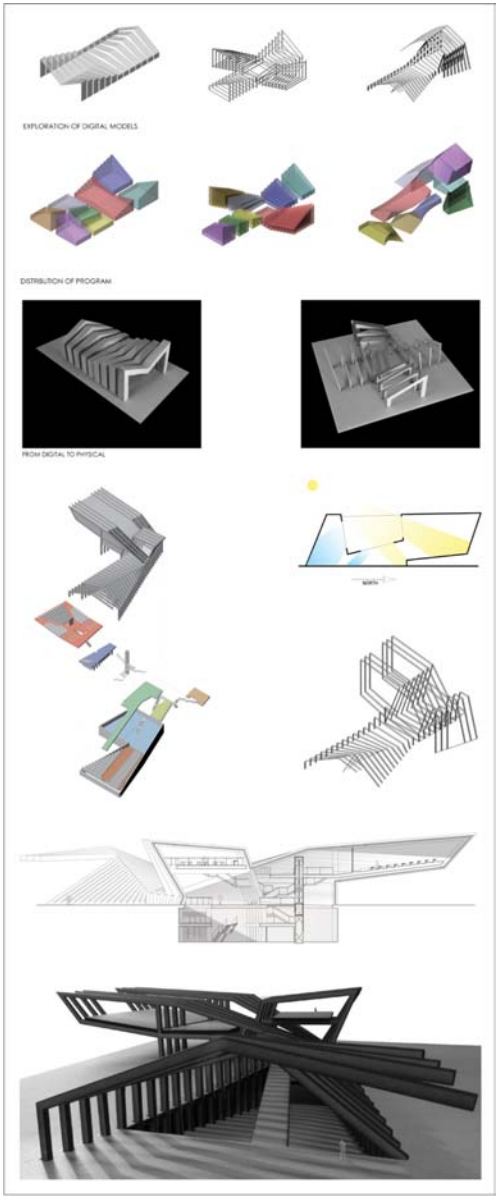
This emphasized the diagrammatic qualities of the process: On the one hand, the consideration of additional constrains -such as the scale and organization of a library program, or their possible arrangement and differentiation- led students to progressively incorporate them into their recipe-based spatial experimentations, therefore producing multiple iterations of the same spatial study over time, each one introducing an additional degree of complexity. Students willing to expand and deepen their explorations were invited to consider aspects such as materiality, tectonic organisation and possible articulations of social interactions within the framework of the library considered as an urban public space.

On the other hand, the introduction of metric information and additional constrains, as well as the manipulation of the recipe procedures led these spatial studies to quickly transcend the static, generic qualities of the original recipes, effectively mobilizing them as generative diagrams and demonstrating their ability to be materialised as a potentially infinite number of dynamically generated instances.

Students were asked to document the development process from the generic 'digital recipe' of their choice into a conceptual library prototype and present it as a consistent design argument, using diagrams, axonometric drawings, plans, sections and elevations. Students also produced multiple physical models experimenting with different geometric variations and arrangements, therefore introducing additional constrains related to the logics embedded into the digital fabrication of such models, which had the potential to suggest possible tectonic arrangements for future developments of their projects.

Figure 3
Student work
image: James
Duffield

Figure 4
Student work sample: James Duffield



STAGE 2 - PROJECT DEVELOPMENT

After the first stage of exploration was completed, students travelled to Madrid and were assigned specific sites to implement their library projects. This led to a remobilization of the diagrammatic process initiated in the previous stage, in which students were asked to test the viability of their initial exploratory schemes against the specific conditions of the context in which it was going to be implemented.

The remainder of the course has been spent producing and testing as many design iterations as possible, in an attempt to articulate a continuum of responses to the initial design problem that would progressively incorporate an increasing number of constrains and considerations. As a general summary, the following inputs have been introduced:

Firstly, metric considerations of scale and proportion, related to the specific conditions of the site. Secondly, relational qualities such as the organization of the massing -attuned to site characteristics such as orientation, topography, boundary geometry and boundary conditions. Thirdly, other non-geometric constrains, such as those concerned with both the articulation of social spaces and the response to specific social and cultural conditions at a metropolitan scale.

In order to emphasize the productive, accumulative value of this design process, students were currently expected to materialise each of their design iterations in the form of a combination of Cartesian representations, physical models and three-dimensional digital models. This effort of materialisation played an important role in the design process by constituting an extremely efficient source of feedback on the validity of the proposed solutions, which in turn initiated further design iterations.

