Signal/Noise: Code and Craft in Architectural Drawing

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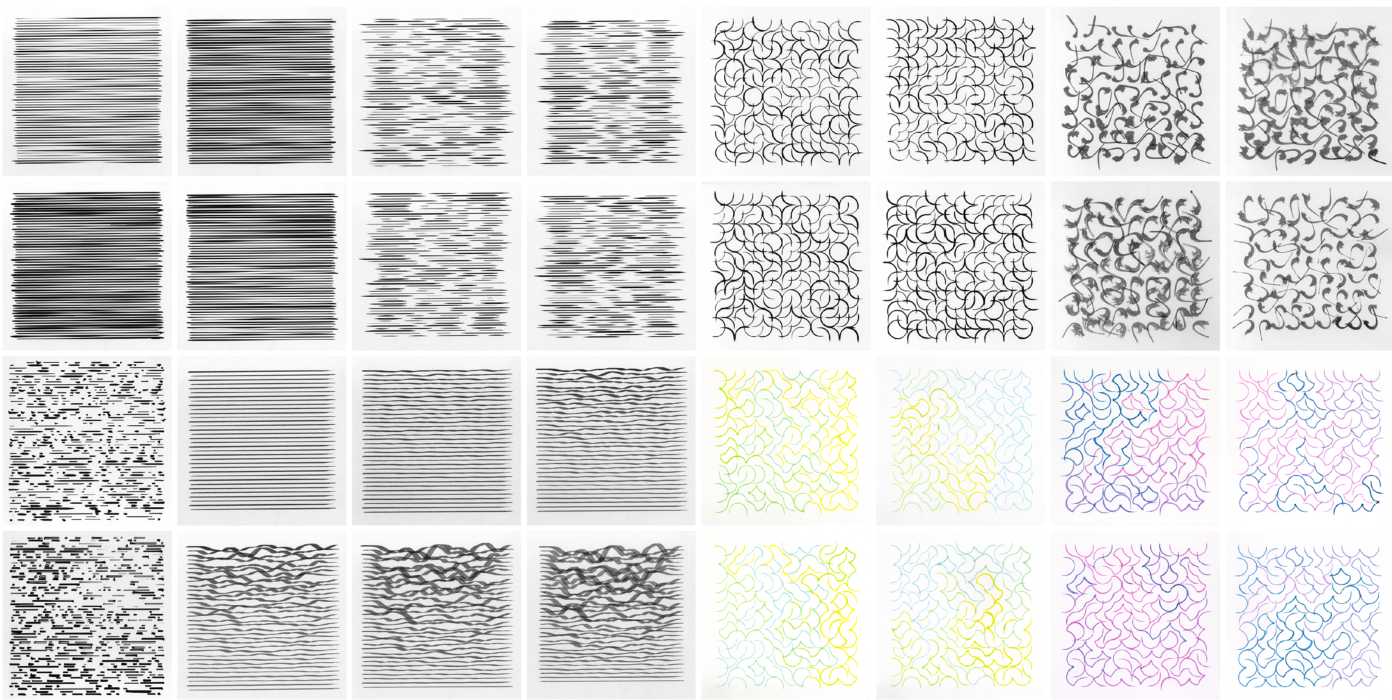

Figure 1: Matrix of *Signal/Noise* drawings.

This paper presents ongoing research into parametrically generated and robotically produced drawings. The work explores overlaps between procedural design techniques, computer numerically controlled (CNC) machinery, conventions of architectural representation, and the craft of analog drawing. The work leverages technology to subvert its own biases for precision and predictability, using computational design and fabrication techniques to re-introduce error in productive and measured ways that open up new and evocative aesthetic possibilities.

