DE-COMPUTATION: PROGRAMMING THE WORLD THROUGH DESIGN

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ABSTRACT

We describe a developing methodology called 'de-computation' which combines design making and computational thinking in a two-way exchange aimed at understanding and reacting against increasing computational control of humans' natural, artificial and social systems, by using the tools and methods of computation in the design process. The steps of de-computation are detailed, its relation to similar approaches is explained, examples are given, and we explain its relevance for design research, theory construction and practical design work.

INTRODUCTION

There seems to be a growing anxiety that computers are taking over the world. Some feel we have already lost control of our systems of climate, food, finance, and social interaction to increasing automation and complexity. Some go even further, believing that artificial intelligence, the internet, smart objects, buildings and cities make for dumb humans, in a perverse role reversal – the calculating machines that were supposed to liberate us from drudgery have instead made us their automatons, and we now stare into screens all day, trying to keep up, conforming to machine rhythms. Van de Velde (2003) sees computers as an 'anthropotechnology' which serves to remove us ever further from the natural world, but proposes an alternative, ecological approach which recognises the social roles of computing as a process in the world.

Figure 1: De-computation student Katie Johnston's critical inversion of food processes resulted in processed food stuffed inside innocent and 'natural' looking foods, questioning how food values are perceived and manipulated by outward appearance..

Figure 2: *Space Replay* by RCA students Francesco Tacchini, Julinka Ebhardt and Will Yates-Johnson is a hovering object that explores and manipulates transitional public spaces with particular acoustic properties. By constantly recording and later replaying ambient sounds, the levitating sphere produces a delayed echo of human activity, reflecting a menacing vision of contemporary surveillance.

Our own definition of computers and computation draws on this alternative view. Algorithms are here defined as procedures or formulas that perform computational operations; they are seen as culturally determined products of human and machine intelligence.

In the Information Experience Design (IED) programme at the Royal College of Art (RCA), we have developed an approach we call 'de-computation' to help designers understand the ways computers and algorithms shape behaviour and influence our understanding of the world. We propose that de-computation can help in the process of humanising technology, harnessing its speed and capacity for social and creative benefit, and showing ways of resisting its inexorable logic. De-computation poses an alternative to 'design thinking' by providing a framework for two-way exchange between design and technology, specifically combining design making with computational thinking, thereby integrating digital data and technology with analog materials and processes in a systematic, structured way. It thus acts as a means for designers to approach technology, and conversely to view design through a computational lens. Designers, researchers and technologists may each recognise some of the processes we describe, and our aim is to synthesise these into a cohesive methodology for both research and practice.

BACKGROUND

Design thinking' has become popular in the commercial world, and we assume that readers of this paper may be familiar with the approaches of, for example, IDEO (http://www.ideo.com/about/) or Stanford's d-school (http://dschool.stanford.edu/dgift/). Our approach is balanced more toward making than thinking, seeing 'design' as a verb rather than a noun – as a practical process instead of an end product or a monolithic field in itself. Design thinking aims to prompt non-designers to think like designers in order to address problems. We aim to use designed objects and interventions to prompt people to identify problems and question designed solutions.

Computational thinking has increased in visibility alongside the rise of 'big data' and data-driven design and business processes. More broadly, information, and specifically computation, has come to be regarded as a central concept in biology (e.g. Walker and Davies 2013) and physics (Wheeler and Ford 1998). Physical computing (Igoe and O'Sullivan 2004) has put DIY digital tools into the hands of artists and designers, and ubiquitous computing (Weiser 1991) has increasingly embedded digital technology into the world. Organisms such as plants (Scialdone 2013), the world (Van de Velde 2003), and the universe (Lloyd 2010) have all been viewed as computing entities.

