ARCHITECTURE IN THE ERA OF ACCELERATING CHANGE

ABSTRACT

Building upon the accelerating progress of technological innovation and the associated increase in human population and life expectancy, the present paper highlights the necessity for architecture to become more responsive and adaptable to deal with unprecedented societal and environmental challenges. Elaborating on a number of (historical) approaches to achieve spatial flexibility, it emphasizes the potential of Smart Materials for future adaptive architecture. While explaining why such materials haven’t yet been noticeably incorporated into contemporary buildings, it calls for new models of education and the acquisition of knowledge based on cross-disciplinary exchange and communication. The particular methodology of the ‘materiability research’ is demonstrated and exemplarily concluded with an interactive Smart Material installation that emerged from this approach and which was exhibited at the 2013 Acadia Conference in Waterloo, Ontario, Canada.
THE NEED FOR ARCHITECTURE OF CHANGE

We live in an era of accelerating change, with technological progress advancing at an ever-increasing pace. According to Ray Kurzweil, the rate of change in a large number of systems increases exponentially. He underpins his theory by evaluating the growth rate of numerous developments, for example the growth of computational power (Figure 1), and uses this to predict that by 2045, technological evolution will lead to a state of singularity, “representing a profound and disruptive transformation in human capability” (Kurzweil 2005, 136), essentially allowing mankind to overcome the limitations of the mortal body and brain.

Paul Davis recommends remaining cautious and not taking such predictions too seriously, since exponential growth is usually short-lived and stops when it runs out of resources. Whether or not progress increases exponentially, architecture is still a very conservative discipline that evolves only slowly and tends to follow established rules. Yet, with the world population doubling in the past 50 years, and estimated to reach 9.6 billion by the end of 2050 (Figure 2), and a simultaneous rise in global life expectancy from 52 years of age in 1962 to 76 in 2050 (Figure 3), a consequent increase and densification of built volume is not only an observation, but a necessity, especially since 70 per cent of all people are believed to relocate towards cities and urban areas by mid-century.

When faced with prospects like massive urbanization, economic and political globalization, ecologic scarcities, meteorological shifts, ethnic variety, techno-social connectivity, and the rise of young generations who strive for independence, self-expression and the celebration of their diversity, it seems obvious that architecture needs to develop new solutions.

Undoubtedly, digital technologies have over the past twenty years influenced how architecture is made and perceived. Still, this shift has largely happened on a formal level. Simone Jeska observes that the benefits of computational design and fabrication are reflected in terminologies such as “transarchitecture, genetic architecture or flowing architecture” (Jeska 2008, 25). Yet, despite the dynamic notions of such expressions, they only remain flexible as long as they are kept virtual, which leads to the assumption that the understanding of physical form has been replaced by the term digital design. To bring digital dynamics into the real world, Kas Oosterhuis demands the creation of so-called Hyperbodies, which are “programmable building bodies that change their shape and content in real time” (Oosterhuis 2002, 42). These will lead to architecture which “will no longer remain static” but become liquid “not only as a metaphor in the design process, but in real life and in real time” (Oosterhuis, 76).
FLEXIBILITY IS THE ANSWER, BUT WHAT WAS THE QUESTION?

Jonathan Hill refers to Adrian Forty when highlighting spatial flexibility as a solution for buildings to adapt to changes and engage with their users on various levels. Forty classifies three strategies for architectural flexibility: by technical methods, by spatial redundancy and as a political scheme.9

The latter, flexibility as a political strategy, emerged as a criticism towards capitalism in the early 1960s, strongly promoted by Constant Nieuwenhuys and the Situationist International, who imagined modern society as an accumulation of playful moments in time. Their concepts inspired other radical groups like Archigram, Haus Rucker Co. (Figure 4), Coop Himmelblau, or AntFarm who not only developed utopian visions of modern cities but also staged public happenings demanding the active engagement of users to question the current society and propose anti-consumerist alternatives.

The second possibility, flexibility by spatial redundancy, assumes that a room would be so big that it could easily contain a variety of uses, like for example the spaces in baroque palaces, which were not predetermined to certain actions.10 Hill goes on to describe the (modernist) open plan as another type of spatial redundancy, which, distinct from flexibility by technical means, is less tied to a physical adaptation of the space than to a change in perception of the consumer. As prominent examples he mentions the Barcelona Pavilion by Mies van der Rohe (Figure 5) or Le Corbusier’s Villa Savoye (1931).

