Hybrid Aesthetics: Design of New Media Practices within Digital Fabrication

Cesar Torres
Electrical Engineering and Computer Sciences
UC Berkeley
cearto@eecs.berkeley.edu

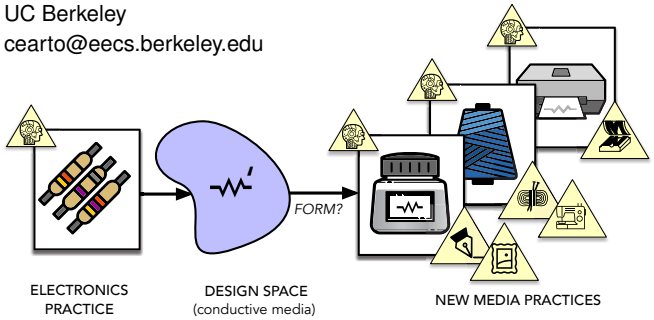

Figure 1: Conductors and their prescriptive form, use, and function have evolved from a long-standing electronics practice and culture. As new materials and techniques expand the design space of conductive mediums (e.g. silver ink, conductive thread, inkjet circuits), there remains an open question of how to form these new components into rich, reflective new media practices that leverage existing bodies of knowledge and practices around materials.

DIS'18 Companion, June 9–13, 2018, Hong Kong

ACM ISBN 978-1-4503-5631-2/18/06.
https://doi.org/10.1145/3197391.3205381

Abstract
Practices are emerging which blend both physical and computational techniques and materials. This thesis contributes a framework for understanding how to compose these hybrid elements into rich, reflective new media practices that expand the aesthetic repertoire and facilitate the adoption, sharing, and teaching of hybrid techniques.

Author Keywords
New Media; creativity support tools; digital fabrication; materiality

ACM Classification Keywords
H.5.m. [Information interfaces and presentation]: User Interfaces - Interaction Styles; D.2.2 [Design Tools and Techniques]: User interfaces

Introduction
Creativity is taking on new forms with advances in digital fabrication (DF), new materials, and new media technologies. In this evolving ecology of components, techniques, and automata, human-computer interaction is uniquely positioned to compose new practices that can expand aesthetic repertoires, incorporate rich cultural and material histories of creative practitioners, and challenge the narrative of who can participate in digital fabrication.

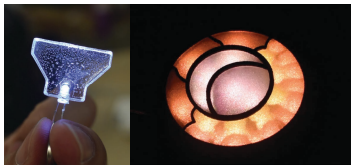

Figure 2: (left) An LED cast in a clear resin exposes the different ways that light interacts with secondary optics - imperfections in the casting process leave bubbles that refract and reflect light casting internal shadows and highlights; total internal reflection (TIR) is exposed at the edges of the resin. (right) Illumination aesthetics [11] exposes these formal properties of light in a series of digital fabrication techniques for the creation of diffusers, lenses, reflectors, and electronic housing that allows light to be treated as a material. A sun/moon luminaire shows a non-matrix arrangement of LEDs with a computationally designed reflector that redirects light to form soft and hard edges.

A growing body of work investigates how digital fabrication can exist outside or diversify engineering practices. Especially within physical making, craft-based approaches have been shown to influence both engagement and participation in this growing community of practitioners [4], yet at the same time cause tensions within the hybrid medium [2, 8]. Unfortunately, the rich, long, and valuable history of creative practitioners' exploration of physical materials has been neglected from the computer-aided design conversation. A 3D printer is a vibrant tool within a university makerspace, but in creative spaces like sculpture studios, these devices, techniques, and materials gather dust. Larger questions remain with respect to how such technologies can be designed for adoption and appropriation and support epistemological pluralism within such spaces.

This dissertation invites discussion and forms a framework around how *mediums* may be developed that invite creative practitioners to use existing material knowledge, methods of investigation, and cultural practices in the emerging ecology of digital fabrication and new materials.

Expanding Formal Expression

Ecological analysis of media can engender new aesthetics that diversify the creative reportoire.

Seminal work by media scholar Marshall McLuhan advocates for a greater study of how components of a medium form a cultural matrix that ultimately influences its interactions with society [7]. For example, the design space of conductive materials is derived from a long culture and tradition within engineering and has expanded to include form factors such as conductive tape, ink, paint, and thread (Figure 1). However, form factors like the conductive thread carry longstanding influence from textile and needleworking practices. An ecological analysis (e.g. actor-network analysis [3]) of these elements can highlight epistemologies, theories, beliefs, and aesthetics that are in concert or in tension with each other. This work demonstrates how fabrication techniques can reveal and reappropriate these aesthetic systems and engender forms that challenge and diversify the cultural matrix.

We examine one such element, the LED – a staple of the electronics practice – and unveil how the form, function, and use of LEDs come from a large influence in signage manufacturing that prioritizes the transport of light across large distances. *Illumination Aesthetics* [11] explores how light can exist as a first-class creative material by treating light as a physical material. In order to foreground light as an equal actor with other physical materials, we contributed a pipeline for creating luminaires — a device that produces, controls, and distributes light (Figure 2).

Formed from computational design and fabrication techniques, *Illumination Aesthetics* introduces manipulable, open-ended material elements that allow manipulation of formal light properties. Diffusers can be created by doping maker-friendly PDMS silicone with glass beads at different sizes (or other refractive elements) to create unique light textures. Reflectors and lenses are supported by a ray-tracing simulation which allows users to view how light can be directed to achieve interplay of soft and hard edges. Electronics housing and control is supported by a computational layout algorithm that more readily allows LEDs to be arranged in non-linear and non-matrix geometries. Notably, these computational mechanisms are integrated and activated from an annotated SVG, allowing users to leverage existing skillsets with programs like Adobe Illustrator move fluidly between current workflows.

