

The Object of Design and research methods

1. AN UNDISCIPLINARY TERRAIN
2. THE EXCURSIVE METHOD
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1. AN UNDISCIPLINARY TERRAIN

When the architect and artist Didier Faustino presented his work at Harvard GSD in April 2016, he described the approach of his company as such: “[we] have one point very clear to explore: this notion of fragility (...) This fragility appears in many situations, most of the time a situation we can look as intermediary, or in between (...) the work is more to explore a series of fragments to propose something (...) not pluridisciplinary, as was presented, but maybe more undisciplinary.” (Faustino 2016).

Upon its enunciation, the word ‘undisciplinary’ resonated in my mind as a sudden evidence. It echoes a misfit attitude and a resistance to be ‘disciplined’ and to conform to labels. It’s also an acknowledgement that unless the research pursuit is to find a single solution to a very narrow problem, the heuristic cannot be tied to a single discipline. My mindset is to assume that sources and data from disparate origins could contribute to a set of knowledge, that methods and tools can be borrowed and combined from a wide range of disciplines, that new skills may have to be learned to engage further in a project, that views may be broaden and that rules should be broken.

For a long time I thought that terms such as ‘interdisciplinary’, ‘multidisciplinary’, ‘transdisciplinary’, ‘pluridisciplinary’ could express the nuances described above, but they still defend somehow a view that disciplines are fixed and that they can sometimes compromise on some topics for a limited duration. This is the stance that permeates the big discourses that regularly promote a reconciliation between art and science in education, or between design and engineering in curricula. Where I’m concerned, these disciplines never even seemed distinct or “having to be brought together”. I feel exasperated that artists who engage in academia keep having their legitimacy as researchers questioned and their contributions held in contempt and disregarded as frivolous. Even more, I’m surprised that this is still an issue and I feel sympathetic for those that seemed to discover only recently that ‘design thinking’ or ‘art practice’ can indeed represent a chance for societal policies and provide solutions to complex problems.

Barthes thought to restore what the word “interdisciplinary” should mean: “Interdisciplinary work, so much discussed these days, is not about confronting already constituted disciplines (none of which, in fact, is willing to let itself go). To do something interdisciplinary it’s not enough to choose a “subject” (a theme) and gather around it two or three sciences. Interdisciplinarity consists in creating a new object that belongs to no one.” (Bleeker 2010 citing Barthes in *Jeunes Chercheurs*). But this definition has been lost along the years and this is probably too late by now to reassert it. Therefore, the term “undisciplinary”, not yet burdened with too many meanings, is entirely adequate to describe a research that upholds its marginal quality, doesn’t apologize for the range of its inspirations and strives for rigour all the same. The important part in this journey is to not get lost in digressions and to stand by a guideline. In my case, this is done first with pursuing an intuition, then surveying the vast terrain of my topic, assessing the different angles that it could be approached from and limiting the scope to that fragment that is possibly unchartered, or unexpected or elusive.

My research terrain here is digital fabrication. It’s a diverse, unevenly covered and multi-faceted terrain. It has applications in the domains of

architecture, manufacturing, design, engineering, computation, craft and many other domains where it changes workflows or facilitates innovation. It can be examined in order to solve specific technical and structural issues. It can be researched from the perspective of its role in the rise of the makers and DIY culture. It can be assessed for its ways of challenging copyrights and intellectual property. It can also be evaluated as the latest proclaimed societal marker for empowerment. And so on. All those angles are valid and alluring but none of them are the object of this study. The object in this study is the odd materiality that is generated from interacting with fabrication machines, the modality of time in that creative process, and the resulting ambiguous opportunities of engaging with the material world.

2. THE EXCURSIVE METHOD

I realised that there was a research opportunity few years ago, with a series of events happening over the past ten years or so: patents of 3D-printing technologies expired, open-source activists contributed to make these technologies known and distributed to a wider audience, physical computing became increasingly accessible to artists and designers with tools such as Arduino and Processing, media discourses built up a hype around 3D-printers and DIY movements, the makers culture was supported and promoted with a wide variety of resources, from online how-tos to fabrication spaces to amateurs fairs and workshops. Something felt compelling in all this.

When this present study began, it was clear very early that an inductive approach was more adapted than a deductive one for engaging with the terrain (*see above*). This meant that along with the typical issues at play with starting a doctoral research, it was facing an additional difficulty: that of arguing for myself and for others the importance and relevance of a topic when it’s not aiming to solve a specific problem, but when it rather seizes an opportunity. A hinder for a long time, that difficulty eventually became a reward.

The inductive approach means the research method is strongly exploratory and what I would call ‘excursive’: it digresses, moves in different directions, experiments, performs some aspects and eventually exposes meaning. It’s concerned with shedding light on the object of the study and showing that it exists on its own and in a lineage of previous works and theories. It’s apt for a research where new uses and applications of the technologies come out every week.

Another difference with a deductive approach is the question of the evaluation of the relevance of the thesis: is an evaluation necessary when problems are not being solved? And if so, what should be evaluated? This thesis will not answer whether or not digital fabrication changes the world according to a random sample of surveyed people. That would be a vain exercise. On the other hand, what could be named ‘evaluation’ here is a ‘proof’ of the emergence of a materiality formulated by a selection of existing works and the development of further prototypes. Additional contributions take the form of methods, frameworks and guidelines that can be repeated for similar productions. Later sections of the thesis will show more in details the ways qualitative tools were nonetheless used for various purposes, including surveys and users observations and feedback. The outcomes that this thesis foresee are proposals of curious creative processes and challenges for future work.

The excursive method is further relevant in regards to my background and training in history, art, design and HCI, as I’ve exposed in the introduction. Again, part of my perspective on a topic is derived from seeing unexpected associations and envisioning possibilities. I’m both a theorist and a practitioner, with a long and diverse professional practice. Along the way, I’ve created my own methodology that has informed this doctoral research. This excursive method can be defined in different stages that are often conducted in parallel: *investigation, play, everyday, tensions, enactment, dissemination*.

