Resisting Alignment: Code and Clay

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ABSTRACT
Today thousands of artists, designers, and craftspeople turn to digital fabrication tools to invent and manufacture new forms. They use vector-graphics software to sketch models, laser-cutters to customize parts, and 3D printers to generate prototypes. However, how our experiences of expressivity, skill and value shift with these developments remains under-explored. This paper describes our early engagements with emerging fabrication technologies in the domain of ceramics, one of our oldest and most enduring artistic mediums. In particular, we detail a collaboration with Helen Martino that resulted in the Sound Bowl, a vessel designed to record an audio message through surface undulations, much like a vinyl record. As an example of *design as inquiry*, we developed the bowl to explore the integration of digital fabrication in ceramics production. In the process, we found new and intriguing tensions in the entanglement of code and clay: contrasting temporal frames, blurred traces of breakage, and coinciding human senses. We discuss implications of these observations on the nature and organization of embodied interaction.

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Craft, ceramic, clay, handwork, sound, code, digital grips.

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K.4.0. Computers in Society: general.

INTRODUCTION
Developing production-focused computational tools that amplify our expressive experience has become an important challenge facing design and human-computer interaction. Today makers use instructional resources to learn new techniques; physical computing hobbyists join social networks to share personal narratives of production; and design hopefuls use social media to scaffold idea generation and manufacturing. In parallel, a growing number of people use digital technologies to extend craft production: generating furniture with 3D printers, altering jewelry with laser cutters, and sewing circuitry into clothing [3]. However, we understand little about how these tools to support craft (*e.g.* laser cutters, 3D printers) account for and change people's experiences developing form and meaning. Conversely, most existing technologies for communication and collaboration around craft (e.g., social networks, blogs, tutorials) that integrate with makers' tools could help us map and extend possibilities for expressivity, engagement and value.

This paper examines emerging possibilities of *hybrid craft* [17,23] — the use of computational resources within and around traditional modes of craft activity — and how this confluence might lead to new understandings of expressivity, skill and value in TEI. By attending to the specific mediums of code and clay we focus our investigation on media that stretch the gamut of human production over time. In this exercise, we find that code and clay resist alignment due to the temporal frames they embody. We further show how tools for production uniquely shape, envelope, and coerce our ways of thinking with material.

We develop this line of inquiry through a research through design approach [8] that relies on material engagement not as an end in itself but as a way to investigate shifting practices of craft. This follows on recent design-led research by Jackson and Kang [15] proposing an integrated program of theoretical, empirical and material work. In what follows we begin by laying out some of our core theoretical foundations around embodiment, medium and craft, drawing especially on the scholarship of Tim Ingold and Karen Barad. These theorists, hailing from anthropology and feminist science studies, interrogate questions of engagement with particular attention to matter and agency. We then describe

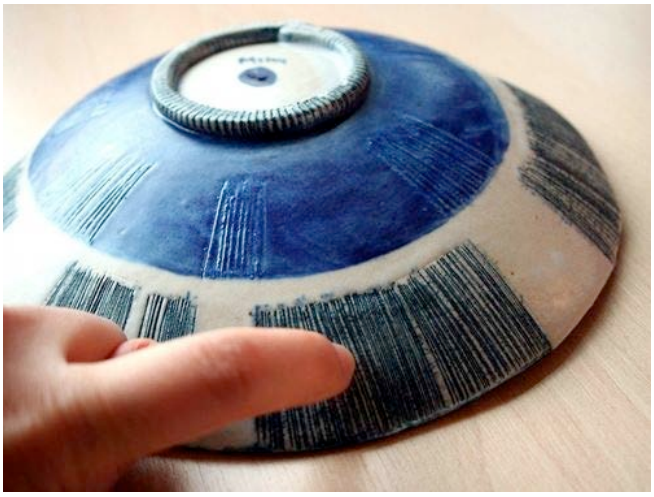

Figure 1: Running a fingernail along the surface plays "Happy New Year," much like a vinyl record. © Miwa Ikemiya

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an ethnographic interview study of pottery and ceramics, focusing on activities of people who create, use, and care for pottery on a daily basis. Lastly, we turn to a project of our own making: the Sound Bowl. This project evolved through collaborative experiments around code and clay and three stages of design: framing, modeling, and amplifying.