Computational thinking is a way of systematically tackling a dataset, a problem, or, in our case, a design project – such as making predictions from real-time financial data, rethinking a rail switching system, or creating a game. As defined for example by Google (https://www.google.com/edu/programs/exploring-

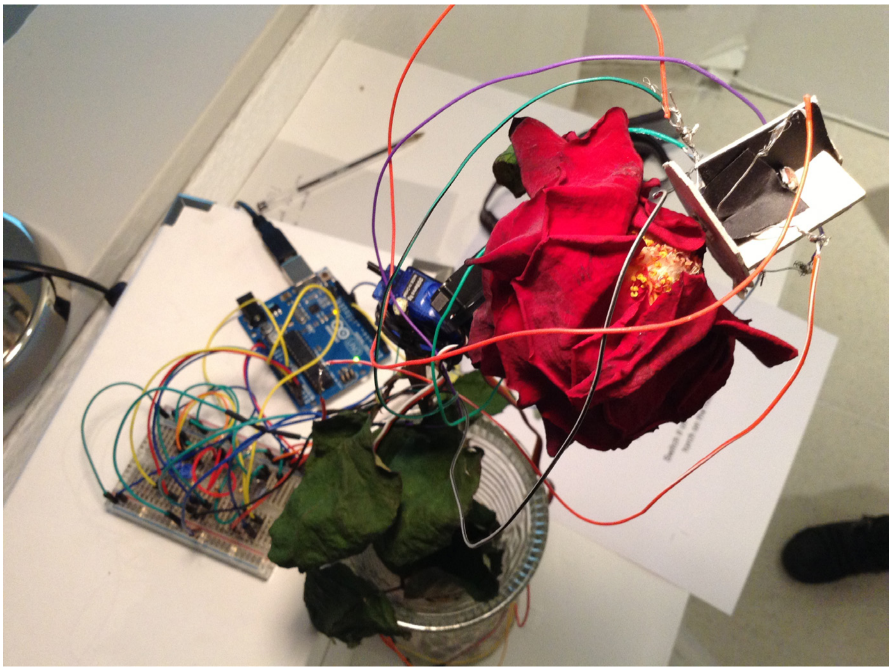

Figure 3: A flower, augmented with electronics by our student .Christopher Anyango, is forced to turn toward the light, which simultaneously nourishes it and destroys it.

computational-thinking/), computational thinking has four steps: decomposition, pattern recognition, abstraction, and design. Simply put, this means breaking something down into manageable or meaningful components, then remaking it in another form or making something new from it, based on an analysis of the parts. De-computation provides a way of applying these categories specifically to design practice.

DE-COMPUTATION

Whereas digitisation brings the physical world into the digital realm, and computational thinking addresses software engineering, de-computation brings computational thinking out into the world through creative design practice. While this may seem a counterintuitive means to counteract digital dominance, our reality (in the urban, developed world) is that algorithms and systems already pervade and shape our experience, including our experience and perceptions of natural systems. De-computation is intended to shift focus from devices and systems to computing as a process undertaken by people, plants, places and other things. We define computation as broad set of cultural practices driven by a belief that algorithms can shape behaviour, opinions and actions, in opposition to 20th Century notions of computers as monolithic, fixed devices. De-computation thus incorporates a view of computation different from its usual definition, one that encompasses non-digital life, microscopic and astronomical processes, and poetic data exploration.

De-computational thinking uses similar steps to those in computational thinking, but in sometimes varying order. While the steps may be familiar, the phenomena they are applied to are distinct. We interpret the steps as follows:

1. De-construction

The problem, research question, dataset or brief is broken down into smaller parts. It is typical to chunk data into smaller pieces by time, source or type. For a research question or brief, key terms used can be unpacked and defined more narrowly, to fit the project at hand. We encourage the use of carefully-worded research questions to focus a project (see e.g. http://bit.ly/1E1oHlf).

2. Pattern recognition

Each part is examined and compared with others – sometimes by placing them side by side literally and visually. If a pattern is not immediately apparent, we suggest counting or measuring, or looking for criteria for measurement. Here, more traditional research methods can be useful – for example comparing a pattern against other data or other researchers' findings, whether directly related or not, while being wary of making spurious correlations. Computers can also help in this step, as they are good at recognising certain types of patterns, as well as counting and calculating things. Patterns can be highly abstract – the rhythms of human behaviour for example, patterns of play in a game, circadian rhythms, or turn-taking in a conversation.

3. Abstraction

Once something interesting has been found, whether a pattern in the data or an innovative way to address the problem, brief or research question, this can then be generalised in order to make some statement about the larger population or the world at large. Here we encourage thinking of 'abstract' as in fine art – for example in terms of simplified shapes and colours; the less something resembles some specific thing in the world, the more it communicates across categories (McCloud 1994). Here, de-computation galvanises design methods to speculate on possible applications for the observed patterns. Using experimental making and synthesis across design disciplines, abstraction becomes an expressive means for generalising in surprising domains.