Investigation

The investigation is the process of looking at the literature, of understanding what are the inspirations that colour the overall thesis and of making explicit a number of thought processes: the articulation between the personal and the academic motivations for pursuing the research, the reasoning of how the topic even came about, the choices that are made to constrain the research, the definition of the words that are used to make sure that the words that are used are the ones that mean what is meant, the roles that different disciplines have in the study, etc.

The methods borrowed from various disciplines could each pertain to either ontology, epistemology and heuristic. I’m reviewing them in details in this chapter, in two sub-sections:

- the framework of everyday life with constructionist ontology, semiotics, history of mentalities, and material culture
- the fabrication of meaning with art, design and HCI practices and the role of prototyping for research

The overview of related work let the research to situate itself, and to iterate on what’s existing. The acknowledgment of what allowed for that research to emerge is that way quite essential. Some related work make for a selection of case studies illustrate the discourse in a very eloquent manner. The research advances with other ‘visual’ formulations (mindmaps and diagrams) that are needed at times to get a sense of the whole. But it’s in the writing that the investigation comes together and expands.

Play

Part of the knowledge drawn in the ‘excursive’ method comes from making, designing, prototyping, actions that all define the practice of a topic. Again, this section will be detailed at-length below. In summary, I’m arguing for a research that is ‘testing’ its discourse, that is not only suggesting a possibility but that is experimenting it. In a curiosity-driven research, concrete outcomes are expected, creating interfaces for ‘real’ users are

motivating part of the research and conducting workshops, learning skills and collaborating with peers help keep the research meaningful over time.

Everyday

This research is motivated by the ‘real’ world, it’s meant to be put in effect. It’s also grounded in the popular culture, if just for the way it taps into common references of technology, science-fiction, consumerism. I’m looking at the discourses found in typical newspapers, at the representations of technologies in TV series such as *CSI* (see image below), in books, movies, conversations, that can both illustrate and amplify phenomena. In that sense, I’m not so much interested in the expert or professional terrains as much as I am in the mainstream, the casual, the domestic, the everyday life terrains.



Fig 05. A 3D-printed gun is the murder weapon on the show *CSI New York*. Episode “Command + P”, broadcasted January 4, 2013. CBS.

Tensions

I use both theory and practice to inform the research, there is that way a constant tension between the theoretical framework and the experimentations that I’m conducting. That tension is most of the time productive and at other times can be taking me in different directions. Other tensions appear. For instance, between art and design, the disciplines that I’m prevailing from. Again, this is explained further in depth, but in an ‘undisciplinary’ research, it is a matter of acknowledging the possible contradictions.

Enactment

The research should be practiced, rehearsed, performed and discussed in public settings as early as possible into the process. The shapes this can take are manifold: public presentations with small and large audience, lectures, conferences, publications, submissions to grants, pitches, competitions, social media exposure, online presence with photos, videos, blogs and documentations, etc. The main purpose of all this is to get familiar with the topics at hand, to precise thoughts, to assert arguments and to advance the knowledge. Confrontations with an audience also allow to assess the relevance of the topics, of the angles taken and of the hypotheses drawn. The other important benefit is simply to make the research known, and for the researcher to build a reputation and to be identified as an expert in the field. In turn, the researcher can identify better the audience interested in the topic and the other experts in the field. Moreover if the topic has anything to do with user-experience and social impact, it becomes substantial to bring the research to a public setting.

Other more complex forms of public discussion shed light on the topic, and allow for user feedback and evaluation. They can contribute to foster communities of interest. Those are workshops, classes, exhibitions, symposia, user-studies and surveys. A section of this thesis showcases how the J-term class ‘Self-Fab’ that I co-instructed and the ‘Data Across Scales’ conference that I co-organised helped advance my research and promote the

topic. Surveys and user studies don't produce necessarily compelling results in a qualitative research but they do allow for feedback, expressions of opinions, a 'feel' of what matters, or not. It doesn't mean that the relevance of the research should rest on this feedback, but it means that there is a way to share and discuss matters. Surveys are also useful to gauge what's perceived by an audience beyond the 'hype' of the discourses. The survey I conducted helped me in that sense gather informations on actual practices of people, on their uses of fabrication machines, and their wishes.

Another aspect of 'enactment' is related to the collaborative nature of this 'excursive' method. In technology-related projects, one person cannot master all the skills necessary for production. It's time-consuming to work alone. Working with other people and joining efforts allow for discussions, confrontations of opinions and methods, fights, assertions and compromises. It's also time-consuming to work with others. It could easily be noted among the sources of tension, written above. But it's still one of the best ways to get a project 'out' of one mind's bubble.

Dissemination

In the previous section, I discussed sharing the research during its formation. Its dissemination as it comes to an end is quite distinct even though it can share many similar modes of delivery. The dissemination is about envisioning the legacy of the thesis and making sure that it can keep reinventing itself. Evidently, the main formal outcome of the DDes thesis is a dissertation. But it's only one of the objects, one of the shapes that are actually being produced. There are of course the prototypes and artworks that were created in the course of this research. But as an artist and designer, I consider that the thesis should be strongly disseminated in creative ways. It's meant to be used and enjoyed in its written form as a book or other forms of publications but also fragmented on a website, as an exhibition, a symposium, an installation, a performance, a manifest, a workshop, a course, etc. The thesis can hopefully take part in a corpus of knowledge shared by a community, contributing to it with guidelines, frameworks and online instructions. The work itself is a lively matter, beyond the written piece.

The stages described above define the method and constitute a workflow that give the research a rhythm with beats and interruptions, anticipations and panic attacks. Other aspects of the research workflow are more transiting in between all the stages, they involve meetings with advisors to track progress, discussions with peers for feedback, taking hundreds of small notes, incessant web browsing and bookmarks savings, and finding ways to actually read and process all that information and to keep it organised and manageable.