BACKGROUND AND THEORETICAL DEVELOPMENT

In Edmund de Waal's [6] essay "The event of a thread, the event of clay: Black Mountain College & the Crafts", de Waal suggests celebrated artist Josef Albers refused to sanction the teaching of ceramics at the Black Mountain College. He believed clay to be too resistant a material for students to handle. For a medium with significant physical malleability, this may seem peculiar, and indeed other accounts reverse Albers' objection [9]. Clay may be flattened, molded, roughened, hardened or softened. What does it mean for a medium to resist or align with another? And how might alignment change, especially with respect to the most 'malleable' material of all, software?

Here we draw primarily from anthropologist Tim Ingold [12,13] who seeks to understand how mediums of making characterize, shape and envelop worldly actions. Ingold argues, "we need to think of making in terms not of the simple, mechanical execution of complex structures, but of the form generating potentials of complex processes" [13:22]. Making consists of recognizable phases that become improvisational in character, much like walking. They do not follow each other in succession, but get drawn into relation according to a program of action. The materials brought into alignment become histories told through experienced engagement. Ingold's conception of material reappears in the scholarship of feminist sciences studies scholar Karen Barad [2] who describes *intra-actions* between the semiotic and material (neither existing before the other). In their entanglement, individual agencies precede their practices and lack an "independent, self contained" status [2:ix]. As for Ingold, meaning is material in nature, developing out of our engagements with the world. To develop this point, Ingold relates drawing to storytelling and wayfaring, wherein people produce itineraries without fixed templates or "pre-composed plots" underwriting the journey [12:75). This contrasts with modern assemblies of "point-to-point connections" [13:3] embodied in digital tools like Computer-aided design (CAD).

Turning now to digital craft, we ask what it might mean to extend material interactions with code? What forms of understanding emerge through the confluence of discourse and material, digital and non-digital, or code and clay? This paper takes up Ingold's notion of making as wayfaring — travelling with an itinerary rather than a map — and Barad's concern for entangled agencies to examine digital craft as series of guided agential alignments, each with its own appetite for change and disruption. We examine these themes in the domain of ceramics.

Over the years, ceramicists have produced some of our oldest and most cherished cultural artifacts, from teatime china to religious figurines. "A smashed and discarded ceramic pot literally kills time as it waits to be discovered," notes art historian Glenn Adamson [1]. "When unearthed, it seems to provide a direct connection to the point at which it was made or used; a cultural trace that transports a sense of immediacy across the centuries." Drawing from our first-hand accounts, we focus on this succession of changes underlying ceramics work. The observation that material is not so much an object of study as a set of situated relationships highlights the development of digital craft as part of both moral and material accountabilities. Our research extends this analytic stance by locating those accountabilities within the specific material relations of clay and code. Before we turn to our program of research and making, we wish to briefly review scholarship that set this project in motion.

Ceramics and Computing

Traditional craft materials have increasingly found their place in the worlds of digital fabrication, including developments in computing with wool [6] sand [9] and clay [20]. These hybrid forms provide opportunities for exploring the interweaving of analogue and analytical feedback. In the *Whispering Table*, made by the Green Eyl design group (thegreeneyl.com/whispering-table), museumgoers can listen to audio-recorded stories about food and tradition coming from inside the bowls and vases. The Particules Studio (particules-studio.com/objets-sans-âge.html) recently sought to bring a kind of "poetry to everyday life" by blurring the boundary between craftsmanship and technology with a series of porcelain speakers resembling bowls.