4. Construction

We regard both design and computing as wide-ranging practical skills and activities. The object of construction in this step may not be a physical or digital thing but a workflow, performance, or hands-on activity in which others make things. Design is programming in a broad sense, whether coding an app, curating an exhibition, or influencing passenger behaviour at the airport security checkpoint.

Such a structured approach to design constitutes an algorithm itself – the latter defined as a self-contained procedure for solving problems. In the case of de-computation this is manifest as a nonlinear system, which accounts for unknown functions as variables, and in which the outputs can vary proportionally from the inputs; the examples shown in the Figures illustrate a variety of outputs possible from a comparatively small set of inputs.

Our broader intention is to exploit the systematic ways of thinking found in the natural sciences, in ways that enable experimental outcomes which cannot be fully predicted due to randomness and variation introduced particularly through the use of physical materials and processes. De-computation thus strives for a balance between research-led practice which proceeds from data and a set design brief, and the kind of practice-led research more common in fine art contexts, in which materials exploration leads to unexpected outcomes.

DE-COMPUTATION V. AGILE METHODS

As mentioned, the steps can be used in any order. Ideally they can and should also be used repeatedly and iteratively. We encourage thinking of this as a spiral, moving outward from a starting point, cycling through the steps, building and improving each time. As an adaptive, lightweight approach, this kind of iterative cycle bears some resemblance to agile methods used in software design and business processes (Matharu, et al 2015).

We have a similar focus on rapid prototyping and evolving development, as well as an approach that is readily open to change. There are some differences however. Agile development is almost always employed by companies, whether for software or other products or services, using cross-functional teams. While some of the projects shown here were created by pairs, groups or teams, de-computation is easily used by just one person.

Perhaps the most important difference is that de-computation maintains a contextual and critical perspective. Agile methodology maintains a focus on individuals and teams within a company, and on frequent communication with customers (Meyer 2014). De-computation, however, is more than just a collection of methods for putting out products; it takes a broad view of personal, social and physical contexts, continually questioning the problem or task in relation to these. Here, De-computation overlaps with user experience or interaction design, with its focus on contexts of use (Kaptelinin and Bannon 2012). But it goes further, to interrogate how a design product might impact a user's cognitive load (Sweller, et al 1994), or society at large. Might it add to or subtract from visual or noise pollution – or indeed the environment and climate change? Is the product really necessary, or alternatively, is it something that can be used to critique some aspect of contemporary society?

De-computation is thus about using the algorithms and systems of design process and method to question the influence of computer algorithms and digital systems, as well as the designer's own assumptions. Its broad applicability means that it can be used in a straightforward way – perhaps as part of an agile methodology for example – but it is focused more on people and processes than products.

We have been using it for a range of projects and topics, from one-hour corporate workshops to two-week design sprints, to design research projects lasting several months. We find each of the above steps useful on its own, and next we discuss each in more detail, illustrating with some examples.

DE-CONSTRUCTION

Simply breaking something down into parts is perhaps the most important step, which can yield insights – for example the way a company disassembles new consumer devices in order to invest in manufacturers of the various components, or the way rail switching involves detailed understanding of network capacity and fault tolerance.

We typically approach broad subject areas and de-construct them in order to interrogate relevant parts and sub-systems. For example, investigating the topic of food, our MA student Jae Kyung Kim first extracted specific aspects of flavour perception, and found that sound was an under-utilised sense in this regard (Fig. 4). She then analysed the sounds created when eating various types of crispy foods, and designed a rhythmic performance for a group of people, conducted by her in complete darkness.

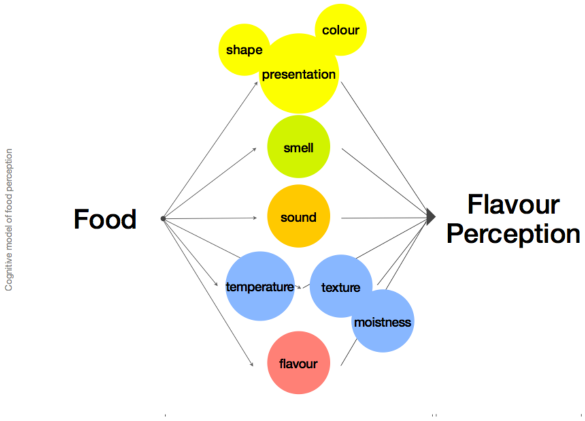

Figure 4: Feature extraction diagram by our student Jae Kyung Kim de-constructing the elements of flavour perception.