Regarding that last note, I'm sharing here the main software I used to establish a 'software workflow', in case it could help other researchers to make choices. In most cases, software tools don't fit a research and academic process. They often cause more issues than they support the journey. I found an acceptable balance by combining a few of these tools. I used 'Scrivener' to organise hundreds of notes and devise an outline, 'Google Docs' and 'Apple Pages' for writing, an ad-hoc system for managing my bibliography and papers, 'Xmind' for the occasional mindmaps and for arranging topics with a different perspective, 'Scanbot', an iPhone app for scanning pages, 'Raindrop.io' and 'Dewey' for visualising bookmarks, 'Self Control' to cut me off online distractions, 'Apple Notes', the quickest way to write down a thought, 'Adobe InDesign' for the formatting of the dissertation (along with other Adobe tools for anything related to images and diagrams), 'Apple Keynote' for all slide presentations and 'Google Spreadsheet' for project management⁴.

And then there's life. Finding a routine amid the life of a graduate student is probably the hardest thing to achieve and it's always elusive. No two days look the same. I found that in the best times, I could maintain a routine for two weeks in a row before it was disrupted one way or another. Life happens all the time and is not suspended where I assumed it would. If you're advanced in age and career, it's likely that existing responsibilities and expectations will still require a lot of the time and attention that could have been, in other circumstances, devoted to the thesis research. Starting with a

⁴ Additional tools and software were used for the prototyping of projects and are cited in the sections describing them (last chapter).

rich professional expertise is a mixed blessing, as it adds to the loneliness of the long distance researcher, in that you don't belong to the faculty nor you can easily build a social life with students that are generally much younger and just starting their professional journey. And of course, it's difficult to accept the subpar status of the "student", when you've been many times over in the situation of the teacher. And for the first few weeks of my program, simple things such as technical words and vocabulary related to the field of architecture that I wasn't familiar with made me feel excluded from the school culture. Of course, money is a permanent concern: I'm always spending time trying to find money, either for living or for research: teaching, applying to grants, taking summer jobs are all strongly beneficial but they end up making half of the time overall that you spend in the program.

Other disruptions have included moving home six or seven times, moving office space a few times as well, breaking a hand and undergoing surgery, breaking up. Then there is the unthinkable, losses and terrible grief. Life is really not suspended at all while you do a thesis. But it's in the midst of all this that I realised that life would have happened no matter what I'd be doing or where I'd be living, and so I feel truly grateful that this happened while I was working on such a wonderful and exciting research, supported by caring friends and kind advisors. And where the thesis is concerned, keeping a purpose, staying on a loose track, doubting healthily and not losing confidence in the relevance of the research, is all that matters.

3. THE FRAMEWORK OF EVERYDAY LIFE

This research draws on a convergence of theoretical frameworks that share a certain appreciation of knowledge produced in the observation and in the practice of everyday life, whether past, present, near or distant: namely constructionist ontology, history of ideas and material culture. As technology is both revealing perceptions people have of themselves and the world around them and creating some of those perceptions, it's particularly adequate to look at a technology like digital fabrication, in the context of its

transition into the mainstream, and thus into the social fabric.

Specific thinking movements are informing the methodological approach of this research. Constructionist ontology proposes to uncover meanings hidden in individual and collective assumptions and to notice the ambiguity and changeability of meanings. Hence, the constructionist ontology supports a qualitative research concerned with context, discourses, uses and creativity. Among the thinkers that have shaped that approach, Roland Barthes, Jacques Derrida and Michel Foucault are references in the arguments that this research is defending. Barthes, in particular, provides guidelines for challenging all discourses as constructs. Semiotics thus constitute an essential tool for questions related to technology and society. Barthes's essay, *Mythologies* (1970) exposes the numerous layers of images, signs and values, often bourgeois, that we associate with mundane ideas and suggests that they can either contribute to our servitude or to our emancipation (his example of inert toys vs building sets is later mentioned in this dissertation about relations to everyday objects). Jacques Derrida with his considerations of words as containing worlds in themselves invites us to ponder upon definitions, associations and metaphors, almost in a playful manner. When historian Christophe Studeny studied the idea of speed in the 18th and the 19th century (1995), he refers to discourses of politicians, intellectuals, writers, testimonies of men and women of their time. Foucault describes this type of sources in *The Archeology of Knowledge*: "[...] the history of those age old themes that are never crystallized in a rigorous and individual system, but which have formed the spontaneous philosophy of those who did not philosophize [...] The analysis of opinions rather than of knowledge, of errors rather than of truth, of types of mentality rather than of forms of thought." (Huhtamo 1996 *citing Foucault*).

French historians Fernand Braudel and Jacques LeGoff, among others, have argued from the Sixties onward for a 'history of ideas' (or 'mentalities') that would uncover social behaviors, materialities and imaginaries beyond mere facts. Thought as a subdiscipline of history for a long time, the history of ideas has now permeated historiography as a whole, as a 'living history'. Derived from the pioneering works of l'École des Annales and the works

of Marc Bloch in particular (1983), this take on history invites comparative studies and turns ‘everyday life’ as a knowledge tool, that leaves in time material or discursive traces to excavate (Braudel 1979, LeGoff 1983).

Again, when considering technology and its uses, this historical approach unfolds as a formidable tool, especially when establishing parallels in time. In *Mechanization Takes Command*, Giedion uses the term “anonymous history” which underlines the attributes of ways of life and ordinary objects. In his attempts to demonstrate how mechanization is intertwined with the “slow shaping of daily life” (1969: 3), he writes a manifesto for anonymous history: “(...) research is needed into the *anonymous history* of our period, tracing our mode of life as affected by mechanization its impact on our dwellings, our food, our furniture” (1969: vi). He advocates as well to seek the links between industrial methods and “methods used outside the industry in art, in visualization” (*idem*). Giedion hints here that the modes of technological production can be regarded as indicators of the social and cultural mechanisms in which they emerge.

Huhtamo applies Giedion’s ideas when he looks of the history of the computer (1996). The anonymous history of the computer is an account of many histories: the social history of the computer user; the history of the computer as a design object and as a source of style and fashion; the history of the computer as a counter culture and a subculture, in its encounter and its gradual merger with the media culture; the ‘mental’ history of the computer as a “machine of dreams”, an intangible object of desires, fantasies, fears and utopias. Huhtamo argues here for an “archeology of media”.

