Performing Form
Judgment and Subjectivity in Algorithmic Architectural Design

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INTRODUCTION: BLACK BOXES AND GLASS BOXES

It is an oft-made claim that digital computers are changing architectural discourse and professional practice. These changes are plural, varied, and often prosaic. They do not fit one definition of "digital architecture", nor one manifesto of "digital revolution." While historians, theorists, and ethnographers of architectural practice are beginning to map the disciplinary valencies and professional effects of digital computers, architectural curricula grapple with questions about when, where, how, and why to introduce computers in an architecture student's education.[1] Professionally accredited architecture curricula negotiate a stifling demand for student proficiency in various kinds of commercial software, with the broader pedagogical possibilities that emerge from the many variances of computational design and making.[2] In the parts of a curriculum that integrate a "digital" component, this negotiation usually manifests as a dilemma between training students in software skills and teaching computational processes of thinking, designing, and making architecture. In courses that teach software, computational techniques are often hidden, or "black boxed," behind the screen. Students deploy them indirectly (through software interfaces) to produce drawings, output construction documents, simulate, and analyze a design's various performances. Meanwhile, in courses that focus on computational thinking and making, rules and algorithms are out in the open and take on an active role in the creation of architectural space and form.

These two approaches echo distinct attitudes toward design processes themselves that surrounded early work on design and computing. In a report on the first international conference of the Design Methods Group—a North American "coalition" of researchers working on "rational" theories and methods of environmental design,[3] often through the use of digital computers—architect and urban designer Jonathan Barnett called these two attitudes "black box" and "glass box."[4] "Glass box" approaches were concerned with an analytico-mathematical rendition of the design process—asking the question of whether architectural design, or rather which parts of it, could be conceived as a kind of computation: a step-wise process amenable to logico-mathematical description and analysis. Examples of "glass box" work included systematic methods for "fitting" geometric form to functional goals and various methods for enumerating possible geometric configurations based on certain rules and constraints, broadly falling under the label of "generative design." "Black box" approaches, on the other hand, aspired to enhance specific tasks that designers faced in a traditional process through the aid of new graphical and interactive technologies. "Black box" examples included computer aids of different kinds, from drafting tools to conversational interfaces that informed the designer about the impacts of their decisions. In other words, "glass box" approaches recast design as a kind of computation (a step-wise, algorithmic process), while "black box" approaches used computation as a tool for various familiar design tasks.

Although the "glass box" approach to design has arguably lost the appeal that it carried when Barnett was writing his report, and has had limited presence in architectural practice, some of its variances continue to manifest. In architecture schools, traditions and techniques of generative design are often taught in studios and courses

with a stated focus on architectural form, its orders, and its logics. In broad-brush strokes, such studios on "formal systems" teach students to develop a geometric language and explore its manifestations with or without an architectural program while bracketing functional and contextual concerns within part of the sequence. Timothy Love describes such approaches, which "frame the possibilities of creative endeavor on the specific attributes of a set of physical elements" as placing emphasis on the "syntactical" and "phenomenal" over the "semantic."[5] Due to this syntactical focus, "formal systems" studios also provide a soft introduction to computational thinking and generative design in that they teach students to think about architectural geometry through explicit rules that dictate the relating and manipulating of shapes. Such studios often take place in proximity to the teaching of digital tools because computers are particularly good at permutational and combinatorial operations frequently included in this kind of design. Further, the exercise of algorithmically deriving architectural geometry teaches students something about how computers work.

This paper presents a pilot pairing of a core second-year undergraduate studio on formal systems and a lecture course on digital representation, which together frame students' introduction to digital computers in the context of a three-year accredited architecture program.

The sequential position of the pairing in the curriculum informs the pedagogy: while such a pairing might, at a later stage in architectural training, give students the tools to facilitate self-initiated interests and concerns, at this introductory stage, the courses instead cultivate the development of those interests and concerns. Both courses are thus conceived around sequences of exploratory *exercises* rather than *projects*.