In other work, digital or computed patterns that decorate ceramics begin to shape resulting interactions as well as ceramics process. Meese and colleagues [18] collaborated with ceramic designers to create complex decorative patterns on plates and bowls identifiable by computer vision software. Jonathan Keep (ww.keep-art.co.uk) produces two categories of work each with a different digital genesis. In one Keep adapted a 3D printer to extrude carefully formulated slip to thus construct digitally formed ceramic objects, what Keep calls "Digital Pots." A different digital genesis precedes some of Keep's larger works, where the curved form of the ceramic arise from repeated sketching in the Processing visualization software. Using a similar process, Geoffrey Mann (www.mrmann.co.uk) materializes in clay that which cannot otherwise be seen, such as the flight pattern of a moth around light or the ripples created by blowing on a cup of tea. His piece *Crossfire* comprises a series of dinner table vessels representing the sound of an argument passing through them. Collectively, this work demonstrates the broad attention to digital and material sensitivities (e.g., light, touch, sound) in the ceramic medium. Our work broadens these developments by examining questions of ceramic and computational co-production.

UNDERSTANDING CERAMICS

In this section we report findings from an ethnographic interview study conducted between September 2012 and February 2013 with six artists and designers who work with ceramics as central methods or topics in their work. To develop a richer understanding of ceramic materials and processes, the second author visited four studios, four homes, and a symposium on the intersection of craftwork and networked objects. We designed our interview questions to elicit reflections on the use or potential use of clay and ceramic processes. Our interviews were guided towards the stories associated with ceramic materials, the potential future life of these materials, and techniques and obstacles around the integration of ceramics and technology.

Our work draws on interpretivist approaches that focus on the translation rather than transcription of social phenomena. Instead of seeking an objective, transparent view of these settings, we used our own subjective experiences — often closely tied to the subjects we studied — to generate intersubjective knowledge (falling "somewhere between the subjectivity of the researcher and that of the researched" [4:85]). While studying members' justification of belief, we reflected on the extent to which we resembled our subjects in background and ideology. In particular, we recognized how the second author's working knowledge of ceramic throwing, glazing and firing techniques influenced our accounts. The second author studied in both the United States and Japan over fourteen years and to a certain degree identifies as a ceramicist. In conducting our analysis, we sought to use these experiences to deepen our discussions of subsequent design activities [4].

Articulating Endurance

The longevity of ceramic materials was important to Helen, a ceramicist, who described teaching a group of school children how to create ceramics at a museum. She made the children's eyes widen when she explained that, even if the pots break, their shards would stick around through the rise and fall of civilizations. When probed further about this quality of endurance, Helen brought out four vessels she had used to capture images of four generations of her family (Figure 2).

> "*These are the bottles I made, so they are like women, and the images are from photos, so there is my mother with me, me with my daughter, my mother with my daughter, and my daughter with her daughter. So it's to do with mothers and daughters. And that's what I've drawn from the photos and made photocopies of those drawings, so you can see it's not very precise, extra spots and things happening but it's gives it a sort of freedom to be not too photographic anymore.*"

Here the ceramic objects merged with the high-contrast images of intimate family portraits Helen created on a photocopier. The warped shape of the vessels reminded Helen of gestural, talking women, producing generative intra-actions [2] between the female stories and their form. Even as the photos referenced specific moments, they lost precision with their translation into clay, giving the image a kind of "freedom." This notion of freedom stands apart from the issues of clarity and accuracy Helen associated with photographic prints. Sean, who calls himself a potter, explored this through *test tiles,* small trials he used to consider the integration of different materials such as copper wire in clay. Such experiments enabled Sean to surprise himself, expanding the possibilities of clay. Though the artists we visited reported clear expectations for how their work would be communicated over time, they remained open to different ways of getting there.

Knowing Imperfection from the Inside

Like other potters, Evelyn was intimately aware of her material; so much so that she could spot small nuanced inconsistencies in industrially produced tableware that other people might overlook.