This archeology of media could possibly explain the meaning of *déjà vu*, of familiarity of occurrences that have already happened in different technological contexts. In the title of her essay *When Old Technologies Were New*, Marvin (1988) infers at that sense of *déjà vu*: somehow what we experience today in terms of radical shift in human mediations begins with the invention of the telegraph. And because those machines aroused both sentiments of fascination and fear they constituted a bed for “social experimentation” (Marvin 1988). Thus the history of the uses of these

machines are as much telling as the history of the machines themselves. In the *Arcades Project*, Walter Benjamin (1997) considers the remains of the 19th century culture that are “buildings, technologies, goods, fashion, literature” as “actors of a culture understood as a dynamic construction”. Benjamin took seriously the “debris of mass culture as a source of philosophical truth” (Huhtamo 1996 *citing Susan Buck-Morss*).

These “traces of everyday life” is very much the elements of study of the research field of Material Culture. Established gradually as a discipline since the Eighties, the premises of material culture studies have nonetheless long been discussed first as subsets of anthropology and archeology then as advocacies for looking at materiality as a meaningful subject. Prown gives a definition in 1982: “Material culture is the study through artifacts of the beliefs - values, ideas, attitudes, and assumptions - of a particular community or society at a given time.” (Prown 1982). Within the parameters of our research, the field of material culture would thus address in particular the tangible outcomes of digital fabrication.

The anthropologist Daniel Miller has argued for a materialism demoted from its traditional antagonism of spirituality and has showed that the two actually accommodate well with each other (Miller 2005). And so did Walker Bynum in her essay *Christian Materiality* (2011) that showcases the living nature of objects to which individuals can attribute power, in particular when objects are considered as tangible traces of faith. The human attachment to objects forms a narrative, which in our case is heightened by notions of personal fabrication, creativity, and personal machines.

The theorist Michel de Certeau underlines the role of these everyday life elements of culture: “Creativity is the act of reusing and recombining heterogeneous materials” (de Certeau 1997:49). Tactics of “making do” and “making with” are themselves traces to uncover to bring about the ways technologies are used for negotiation and change (de Certeau 1990). For marxist Henri Lefebvre, the *other* theorist of everyday life, we have an opportunity to transform our daily lives into something else than a consumer’s controlled convenience (1947). Even though very different from de Certeau in his approach as a critique, creativity here again is a mode of regaining control over one’s life (which we’re addressing later in our

discussion of self-sufficiency).

4. THE FABRICATION OF MEANING

This research produces a theoretical discourse and meanings as well as artefacts. The artefacts are not mere supports of the theory. They generate their own set of ideas. To some extent, this research produces meanings by producing artefacts: “Making is ubiquitous, and it is as ancient as culture. In fact, making is the practical dimension of culture. It transforms matter, and it articulates meaning. Making has a cognitive dimension; it makes sense.” (Tin 2013).

Fields of art and design, especially when they relate to technology, provide some insights into how theory and practice can articulate with one another. Similarly, the field of HCI often navigate across methods to produce both a technology and its meaning. These fields epitomise in a sense the notion of research itself, they fabricate meanings within their creative processes.

Research in art

The debate about academic research in art, with art or for art is somewhat out of this scope. I stated my position on the matter in the introduction, underlining notably the artistic values of boldness and curiosity for research. Many researchers have done similar statements in PhDs and essays that support art as a valid and provocative method of inquiry. (Brucker-Cohen 2010, Asempere 2015).

In the context of my studies at the GSD, my artistic proposals were oftentimes perceived as surprising, unexpected and I’ve had informal comments of expert designers saying that they would have never imagined those tools used that way and that it was opening possibilities for them.

One could infer that this was in part my position of novice in the world of architecture that gave me an unrestrained vision of rules. But this is in a brief summary, what art means for research: it proposes unusual scenarios that are uninhibited, that push boundaries, and that shift angles about what a tool is supposed to do or what an artefact is supposed to mean. It’s apt to recall that when related to technologies, art is more often than not a force of innovation. In a brief history of new media artworks as precursors of well-known commercial products, Golan Levin reminded his audience that many artists see their work regularly being rebranded by marketing and advertising companies:

“...some of today’s most commonplace and widely-appreciated technologies were initially conceived and prototyped, years ago, by new-media artists. In some instances, we can pick out the unmistakable signature of a single person’s original artistic idea, released into the world decades ahead of its time — perhaps even dismissed, in its day, as useless or impractical — which after complex chains of influence and reinterpretation has become absorbed, generations of computers later, into the culture as an everyday product. [...] the artists posed novel questions which wouldn’t have arisen otherwise. To get a jump on the future, in other words, bring in some artists who have made theirs the problem of exploring the social implications and experiential possibilities of technology.” (Levin 2009).

With art, the audience is often at the centre of the process, especially with interactive art: “audience engagement with an artwork is an essential part of the creative process. The audience is seen to join with the artist in making the work complete.” (Candy & Ferguson 2014). It means that the research wants to be made public, wants to be shared, exhibited in spaces where a mainstream audience can get access to. It means that ideas can be prototyped

fairly rapidly and tested in informal situations. In that sense, digital art for instance, has been consistently a way for novices to discover professional technologies: with a curated experience, they're introduced to processes that are usually very exclusive (e.g. 3D modelling can take years to learn):

“Especially with respect to emerging technologies that may not have any ‘users’ to study from a social scientific perspective, art and design examples provide valuable empirical evidence that can shed light on complex theoretical questions such as digital materiality. In this way, artists and designers can be understood as a kind of lead user or early adopter of emerging technology, and their experiments with digital fabrication tools are helpful in understanding and specifying the material and aesthetic properties of the digital.” (Forlano 2013).