Flexibility by technical means highlights the use of mechanical systems to transform space either in an automated or user-induced way. Early examples include the Rietveld-Schröder House in Utrecht (1924) as well as the Maison de Verre in Paris (Figure 6), which both incorporated movable parts that allowed the space to be reconfigured.11 Referring to the work of Cedric Price, Hill mentions the Generator Project, a visionary, unfortunately unrealized collaboration with cybernetician John Frazer, as a key development “towards a building with intelligence” (Hill 2003, 32).

Michael Fox and Miles Kemp further emphasize the importance of John Frazer’s work but criticize that evolutionary systems, and in particular genetic algorithms, are today still mainly used as design tools and not for the creation of intelligent buildings (Figure 7).12

FROM SMART BUILDINGS TO ALIVE BUILDINGS

In relation to kinetics, Fox and Kemp predict “the end of mechanics” as a “paradigm shift from the mechanical to the biological in terms of adaptation in architecture” (Fox and Kemp 2009, 226). This
will be achieved through novel material development and the close look at biological systems, essentially mimicking natural solutions. Rachel Armstrong calls for the creation of “materials and construction approaches [that] need to be connected to and responsive to their environmental context in time and space.” Since the incorporation of real biological systems into built spaces involves energy- and maintenance-intense support, she suggests the invention of a “new kind of [synthetic] biology,” native to its surrounding and inherently sustainable (Armstrong 2011, 72). One possible alternative would be so-called Protocells (Figure 8), which Martin Hanczyc describes as “simple chemical models of living cells that possess some of their properties, such as metabolism, movement, replication, information, and evolution but are not necessarily alive” (Hanzyc 2011, 27). Leroy Cronin imagines the outcomes of such a paradigmatic shift as:

Buildings [that] would have a cellular structure with living inorganic components that would allow the entire structure to self-repair, to sense environmental changes, establish a central nervous system, and even use the environment to sequester water, develop solar energy systems, and regulate the atmosphere, internal temperature and humidity. (Cronin 2011, 36)

SMART MATERIALS

Essential for the realization of such buildings will be dynamic materials, also commonly referred to as Smart Materials, which Blaine Brownell defines as materials that “undergo a physical morphosis based on environmental stimuli” (Brownell 2006, 120). They can reversibly, and in a controlled way, change their properties over time and can be used as both sensors and actuators. Smart Materials are currently at different stages of commercialization, yet many of them are still immature in regards to practical applications. The global market for Smart Materials was at about $19,600,000,000 in 2010 and is expected to pass $40,000,000,000 by 2016 at an annual growth rate of 12.8 per cent between 2010 and 2016 (Figure 9).

POTENTIAL OF SMART MATERIALS FOR ARCHITECTURAL USAGE

Michael Schumacher et al. see the advantages of Smart Materials “in the potential to make constructions lighter, more slender and more comfortable,” and believe that they will “have a significant impact on the appearance and the impression of buildings as well as improve their functionality” (Schumacher et al. 2010, 88). Patrick Lochmatter argues that the main benefits lie in integrated actuator technology. “Especially when it comes to active structures, the advantages of active materials over conventional actuator technologies […] become obvious: with conventional technologies one would end up with a very complex framework structure, consisting of interlinked rigid parts. Using active materials, however, a

separation between the structure and the driving actuators can be avoided” (Lochmatter 2007, 6). Another interesting property of some Smart Materials is their nonlinear actuation to transformation ratio. In most cases this effect is regarded as a disadvantage, since precision is a major concern and the difficulty in controlling them in a predictable manner poses notable technological challenges. Yet in terms of aesthetics and behavior, this particular character-
istic distinguishes Smart Materials from the rigidity of mechanical systems and reminds of very soft, almost organic transformations that occur in nature. This allows for a very intuitive human association and especially in relation to spaces could be valuable to establish a (re-)connection between external, natural environments and internal atmospheres and situations.

SHORTCOMINGS OF SMART MATERIALS

Albeit their obvious potential and the vastly growing interest in their usage, Smart Materials are still mostly used within the context of experimental and artistic work rather than real architectural projects, due to a number of reasons.

1. CONJUNCTION WITH RIGID MATERIALS

In many cases the dynamic properties of Smart Materials cannot be used to their full extent as they are either attached to or “patched atop an existing structural or architectural system,” which constrains their abilities and efficiency (Oxman 2010, 83).