For de-constructing a topic area, we introduce methods from scientific research and investigative journalism. For example we developed a method called 'micro research' in which we attempt to conduct and present an entire scientific investigation – forming a research question and methodology for investigation, collecting and analysing data, then presenting the results – within a few hours.

For one such project we asked our students and staff to construct a one-metre square wooden frame as an instrument to investigate a sample of the natural world and transform the resulting data into new forms through a design process (Fig. 5); this combined a scientific method with an artistic approach used by, for example, the Boyle Family (http://www.boylefamily.co.uk).

Figure 5: IED Visiting Lecturer Caroline Claisse holds up a 1m square frame built for data collection in our Micro Research workshop in Oct 2014.

One group of students suspended the frame one metre off of the ground and collected data both above and below, operating with a fictional narrative that this data represented the last remaining traces of an urban park (Fig. 6). They then created outcomes for various senses, including a stop-motion animation, a perfume collection, a haptic and visual ground mapping, and a color mapping matched with Google images. These, as well as the data collection tools, were then presented in a mock auction in order to question the financial value of nature as well as of artworks.

Figure 6: IED student Tom Gayler engaged in micro research data collection.

Investigative journalism similarly operates around narrative conventions, but in an inverse direction to science, it often starts with 'a story,' then seeks to collect data (in the form of interviews or documentary research) to provide multiple viewpoints. Importantly for us, the journalistic convention of clearly and concisely communicating a story by clearly stating who, what, where, when, how and especially why, acts as an effective design principle. Journalistic stories can be regarded as de-constructed and re-constructed representations of events.

PATTERN RECOGNITION

Patterns can be identified for example in the way we travel to work or school. We have found value in taking a multimodal approach to spotting patterns, drawing in part from multimodal social semiotics (e.g. Bessemer, et al 2013). For example, IED student Hyunchung Kim created a colour-coded mapping of language in order to visually compare Korean and English translations of a text (Fig. 7). Another student, Jelka Kretzschmar, smelled the original notebooks of Francis Crick, from the year that he and James Watson discovered the structure of DNA, attempting to create a long-term sensory memory which might inform her later design work in synthetic biology (Fig. 8).

Figure 7: Visual analysis of the same text in Korean and English using colour coding developed by IED student Hyunchung Kim..

Her resulting work, undertaken with fellow students Tom Gayler and SzeMin Ng, took the form of a concrete poem, which was then modelled in clay sculptures, then abstracted to petri dishes displaying the experimental results. Thus, drawing from artistic practice – for example concepts of serendipity, randomness, play and performance – has value when combined with scientific and computational approaches – for example probabilities, Bayesian algorithms or Markov chains.

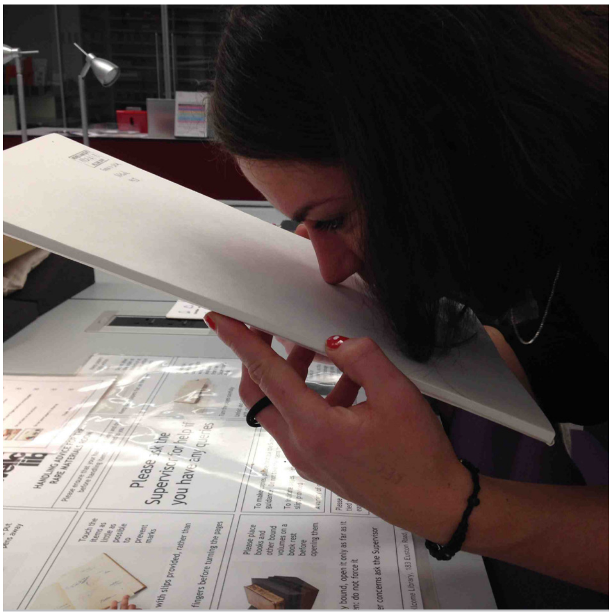

Figure 8: IED student Jelka Kretzschmar smelling a document of Francis Crick's in an attempt at multimodal data collection.