The widespread adoption of techniques of parametric design and digital fabrication within architecture has expanded the discipline's capacity for new approaches to the form, performance, and manufacture of buildings. But a generation into architecture's digital turn, these tools have contributed to a new kind of inertia. Computational practices today are often associated with stylistic tropes of continuous differentiation, panelized surfaces, twisty towers, and the like—so much so that "parametric" is now casual shorthand for anything curvy.[1] Somewhere along the way, the critical understanding of what it means to design with parametric processes and make things with digitally-driven machines has been lost, superseded by a more product-driven approach towards computation as a means to achieve predetermined outcomes. With increasing access to tools that package previously complex algorithms and scripts into easily deployed "push-button" techniques of translating complex forms to componentized systems, architects are further distanced from the underlying processes of such translations. This distance forecloses opportunities for the glitches, errors, and unpredictable surprises that can often contribute to a sense of craft in the translation from digital space to physical material.

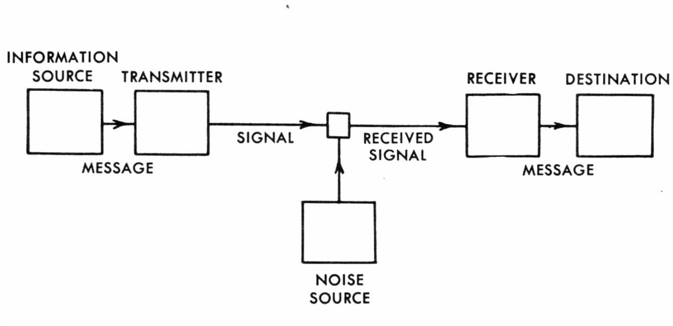

Figure 2: Claude Shannon's schematic diagram of communication, from his seminal 1948 paper "A Mathematical Theory of Communication."

This paper presents ongoing research into parametrically generated and robotically produced drawings that resist the contemporary tropes of computational design and digital fabrication to articulate a more critical and elemental understanding of how such technologies can inform architectural design. The work explores overlaps between procedural design techniques, computer numerically controlled (CNC) machinery, conventions of architectural representation, and the craft of analog drawing—all in parallel, to explore productive convergences and unexpected resonances. The research focuses not on form, performance, or affect, but rather media and representation—literally how information is translated from one medium to another, and how a sense of craft can be located in this translation.

INFORMATION AND NOISE

This research draws inspiration from three unique but related historical and architectural discourses. As a first step in developing a more elemental understanding of computational processes as they relate to architectural representation, it is helpful to return to the origins of computation itself. Claude Shannon's seminal 1948 paper "A Mathematical Theory of Communication," considered the foundation of the discipline of information theory, codified the fundamental processes of communication that underlie digital computation.[2] Shannon, an engineer and mathematician whose work bridged cryptography, ballistics, and genetics, articulated a theory of *information as matter*: quantifiable, predictable, and communicable. His famous diagram of communication outlines the process by which a signal is transmitted from a source to a destination, recognizing the probability that it will be distorted or compromised by a noise source (Figure 2). Importantly, Shannon defined information as independent from "meaning" or the actual content of the message; instead, he defined it as the *fidelity* or *accuracy* of the transmission process itself.

Underlying Shannon's theory is a complex and paradoxical contingency between information (the signal) and noise. On the one hand, the noise source is an obstacle or impediment that needs to be mitigated in order for a message to be clearly transmitted. But on the other hand, if there is no noise (or at least the *possibility* of noise—the possibility that one message could be mistaken for a different message), then the informational value of that message is negligible. Shannon's understanding and embrace of the uncertainty, surprise, and difficulty of transmitting a message recognizes that noise in fact has a productive role, that information and noise are inextricably linked. To put it simply, paraphrasing Shannon via historian James Gleick, "information is closely associated with uncertainty."[3]

ECOLOGIES OF REPETITION AND DIFFERENCE

This contingency between certainty and uncertainty is always present in the production of architectural drawings and artifacts, despite the architect's best efforts to minimize error. Mario Carpo, who has written extensively on the history of architectural representation in this regard, argues how architecture's so-called "digital turn" has brought with it a return to the pre-Albertian paradigms of variation and difference that existed prior to the advent of standardized mass production.[4] The computer's capacity for calculating variation and difference in great quantity and complexity now enables the designer to employ mass customization rather than relying on logics of standardization that informed much of architectural production since the Industrial Revolution. Carpo notes with some irony how today's computation enables a mode of production that is more akin to the bespoke and handmade practices that predate industrialization—although of course with far greater precision and control.

