DRS2016
Design + Research + Society
Future-Focused Thinking

50
2016 Design Research Society
50th Anniversary Conference
27-30 June 2016, Brighton, UK

From nano to macro: material inspiration within ubiquitous computing research

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DOI: 10.21606/drs.2016.414

Abstract: Technological disruption grants continuous inspiration for design innovation. In particular, current paper focuses on the emergent interaction between the fields of ubiquitous computing (U.C.) and design. The interdisciplinary character of U.C. research requires knowledge from art, design, and architecture (A.D.A.) and as such, presents opportunity for cross-fertilization and future design. Within U.C., the inquiry labelled as material turn frames a particular dialogue between nanotechnology and traditional materials. Nanotechnology opened new material avenues and has impacted methodologies of design and drives the discussion throughout this paper. In addition, the way these new technologies might address human centred design approach are considered. In sum, this paper discusses routes for disciplinary displacements of A.D.A. suggesting that these have a positive impact in the future of the practice.

Keywords: Computing, Design, Research, Interdisciplinary, Future, Materials

1. Introduction

In the 80’s the dominant interaction model with computers was linked to the rise of personal computers. Mark Weiser, a chief scientist at Xerox PARC in the United States considered this interaction with computers to be complex, demanding too much attention, and isolating people. Indeed, personal computers were imposing objects on desktops and restraining people from other activities (Weiser, Gold, & Brown, 1999). Solving these issues meant to create a new vision for the interaction model.

Weiser’s analysis on trends on computing in relation to humans is a starting point for reflection. The pioneer mainframe computer in the early 40’s had a management model of “one computer to many people” and personal computing evolved to a one-to-one model. Finally, Weiser projects the future to be of Ubiquitous Computing (U.C.) where “one person to many computers relationship” is established. The computer for the 21st Century would be integrated within a range of environmental contexts aiming to augment, aid or complement human capacity in a most natural and unobtrusive way. Thus, technology would serve as an enhancer, instead of a disrupter of life, and the paraphernalia of peripheral devices (e.g., mouses, printers, screens) would disappear. In this future scenario computers are invisible, and the process of interaction is calm (Weiser, 1991).

2. Approaches to Ubiquitous Computation

Weiser's definition of computing centres on human beings. In fact, the concept of U.C. proposes "a very difficult integration of human factors, computer science, engineering, and social sciences" ("Ubiquitous Computing," 2015) thus getting insight from several disciplinary backgrounds. For instance, during 1988's Ubiquitous Computing program in the Computer Science Laboratory (CSL) at Xerox PARC, evaluation methods were taken from Anthropology and integrated into research. The use of participatory observation enabled researchers to perceive the radical difference between how people used technology from the way they claimed to (Weiser et al., 1999).

The incorporation of social sciences brings additional advantages to research in computation design. This is the case when acknowledging the susceptibility for "confirmation biases", that is, researchers' inability to not influence results. Thus outcomes are presented as a perspective, thus, as hybridization of point of views. Furthermore, social sciences methods consider the gap between information and hard data, while applying qualitative versus the quantitative evaluations. As Weiser stated, the point of view of social sciences was determinant to drive computing research "from atoms to culture": if the disappearance of interface is a goal of U.C., culture(s) as a value is emphasized. Therefore, culture becomes the source from which research could start from and that practice could aim to create. In this sense, design within computing contexts would ultimately achieve a human-to-human interaction instead of a human-computer one (Weiser et al., 1999).

Currently, Ubiquitous Computing research has divergent views and outcomes. For instance, the overlapping concept "internet of things" is a model that proposes to design everyday objects - such as domestic appliances - connected to the Internet. These devices range from wearables to any surface that might be embedded with electronics and sensors. The main idea is having an object-to-object communication able to sense the world that can dynamically adapt to variation without direct human intervention (Kellmereit & Obodovski, 2013).

David Rose proposes, on the other hand, an alternative version on U.C. He suggests creating "enchanted objects", i.e., "instead of having a conversation of media, having a dispersion of intelligence in several objects" (Rose, 2014). In this case a constrained degree of technology is embedded into things. Practice research stems from first i) identifying core human values and desires from which a relation to objects is noted, and ii) intensifying that relation through technological features. Technology would work like magic, looking less for efficiency than for affectivity and expressivity. The perception of technology would be a symbolic manifestation in objects coming from an imperceptible source.