In the digital representation course, software stubbornly remains an electronic pencil, placing emphasis on digital *drawing* as a craft-like form of skilled practice enmeshed with particular visual cultures. The formal systems studio integrates generative design methods and ideas with visual and interpretative acts, helping students cultivate agency and judgment when working within rule-bound processes. A chief intention of this course pairing is to cultivate digital and computational literacy: skilled use of certain tools and also a reflective, critical, and creative understanding of the computational processes embedded within.

DESIGN STUDIO: FORMAL SYSTEMS

The studio is a reflexive and critical take on generative design, capitalizing on some important implications that arise when judging humans, as opposed to non-deliberative computers, perform a computation. This approach is founded upon what Terry Knight has called "slow computing:"[6] students become computers themselves and perform algorithms slowly and by hand so as to afford opportunities for reflection and a reformulation of the rules or the entities onto which they are applied. In alignment with the "slow computing" approach, the aim of the design studio we discuss here is to integrate ideas from generative design, often seen as objective, non-deliberative, and automatic, with *judgment* so as to cultivate an ethos of *attention, intention,* and *care*. Furthermore, rather than remain autonomous and self-referential, geometric form becomes a generator of programmatic and material possibilities through contextually-driven fictions. Throughout the course of the studio, students learn about histories and practices of generative design and shape computation; they evaluate the architectural potential of resultant geometric configurations in two and three dimensions; they translate between drawings and models (digital or physical) and creatively exploit gaps in moving between formats and media; and they talk intentionally about the inter-relationship between geometric form and contextual forces.

The first part of the studio consists of short exercises in which students define and iterate formal systems of shapes and relations in two- and three-dimensional space, in order to generate architectural conditions amenable to human habitation. Through these exercises, students are introduced to methods of visual computing and formal interpretation. Visual computing in this context does not mean the computer-aided analysis and modelling of images and shapes through symbols and data, but instead the use of one's eyes to interpret shapes and apply shape rules in a stepwise, algorithmic process.[7] This approach draws heavily from shape grammars, a theory of generative design developed by George Stiny and James Gips in the early 1970s.[8]

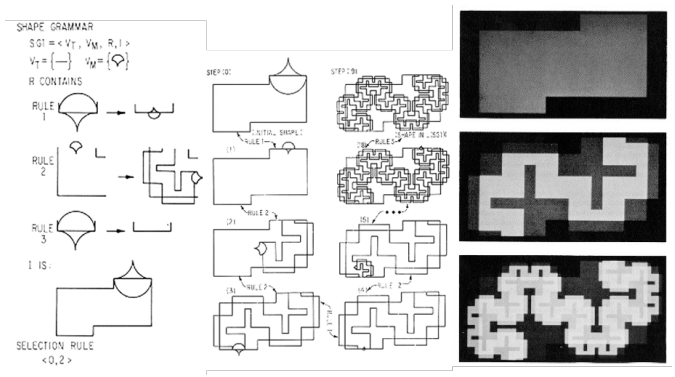

Figure 1. Rules of a shape grammar and their application to generate a visual composition. (Source: Stiny, George, and James Gips. 1972. "Shape Grammars and the Generative Specification of Painting and Sculpture." In Proceedings of IFIP Congress 1971. Amsterdam: North Holland Publishing Co).

Shape grammars were an adaptation of MIT linguist Noam Chomsky's transformational grammars: sets of replacement rules that were used to generate sentences, indicated by arrows while diagramming language.[9] These rules were used to identify linguistic elements in a phrase (nouns, verbs, adverbs, et cetera) and to replace them with other types of single or concatenations of elements. Shape grammars adopted the idea of transformation rules, but replaced linguistic elements (words) with spatial entities (shapes). In shape grammars, transformation rules took the form of A —> B, where A and B were drawings of shapes (as opposed to symbols standing in for shapes) and the —> was a replacement operation. In a drawing, the replacement operation would identify an instance or a transformed (scaled, rotated, or reflected) copy of a shape A and replace it with a shape B. Stiny

framed this as a shift from "identity," in which a rule requires the recognition of a specific symbol, to "embedding," in which a rule requires the perception of a shape, possibly within another shape.[10]