> "*I've started looking at shapes that I like from supermarkets, they are all different. They are both Churchill but they are at different times. Can you see that? Very subtle but this has a pinkier glaze and is slightly bigger.*"

She spoke of enjoying their subtle differences: how the various mass-produced white plates and bowls remained unique despite their industrial heritage. Imperfections were central for Evelyn. The only plates in her collection made by her that did not get sold were the plates that had a chip, a glaze defect, or a hairline crack in the surface. All defects were reasons why she could not sell the plates and had to keep them. The plates were in heavy use in her kitchen alongside industrially produced tableware, which she reported caring less about. She said,

> "*It's got a chip there that I've mended. So if somebody breaks this I don't mind so much but the ones I really like I'd be so upset."*

The plates with imperfections may have been the only plates left for Evelyn's family because she sold the others. Yet, as for others we interviewed, imperfection could also be considered a virtue. Later in our interview, Evelyn described a cup (created by another potter) as being "terribly warped": "*There are things I find really wrong with it, but I still like it."* She appreciated the serendipitous way the warping seemed to occur. She then spoke about her electricity free kick-wheel designed by Bernard Leach, a well-known British potter, whose style of pottery she had studied. Having worked with this specific wheel for 25 years

Figure 2: Helen's images of a mother-daughter relationship. The warped shape was meant to reflect talking gestures.

she felt she had complete control over the tool and this part of the process, being able to make the wheel go at precise speeds (even slow speeds which are notoriously difficult to achieve on electric wheels). She felt she had reached a point where she had mastered wheel throwing defined as being able to exactly execute what she had envisioned. She threw her plates symmetrically and perfectly yet delighted over a series of plates that she unintentionally warped.

Ceramic flaws were equally relevant to other artists we spoke with. In the evolution of a style from naïve and rustic to smooth and polished, one explained, "*This is one I made at school. Do you see what I mean? About the naive painting. It's just so naive, it's before I knew anything about drawing*." She seemed surprised to see the differences between her work now and her work at that time. The inconsistent treatment of the clay indicated that time had passed.

Our ethnographic interviews revealed a defiant quality to clay: how it resists fine control and embraces imperfection. We also saw how it can often perform the role of either a mundane object (the plates and cups used everyday) or an heirloom object (objects that are cherished, and passed on from generation to generation). Many people we spoke with kept clay objects in display cases, hung them on the walls, or stored them away, while they kept other clay objects in easily accessible places.

TELLING BY HAND: BUILDING THE SOUND BOWL

To further examine these ethnographic insights, we decided to use the material of clay to build on this fieldwork and the theoretical foundations we outlined earlier. Our series of experiments would ultimately produce the "Sound Bowl," a piece of pottery created during fall 2012 and developed by the second author in collaboration with Helen Martino, a ceramicist she met in the course of fieldwork. The Sound Bowl plays back encoded sounds through ridges carved into its surface. We used the bowl to explore multiple concepts: the material process of inquiry, knowing from the inside,

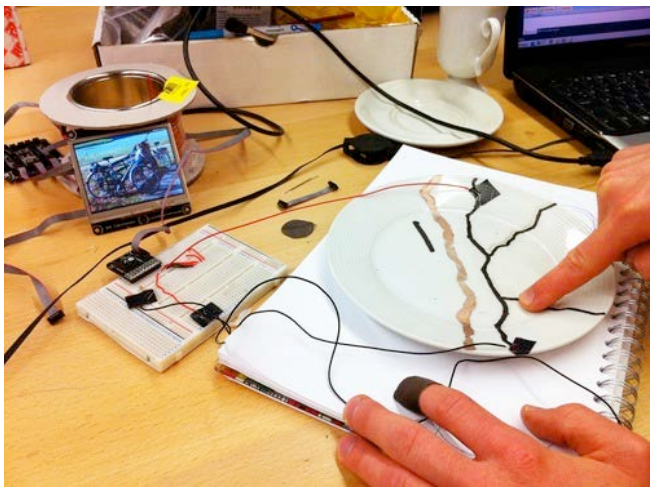

Figure 3: A line of conductive paint is used as a potentiometer to read out different levels of resistance when current travels through the finger to the microcontroller.

and alignments between code and clay. This process of design began with a series of sensing experiments to which we now turn.