Rose mapped human desires in relation to objects in six categories:

I. omniscience. the desire to know all
II. telepathy, the desire for human connection
III. safekeeping, to protect and be protected
IV. immortality, to be healthy and vital
V. teleportation, to move effortless, and
VI. expression, to create, make and play

An example of the application of this method, falling under the category of safekeeping, would be an umbrella calling attention to his owner whenever there is a rain forecast, or bottle cap on pills case outputting clues on the right time for taking medicine. Rose's proposal stems from a systematic analysis of cultural environment beforehand. This is a design method that initiates research driven by cultural values, and presents technology as open solutions and flexible. Indeed, the adaptation to different cultural contexts is prone to design critic.

The "material turn" in U.C. brings smart materials, ubiquitous computing, computational composites, interactive architectures, the internet of things, and tangible bits in relation to one another. The role that "non-computational materials" have in Human Computer Interaction (HCI) (Wiberg, Kaye, & Thomas, 2014) is simultaneously recognized. This means "making the digital real (again)" (Kitzmann, 2006), having computing and information re-imagined as just another material (Kuniavsky, 2010). As such, the material turn builds research upon the materials as defined in the arts and humanities, science, and applied science. Mainly, materials are foregrounded from interaction design, design practice and the notion of ''craft'' - traditional and ancient materials are presented as computable - further integrating ground-breaking achievements on materials with software engineering. Two approaches to this relation between new materials and crafts, are explored by Leah Buechley's in the low tech and high tech research group ("Leah Buechley," 2015), and by Catarina Mota's open materials work, which presents new materials and traditional technics, as open source (Mota, 2015), and dislocates experimentation from the research lab to a Do It Yourself (D.I.Y.) setting.

3. From nano to macro

Nanotechnology gave a definitive contribution to materials technological dialogue. The invention of the scanning tunnelling microscope (S.T.M.) at IBM Research Division by two physicists, Gerd Binnig and Heinrich Rohrer, enabled to visualize a new world of the very small. Indeed, Dr. John E. Kelly III, IBM director of research confirms that S.T.M. "opened new avenues for information technology that is still being pursued today". S.T.M. is a ground-breaking instrument able to go beyond imagining and measurement. It allows to manipulate atoms and therefore the creation of new materials stemming from the nano scale (IBM, 2015).

S.T.M. is an electron microscope that applies quantum physics to reveal the surface of matter. Simply put, readings at the quantum level are acquired by directing particles to surfaces that return a specific electronic feedback according to materials' different atomic structure. Materials are energy-matter bounding in permanent motion, and measurements reveal that these particles can have two positions at the same time, a quantum superposition of states. Quantum decoherence results from analysing the frequency on the position of particles in time, and thus determining the wavelength. Hence, matter behave both as waves and particles. The determination of the atoms' position depends on computation, and images are then created and taken from data reading. ("Tout est quantique," 2015). The microscope "observes" through data taken from a material (energy) interaction.

In fact, nano-technological materials, physics, and mechanical engineering research labs have "a direct implication on the historical processes of design"(DeLanda, 2004). The traditional paradigm of the genesis of form depends on "historical processes of homogenization and routinization that have promoted the "hylomorphic schema". Neri Oxman further adds that the modern program reinforces form (idea) over skills, and assigns to materiality a secondary role. In the context of art, design and architecture (ADA) materials are traditionally part of the discourse of a project, and not the source that serves the form (Oxman, 2010). The modern paradigm is confronted with nanotechnology and "new theories of self-organization" and "the potential complexity of behaviour of even the humbler forms of matter-energy" (DeLanda, 2004). This notion inspired Oxman's approach to making. For her in Nature's way of building "there is always a direct relation between matter and energy, between form and environment and between organ and function" (Oxman, 2010). Thus, applied quantum physics brings forward a new relation between form and structure. The enunciation between matter, energy and environment as givers of form is set ("Tout est quantique," 2015).