As computationally-informed work becomes increasingly associated with stylistic tropes divorced from the underlying processes at play, it loses this kind of historical and critical understanding of contemporary technology's origins. This project seeks to recover critical agency operating firmly within the territory mapped by Carpo—the strange collapse of digital computation back into the analog and artisanal. By engaging simultaneously in parametric processes, machine production, and analog drawing, the project professes kinship with historical figures who embraced similarly ambiguous processes of production of difference. These range from Leon Battista Alberti, whose 15th century *Descriptio vrbis Romæ* experiment in radial cartography and numerical notation represents one of the earliest examples of digitally encoded spatial data,[5] to the nineteenth century designer and industrialist William Morris, who operated firmly within the paradigm of standardized mass production but was nonetheless able to imbue his wallpaper patterns with a remarkable degree of visual difference and complexity.[6] Both precedents share a critical understanding of the technology of their time and how to work within its limits to produce and represent difference.

COMPUTATION AND CRAFT

The third reference point for this project is the discourse on craft in architectural production, specifically in regard to computational workflows of design and fabrication. The work looks to the notion of craft as defined by furniture maker David Pye in his seminal treatise *The Nature and Art of Workmanship*. Pye locates the genesis of craft in what he calls the "workmanship of risk," in which "the quality of the result is continually at risk during the process of making." He contrasts this to the "workmanship of certainty" that governs machine production, which he disapprovingly rejects as devoid of the possibility for the unexpected surprises that can give artifacts unique character and value. In a loose parallel to Shannon's

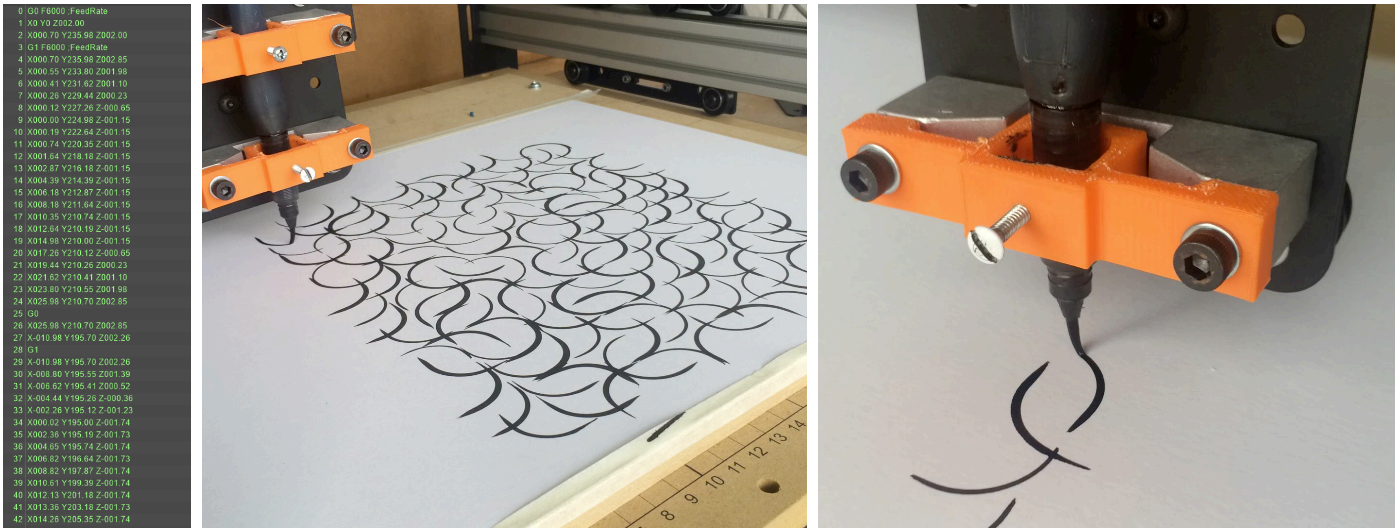

Figure 3: The drawings are produced using a custom-built, computer numerically controlled (CNC) 3-axis router with a brush pen end effector. The instructions for the machine are communicated using the G-code programming language.