Although the studio does not require students to write rigorous shape rules or to derive designs through their systematic application, the studio strongly promotes the iterative "see-do" cycle that is central to shape grammars. The course is structured in a stepwise manner through a series of exercises, each confronting the students with a specific set of tasks, media, and materials. After each exercise, students reflect on the outcome and on their own process, and extract new rules or strategies that they carry over to the next exercise. The students begin with a familiar object and transform it into an architectural proposition through a sequence of operations, each corresponding to a week-long exercise: *flattening, transforming, generating, lifting,* and *spatializing*. In **flattening**, students use drawing strategies to abstract salient features (shapes and spatial relationships between shapes) from an object that they encounter in their everyday environment using a maximum of twenty lines, arcs, or points. This cultivates an economy of representation and introduces students to a mindset of working within constraints. In **transforming**, students overlay these drawings, identify emergent shapes, and apply affine transformations (translation, rotation, scaling, reflection) to amplify select spatial relationships that were identified in their flattening drawings. In **generating**, students produce new drawings based on elementary shapes and transformation rules that they define by reading the outcomes of the "transforming" exercise. In **lifting**, students develop strategies and rules for giving depth to their drawings by moving points and lines along the z-axis. Finally, in **spatializing**, they materialize a three-dimensional space by placing two of their "deep" drawings, one on the x-y plane and the other on the y-z plane, in dialogue. These exercises culminate in a culling of space-making strategies as well as a cataloging of specific moments that students judge as collectible and potentially worth revisiting in later stages of the project that are not yet disclosed to them). A measure of success is each student's ability to carry spatial and formal ideas from one exercise to another and to use each exercise so as to enrich and expand them. Over the course of this first studio phase, each student develops a set of spatial *dispositions* as well as a recognizable formal language that is expressed as a loose "recipe" or rule-set.

Each studio exercise is coupled with a particular digital modelling module from the representation lecture course (respectively, two-dimensional line abstraction of an object, application of affine transformations, a two-dimensional compositional drawing and application of line weights to express saliences, the relocation of elements along the z-axis, and three-dimensional spatial modelling through Boolean operations upon volumes or surface manipulations). This coupling is to keep students mindful of representation spaces and the range of manipulations available to them. The course is thus an environment for honing in ideas and techniques introduced in studio.

In the second part of the studio, students edit, merge, and refine their formal systems in response to an urban context that they abstract as a set of material and immaterial parameters (social, cultural, environmental, demographic, etc.). Students are given a list of