Consequently, it is no longer possible to define design "from the outside on an inert matter" (…) as a hierarchical command from above as in an assembly line" (DeLanda, 2004). Indeed, form "may come from within the materials" which becomes something "that we tease out of those materials as we allow them to have their say in the structures we create" (DeLanda, 2004). Therefore, applied Science has the potential to dislocate purposes and methods of design practice. When designing at a nano-scale level, materials acquire meaning while moving into the macro scale, i.e., to human scale. Designing at this new nano scale is made from the matter (atom) to the idea, therefore from the bottom-up. In fact this is a direct inversion of the top-down approach in which materiality is chosen to convey an idea, to serve a concept defined *a priori* and then imposed on materials (Figure 1).

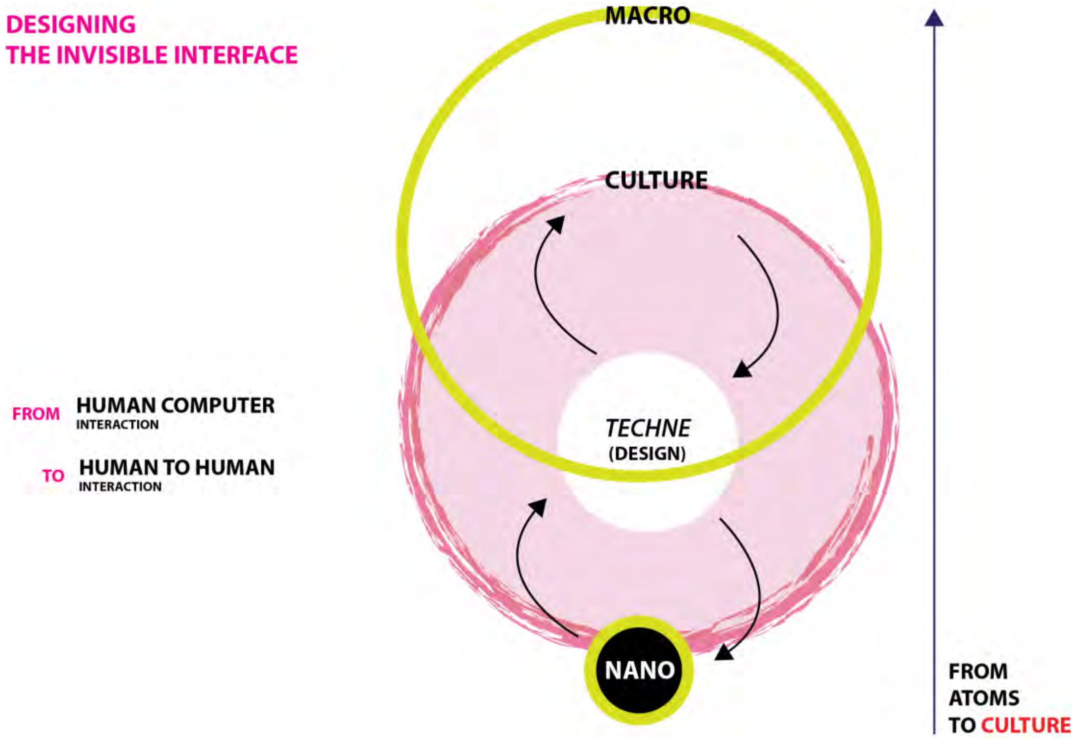

Figure 1 – Technê in context of Human-to-Human interface: research map inspired by Weiser's "Building Invisible Interfaces " (Weiser, 1994) and nanotechnology (DeLanda, 2004).

Accordingly, these considerations on matter inspired new strategies and methods in design, such as those enunciated by Oxman. For her the main point is to "copy nature's inventions" intending to design while desiring "to survive on earth", that is, for sustainability. Oxman finds inspiration in biotechnology, biomimetics and biogenesis (Oxman, 2010) which she applies to material-based design computation processes.

The materialization of these strategies has a broad expression, and only a glimpse illustration can be made on their wide range and impact, but above all, their disruptive potential. In a simplified manner, biotechnology uses living organisms to create new products. An example could be given with the use of mycelia to create bio-plastic, as applied to Lynn Rothschild's drone that is biodegradable, with all electronics components dissolving into the environment (iGEM2014, 2015). Nano-biomimecry suggests mirroring nature's witty behaviours into materials. An example of the latter is self-repairing concrete (Brownell, 2010), behaving like self-healing human skin. Indeed, biogenesis intends to create life in a laboratory. Furthermore, these bio-based methods have outgrown the science lab set, and inspired designers like Suzanne Lee who makes use of "biocouture" to grow wearable fabrics by using yeast and bacteria ("Meet The Woman," 2015).