assertion that noise plays a productive role in the communication of a signal, Pye places a value on risk, unpredictability, and what he calls "dexterity": one's ability to master and manage unpredictability in the production of an artifact.[7] This project embraces Pye's notion of craft rooted in risk, but it also resists the either-or binary of risk and certainty, instead arguing that craft *can* be found in computational modes of design and fabrication.

PROCEDURAL DRAWINGS

This work builds upon the rich history of procedural drawing that parallels the emergence of computation in the past 70 years. This includes the algorithmic art of Sol LeWitt, who used simple geometries and procedures to explore process-based relationships between code, craft, and space,[8] as well as the work of early pioneers of computational art, like Vera Molnár and Manfred Mohr, who employed pen plotter machines to execute procedures akin to LeWitt's analog experiments.[9] There are also a number of contemporary architects and designers exploring these processes in the context of contemporary technologies like parametric modeling and robotic fabrication.[10] The motivation for this project is less on the product of the actual drawing, however, and more on the process of communicating information from one medium to another—and what design and aesthetic opportunities may be discovered in that process.

Towards this end, this research explores two-dimensional drawing as a site for considering the role of noise, variation, and craft in contemporary architectural production. It seeks to leverage technology to subvert its own biases for precision and predictability, using computational design and fabrication techniques to re-introduce error in productive and measured ways that open up new and evocative aesthetic possibilities. The medium of drawing provides productive constraints that allow for a focused and intentional exploration of these ideas as they relate to robotic processes. But it also reclaims the medium as a site for experimentation, rejecting the now common marginalization of drawings to merely an afterthought or "deliverable" produced by a commercial software package.

WORKFLOW

Each series of drawings begins with a digital, parametric model that uses algorithmic processes to deploy repetition and difference across a gridded field of simple but slightly variable geometries. The constraint of gridded, primitive lines and arcs neutralizes questions of form and geometry, instead providing a consistent framework for comparing the variation from one drawing to the next. The algorithm typically employs random seeds to strategically distribute variation throughout the field; the parametric nature of the model enables one to vary these seeds and thus change the variation, allowing for the quick production of multiple iterations.

Once established in the digital environment, the geometries are then translated to fabrication instructions via the G-code programming language commonly used in CNC workflows. These instructions are sent to a custom-built drawing machine, which consists of a modified 3-axis computer numerically controlled (CNC) router constructed from off-the-shelf components (Figure 3). The machine then applies ink to paper using a watercolor brush pen, following the sequence as dictated by the digital model. Once complete, the parametric variation is recalibrated by changing the random seeds, and the process is repeated to produce a new drawing.

Each of these acts of translation—from code to mechanical motion to the material deposition of ink on paper—introduces noise into the system: inaccuracies, glitches, and anomalies that compromise the fidelity of the original geometric information, but also generate unexpected and surprising visual effects. In order to foreground these qualities, each drawing is always produced in a set of four; this nonstandard seriality provides a clear basis for understanding the similarities and differences from one drawing to the next.