2. REPLACEMENT OF EXISTING TECHNOLOGIES

Smart Materials are often used to simply replace existing technologies without fully considering the particular capabilities they offer. A popular example is the light bulb, where the change from incandescence towards LED certainly brings benefits regarding longevity and power consumption, yet insisting on the traditional pear shape is like celebrating “a relic of a former manufacturing age”, as Eric Rosenbaum observes (Rosenbaum 2013).

3. STANDARDIZATION AND INCLUSION IN ESTABLISHED CATALOGUES

In many engineering disciplines, materials are generally divided into metals, ceramics and glasses, polymers, composites, and semiconductors. In architecture additional types are added, based on more visual or tactile properties. Accordingly, Smart Materials are being evaluated, standardized and categorized to fit into existing design palettes and catalogues. However by doing so, the active properties of the materials have to be ignored or seriously simplified to make them comparable to traditional materials.

4. SCIENTIFIC MYSTIFICATION AND LIMITED COMMERCIAL AVAILABILITY

Unfortunately, only very little information on new material developments is communicated to the field of architecture in a way that can be comprehended without having expert knowledge or insights. Especially since architecture is much more related to engineering than to materials science, biology or chemistry, attempting to understand these principles often requires serious efforts. Moreover, the fact that it usually takes decades until prototypical materials are available as applicable products on the market greatly slows down the creative process and restricts the designers to thinking within established boundaries. On the one hand, this means that architects have to rely on commercially available Smart Materials that have rather limited properties since they need to comply with building standards and compete with the durabilities and efficiencies of existing technologies. Or, on the other hand, they need to use products that were initially developed for different purposes and adapt their design or—in the lesser cases—the materials to their demands.

MATERIABILITY, A SMART MATERIAL LITERACY

The materiality research network, which was established at the Chair for CAAD, ETH Zürich in 2010, is based on the assumption that in the long run, Smart Materials will not only allow the creation of responsive, dynamic spaces but, in combination with other high-performance materials, also overcome the still prevalent separation of buildings into “skin and bones” (Mies van der Rohe) towards lightweight monocoque structures, and even more importantly, reflect the user’s digital identity within the material itself.

Yet, Klooster is right when he states that “fundamental technological innovations are rarely developed in the building industry” (Klooster, 7), which is due to both the rather slow advancement of architecture but also a general lack of exchange across various relevant fields. Since truly interdisciplinary progress can only happen if all involved parties and communicate a similar interest, a general base knowledge is essential.

The hypothesis of the materiability research is thus that the development of a sufficiently deep knowledge about specific materials will help architects communicate cross-disciplinarily to apply Smart Materials in purposeful new ways and potentially even influence the development of new materials. The approach expands upon existing advances towards Smart Materials, as described above, paired with strategies in accessing and productively applying digital information with the aim to develop educational concepts for a digital material literacy.

To overcome the current superficiality of Smart Material usage in architecture and the helplessness of designers in approaching such tasks, it is essential to understand that Smart Materials are fundamentally distinct from traditional materials. Smart Materials are not found and then post-processed but rather created on a microscopic or molecular level to perform a certain task or to exhibit special dynamic properties and therefore have to be approached in a different way.

Michelle Addington and Daniel Schodek note that it is important to understand that Smart Materials cannot be framed within the architectural discipline since they work at micro-scales, whereas architecture operates at the macro level. For to apply them purposefully one
“must then reach back further than simply the understanding of material properties” but “also be cognizant of the fundamental physics and chemistry of the material’s interactions with its surrounding environment” (Addington and Schodek 2005, 4). They argue that central knowledge of material behavior in relation to energy fields, and specifically the science of thermodynamics, will help understanding any new Smart Material that may be developed.20

The materiability research aims to cultivate such an understanding and promote the development of new ideas but also to form a basis for exchange and communication. But since demanding to analyze the molecular working principles of materials might ask too much from architects who are trained to work at directly graspable scales, the focus is on four major factors:

1. THEORETICAL EVALUATION

Klooster argues that “the properties and usability of a material cannot be assessed satisfactorily on the basis of its technical specifications alone” but only with knowledge “about its scientifically established properties and the industrial fabrication or processing techniques and workmanship involved” (Klooster, 7). Expanding upon this assumption, each material that is evaluated as part of the materiability research is described in terms of its historical development, structure, operating principle, fabrication process, common use, and (potential) architectural application. Such information not only helps to understand a particular material more comprehensively, but also to develop a mutual knowledge and language.

