Seams as Trace Infrastructure: How Tool Architecture Shapes What Creative Activity Traces Can Capture

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Fig. 1. (a) *Uniquely Shaped Spaces* generates shelving around personal artifacts. Through three seamful interventions—at maker, machine, and material boundaries—I redirected the system to produce (b) window-fitted shelving negotiating sunlight, plants, and a cat; (c) curved shelving realized through bent lamination; and (d) generated voids realized as ceramic vessels.

Creative activity traces from creativity support tools are shaped by what the tool makes inspectable. I argue that in generative fabrication, seams—workflow junctures where one computational transformation hands off to another—can function as trace infrastructure, producing legible records of creative reasoning that end-to-end pipelines may obscure. I ground this argument in *Uniquely Shaped Spaces*, a generative shelving tool whose multi-stage pipeline creates seams at each handoff. Drawing on a five-participant user study where participants discovered and exploited seams to steer outcomes, and an autoethnography where I deliberately staged seams at maker, machine, and material boundaries, I show that seams generate traces at multiple scales: interaction logs within the tool, revision episodes in process documentation, and physical consequences in fabricated artifacts. I propose that tool architecture is an analytical variable for trace research, not merely context, and raise questions about comparing traces across tools with different seam structures.

CCS Concepts: • **Human-centered computing** → **Interactive systems and tools**.

Additional Key Words and Phrases: Seamful Design, Digital Fabrication, Algorithmic Design, Computational Fabrication

1 Introduction

Creative activity traces—the recorded sequences of actions, decisions, and artifacts that accumulate as people work with creativity support tools (CSTs) [11]—constitute a rich resource for understanding how tools shape creative processes. Recent work has demonstrated that these traces can be analyzed automatically at scale to reveal temporal patterns, designer archetypes, and the dynamics of human-machine creative exchange [12]. Yet the traces any tool can produce are bounded by what it makes inspectable. In many generative design tools, interaction is treated primarily as specification: makers parameterize a design space, declare constraints up front, and receive outputs. In such pipelines, traces tend to capture inputs and final outputs—the reasoning between is computationally opaque. When a maker changes direction mid-process, the trace may record only that new parameters were entered, not why or what intermediate state prompted revision.

I argue that tools whose architectures expose intermediate states at workflow boundaries produce structurally rich creative activity traces. Specifically, I draw on seamful design [3, 9] to make this case in my own generative fabrication work [7]. I use seams to name junctures where maker intent, algorithmic logic, and material response become jointly consequential—where a site constraint meets the generator's search, where a layout becomes fabrication-ready geometry, or where material behavior pushes back on a computed form—and where these relationships are legible enough that a maker can inspect, interpret, and intervene [Under Review]. Each seam creates a potential trace event: a moment where creative reasoning becomes visible in the process record because the maker acted on an intermediate state rather than waiting for a final output.

This position paper argues that the relationship between seamful tool design and trace richness is not incidental. Tools designed so that makers can steer computational transformations midstream—rather than specifying everything up front—simultaneously produce rich process records, because each steering moment is a capturable trace event. Fabrication-based creative work is largely absent from the trace analysis conversation so far, which has been anchored in screen-based tools for writing, visual art, and game design. In what follows, I ground this claim in a specific generative fabrication system and two complementary bodies of evidence (a user study and an autoethnographic study), then draw out implications for how the workshop's emerging analytical toolkit might account for tool architecture as a variable.

2 Related Work

Research on creativity support tools (CSTs) has mapped the landscape of how interactive systems augment creative work [11], characterized the design space across users, roles, interactions, and technologies [4, 6], and developed techniques for analyzing the process data CSTs produce—from coding cognitive states during co-creation [5], to automatically constructing linkographs from design-move sequences [12], to modeling designer style as archetypical trajectories through a design space [1], to redesigning version control so that creative practices compressed by conventional commit logs become visible [10, 13]. Together, this work shows that what counts as a legible "move" in a creative process depends in part on the tool through which that process is captured. Yet existing surveys characterize CSTs by what they *do*—the roles they serve, the technologies they employ—rather than by what they make *visible* about creative reasoning. What is missing is a vocabulary for describing where in a tool's architecture that legibility gets created.

Seamful design offers one such vocabulary. The concept originated in ubiquitous computing, where Chalmers and colleagues argued that infrastructural discontinuities—gaps in signal, transitions between systems—need not be hidden but can be revealed as resources for situated action [2]. Inman and Ribes later emphasized seamfulness as a design stance centered on configurability and user appropriation through revealed system complexity [9]. I apply this framing to generative fabrication workflows, where seams name junctures at which negotiation among maker intent, algorithmic structure, and material response becomes inspectable and revisable [Under Review]. This builds on work in mixed-initiative computational design [8], where systems stage negotiated control through generation, evaluation, and selection, and where intermediate representations serve as sites of shared authorship between human and machine [7].