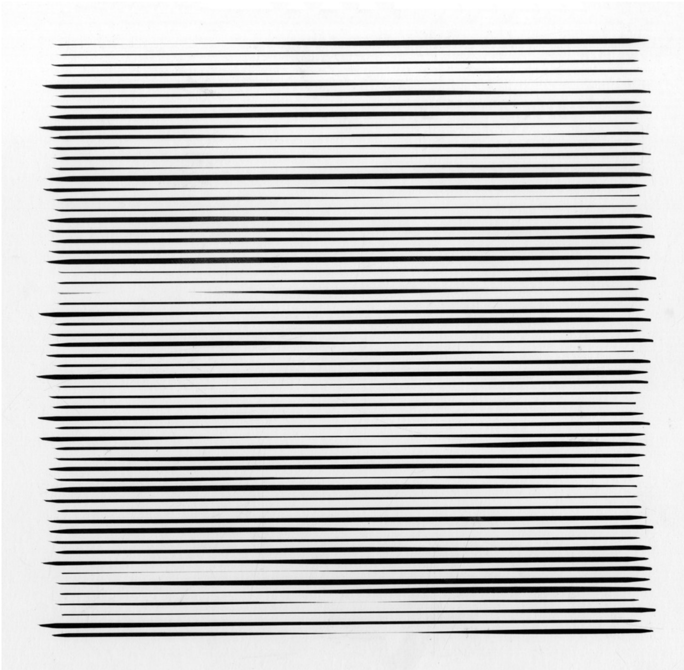
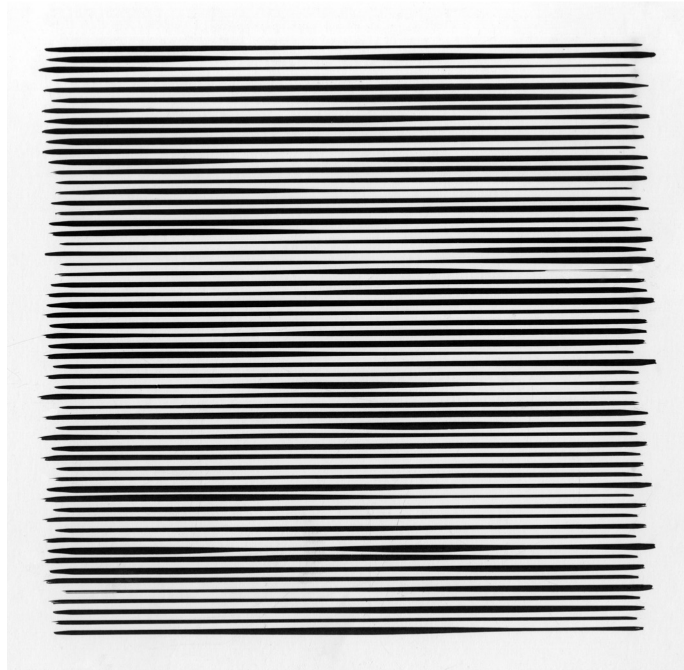

Figure 4: *Lines, Seed 132* (left) and *Lines, Seed 234* (right).

ITERATIVE STUDIES

A look at several of the iterations demonstrates several different approaches to the balance of risk and certainty in the production of the drawings. The simplest is the *Lines* series, which consists of an array of 58 horizontal lines drawn separately on the page (Figure 4). The process mimics the act of hand drawing, in which the pressure between the tip of the pen and the paper can vary to produce different line weights. In the digital model, the control points of each line are modulated in the z direction to create a three-dimensional curve. When translated to machine movement, these curves produce lines with variable thicknesses; some portions of the lines even disappear (to a line weight of zero) if the tip of the brush moves too far up in the vertical direction to touch the paper. In recreating the range of variations that often characterize analog hand drawing, this series identifies the conditions of possibility for deploying similar variations in a controlled, mechanized way.

The *Rotated Arcs* series expands this logic by introducing qualities of sequence and overlap into the drawing process (Figure 5). In the digital model, random seeds are used both to rotate each arc in variable 90 degree increments and to move each arc in the z direction in different quantities. As the machine draws each arc, the ends overlap each other, producing unexpected and unpredictable behaviors that arise from both the variable line weights and the tolerances of the machine as it moves. These qualities are further explored in the *Pressed Splines* series, which pushes the machine to its limits by exaggerating the vertical motion along each curve (Figure 6). A dramatic dip in the negative z direction at the start of the curve results in a messy collision between brush and paper, producing complex forms and sometimes splattering ink across the page. This series uses a lighter, more watered-down gray ink, which indexes the overlaps between curves in a more legible way. The resulting output differs significantly from the digital model in both its geometric unpredictability and overlaps of brush strokes, which add a new sense of sequence and depth to the drawing.