Figure 4: Sensing experiments: plate is coated with conductive material on the bottom and sits on a coin-sized soft conductive pad. The weight of the plate completes the connection. Additional ceramic housing for Sensing Plates (left).

Sensing Experiments

Our initial experiments explored questions of breakage in code and clay over a period of four weeks. This focus developed from the concerns for wear and imperfection we observed in our fieldwork as well as two prior experiments: first, a series of broken probes [11] designed by members of the research team to explore the use of ceramic cracks as a material anchor for digital messages (building on Japanese concepts of *kintsugi* and *wabi-sabi*); second, a collaborative interaction with designer Tommy Dykes, who had worked the previous year with a member of the project team to build a set of interactive tea cups and saucers with conductive gilded edges. Unlike the teacups, the probes used a mobile phone application to enable people to associate digital images with specific cracks on pottery. The cracks became a unique barcode for digital annotation. During interviews, people expressed the desire to elicit the images directly by touching the cracks — focusing on the object rather than the phone as an intermediary.

Our intention for this early experimentation was to consider interactions (or intra-actions, after Barad [2]) between the meanings accrued through breakage and tactile modes of storytelling. Using a conductive material called BareConductive, a black conductive poster paint, we built a potentiometer to read out different levels of resistance when current traveled to the microcontroller through a conductive glove. We associated specific ranges of resistance with personal photographs. Touching a point along the crack yielded a specific photo on the small screen based on an arbitrary mapping between resistance values and digital photos.

Much of our process was guided by serendipitous discovery rather than particular aims for an outcome. For example, we discovered we could put a conductive finger glove on the opposite hand and use a bare finger to effectively interact with the painted line (soon indicating breakage). Following this, we tried using an aluminum circle on the plate instead of a finger glove. When we broke a plate and pieced it back together, filling the cracks with conductive paint, the interaction failed to connect to the server. We then created a second plate, reproducing the cracked lines using thick

raised steams of conductive paint. This 'worked' the first day (producing photographs upon touch) but ceased to work the second day. When we inspected the plates, we found he dried paint had cracked, leaving gaps in the circuitry.

Here the *cracks* accrued a dual purpose: becoming materials for refection and traces of fracture. Though our design process was driven by the use of cracks, we had not expected to find breakage in other places besides clay. Cracks in the code left us searching for hidden bugs; cracks in the paint left us wishing we could control the process of drying paint. Cracking became a mode of aesthetic interaction, inspiring us to touch and reconnect with traces of wear. Yet, trying to determine the most stable method of conductive glazing prompted us to question how stability became a condition of this project being made. Stability invited instability: rewriting code, checking electrical connections, and letting the materials dry, crack and rub away. Grappling with these ambiguities not only pointed to the difficulties of locating the origin of breakdowns, but also suggested initial incongruences between the mediums of code and clay.

Before turning to our Sound Bowl, we wish to highlight one final phase of our sensing experimentation. As part of our early trials, we resolved to explore how the design of pottery might enable serendipitous storytelling—framing bowls or plates as tools for *telling by hand* [13]. Inspired by related work [16], we built a second system that sensed hand gestures over a ceramic plate (with or without eating utensils) to produce simple visual patterns of interactivity. The plates sat on a coin-sized soft conductive pad connected to a WI-FI enabled microcontroller that acted as a capacitive proximity sensor (Figure 4). We used the plate during meals and explored a variety of common gestures — e.g., cutting with a knife and fork, twirling and lifting a fork, and scooping with a spoon. Because the system used capacitance to read proximity, the conductivity of the items above the plate affected the visual output in the system. For instance, soupy dishes read differently from dry dishes, heavy