ANALYSIS OF WORK SAMPLES

At the time of writing this paper, the project development stage had ended and students had submitted their final portfolios for assessment. At this stage, most projects have a substantial level of resolution, and therefore this paper will conclude by analysing

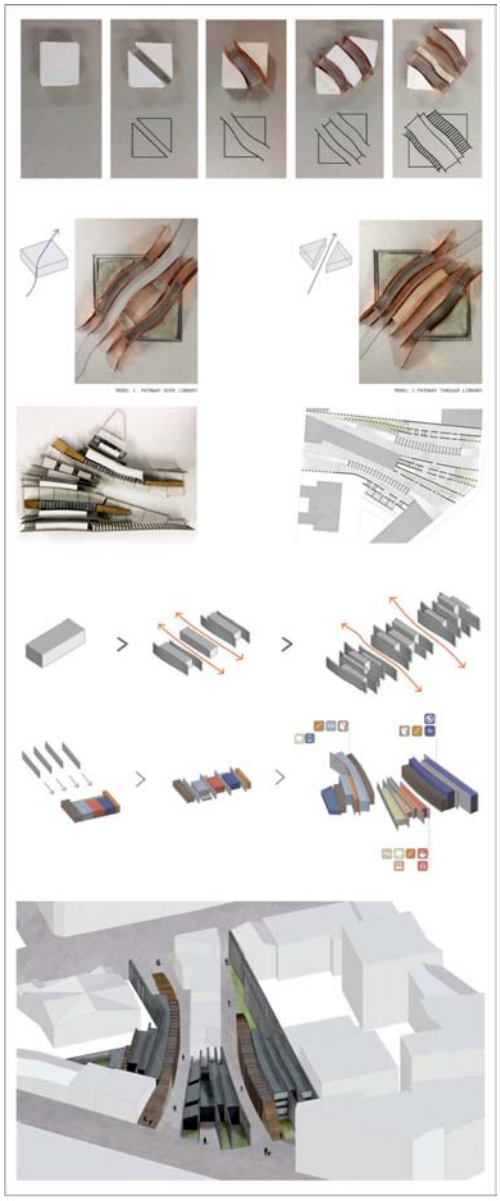
the design processes that were undertaken by three selected students.

James Duffield took the recipe for a 'space of structural frames' as a base to trigger an investigation on the progressive sectional variations of an elongated structure. Branching, compressions and expansions of space constituted the spatial vocabulary of his first proposals, which also incorporated programmatic and organizational aspects. Further investigations were concerned with the serialised vibration that this formal approach could potentially offer, especially in regards to the articulation of both shading and lighting. Once confronted with the physical constrains of the Madrid project site, James' spatial strategy was extended to the ground floor plane. This led to a final design solution that organises the library program as a single, continuously flowing space that is diverted into various functional branches with distinct sectional qualities, each articulating local relationships with the different boundary conditions of the site (figure 3, 4).

Lynn Lin's work initially tapped into the recipe for a 'smooth, punctured space' to develop an open-plan library prototype in which different strategies for articulating spatial relationships between floor slabs were tested. Her initial studies used the deformation along the vertical axis of an otherwise regular grid to deploy a topographic field of courtyards, folds and ramps, along which functional areas were laid out in the form of overlapping patterns rather than enclosed spaces. This resulted in a spatial experience that emphasised continuity and flow. Once constrains present in the Madrid site were introduced, Lin's design response was articulated through the complex functional relationships of two compressed, horizontal spaces: a ground-level organic topography that occupies the whole site and an elevated, punctured slab with a strictly rectangular perimeter and subtle sectional variations (figure 5).

Figure 5
Student work sample: Lynn Lin

Figure 6
Student work sample: Edda Steingrimsdottir



Edda Steingrimsdottir blended together the recipes for a 'carved, sculpted space' and a 'space of continuous strips' to organize a system with the ability to penetrate existing urban fabrics while simultaneously remaining highly organised from a programmatic point of view. The structural, tectonic and experiential aspects originated by the interaction between the resulting series of differentiated functional bands where the subject of further design research. After returning from Madrid, Edda was able to consolidate her strategy for 'cutting through' urban fabrics by proposing the colonization of the derelict interior of a typical building block. Her original system of parallel functional bands was formally adapted to fit the boundary conditions of her intervention, and walkable roof topographies emerged as a reaction to existing differences in height. Edda's final proposal reoriented public flows by opening up the traditionally enclosed blocks and articulating functional spaces with an urban scale within them (figure 6).

CONCLUSIONS

Digital techniques of spatial exploration constitute an excellent vehicle to articulate pedagogic approaches to design that are based on the development of open diagrammatic processes. Introducing these methodologies in undergraduate design studios has two main effects. On the one hand, students can be liberated from the misunderstandings and anxieties normally associated with the use of digital technologies in architecture. On the other hand, this approach can significantly leverage the rigour, depth and breadth of the architectural design enquiries being conducted -especially in the early stages of undergraduate studies- therefore constituting a major improvement to the overall learning experience. Finally, since this methodological approach unashamedly emphasizes process over final results, it is particularly well attuned to contemporary sensibilities that consider the materialisation of architecture as the continuously animated fabrication of a progressively differentiated milieu of spatial and tectonic assemblages.

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