Finally, it's simply artists that inspire some of the aesthetics at play in this research, as well as epitomise the general spirit of this endeavour. I can cite John Cage's variations on the notion of chance that are reflected in the quality of an interactive piece and that embrace an uncertain materiality. Or Bruno Munari's useless machines and his visionary understanding of everyday art. Or Calder's installations that best express the elusiveness of the material world (see *fig. 6* below). I already evoked dadaists and visual poets that used everyday life as a playground. Poetry in that sense proves to be riveting. The emergence of systems art, influenced by cybernetics, is pivotal - interactive art is in direct correlation with the idea of systems and control. I can also mention the Independent Group that has curated the products of mass culture in immersive exhibitions. And artists who have captured the 'minimalist' expressions of materials such as Lucio Fontana (see *image below*) or more recently Pe Lang. There are many additional references that will be made explicit throughout the dissertation.



Fig 06. Alexander Calder, 'Small Sphere and Heavy Sphere', 1932-1933, Fer, bois, cordes, tiges et objets divers, H.317,5cm (dimensions variables) New York, Calder Foundation.

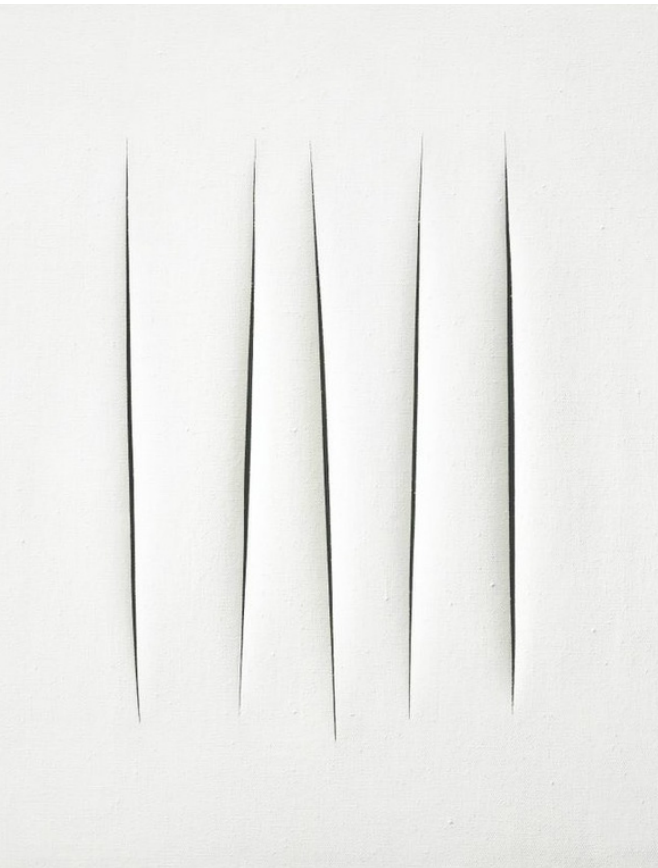


Fig 07. Lucio Fontana,
'Concetto Spaziale, Attese'.
Inscribed 'volevo andare a
Albissola ma il tempo era cattivo'
on the reverse. Waterpaint on
canvas, 73.5cm by 60.5cm.
Executed in 1965. Photo
Sotheby's.

Research in design

I contend that design, as the modern discipline that we know, is in part an agent of optimisation defined by Leibniz in his "best of possible worlds" and in part a product of the Industrial Revolution and of an era of mass-production and reproduction. Design branched out of craft and other creative practices when it started to think with and about technologies,

all the while making its mission to advance social conditions. This can be reflected in many design discourses and products, since the early 19th century to nowadays, whether the angle is architecture, graphic design, urbanism, typography, etc. My thesis thus situates itself within that history, given as well that it is conducted in a design school.

When I refer to my career, I mention that I'm both an artist and a designer. The distinction between the two is traditionally that of a noble affair for one, and that of a menial trade for the other, or elsewhere the distinction is made that one is whimsical and quirky and the latter rigorous and proficient, or it could be said that art is concerned with aesthetics and design with function. Of course, those examples are just regrettable and pernicious clichés masking the actual assets of practicing both disciplines. Both are creative processes, worlds apart. In my practice, and for this research in particular, I make an important distinction with two aspects. One aspect relates to the term design itself. Etymologically, design looks to the future. It's projecting itself with a purpose, that of being implemented: it needs to be fruitful. The second aspect is that design needs to convince people of that future. It's therefore a missionary with a destiny. Art is much more flexible with the shape it can take, it will insert itself in the world, undetected or in plain view, whether it's wanted or not. Both have the vantages and the dangers pertaining to these qualities.

So if design is a project, it means that it's a joined process of conception and implementation. Design is thinking its action, its 'materialisation', which is a process that this thesis aims to make explicit. Design thinks thoughts and futures, and the shapes, the containers to embed those thoughts, because essentially it's the only way for these futures to become real: tangible artefacts can convince people, can 'sell' them the reality of an ideal. Whether that reality is authentic, that remains to be seen. This scheme is not more blatant than in the field of speculative design (Dunne 1999). In this case, the future, the possibility, often dystopian, are embedded in a design probe, an object that allows people to experience a narrative, a way of thinking when they engage with it. This process can also be defined as design fiction or in other cases critical design. The purpose of these proposals can be at

times to challenge product functions and design processes, especially when technologies emerge in the mainstream public and private domains and disrupt habits. In his study on the domestication of robots, James Auger uses speculative design to “question technological development and its subsequent application in everyday life” (Auger 2012). For him, methods of speculative design consider the “products that could arise as a consequence of the domestication [of emergent technologies]” (*idem*). In that sense, the prototypes that I have formulated for this research are in part speculative experimentations, when they question conventions of digital fabrication, the linearity of the production process and the expectations of the roles it should play for society, whether they’re grounded in reality or in fantasy. If art is about unhinging rules to unlock creativity, speculative design is about reflecting on the existing rules to foresee the future ones.

This research does disrupt indeed the linear process from file to outcome of digital fabrication. It’s proposing to fabricate without a clear understanding of the outcome. This might seem in contradiction to what was stated earlier about the implementation of a purpose. But in this case, the purpose is abandon. In their paper ‘*Paradox of spontaneity of design*’, Erik and Ronald Rietveld frame the “deliberate design of spontaneous interactions”, “an environment [that] provides ‘possibilities for action’ or affordances” (in reference to J.J. Gibson and his essay *The Ecological Approach to Visual Perception*). With this thesis, I set as rules that the body and its data are parameters for machine control, and as “some affordances are more or less predictable”, I create “the framework for people to make their own discoveries and create specific uses” (Rietveld & Rietveld 2011).