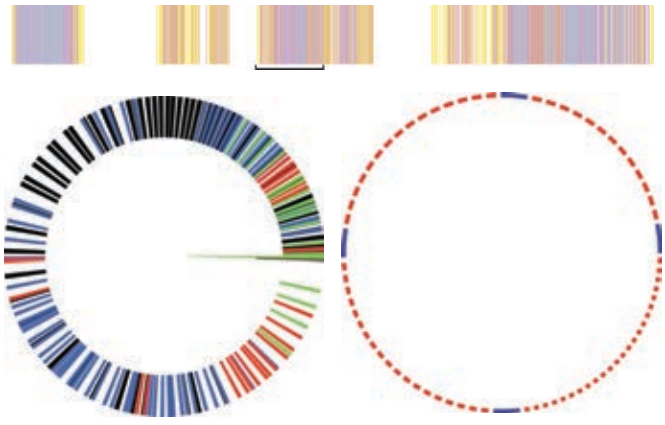

Figure 5: Digital vector diagram of sound from Talkie Tape, a piece of plastic with ridges that produces sound by running a nail across the surface, much like a vinyl record.

Figure 6: Plastic Talkie Tape (left); laser cut acrylic reproduction of the Talkie Tape (right). © Miwa Ikemiya

or wide utensils read differently from light or narrow utensils, and food eaten with fingers contrasted with utensils.

Although this assemblage of code and clay characterized ephemeral patterns of interaction in provocative ways, the accounts also struck us as strange. We felt differently knowing that our gestures were being captured, prompting us to become more purposeful about where we put our hands. Consequently, our search for the serendipitous and accidental got skewed. As we traced the ephemeral in code and clay, it changed the behavior we hoped to trace.

Sound Bowl

These initial sensing experiments warned us of incompatibilities between code and clay, raising tensions between the dual purpose of cracks, on the one hand, and the nature of digital ephemerality, on the other. The experiments also recalled qualities of clay we encountered in our fieldwork: the improvisational quality of working with clay and its resistance to change or capacity for imperfection. Our process of defining and building the *Sound Bowl* developed these concerns across three stages: framing, modeling, and amplifying.

Framing

Meeting and working with Helen provided an initial framing for our project. Most of the work she made came from slabs of clay stamped to create textures and hand painted to evoke time and place (by the sea, on a hill, under the moon, etc.). She explained that she does this type of *slab work* to keep her from being too 'fussy' about the forms. Her pieces include figurines, which she described as representations of people she knew in specific environments. In this way, she felt viewers could interpret the clay as personal moments, making the pieces relevant to their lives on their own terms.

During our initial discussions with Helen about her work as a potter and a ceramicist, we had interacted with a ribbon called Talkie Tape (Figure 6), a plastic strip with ridges that encodes sound much like a vinyl record. Running a fingernail along its surface audibly produced the phrase 'happy new year.' Inspired by Helen's attention to unintended, emergent form, we hoped to merge the subtle ceramic textures with unexpected meanings and functions. As we will see, this symbolic framing would prompt us to reengage with questions of accuracy around clay.

Modeling

Once envisioned, we began building the Sound Bowl by creating an illustrator file that represented the grooves on

the Talkie Tape. We first rubbed ink into the ridges of the tape so that the ink was only visible in the grooves. We then scanned the tape and traced the lines in our vector graphic software, taking note of the lines that appeared darker (deeper grooves) or lighter (shallower grooves). To account for these layers on the laser cutter — i.e., shallowest to deepest cuts — we codified the cuts into four categories of color, each with its own layers within our vector graphic software (see Figure 5). Yellow is the shallowest, followed by red, purple, and finally blue. When we sent the vector graphics file to laser cutter, we adjusted the depth of cuts according to the encoded layers, varying the speed and power of the machine. To move these grooves into clay we used the acrylic as a stamp (Figure 5). Yet, the fine detail in the resulting pattern produced intersecting lines in the clay. Even as the laser cutter retained the structure of the lines, the stamp did not. The ridges became too subtle to reproduce using our laser cutter given its resolution and the depth it could carve into plastic. Thus began a process of amplifying Helen's slab technique with a digital stamp.

Unable to recreate this process in clay, we moved to a 3D printer. Though cutting acrylic proved simple on the laser cutter it became another obstacle while 3D printing. The space between the vector graphic lines remained much smaller than the minimum (3mm) required by the printer. With no hope of recreating an audible sound, we decided to simplify the form to focus on pitch (see Figure 8). The deeper blue lines became larger gaps between the different "pitches." Through modeling and printing the 3D bowl, the process became deceptively bland — introducing entirely different questions and constraints from the process we went through during our sensing experiments.