Recent studies continue to explore how computational tools can recreate the time-based aspects of analog drawing. The *Rotated and Joined Arcs* series uses the same geometries from the *Rotated Arcs* series, with two important variations. In the digital model, the arcs are joined together into longer polylines; the joining logic depends entirely upon the alignment of the arc ends to each other, which varies based on the randomly seeded rotation. In the translation to the drawing machine, two colors of ink are used to index the sequence of this process. The brush pen is loaded with one color, while the brush tip is dipped in a second color directly before starting the drawing. As the machine proceeds through the drawing sequence, the second color is slowly replaced by the first color, producing a gradient that records change over time and references the joining logic from the parametric model. The *After William Morris* series employs a similar process with different geometries—in this case, patterns abstracted from the wallpaper designs of William Morris. In their use of overlapping leaves and gradated ink to study the relationship between repetition and difference, the drawings reference Morris's sophisticated mastery of variation within a paradigm of standardized mechanical production.

CONCLUSION

The contribution of this work is less in the singular artifact and more in the collective body of experiments, which explore a range of approaches to processes of risk and certainty in robotically produced drawings. The work steps back from the exuberance of

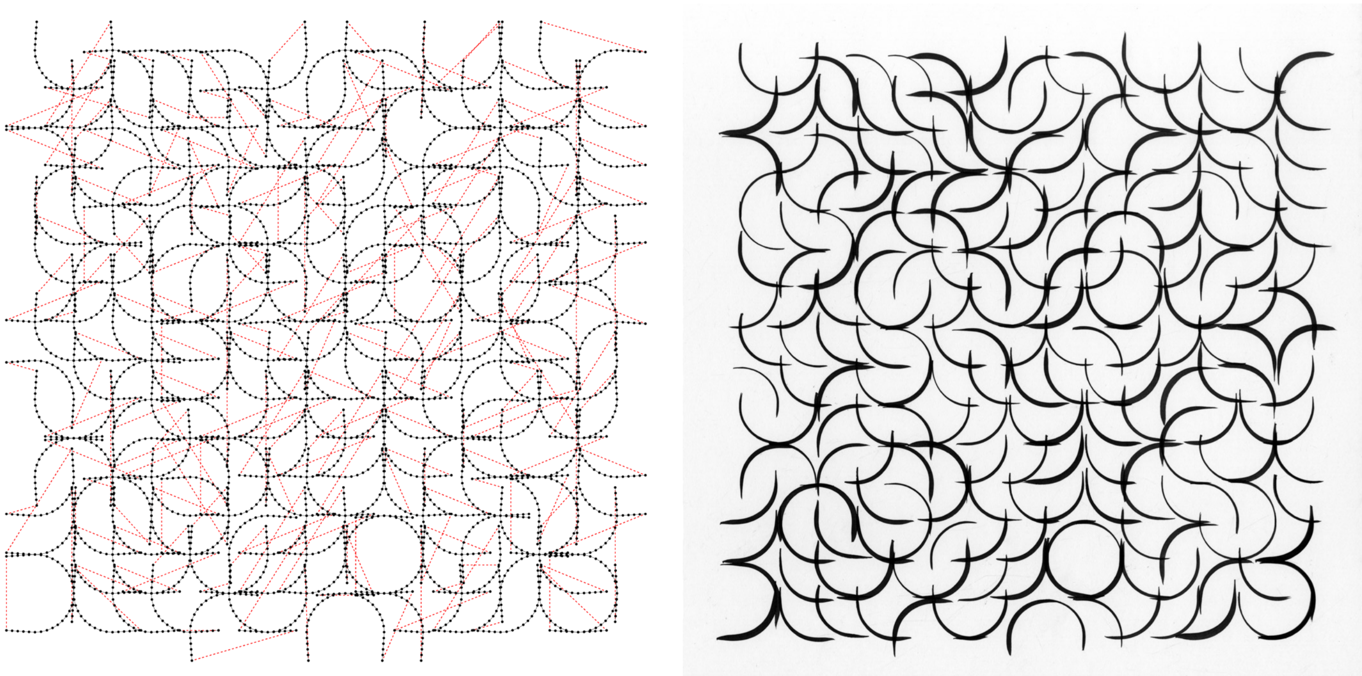

Figure 5: ***Rotated Arcs, Seed 239/12***. A comparison of the digital toolpath drawing (left) with the physical output drawing (right) demonstrates the qualities that emerge from the translation of information from one medium to another.