This stance acknowledges that digital fabrication technologies are not the precise tools that we could think they are. Errors in the production process happen and there are contexts where instead of being eliminated, they could be welcome. Some materials are known as well to behave inconsistently, such as ceramics. They are “always in a state of becoming” (Freitas 2008), so they should be given an agency in the process. So this is about materials again, or rather the dialogue between ideas, forms and materials: “forms are the containers of models/ideas which are then made into a physical or

material stage temporarily” (Freitas *referring to Flusser*). It’s in the distance between what is conceived (usually made on screen or drawn on paper) and what is finally made that is the moment that is being staged in this research: that moment that goes from an abstraction to a tangible representation. The outcomes or artefacts resulting of that process are beyond the useful/ornamental dichotomy. They could result instead in “forms that can change, morph and move: a new category of objects defined not by what they are, but by the way they change and by the laws that describe their continuous variations.” (Philpott 2013 *citing Carpo 2004:14-15*).

Research in HCI

‘Human-Computer Interaction’ is the field of research that looks at technological innovations, computing systems, tools and interfaces, from the perspective of their uses, either to understand them, to facilitate them, to optimise them, or to identify ones that could be. There’s again here a “humanist agenda” that should be about bettering the lives of users. (Wright & McCarthy 2010) Too often, research in HCI is expected to bring about ‘useful’ outcomes for society thanks to technology: “how will you change the world today?” you could almost hear in the walls of research labs. It’s true that the field comes dangerously close to evangelistic tones when it’s forgetting that people who do change the world, don’t usually set out to do so (unless they’re dictators).

That said, I’m strongly influenced by methods and tools acquired when I was working at Media Lab Europe, the lab that the MIT Media Lab set in Dublin for a few years. Without giving up the iconoclast historian in me, I did acknowledge that naivety was a quality needed for the process of invention, that the world needed to be reduced temporarily for establishing a narrative, that utopias have practical aspects too for making the future happen. The typical creative process at the Media Lab or similar is curiosity-driven: it starts with an interest of the researcher, an intuition, framed by the statement of the research group that hosts the research. In that sense, a lot of trust and autonomy is put in the researcher (most of the time). A

concept is then developed with a top-down or bottom-up approach, or a mix of both, depending on issues: either a design process will involve from the start a community of users, in a workshop for instance, to identify needs or the research is not based on needs but rather proposes experiences which can be tested at later stages. There's an investigation into related work to identify similar endeavours, holes, works that can be reiterated or ones that need to be continued. The prototype phase comes like a reward, possibly the true motivation for all this, it's built often as an interactive device for users to interact with, with the assumption that interaction is the operative factor. The evaluation usually comes with user studies: by setting up the experiences and scenarios of uses and getting feedback with observations, interviews, surveys, etc. The final step and most important one for the recognition of the research is the publication, in a conference or a journal. Throughout the process, the researcher is encouraged to demo the work at all possible stages and to publicise it on various outlets. The timeframe is set on the calendar of annual conferences and thus a project takes about 8 months-a year, depending on the resources, budgets, collaborations, and the support of the lab.

My research didn't follow that track exactly, I borrowed elements related in particular to the definition of the opportunity, the scope of the related work, the prototyping, the user-experience and the dissemination. It's at the Media Lab that I learned indeed the values of prototyping to comprehend a research for oneself and to communicate it for others to appreciate it. It's there as well that I trained to address an audience as diverse as possible, and in an enthusiastic and accomplished fashion. This is generally these methods that have enabled me to establish bridges between the trends of personal fabrication and the expansion of personal data tracking. I devised then interactive experimentations that typically mediate technological innovations to a wider audience.

The question of evaluation

This the question that this type of 'undisciplinary' and inductive research is confronted to with no clear answers: what is the evidence? Vetting *et al* listed four qualities of creative design (as opposed to engineering design): "1) a non-linear process of intent and discovery, 2) design judgment, which is informed by a combination of knowledge, reflection, practice and action, 3) the making of artefacts, and 4) the design critique." (Freitas 2008 citing Vetting *et al* 2006: 524). What then constitutes the premise of the critique?

I used a palette of tools that constituted critique and evidence during and after the research. In a way, the tools can be distinguished as methods for what happens during the research and as contributions for what happens at the end.

Methods of evaluation or tools of critique:

- The "reflection practice", which is the use of practice or making for research, where the researcher can react to mishaps, change directions in a flexible manner and self-assess.
- A set of rules that are established for what the experimentations should address and not address.
- Rules for what are interactive fabrication and embodied fabrication.
- Observations and users feedback when relevant.
- Surveys (that I would use not as 'proofs' but rather as 'gauges').
- Discussions with advisors and peers.

Contributions or tools of evidence of this research:

- The documentation of the experimentations: a report that showcases problems to address, and expectations and flaws and that provides in turn guidelines to be used or referred to, or lessons learned that can be of use to others.
- Exposé of the methodologies used to conduct the overall research that make explicit many of the tacit knowledge and motivations of

the researcher.

- The framework of interactions for interactive fabrication.
- The artefacts themselves, bearing that “the artefacts that result from making are particular, not general; and the meaning they articulate is specific rather than typical. In that sense, making exceeds the scientific paradigm.” (Tin 2013).
- Other contributions include the taxonomy of related work, diagrams for interactive fabrication, scenarios of uses and the expansion of fields of interactive fabrication and embodied fabrication.

Some shortcomings lie in that I intended to draw more conclusions from user interactions with the artefacts, in particular I thought I could impart a typology of uses. I realised that this would have to be the object of future studies, as I didn’t address their *usage or usefulness* per se in this particular context. My main contribution in this thesis showcases the ways that personal data could manifest in the physical environment and the types of interactions that can facilitate this process.