3 Seams Discovered and Seams Staged

I ground this argument in *Uniquely Shaped Spaces* [7], a generative shelving tool that creates custom shelving around the silhouettes of users' personal objects. The system's pipeline has three stages—simulated annealing arranges object silhouettes into a compact layout, cellular automata grow wall structures around the arrangement, and a joinery generator produces fabrication-ready parts for laser cutting—each of which surfaces an intermediate representation that the user can inspect. These stages create seams within the algorithmic pipeline (e.g., the mask-to-void relationship,

the layout-to-wall relationship), but seams also arise at the boundaries of the pipeline: where a maker's site constraints or lived context meet the generator's search, and where fabricated geometry meets material behavior. Together, these seams span the full maker–machine–material range.

I draw on two bodies of evidence that show these seams generating traces at different scales and under different conditions.

3.1 Participant-Discovered Seams

In a five-participant, twelve-week user study, participants designed shelves in guided workshops, then lived with the fabricated pieces for at least two weeks. The study collected screen recordings of all tool interactions, video of object handling during workshops, audio of verbal reflections, written notes, and semi-structured exit interviews at each participant's installation site.

Participants discovered and exploited seams without being instructed to do so—and these exploitations constitute some of the richest trace data from the study. One participant wanted to understand why her thin, delicate bones produced larger shelving voids than she expected (Fig. 1a). After being shown a diagnostic view that displayed the buffers around object masks and the step-by-step cellular automata wall generation, she deliberately trimmed her object masks smaller to shrink the resulting voids. This intervention is legible only because the mask-to-void seam exists: she could see the relationship between her input representation and the generated output, form a hypothesis about how to steer it, and act. The resulting trace—her iterative mask edits visible in the interaction log, the changed void dimensions in subsequent layout generations, and her eventual need to swap two bone positions after fabrication when one void proved too tight—records a rich episode of creative reasoning that would be invisible in a tool where silhouette processing happened opaquely.

Other participants generated traces at different seams. One participant removed an object from layout generation entirely to push the system toward the tall, narrow shelving she envisioned—exploiting the seam between object selection and layout generation, where adding or removing objects reshapes what arrangements are possible. Another participant opened multiple browser tabs to compare the outer dimensions of layouts generated from different object sets, exploiting the same seam to coordinate two shelving units for stacking into a sculpture. In each case, the participants' creative reasoning became capturable because the seam made an intermediate state inspectable and the intervention left a record.

3.2 Deliberately Staged Seams

In a subsequent autoethnographic inquiry [Under Review], I inserted designed seams into the *Uniquely Shaped Spaces* pipeline deliberately, staging three interventions at maker, machine, and material boundaries, and fabricated three artifacts: a window-bounded plant shelf that preserves a cat's perch (Fig. 1b), a bent-laminated curved shelf shaped by wood's springback (Fig. 1c), and clay-printed vessels reinterpreting generated negative space (Fig. 1d). Each intervention was documented through interface screenshots, parameter and export records, site photos, and reflexive memos.

The deliberately staged seams produced even richer trace data because they were designed as revision points. For the window shelf, introducing a perimeter constraint made the window's boundary operative during search—every layout state generated under this constraint records the site's pushback on the algorithm, visible as red-highlighted objects that exceed the envelope. A subsequent post-layout repositioning—moving the cat's silhouette to the bottom of the frame so the generated void would align with the cat's actual behavior of jumping onto the sill—left a before/after record of a revision whose rationale (accommodating a living creature's habits) would never appear in a parameterized

objective function. For the curved shelf, switching the wall-growth algorithm from rectilinear to curved segments made curvature a primary design decision tied to fabrication constraints—mold geometry, bent-lamination behavior, and assembly sequence—rather than a cosmetic adjustment applied after generation. For the clay vessels, exporting the generator's void footprints as standalone geometry and translating them into 3D-printable vessel forms created a material seam: a boundary where the pipeline's logic enters a new fabrication materiality, and assumptions embedded in the shelving workflow (orientation, clearance, wall thickness) had to be renegotiated locally for each piece.

Beyond the tool, these seams generated physical traces: the installed window shelf carries slight asymmetries that record the window's actual geometry rather than the ideal rectangle specified in the interface, and the preserved lower void that stabilizes the cat's perch persists as a legible consequence of the post-layout revision. The curved wooden shelf records negotiation with material in springback-induced angular drift and visible joint substitutions. The clay vessels preserve the generative pipeline's logic in their forms—void footprints carried into a new materiality—and continue to generate traces through use as I rearrange them into new configurations.

4 Implications for Creative Activity Trace Analysis

Across the user study and autoethnography, seams produced traces because they make intermediate computational states inspectable and intervenable. This suggests that tool architecture should be treated as an analytical variable, not merely as context, when comparing creative activity traces across systems. Tools that do not expose intermediate states will produce thinner traces of the same creative work—not because makers reason less, but because the tool offers fewer moments where reasoning becomes visible in the record. Seam structure is one dimension of the technique design space this workshop aims to sketch: it determines not only what interventions are possible for the maker, but what events are capturable for the analyst. This has direct consequences for trace analysis techniques: in fuzzy linkography [12], for instance, a linkograph's structure depends on what counts as a move. In a seamful tool, an intervention registers as a semantically rich move (e.g., shaved mask to shrink void); in a seamless tool, the same reasoning compresses to "changed input" or vanishes entirely. Techniques calibrated on seamful tools may overestimate revision richness elsewhere; techniques calibrated on specification-first tools may undercount steering behaviors that seams make visible.