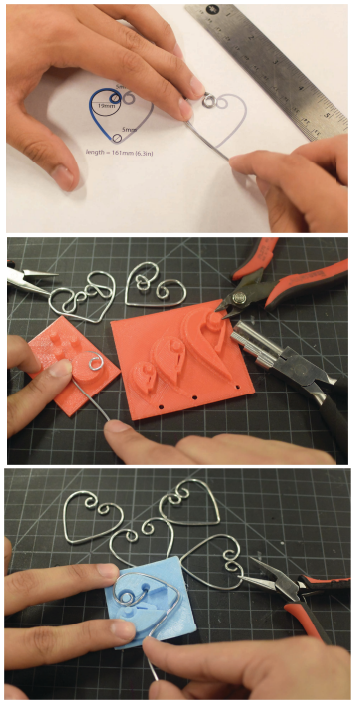

Figure 3: Three different proxies, or tools that aid users in the construction of an artifact, with different profiles of assistance. A schematic (top) provides fabrication feedback via an annotated construction proxy; a stencil (center) breaks down designs into elementary forms, c) a jig provides a ritual high-fidelity fabrication process via a fabrication and construction proxy.

Grounding Tools in Material Epistemology

Leveraging computational design and simulation is key to exposing creative handles to immaterials[1].

Trends within DF remove manual creation from the pipeline, yet interacting or "conversing" with a material is central to a creative process shared amongst practitioners in a variety of disciplines [1]. Schön [9] further highlights these conversational elements as an incremental development and reflection cycle. However within hybrid practices, we encounter immaterials that complicate the ability for a "conversation" to take place; within HCI, resolving these immaterial complications manifests in three conceptual approaches [5]: the tangible user interface, computational materiality [13], and craft-based approaches [4].

As DF practices abstract away material interaction, ProxyPrint [10] positions the DF machine not as the creator of the final artifact, but as a creator of a tool to allow practitioners to directly interact with the material. This craft-based approach combines the convenience of automated fabrication and the advantages of working directly with materials. ProxyPrints are computationally generated physical artifacts that facilitate, inform, and influence the manual creation processes, functioning similarly to armatures in traditional sculpture. Within the wirewrap tradition, we demonstrate how proxies can assist in a variety of fabrication tasks and scaffold assistance (Figure 3). In a formal user study, scaffolded proxies were shown to aid and influence crafting methodologies between novice and expert craftspeople.

[1] Immaterials refers to a class of materials, such as computation, light, heat, electricity, that are not matter for a project; these elements are denoted as (1) having a message that cannot be diassociated from the support(material) (e.g. light waves), and (2) operate at a scale that is no longer human-operational (e.g. genetics, biochemistry) [6].

Designing for Socio-cultural Factors

Understanding how established creative practices handle socio-cultural tensions can inform the design and development of nascent digital fabrication practices.

Socio-cultural factors affect how creative practitioners adopt and appropriate new materials. In researcher-artist collaborations, several tensions around hybrid craft have been found to arise from mismatched scales with distinct human and non-human constraints [8]. Other tensions arise from underlying technological stigmas, issues surrounding displacement, deskilling, or masking of the "hand of the artist", or from the intrusion on tradition such as a "tacking on" of other media [2]. Through contextual inquiry and cultural probes, this thesis looks at a wide range of existing creative practices to inform how mechanisms that promote agency and appropriation can be designed into nascent digital fabrication processes.

Creative practices have a long history of mechanisms for approaching, mitigating, and defusing error in constructive and positive ways. To promote agency and sustain engagement and exploration, Guardians of Practice [12] draws from these creative practices to develop a set of themes and guidelines for designing more resilient and reflective practices that encourage positive attitudes towards failure within physical making (Figure 4).

Ongoing work also explores the creation of a hybrid atelier, or artist studio, that scaffolds interactions with technologically-mediated materials. In a case study with thermoreactive composites, a practice where thermoreactive materials are activated by inkjet-printed resistive heaters, we probe how the introduction of an immaterial (heat) can be integrated into a creative environment that allows for a seamful transition between digital and physical manipulation spaces.

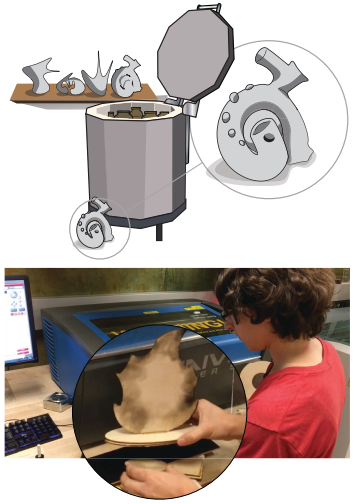

Figure 4: Socio-cultural failure mitigation strategies. Within ceramics, kiln gods (top) acts as a method of mitigating the fickle nature of the kiln. Derived from mythic origins, kiln gods are typically made at first firing by each member of a ceramics space and placed around the kiln to guard against poor firings. A laser cutter (bottom) effigy is inspired from the kiln god guardian; a user interaction is depicted during a lasercutting mishap. A burnt outcome is offered to the effigy and added to its collection of similar mishaps, serving as a gallery of error within the makerspace.

In conclusion, this thesis provides a framework for understanding how to convert an amorphous digital fabrication design space into rich, deep, and reflective new media practices. This work serves as a bridge between art and technology and challenges the narrative of who can participate and use DF technologies to include the broader community of creative practitioners.

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