The "material turn" proposes to tackle the division between the physical and the digital. A deeper look at this new approach to design reveals that this is a reconciliation that transcends a mere translation of the digital to physical interface. An example of the latter, can be found on Graphic User Interfaces (G.U.I.) transition into Tangible User Interfaces (T.U.I.) (Ishii & Ullmer, 1997). In the light of material turn, the initial statement on

Ubiquitous Computing proposed by Weiser, expands beyond the disciplinary delimitations of practice-led design research, but simultaneously widens the notion of the "ubiquitously of computation": materials reveal their own computable nature and a myriad of new possibilities arise.

Hence, smart materials and computational composites are visible product outcomes from nanotechnology research labs. Manzini considered them to be "the highest expression of the paradigm of tailor-made materials" (Ferrara & Bengisu, 2014), and consolidating a "contemporary third phase of the industrial revolution". The vast array of high-performance materials, range from changing colour, form, dimensions, temperature, to moving by themselves (Ferrara & Bengisu, 2014).

Smart materials present materiality as embedded smart systems, which resonate with what was described by U.C. typically associated to digital systems. Indeed, smart systems combine (input) sensors, a data processor, and an actuator (output), and perform a specific action. The same interaction model can be identified in a smart material: an array of stimuli triggers atomic processes, which configures a transformation as the output. Indeed, Addington and Schodeck point of view reinforce the concept of materials as systems. In their perspective "smart materials and structures are those objects that sense environmental event, process that sensory information, and then act on the environment" (Addington & Schodek, 2005b).

Considering U.C., Varadan and Smith make an important distinction between a smart system and smart materials. In fact, "smart systems do not necessarily contain smart materials, so the ones that do contain them are properly called smart material systems" (Ferrara & Bengisu, 2014). This is a fundamental difference to take into account when considering designing a U.C. system. A responsive environment is typically a smart system, and often presents a hybridization between architecture and technology (Bullivant, 2006.). However, in the context of architecture, a smart system refers to an intelligent environment, that might use smart materials, but not necessarily. Understandably, art, design and architecture disciplinary realms have strong tradition of humanism, and in designing considering humans and their bodies as the centre and measure of all things. Therefore the interdisciplinary encounter within U.C., materials, and human factors offers mutual novelty, specifically by building on different traditions and backgrounds.

4. Defining problems within design and computing research

Smart materials resulting from engineering research are effective systems, but their applications in life are less obvious. Often, smart materials are described as a "technology push", in the case, materials looking for a problem resolution (Addington & Schodek, 2005).

On the other hand, the issue of incorporating social-cultural values in UC research, this being within the material turn, or not, begins with its definition. U.C. is described as a "platform for encounters between people and technology", proposing, fundamentally, a disciplinary "conversation": science and technology studies, sociocultural anthropology, and media and cultural studies. These might be particularly relevant when defining problems (Dourish &

Bell, 2011.). However, Dourish and Bell state that there is a dearth of trends in U.C. that focus on an “emancipatory and democratic information technology”, visions “involving people in public debates”, and “issues of science and governance concerning climate change, environmental pollution, health care”. The acknowledgment of research outcomes “in the social sciences” “concerning, learning, participation, motivation, and behaviour change”(Dourish & Bell, 2011) is absent. Indeed, these are problems that U.C. is not typically addressing, and identify terrains for innovative exploration and contribution stemming from the humanities and arts.

The human-to-human interaction design model has social and cultural values prevail over technology. The privileged placing of technology would be to function on the background. As such, defining what problematic terms such as ‘social’ and ‘culture’ might mean in the context of UC research becomes imperative. To frame a practice led research social framing can range from locating settings - the workplace and factory, schools, domestic environments (Dourish & Bell), to analyse impact, as is the case of evaluating sustainability. Indeed culture is a problematic term. As a subject of study, academic definitions are substantially different, varying according to traditions in both sides of the Atlantic. Further dispersion can be found when examining design “cultures” among disciplinary backgrounds (Dourish & Bell, 2011.). In fact, specifically for the concern of a design-led research, culture will be suggest to firstly i) consider it as a generative process, secondly ii) as a method of analysis that enables to give an account of everyday phenomena, and in the context of UC iii) the “examination of information technology as a site of cultural production” (Dourish & Bell, 2011.).