This raises several questions I hope to explore at the workshop:

- **How should we compare traces across tools with different seam structures?** If two generative design tools produce outputs from similar inputs but one exposes intermediate layout states while the other does not, the traces will differ not because the makers reasoned differently, but because the tools made different reasoning visible. Analytical techniques need ways to account for this.
- **What creative reasoning is invisible when seams are absent?** One user study participant's mask-shaving strategy would appear in an end-to-end tool's trace as "the user changed her input images"—a description that loses the causal reasoning about mask-to-void relationships. How much creative reasoning in existing trace datasets is similarly compressed by tool architecture?
- **How does trace analysis handle the physical gap?** In fabrication, creative processes routinely leave the tool and enter the material—the loom, the laser cutter, the clay printer. My autoethnographic traces include physical consequences (springback, fit asymmetries, clay shrinkage) that are analytically continuous with the in-tool traces but captured through different means (photos, measurements, reflexive memos). As the workshop sketches a technique design space, fabrication offers a test case for how trace analysis extends beyond screen-captured interaction.

References

[1] Alberto Alvarez, Jose Font, and Julian Togelius. 2022. Toward Designer Modeling Through Design Style Clustering. *IEEE Transactions on Games* 14, 4 (Dec. 2022), 676–686. doi:10.1109/TG.2022.3143800

[2] Matthew Chalmers and Areti Galani. 2004. Seamful interweaving: heterogeneity in the theory and design of interactive systems. In *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques (DIS '04)*. Association for Computing Machinery, New York, NY, USA, 243–252. doi:10.1145/1013115.1013149

[3] Matthew Chalmers and Ian MacColl. 2003. Seamful and Seamless Design in Ubiquitous Computing. In *Workshop at the crossroads: The interaction of HCI and systems issues in UbiComp*, Vol. 8.

[4] John Joon Young Chung, Shiqing He, and Eytan Adar. 2021. The Intersection of Users, Roles, Interactions, and Technologies in Creativity Support Tools. In *Proceedings of the 2021 ACM Designing Interactive Systems Conference (DIS '21)*. Association for Computing Machinery, New York, NY, USA, 1817–1833. doi:10.1145/3461778.3462050

[5] Nicholas Davis, Chih-Pin Hsiao, Kunwar Yashraj Singh, Brenda Lin, and Brian Magerko. 2017. Creative Sense-Making: Quantifying Interaction Dynamics in Co-Creation. In *Proceedings of the 2017 ACM SIGCHI Conference on Creativity and Cognition (C&C '17)*. Association for Computing Machinery, New York, NY, USA, 356–366. doi:10.1145/3059454.3059478

[6] Jonas Frich, Lindsay MacDonald Vermeulen, Christian Remy, Michael Mose Biskjaer, and Peter Dalsgaard. 2019. Mapping the Landscape of Creativity Support Tools in HCI. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–18. doi:10.1145/3290605.3300619

[7] Deanna Gelosi, Michael L. Rivera, and Laura Devendorf. 2026. Uniquely Shaped Spaces: Object-Driven Algorithmic Shelving Design and Fabrication. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '26)*. Association for Computing Machinery, New York, NY, USA, 1–19. doi:10.1145/3772318.3791627

[8] Eric Horvitz. 1999. Principles of mixed-initiative user interfaces. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems (CHI '99)*. Association for Computing Machinery, New York, NY, USA, 159–166. doi:10.1145/302979.303030

[9] Sarah Inman and David Ribes. 2019. "Beautiful Seams": Strategic Revelations and Concealments. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–14. doi:10.1145/3290605.3300508

[10] Eric Rawn, Jingyi Li, Eric Paulos, and Sarah E. Chasins. 2023. Understanding Version Control as Material Interaction with Quickpose. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. Association for Computing Machinery, New York, NY, USA, 1–18. doi:10.1145/3544548.3581394

[11] Ben Shneiderman. 2007. Creativity support tools: accelerating discovery and innovation. *Commun. ACM* 50, 12 (Dec. 2007), 20–32. doi:10.1145/1323688.1323689

[12] Amy Smith, Barrett R Anderson, Jasmine Tan Otto, Isaac Karth, Yuqian Sun, John Joon Young Chung, Melissa Roemmele, and Max Kreminski. 2025. Fuzzy Linkography: Automatic Graphical Summarization of Creative Activity Traces. In *Proceedings of the 2025 Conference on Creativity and Cognition (C&C '25)*. Association for Computing Machinery, New York, NY, USA, 637–650. doi:10.1145/3698061.3726915

[13] Sarah Sterman, Molly Jane Nicholas, and Eric Paulos. 2022. Towards Creative Version Control. *Proc. ACM Hum.-Comput. Interact.* 6, CSCW2 (Nov. 2022), 336:1–336:25. doi:10.1145/3555756