Amplifying

Helen's slab technique involved creating an even and flat area of clay and wrapping it around a ball (Figure 7). Laying out a clay slab, we cut a circle in the clay, and then created small hatch mark tests with pin tool by hand, like Sean's 'test tiles.' A paper printout of the vector graphics file guided our acts of mark making (Figure 5). Once complete, we painted directly onto clay with an underglaze in blue and drew lines into clay painted blue to highlight both the algorithmic marks and their imprecision. The impossibility of replicating the pattern faithfully offered a way out of the translation between code and clay.

The rhythms of production in this setting also contrasted with our prior sensing experiments. Firing in Helen's studio

Figure 7: Slab process creating the bowl.

Figure 8: Resulting handmade Sound Bowl with an auditory "china mark" (top right). © Miwa Ikemiya

took place every three months. Helen often waited until she had a good number of pieces ready before setting up to fire. Given this cycle, we expected to get only one chance to produce our bowl. As the final stage of ceramic work, the firing not only organized the pace of production, it also influenced the kind of project we could take on.

After the initial bisque firing, we painted blue underglazed area with wax and dipped the whole bowl in overglaze. We wanted to avoid having too much glaze on the lines, which would have diminished the possible sound quality. We left the areas on the outer ring where the lines without overglaze and only underglaze to create definition. The clay was also rougher in those areas, not smooth like the other parts of the bowl. We also painted patterns with words hidden on the inner rim and signed the bowl with an auditory "china mark" (Figure 8, top right). The resulting form produced scratchy but audible intonations.

THE HUMANITY OF THE DIGITAL HAND

Through making and testing, we discovered qualities of code and clay unfamiliar to all members of our project team, technologists and ceramicists alike. After our initial sessions of experimentation, we began to build a richer understanding of our materials (the resistive paint and the sensing technology). We also developed capacities to articulate their differing temperaments and tactile qualities. The code functioned at one moment and stopped working the next. The black conductive paint began to dry, producing miniscule cracks that were difficult for us to perceive. Because we applied the paint with a paintbrush, its thickness challenged uniformity and resistance became unpredictable. Despite these discrepancies, serendipitous discovery helped us develop previously unanticipated ideas. Early on, for instance, we thought we needed a snug finger glove made from conductive fabric to touch the cracks and change the image. However, we noticed the other hand with no finger glove was still able to activate the image because the electricity was passing through the user's body. This meant that a finger glove was unnecessary to touch the resistive paint

with conductive fabric (Figure 3). Thus, we encountered technical barriers that prompted course corrections and afforded the possibility of creating strange and unusual forms.

However, aspects of this ad hoc assembly began to surface tensions with clay. Echoing insight from our fieldwork, clay presented surprising resistances that contrasted with our computational hacks. While gathering together existing pieces to create 'working' systems, conductive soft-circuit pads and the Arduino and WI-FI shields were easy to replace and wireless networks were easy to come by. The ceramic form and process unfolded something more precious, as exemplified by Helen's three-month cycles of kiln use. While creating the handmade Sound Bowl, we made aesthetic choices about glaze, decorative elements, shape and thickness of clay that incorporated Helen's techniques and background. Inspired by her slab technique, we sculpted the clay by hand instead of throwing clay from a wheel, purposefully emphasizing small imperfections and irregularities. While 3D printing, we uncovered need for precision and predictable material consistency that avoided clogging or other system snags. The clay used was as uniform as possible, and could not accommodate the gritty, coarse clays that helped define Sound Bowl design. As such, each bowl revealed distinct human and non-human constraints that put different emphases on care and precision.

In closing, we wish to reflect on three relations of precision and improvisation that emerged at the interface of computational and traditional craft-based production: (1) our ways of knowing through gestures, (2) our digital grips, and (3) the regression of our digital hands.