Approaches such as 'social physics' (Pentland 2014) claim that theory is no longer relevant in an era of 'big data' when individual social transactions can reveal 'micro-patterns' with the help of computers. We believe that spotting patterns in data is, however, a subjective process of interpretation, whether undertaken by humans or computers (which are programmed by humans).

This has implications, for example, when extrapolating from a pattern to look for causal effects. Viewed from the perspective of computation as a process (as opposed to using computers to calculate probabilities) helps to conceptualise notions of linearity in information flow: "one set of information 'specifies' another if the latter can be deduced or computed from the former." (Dalrymple 2011) But this depends on prior assumptions and our knowledge of the baseline population or dataset. According to Dalrymple, "in the real world, not only are we limited to observing events in the past, but we may also discover information about those events out of order." This has important implications for design, and the assumptions that go into designed artefacts and processes. For example, one constant factor is time, which consistently flows linearly in one direction, and if two datasets can be separated by time, this aids in analysis.

ABSTRACTION

Science is useful for explaining, predicting and generating new knowledge, and materials for the design of new products and processes, and we can abstract rules from nature to apply to other types of systems. Design research aims at describing user needs and practices on the one hand (Zimmerman, et al 1997), and evaluating design in use on the other (Iacob 2011). Speculative design points to possible (often dystopian) futures (Dunne and Raby, 2013). But more conventional forms of design often miss the middle step of prediction – specifically, predicting the uses, consequences, lifespans and afterlives of design products.

Analysis and interpretation of data facilitates theory construction (Friedman 2003), and theories enable predictions, giving also a lens through which to interrogate additional data and to guide design processes. For example, designed artefacts such as financial 'candlestick charts' enable prediction of price movements by making patterns visible (Fig. 9), patterns devised through theory such as Dow theory (Murphy 1998). Theories combined with additional data then facilitate the control of systems, including financial systems (Wilkins and Drago 2013)

Incorporating artistic approaches can serve to illustrate theory and data in evocative ways, as well as raising unexpected connections. For example, Hyunchung Kim's Stock Screen materialised real-time currency pair data to control daylight entering a room via Fibonacci trading patterns laser-cut into a dual-layer, motorised textile window screen (Fig. 10).

Prediction through abstraction thus moves from analysis to synthesis. According to Hill (2011), analysis tells us why things are, while synthesis tells us how things could be. The use of models in design (in the form of prototypes) and science (computer simulations) is widespread, and both facilitate prediction to varying

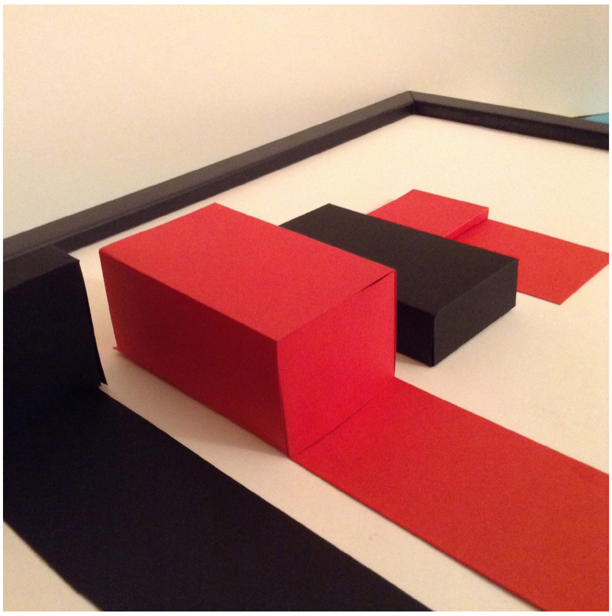

Figure 9: 3D paper version of a financial 'candlestick' chart created for analysis of historical data by Kevin Walker.

degrees. A computational approach adds an additional dimension to the design process, in that theory can be translated into instructions (an algorithm) which can then take in data to produce something new.