The role of the prototype

As mentioned before, prototyping is the essence of ‘undisciplinary’ research, it’s the making and practice of the topic at hand. I’m acknowledging here the role of the prototype, of the experiment and their iterations. The practice is not just an excuse to invent things, it’s also a learning and discovery process, the heuristic of research in technology: it’s knowing by making, by being the first user of the invention. M. Tin defends ‘making’ as a form of research in his manifesto *Making and the sense it makes*: “Making, obviously, is practical, yet we may agree that there is a cognitive potential in its approach as well as its results” (Tin 2013). Freitas argues furthermore that practice is a requisite in design research: “The act of designing (...) is always the primary source of design expertise and must remain the locus of design theory and scholarship”, it’s a way to “manoeuvre between the ideal and the attainable” (Freitas 2008). It’s worth noting that in the literature addressing the place of the prototype (Vial 2013), the meanings of making, designing,

prototyping and experimenting often overlap.

Known methods have been shedding light on the crucial role of practice and making for the purposes of advancing knowledge (“Reflection in action”), of evaluation (“Reflective practice”) or of taking action (“Action research”). These methods have in all common the practice of a ‘repertoire’, as defined by Donald Schön: “One of Schön’s main theories is that educated practitioners have a repertoire consisting of techniques, tools, skills, procedures, theories, and experiences (...) Practitioners see it as something already existing in their repertoire. At the same time they see novelty in a new situation and use the familiar to interpret the new. By using the repertoire, the “toolbox”, in new ways and combinations, according to new situations, practitioners add to their knowledge.” (Hansen 2013).

Philpott notes that these methods are “systems [devised] to record and reflect upon both the pragmatic and the phenomenological aspects of the research without losing the spontaneity of embodied, playful and intuitive design practices.” (Philpott 2013). She explains further how her research was guided by the “development of an exploratory series of small, loosely bounded creative exercises that focused my investigation while still allowing a broadness of scope. These constraints gave comprehensible structure to what had hitherto appeared formless and endless.” (*idem*).

Part of including making and practice in the research process relates to the legitimacy of the discourse that is being produced. It appears that the investigation of a field of study, especially where it concerns the ‘aura’ of technologies, has to include expanding skills, acquiring new ones and learning by doing in order to set a critical perspective. It won’t guarantee it but it can be a step towards demystification. It can help to confront the theory to the practice and vice versa. Experimenting hands-on the topic allows for finding issues that were not clearly visible and that could become problems to solve in a research, for instance to improve accessibility. And one could argue that with research investigating materials, practice is in any case unavoidable: “The results turn out the way they have to, according to how the materials and the processing actually behave in action” (Hansen 2013).

Thus, taking a perspective on technologies is not just a matter of being a user or an observer, it can also mean to test ideas and create solutions beyond the conceptual theory.

Then the question prevails of how to consider and design the experiments for this research. What would make sense in this particular case?

Before starting the DDes program, I had already delved into the topic to some extent, while a researcher at Culture Lab, Newcastle University. It allowed me to scope out the field and encounter some of the related work that would drive my motivation, for instance with the works of researchers on interactive fabrication at Carnegie Mellon that open the field (*see image below*). These works gave me a frame of reference for the types of project I wanted to conduct whether to mark the difference of my approach or to underline commonalities. I also ‘practiced’ the topic by building a 3D-printer with two colleagues and created an artwork *White Square Of* that would stage 3D-prints as a visual poem.

Following these first incursions, the DDes program and its timeline gave a tempo for designing and making the experiments: the first year of the program consists in taking classes. In the first semester of the program, I took three different classes at Harvard GSD that each dealt with different aspects of digital fabrication: one about machines and materials, one about general rules of CAD/CAM and one about conceptual architecture and ceramics. They all challenged considerably my assumptions and my skills. It was already late in the semester when I could grasp the tools and the methods that were needed in order to give shape to my concepts. But all the models I did build made for small experiments that started to test ideas about interactive fabrication and odd materiality. I learned what it meant to be a novice in front of 3D modelling and programming tools. I learned a culture, its code, its vocabulary, its rules. I learned that there were immense possibilities ahead of me.

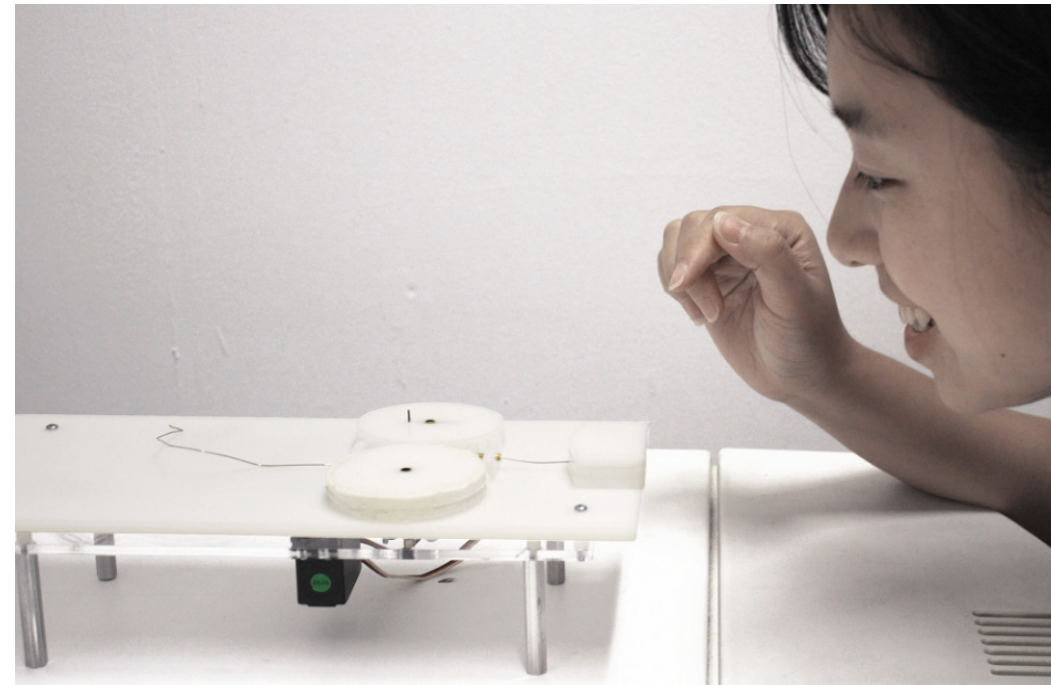


Fig 08. *Speaker*, a project by Cheng Xu and Karl D.D. Willis at Carnegie Mellon University. 2010. A machine created to cut the wire shape of someone's voice. Photo sourced at author's website.