Knowing through Gestures

Our work brought about many ways of learning and understanding digital materials through gestures. Much like the mother-daughter vessels encountered in our interview study, we found clay could embody conversational movements in different ways than code. The attention to accuracy and control demanded by the sensing plate code and digitizing of the Talkie Tape failed to incorporate inconsistencies of the human hand, as apparent from the 3D printed ceramic bowl (Figure 9). Conversely, our sensitive handling of the material, our glazing techniques, and our shaping of the vessels struggled to support the rigid digital encodings.

Figure 9: 3D printed ceramic Sound Bowl. © Miwa Ikemiya

Here we find 'skill' an odd construction for this entanglement of code and clay. The quality of our interactions had little to do with competence in achieving some fixed or essential goal, but rather recognizing notable encounters along the way: feeling caught between a familiar and unfamiliar expertise, using gestures to define an emergent path, and learning to *see* the material, reminiscent of Ingold's wayfarer and the sculptural work we observed during our artisan study. This prompted us to imagine ways of providing room for engagement during the fabrication process and extending ordinary objects by actively embedding sound in their surfaces. Throughout our interactions with clay and code, gestures encouraged us to think differently about everyday artifacts and triggered us to imagine where technology might take another course.

Digital Grips

A second concern for digital craft is how the human senses may be more effectively leveraged. We found that the work of ceramics requires deep sensitivities to material form — manual modes of production that allowed the maker to notice and feel subtle inconsistencies on surfaces, experiencing the roughness of clay. We also saw that while our sensing experiments required detailed attention to breakage across two mediums (bugs in code or cracks in gilded clay), we could not attend to both at the same time.

In creating the Sound Bowl, our moves from hand to machine became quick and recursive: shifting from a machine-produced ribbon, to hand rubbed ink, to a scanned digital image, to a hand traced digital image, to a laser cut plastic. As part of these recursive moves, we acquired digital grips: ways of approaching material that enabled us to add sensitivity and sentience (after Ingold [13]) to material encodings such as the language embedded in glazed lines and the audio indentations of our custom "china mark."

Digital grips like the audio china mark involve sophisticated understandings of how human bodies experience algorithms through material form. They also build on emergent disruptions across mediums to expand opportunities for expression. How can we learn from what these encodings change to produce new kinds of stories and relations? How could we use the weight of a bowl, the texture of a surface, or the thickness of a glaze to challenge our ways of seeing through code? Sensory inputs might welcome new readings of computation and agency, refiguring our auditory, tactile, and kinesthetic capacities. Like musical rumble strips or rings on a tree, digital grips extend the varied 'propensities' [15] handwork makes possible and the layered histories they leave behind.

Regression of the Digital Hand

Today many of us buy our pottery ready-made. We sort through shelves of identical ceramic objects when we require a pot, plate, or cup. Though pottery may appear anachronistic, hidden on shelves or routinely overlooked,

our experiments suggest otherwise. Ceramic techniques can operate as reminders of our agential perspectives, calling forth age-old modes of making that cast people as active citizens rather than passive consumers. “With citizenship comes moral responsibility,” Ingold observes, “yet how can we be responsible for a world that comes to us ready made?” [13:122] Answering this question involves new incarnations of the digital hand. During sensing experiments, we kept track of our footprints and became more aware of where we might tread next, leaving wonderment by the wayside. Yet, in building the Sound Bowl, we found an ensemble of techniques began to shift perceived differences between code and clay.

Carrying these lessons into future work, we find resistance might have a larger role to play in our understanding of aesthetic interaction, practices that engage distinct social, ethical and emotional dimensions of information and communication media, “actively involv[ing] people’s bodily, cognitive, emotional and social skills” [19:3]. What makes a sound ‘crisp’ may align well with what makes a ceramic form brittle. But the rigidity of clay and malleability of code became difficult, if not impossible, to seamlessly combine [5]. Investigations of tangible design might take advantage of those seams by observing how an object comes into being through this resistance, surfacing new discontinuities of the digital hand.

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