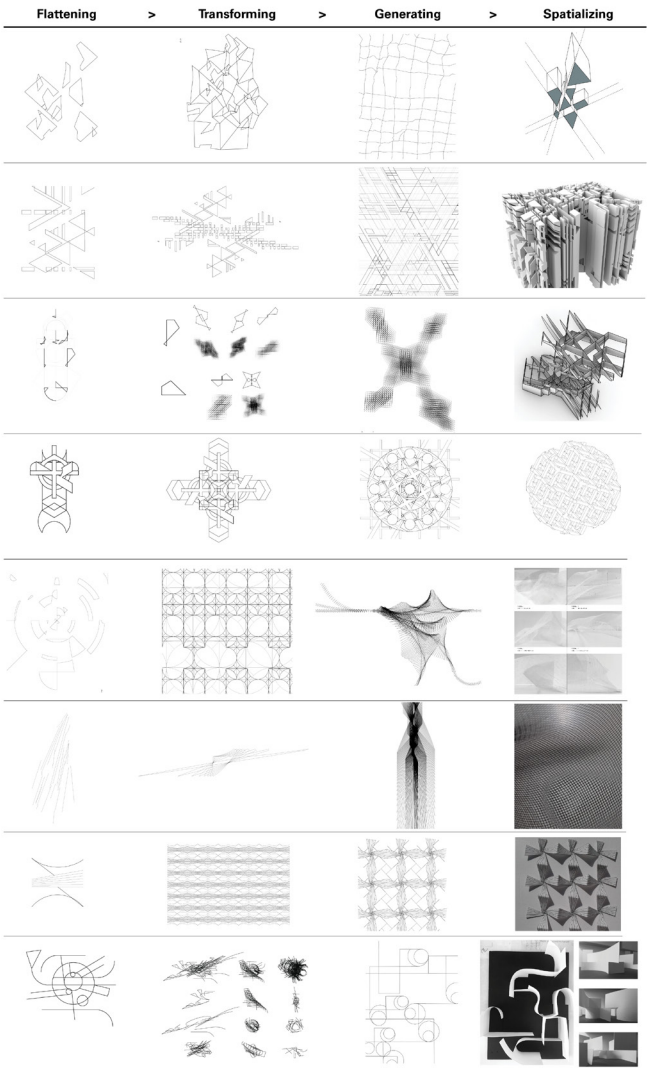

Figure 2. Student work from the first part of the studio, which consisted of five steps/exercices. The student work presented here is by Nathalie Marj, Diana Nigmatulina, Reda Berrada, Ruoyu Zhu, Naomi Julien, Sharon Kim, Isabel Cano and Herve Laurendeau.

sites that are different but equal in area, and each student selects a site that they judge as congruent to the spatial dispositions of their formal system. They abstract salient material and geometric characteristics of the site through drawing and physical and digital modelling, so as to produce a "prepared" surface on which the forms and formal systems that they developed in the first phase of the studio will seek their place.

This happens through an exercise of **locating** in which students either push, pull, or distort a geometry that they developed in the first part of the studio to fit or graft on to the abstracted context. Alternatively, they may use elements of the abstracted context to redeploy the generative processes that they had devised earlier. Then, students map immaterial forces present within the site (as

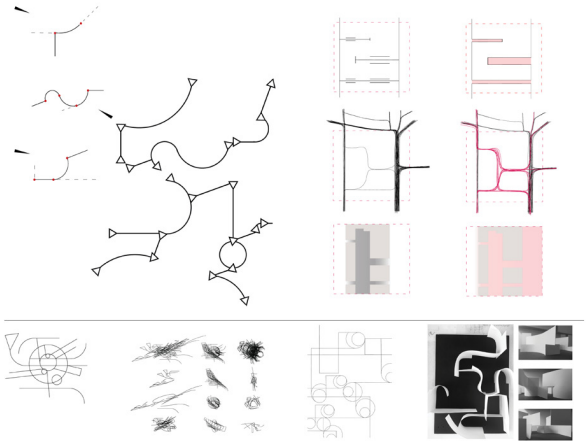

Figure 3. Use of generative drawing produced in the first part of the studio as a lens through which to read a site. Student work by Herve Laurendeau.

hand-drawn maps or data visualizations) so as to challenge, inflect, and ultimately programmatically activate their newly sited compositions. The confrontation of autonomous formal logics with contextual forces becomes a site for intention formation and programmatic imagination. The students work iteratively to develop an architectural intervention that exhibits formal, programmatic, and material resolution with regards to a set of architectural priorities and individual intentions.

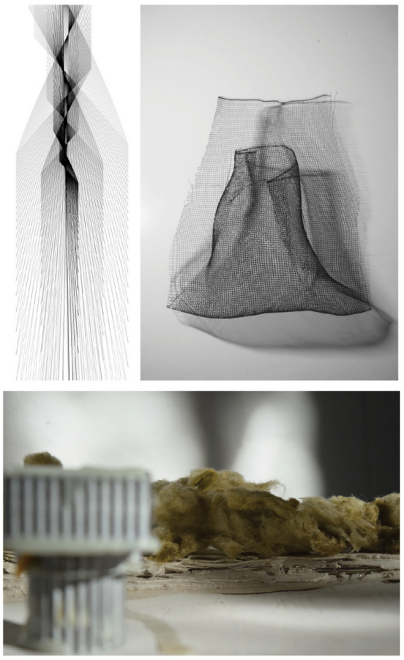

Figure 4. An architectural intervention that acts as a viewing device blending the visual Moiré effects with the material coarseness of the landscape, which the student highlighted in abstracting the site she was given, Student work by Sharon Kim.