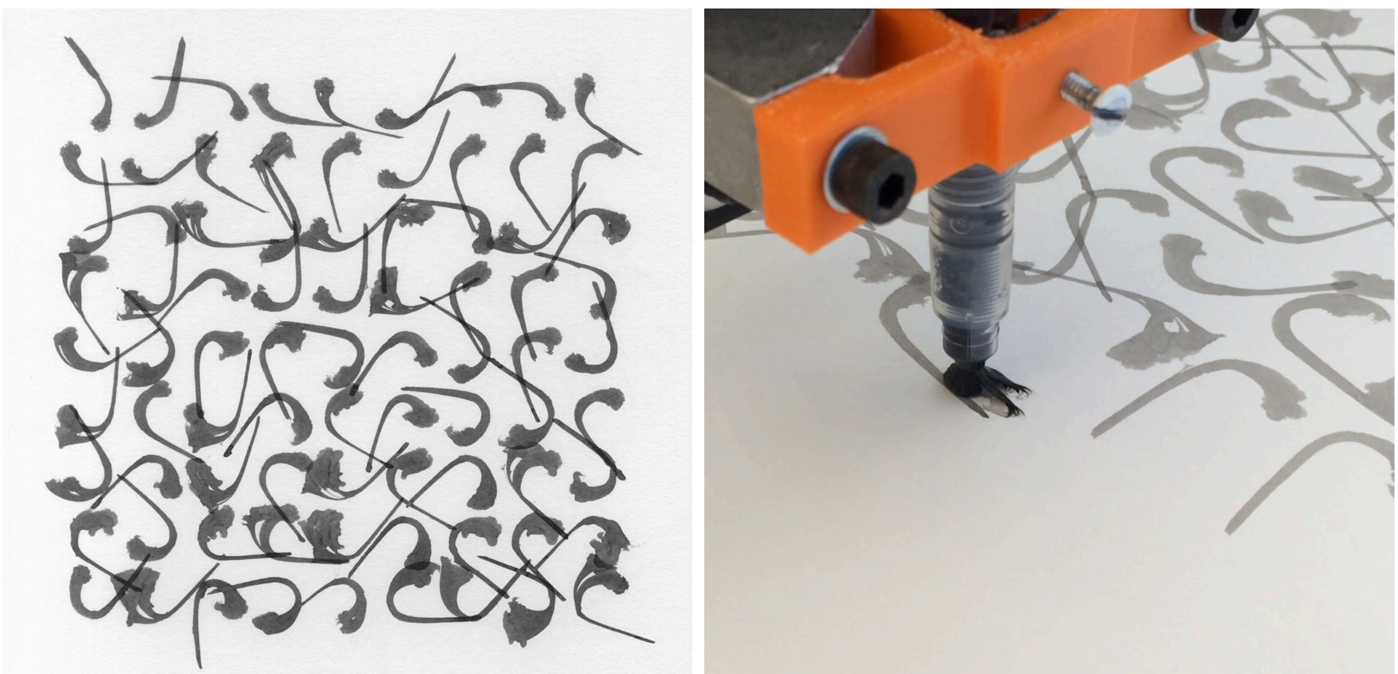

Figure 6: *Pressed Splines, Seed 169* (full drawing at left; detail at right).

contemporary architectural production to develop a critical, elemental understanding of the processes of parametric design and digital fabrication that now inform so much of architectural practice. In focusing on representation—literally the communication and translation of information from one medium to another—the drawings demonstrate how computational tools of design and fabrication can be used to deploy variation and difference in unpredictable yet nonetheless controlled ways.