In the second semester of the program, I took a break from that intense making phase and took classes that discussed the theoretical framework of the research and helped me pass my general exams. It's only at the beginning of the second year that I came back to fabrication, this time with a more specific aim. The structure of a class would be helpful in order to build the first prototype that was putting to test my vision of interactive fabrication. I applied and was accepted into the MIT class *How to make almost anything* instructed by Prof. Gershenfeld who is an important reference in the cultural context of my research topic. This class and his network of ‘fab labs’ have been instrumental in the democratisation of fabrication tools and in the worldwide distribution of knowledge. For me it was in a way going to the source of the matter itself. The class is set upon the premise that each aspect



Fig 09. Joëlle Bitton, 'White Square Of', exhibited at B&D Studios, Newcastle-upon-Tyne, 2012. 50 objects, printed with a MakerBot over a week, and selected for usefulness and familiarity. Visitors of the exhibition are allowed to keep one of the objects and in exchange write up a title and a description on paper, as well as indicating a new object to be printed off in replacement. Photo George Edwards.

of digital fabrication can be 'handmade', and each week is equivalent to a task for making that aspect: the controller board, the construction kit, the circuit design, the motor control, etc.

A few things prevented my final goal to be fully reached: the intense rhythm of the class doesn't leave much time for reflection, and the weekly tasks might not always serve a final project if it's not very defined from the beginning. It's a class where ingenious concepts cannot be realised every week if the student doesn't already master an important set of skills and therefore one has to settle for showcasing average. But average doesn't work anymore when compared to the productions of other proficient students

that are truly marvellous. The loneliness of the work is horrendous - if group work makes a person feel inadequate, loneliness is making that same person feel helpless, and in that situation it's almost impossible to ask for help, especially when you're made to feel that you should find the answers yourself. When towards the end of the semester, the tasks started to involve heavy programming and debugging, I had little time left to master skills that proved too difficult. Yet, taking this class is an formidable intellectual experience. It doesn't allow much reflection while it's happening, but it certainly does after it's passed. It provides a clear understanding of all functions that are at play within the realm of digital fabrication, and it sets



Fig 10. Initial material research stage for the project 'Pulp Fiction', conducted in the GSD class "Expanded Mechanisms / Empirical Materialisms", Fall 2012. In collaboration with Joe Liao and Sean Canty. Photo Joe Liao.

the path for being innovative and groundbreaking each step of the way. My final project for the class, even though it didn't achieve all I set out to do, taught me the processes I needed to put in place for my future experiments (*see details in chapter 5*).

Other devices that helped me formulate my experiments are grants applications. In order to build prototypes, I needed money. Therefore I spent a lot of time throughout my program applying for grants. With each application, comes precision. With each rejection, comes disappointment but as well refinement, assertion in the discourse, confidence in the project.

And then came the thesis proposal, where I had to explain why I'm making the prototypes that I'm making. The thesis proposal itself felt like a contrived exercise, forcing a deductive exposé of the topic and a demonstration of its usefulness. It was a difficult process for me to make my reasoning explicit before I started making the experiments. I knew a few things: that I wanted to test human inputs for interacting with a fabrication machine, and correlate them with scenarios. Possible inputs were voice, gestures, movement, physiological data (heartbeat, pulse) and personal data (emails, texts, tweets). I envisioned three large experiments after the small projects I did in my classes that would each test one of those inputs, with a different type of machine, a different level of interaction, a different material and a different setting. The experiences would emerge out of those correlations. Three projects seemed like the feasible amount to showcase the range of possibilities and infer others. By the second summer, after I was done with teaching fellowship work, I could finally have the time and the budget to tackle the first project, *Twipology*. And I was able to conduct two more projects along the way, *Rabota* and *Streamline* (*see detailed descriptions and implications in chapter 5 and 6*).

Overall, I found that I lacked time and budget to push the prototypes beyond few iterations. I had to accept that they would remain prototypes and not be brought to full completion for public use. I underestimated the resources I could gain with many grant applications rejected. Self-funded research is a trade-off between complete autonomy and project

advancements. It also means that resources for user-studies are particularly limited. Yet I managed to bring each of my experiments to a public setting, sometimes more than once. The prototypes are functional, and can be taken to full public products when the opportunity presents itself.

In general, this note poses the question of the level of achievement a prototype should aim for (Odom *et al* 2016). In some schools that are producing discourses on technology, a proof of concept, a video using actors and staging "what it could be", a model or a probe are just as acceptable and valid to support a theory. While I find these methods meaningful in some contexts, again my position as a designer and a HCI researcher is that the experiment needs to happen, to be 'real', to take the 'possible' to a 'present' for everyday users. But I'm not a scientist nor an engineer, I have to make do as a tinkerer with limited technical skills and with the resources at hand to produce those experiments.

The 'bricolage' stance is a useful one and a creative one, especially for novices and amateurs (Lévi-Strauss 1962) but then it's also not a professional one. A research lab in any case is not an industry nor a start-up environment. The increasing pressure to have for user-studies something good enough to be autonomous and reliable and that can be operated without the constant supervision of the researcher is not on par with the type of budgets or skills that are available in most research circumstances. I expect that this ambiguity will endure for some time in HCI research in general.

In the meantime, the prototypes I built do constitute "part architecture and part knowledge" (Kim & Ibáñez 2015). They're both conceptual sketches and working prototypes. They also suggest "a form of social research to integrate critical aesthetic experience with everyday life" (Dunne 1999). Finally, they made a reality of abstraction.