Digital and computational design is often pejoratively deemed "formalist" to point at a focus on the internal syntax and language of an architectural object and a disregard for its social, cultural, and environmental contexts. Systems that sort configurational possibilities (the "design space") based on specific functional or other performances have historically sought to respond to such concerns. More recently, neologisms such as "performalism" have emerged from efforts to reconcile algorithmic derivations of geometry with contextual parameters (parsed as data and information).[11] This studio challenges the alignment of generative (rule-based) design with architectural ideologies of autonomy. However, it does not achieve that by bringing a data-fied version of "context" into a predefined system of rules, but instead makes the rules and their applications permeable to contexts of various kinds: both students' readings of the specific sites they choose, but also of the various material and perceptual contexts in which they design their interventions.

This studio pedagogy does not directly teach methods for addressing pressing social and environmental issues, but makes room for integrating concerns that students bring to the table. The three year undergraduate curriculum, of which this is part, offers excellent courses on sustainable design, social housing, and spatial justice, in which students tackle urgent challenges facing the architecture profession. Complementing these courses, the studio and lecture course pairing presented here considers the possibility of students working outside a problem-solving mentality and reflecting on their own creative and poetic dispositions as a means to identify certain matters of concern in a given context. This approach prepares them for a problem-setting mentality, in which students acknowledge positionality and subjectivity as an inescapable part of any creative and constructive intervention. This aims to challenge a long history of alignment of computational methods with technical rationality,[12] which has had adverse effects on architects' formation as social actors and a problematic affinity with positivist and scientistic tropes.

LECTURE COURSE: DIGITAL REPRESENTATION

The digital representation lecture course reinforces the studio's aim to develop individual strategies for talking about and making geometric form by extrapolating the constraints and affordances of different media and representation modes. Alongside the studio, it introduces students to basic computational ideas at play in design and representation. Four thematic modules introduce different concepts and techniques: *observing, composing, instructing, presenting*. Throughout the course, exercises are framed and critiqued on the basis of the soundness of students' decisions, foregrounding a deliberate process of distinguishing and choosing appropriate representational strategies.

The **observing** module centers on methods, from inside and outside architecture, that use visual depiction as a way of discovering and articulating orders within or behind empirical perception. Lectures introduce questions about what and how to see, and how to manifest these decisions within representation. A field of reference sights and depictions is established by selecting precedent examples of scientific and art historical origin, as well as from within the discipline of

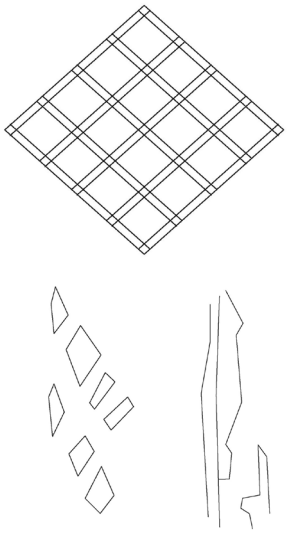

Figure 5. The first assignment in the digital representation was also part of the studio course. The restricted number of geometrical elements that could be used to depict an everyday object imposed a decision on which epistemic values to uphold. Students responded to this prompt generally by representing the geometric properties of the object, with some alternatively focusing on its material traits. A number of students displayed a concern for archetypal composition by depicting what could be described as the "compositional guidelines" of the object, while others chose to value exactitude by drawing parts of the object with precision. Abstraction of a tree and a lattice tree guard by Nathalie Marj.