In addition, the symbolic value of materials can be tackled by an ethnographic approach. But specifically, as the purpose of research in U.C. is to design “new devices”, insight can be retrieved from A.D.A., supported by a contribution from the theories of media, as specifically found in Bolter’s concept of remediation (Bolter & Grusin, 2000). This term accounts for historical continuity both on contents and practices in media design. Remediation examines media by displaying hybridization as a continuous dialogue between new and old narratives. In Bolter & Grusin’s description, ”the representation of one medium in another remediation (…) is a defining characteristic of the new digital media.” In other words, cultural inter-relations are acknowledged, and are pursued, as factors of analyzis throughout the process of making, and not only from a disembodied theoretical framework. The main point of these relations are that by putting theory and cultural perspectives in contact with the more common accomplishments of U.C., the research outcome might access less explored realms. Moreover, cultural values enhance awareness that a research contribution will become part of a new cultural production, and also part of a heritage (legacy), which is frequently local.

Knowledge acquired by architecture, art and design might give grounding insight to UC goals, by recombining materiality with tested traditions, but this contact can also project future configurations within the humanities, and the disciplinary culture. The material dialogue between the old and new was demonstrated to be mutually beneficial and within the interdisciplinary realms that U.C. pursuits.

5. Conclusion

Ubiquitous Computing research is an interdisciplinary exploration, with a majority expression routed in computer science. Addressing U.C. challenges under a design led research follow a less travelled route, and includes the Humanities and Art contribution. Hence, it follows Weiser's suggestion to start rooted in humanities and art aiming to design computation in human-to-human perspective. This approach to the field of studies of U.C. makes cultural and social factors emerge. As such, to survey the particular perspective on computing given by arts and humanities becomes vital.

In particular, on the proposal to design invisible technology, it would be culture that would prevail as the visibility. Computation would be on the background and the world would regain the perception of its physicality. As such, answering to this call, the "material turn" discusses within UC the particularities of humanistic knowledge. For instance, it presents the reification of computing as hybridization – of the physical and digital - which fundamentally consolidates a relation with several disciplinary perspectives and culture(s) of materiality (e.g. high tech, low tech). Thus incorporating knowledge acquired by disciplines such as architecture, art or design, which are fundamental to discuss intelligent environments or materials.

Designing the future of computation is also taking a look into the past. Bolter's concept of remediation reveals practice led research or *technê* (making/skills/knowledge) as a continuity and repetition of mediated contents and strategies of visibility.

The future is inspired by nanotechnology, which presents myriad possibilities on materials and design arising from the invisibility. It produces powerful outcomes that arise from bottom-up, instead of the typical top-down approach. Nanotech being itself a *technê* have impacted on traditions of ADA. As such, nanotech is a disruptive step in the "culture" of materiality, inspiring new takes on interactivity and on design methods. On the other hand, turning these new materials into content, that is, making them become meaningful experiences at a human scale, oblige to invest their designed "functions" with culture. This is the opportunity that the present discussion reveals. In other words, the incorporation of socio-cultural considerations in the realm of high tech materials is to serve them with communication (symbolic) values. As Dourish realized, and as defined by Weiser, defining problems having cultural-social considerations would be a fundamental contribution to the scope of UC making/practice. This is the take that has a minority presence in the literature.

In sum, exploring meaning within material turn and UC, will rely in, firstly, an inquiry arising from contact with materials, belonging either to a high or low-tech realm, and secondly, an overall consideration of social-cultural values regarding those very materials.

Designing for future generations starts now, and sustainability and ethical issues can be guiding beacons in the realm of system design. As such the art and humanities are included and demanded in the process of disciplinary collaboration as an emergence in discussion and making.

Acknowledgements:
Fundação para a Ciência e Tecnologia, Grant SFRH/BD/51302/2010,
Portuguese Ministry for Science and Technology
UT Austin Portugal Program
The author would like to thank Professors Sharon Strover, Kate Catterall, Paulo Ferreira for proofreading.
Professor António Câmara UNL-FCT.

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