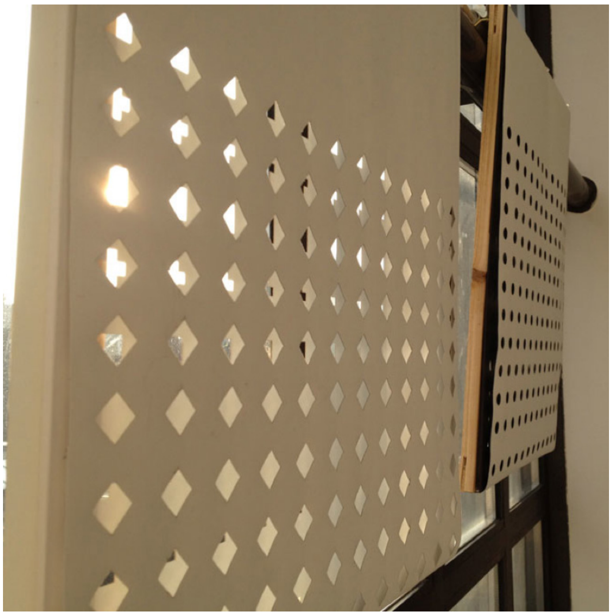

Figure 10: *Stock Screen* by IED student Hyunchung Kim uses two textile layers laser-cut with Fibonacci patterns used for financial analysis. Real-time currency data is fed to a motor which controls the movement of the frontmost screen, altering incoming light accordingly.

CONSTRUCTION

While we adopt a process derived from computational thinking, in practice we often create material, multimodal objects as well as time-based performances and structured activities.

Access to good materials is, we believe, a kind of inverse poverty. Supposedly advanced organisations pride themselves on going completely digital, pouring all data into computers in order to streamline and optimise systems for maximum efficiency. The so-called developed world moves increasingly above and away from the real world and the things it is made of, and we now know the financial and environmental consequences of this.

Every geographic place has its own characteristic resources and materials which are natural and local to the area. People who live in touch with their environment understand this. We are not eco-idealists, nor are we fooled into thinking that people do not aspire to transcend their locality. We are not advocating a mythical return to nature. We do however propose that it is more environmentally-friendly, often cheaper, and usually more interesting to use locally-sourced materials when possible. The internet connects us to countless materials, suppliers and sources of inspiration, but experimenting with local and unexpected materials and techniques is a form of research which can yield surprising and serendipitous results.

In a recent project around the concept of play, for example, students used technology to engage people with the local environment by juxtaposing computer games with adventure playgrounds. This resulted in projects such as a talking tree (Fig. 11) and musically-activated soil (Fig. 12).

Figure 11: Whispering tree by students Shobhan Shah, Joanne Harik, Katie Johnston and Tom Gayler. Hidden in a tree bark panel, a button records a snippet of sound which can then be replayed. An arboreal conversation can be played out between five or six trees and messages left for other players.

Figure 12: A square box of earth, by students Shobhan Shah, Joanne Harik, Katie Johnston and Tom Gayler, sonifies moisture and rainfall. The idea is that existing play styles and characteristics are enhanced and augmented with low cost technology. So making mud pies for example becomes a game of composition, or footsteps in the mud play a scale..

We find great value in making things, and particularly in thinking through making. We are not interested in vague celebrations like 'maker fairs' and the 'maker movement,' but rather in how the materials, tools and processes of making can lead to new insights. Importantly however, this does not mean being entirely led by tools and technologies, which is why it is important to put design in context and keep an eye on the big picture. Achieving a balance between making and thinking is the key, which is why the four steps of de-computation are best used together.

CONCLUSION

Designers today often work primarily at, and from, the computer. But working within ready-made software constrains design choices to those the software makes possible, and the results – readily visible particularly in architecture and product design – reflect those constraints and ingrained conventions. The digital thus increasingly and unwittingly invades and shapes the human world in ways that can be hard to detect – for example walking a specific amount of steps in a day to achieve a computer-generated goal, or the unintentional use of default facial recognition software in digital photography. We thus advocate a reverse design process applying computational thinking to real-world phenomena in order to reveal and critique this, and furthermore to uncover previously unseen design directions.

While the four steps of de-computation are sometimes used together and in traditional order of computational thinking, we also promote moving in alternative directions. When undertaken in reverse order, for example, the steps serve as a critical lens onto technical and cultural practices, using making as a method of knowledge building and transformative synthesis of maker and material, (Ingold 2013) as well as constructionist thinking (e.g. Donaldson 2014). De-computation reconfigures the tools and techniques of computation to empower designers and makers, prioritising analysis, making and experimentation. We hope the design community will find de-computation useful for understanding, and questioning, an increasingly computer-controlled world.

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