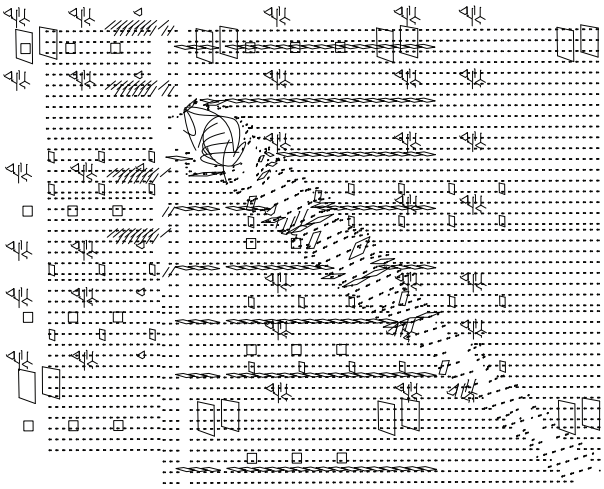

Figure 6. The second assignment of the digital representation course revolved around the use of orthographies. Asked to "represent" an object of their choice in the observing module, students combined their observations with that of a teammate's, curating and synthesizing the spatial/visual ideas that appear salient to them. During this composition process they moved from simple tools and media toward more complex ones. This prepared students to strategically articulate and investigate a project through representation.

Students were first asked to combine their initial representations of an everyday object into a hybrid diagram, which informed the composition of a new, hybrid object. While they worked primarily in 3d software, the various orthographic drawings (not shown here) they were asked to produce (plan, section, elevation, and axonometric) became evaluation devices: moments to take stock of the cumulative decisions made. Student work by Bruce Liang and Antony Suh

architecture. These examples begin to define a domain of methods for the probing of visual materials. The loose organization of examples begins to present cases for the alignments of certain epistemic values and practical contexts with particular formats and media, for example of idealization ("truth") and objectivity,[13] and composing form and evoking experience. The intent in this first stage is not only to present diverse representational formats, but also to foster awareness of the kinds of particular knowledge they tend to produce. Ideas discussed in this first phase apply not only to the lecture course's first assignment but also to the assignments in studio.

The second stage of the digital representation course, themed **composing**, foregrounds the construction of form through rules and principles, gradually shifting from the creation of geometric rules to their application in orthographic and perspective projections. Thematic lectures and discussions introduce the act of abstraction as a way to concurrently observe and construct images. The abstraction of spatial relationships is given particular attention in alignment with the kind of work that students pursue at that stage of the semester in studio (the aforementioned *generating* and *spatializing* exercises). Students are presented with a brief taxonomy of compositional and spatial rules within the visual cultures of early computer art and early digital architecture.

A disciplinary awareness provides a common corpus for critical discussion and opportunities to engage with the particulars of computing in design. In addition, the mathematical definitions of various transformations as defined in Felix Klein's Erlangen Program (the definition of new geometries based on properties of geometric shapes that remain invariant under transformations) are offered concurrently with the studio sequence's concern with transformation rules.

Under the theme of **instructing**, the digital representation course introduces scripting as a way to codify rules, subsequently allowing students to manipulate form through scripted procedures. The section initiates discussions on designer-authored form-generating processes in addition to conversations on the algorithmic undergirding of drawing production. The latter is exhibited in different instances: from the instructions for the reproduction of variations of architectural elements[14] to the mathematical instructions present at the core of our "digital" drawing tools that may reveal some of the "black-boxed" processes of design software.

Instructing exercises first require a scripted re-creation of the design submitted in the prior assignment. The compositional characteristics that either guided the design or were found *a posteriori* through analysis of the students' own work are formalized through scripting tools.

Finding ways to describe the formal inventions of the *composing* assignment leads to the imagination of a family of variations that presents a coherent set of properties. While this expands the number of producible forms, the multiplicity suggests and refines a selection of essential shared qualities.