In the design and production process, several opportunities emerge for testing the balance between control and risk:

- First, the initial procedural logics incorporate random seeds that allow for iterative variation of geometric parameters, such as rotation or length, in the digital environment. The use of random seeds inserts a degree of unpredictability, but always within predetermined limits.

- Second, the translation of the virtual drawing to instructions for the CNC machine introduces issues of tolerance, calibration, and mechanical imprecision that produce strange, accidental artifacts like bumpy lines and variable line weights.
- Finally, the delivery of ink onto the paper is entirely dependent upon the material parameters of the media, the brush quality, and even environmental factors like temperature and humidity.

Whether algorithmic, mechanical, or material in origin, the sources of noise are cumulative and contingent; together they contribute a sense of craft to the drawings that otherwise would not be present. The drawings begin to demonstrate the opportunities that lie within translations from bits to motion to matter—and the possibility of finding craft in computational modes of design and fabrication.

ACKNOWLEDGEMENTS

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ENDNOTES

1. This association of parametric processes with curvilinear geometry is in no small part aided by the prolific writings of Patrik Schumacher, who has popularized the term "parametricism." See Patrik Schumacher, "Parametricism as Style – Parametricist Manifesto," 2008, http://www.patrikschumacher.com/Texts/Parametricism%20as%20Style.htm (accessed November 1, 2017). For an extended theoretical treatise on Parametricism, see: Patrik Schumacher, *The Autopoiesis of Architecture, Volume 1: A New Framework for Architecture* (London: John Wiley & Sons, 2010) and *The Autopoiesis of Architecture, Volume 2: A New Agenda for Architecture* (London: John Wiley & Sons, 2012).
2. C. E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal* 27 (1948): 379–423. For a comprehensive history of information theory and Shannon's central role in its inception, see James Gleick, *The Information: A History, a Theory, a Flood* (New York: Pantheon Books, 2011).
3. Gleick, *The Information*, 219.
4. Mario Carpo, *The Alphabet and the Algorithm* (Cambridge: MIT Press, 2011).
5. *Leon Battista Alberti's Delineation of the City of Rome (Descriptio vrbis Romæ)*, ed. Mario Carpo and Francesco Furlan (Arizona Center for Medieval and Renaissance Studies, 2007).
6. For discussion of William Morris's pattern designs in the context of contemporary technologies of design computation, see Adam Marcus, "Repetition and Difference, After William Morris" in *Drawing Futures: Speculations in Contemporary Drawing for Art and Architecture*, ed. Laura Allen and Luke Caspar Pearson with Bob Sheil and Frédéric Migayrou (London: UCL Press, 2016), 58-60.
7. David Pye, *The Nature and Art of Workmanship* (London: Herbert Press, 1968), 20-24.
8. For an overview of LeWitt's approach to conceptual art, see Sol LeWitt, "Paragraphs on Conceptual Art," *Artforum* 10 (Summer 1967). For a comprehensive collection of his algorithmic wall drawings, see *Sol LeWitt: 100 Views*, ed. Susan Cross and Denise Markonish (New Haven: Yale University Press, 2009).
9. Both artists' websites have a comprehensive documentation of their work. See http://www.veramolnar.com and http://www.emohr.com. For a survey of Molnár's work, see the exhibition catalog *Vera Molnár: (Un)Ordnung. (Dés) Ordre*, ed. Sabine Schaschl and Simoe Schimpf (Zurich: Museum Haus Konstruktiv, 2015). For a survey of Mohr's work, see the exhibition catalog *Der Algorithmus des Manfred Mohr: Texte 1963-1979*, ed. Margit Rosen (Leibzig: Spector Verlag, 2014).
10. Examples include Carl Lostritto, who uses advanced computational workflows and a vintage pen plotter to produce richly layered drawings (see http://lostritto.com) and Andrew Kudless, whose *Scripted Movement* series of drawings employs an industrial robot arm to explore overlaps between natural and technological systems (see http://matsysdesign.com/2014/07/13/scripted-movement-drawings-series-1/).