This construction of a type challenged students to negotiate representations of generalized visual principles with those of detailed particularities. In addition to providing a basis for the use of what is for most students a new method, this exercise also appeared to bridge

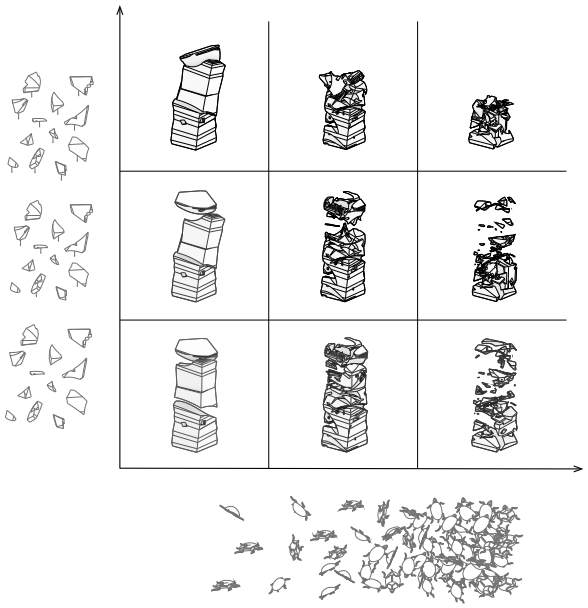

Figure 7. In the *Instructing* assignment of the digital representation course, the qualities explored range from easily definable geometrical, proportional, quantitative principles to more complex, intuitive, and qualitative conditions (instability, integrity (or lack of), age). Student work by Simone Moreau and Florence Primeau-Marcoux.

complex, qualitative, and sometimes ambiguous observations with the rigidity of formal language. This dichotomy is at the center of developing an eventual capacity to resolve problems not easily formalized through algorithmic design and reasoning. While students were working on this exercise in digital representation, they were grappling in studio with reconciling their formal systems with context and program.

Figure 8. Students inserted instances of their object family in new contexts to reframe its reading. Student work by Arlene Chen and Marina Dentico.

Finally, the **presenting** segment of the course examines how formats, reproducible modes of presentation, can be used to investigate and articulate arguments. Lectures pose questions of curating and framing within representation and approach them from, on the one hand, the perspective of reading representation and, on the other hand, from the standpoint of strategizing how to best serve an argument. This aligns with the studio's requirement for fictions that tie the students' formal propositions with the performative concerns that they serve. In the context of the digital representation course, students retroactively formulate a fiction coherent within the entire semester's work. They are specifically asked to produce one perspective and to reformat the sum of their work in a way that purposefully manages attention and frames the work in an intentional context. After cycling though seeing and making throughout the semester, in this final module, students prepare for a final critique that is in essence a synoptic viewing—a viewing by new observers that see all their work at once.

The gradual advancements between these segments allowed the students to preserve their capacity for attention and intention, avoiding as much as possible the relinquishing of control to the digital tool as a driver of design and aesthetic choices.While technical proficiency, as defined by the demands of the industry, has become a staple of undergraduate representation classes, this course posits the training of the eye as an equally important and useful competency. This is supported by a heightened concern for the development of visual literacy through various exercises that aim to expand the corpus of references to which students have access; students become versant in compositional terms. This new framework of references and vocabulary facilitates discussions between faculty and students, as well as between the students themselves, as they collectively develop ways to evaluate and instigate work. These assignments form a structure for individualized design research methodologies—generating for each student a set of prompts to articulate, test, and defend ideas.

CONCLUSION

While digital representation remains a specific medium, it can only be properly understood through its continuities with, and distinctions from, the broader corpus of representation at large. And while algorithmically-derived formal systems bear historical links to debates of architectural autonomy and formalism[15] or automatic synthesis,[16 17] they are not impermeable to, and in fact can become devices for, approaching and understanding the complexities and urgencies of context as well as one's personal aesthetic proclivities. Tactically slowing down and *performing* algorithms can open up these contingencies. Teaching digital tools and computational processes through their *proximity with* as opposed to *distance from* what is traditionally construed as "non-digital" practices, provides an opening for conscious and reflexive engagement of the modes of description and sequences of action that these practices encode. In recent years, the response to digital representation has mainly

taken the form of the "post-digital," an aesthetic driven by concerns of authenticity and autonomy.[18] While the "post-digital" has opted for the emulation of the "hand-made" through software, this pairing of courses sought to introduce digital processes through slow, "hand-made" work as a way to secure attention, intention, and judgment as a pedagogical foundation.

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