2. PRACTICAL RECONSTRUCTION

Since many of the materials are based on chemical, physical or biological interactions between several functional layers, they can be replicated with a bit of sensitivity and training. Hence for many of the materials, the fabrication procedure and assembly is reconstructed as detailed and annotated step-by-step instructions. This approach finds itself in a long tradition of DIY lessons, which were equally present in the world of conceptual art, used for example by Sol Lewitt or Marcel Duchamp, as well as during the rise of home improvement projects in the 1950s in the USA, which led to publications like the Whole Earth Catalogue in 1968, and becomes even more significant in the context of the current open source movement.21

3. SPATIAL EXPERIMENTATION

The intelligibility of the theoretical material research, the substantiality of the developed instructions, as well as the applicability for design and architecture are evaluated and tested through a series of experimental spatial installations that are realized throughout teaching modules and workshops. This format allows linking theory, material experiments and environmental studies to a human-scale experiential situation. Immediate feedback from the participants as well as external users of the final installations offer the possibility to adjust and validate the experiments.

4. DIGITAL DISSEMINATION

While student workshops and courses provide a good platform to test the research in a smaller circle, they can only be considered representative for the evaluation of particular techniques but not a general success of the applied methodology. Hence, in order to reach a larger mass and assess the above-described approach in a less controlled environment, an online platform (www.materiability.com) has been set up. The website allows interested parties to become active members and engage in the larger research approach. It forms a continuously growing database on a wide range of materials, provides hands-on tutorials to self-produce them, and promotes their assembly in speculative projects. This trinity, information, instructions, and inspiration are ought to help develop a common language and bridge the gap between research, education, and practice.

RESINANCE 2.0

A recent example that has emerged from this approach is Resinance 2.0 by Achilleas Xydis and Joel Letkemann under supervision of the author, an interactive spatial installation, which was publicly exhibited at the 2013 ACADIA Conference (Figure 10).

The main concept of the installation was very similar to the project Resinance, which was realized six month earlier at the Chair for CAAD in Zurich.22 Both installations were based on a series of hollow containers consisting of a custom-made thermochromic plastic. The containers held a liquid, which would cyclically heat up and cool down, when physically touched, and hence change the color of the containers’ surface. Information about the amount and intensity of contacts was shared throughout the installation in a swarm-like manner to develop a global, emergent performance from local interactions, strongly related to the behavior of simple organic life forms, in particular the formation and propagation of cellular colonies.

10 Resinance 2.0 as interacted with at the ACADIA 2013 conference, School of Architecture, University of Waterloo, Canada
TOPOLOGY

The layout of the installation was based on a linear arrangement of ten clusters, each containing three elements (Figure 11). The clusters were linked wireless and constantly communicated their current state to a master node, which compiled the information and returned it to the respective module. Every cluster was sitting atop an acrylic base that provided stability when the elements were actuated and housed the necessary electronic and mechanical components (Figure 12).

SENSING

A metallic mesh, embedded into the polyester resin walls of the elements, was used to measure human interaction. The mesh, which was added during the rotational casting process, functioned as a capacitive sensor (Figure 13). This allowed visitors to interact with the modules all over their surface and to physically experience the change of temperature when touching.

ACTUATION

In addition to the subtle, touch-induced color change of the elements’ surface, a shivering response provided immediate feedback to a person’s interaction. This was achieved through vibration motors sitting at the bottom of each element. Moreover, when the elements had reached their peak temperature, a stepper motor slowly raised the center of the cluster. Fans for cooling down the elements were attached to the inwards facing surfaces. Hence, the kinetic transformation, which resembled a blossoming flower, opened the air inlets and was triggered simultaneously with the cooling process.

COMMUNICATION

Custom designed shields were used to control the various electronic components, like heaters, temperature sensors, vibrators, motors, etc. The shields were attached to Arduino Fio boards equipped with X-Bee radios in order to communicate wirelessly with adjacent clusters. A visual interface, which ran on a nearby screen, graphically displayed every element, its current temperature, whether it was in a heating or cooling state, how often it had been touched and when the last touch had occurred. The elements had not only memory of their popularity, measured by the amount of touches, but also tried to return to their initial calm state by gradually deducting points from their counter if not enough interaction would happen. The speed of this process was largely depending on the popularity of the respective unit (Figure 14, 15).
REFLECTION

Compared to other projects that have emerged from the materi-
ability research, such as ShapeShift\textsuperscript{23} or Phototropia\textsuperscript{24} the applied
material technology within Resinance 2.0, thermochromics, can
be considered fairly straightforward. Yet, what has been learned
from experiments in the past was that the more sophisticated
and less established the material, the shorter its durability and ef-
ciciency. Since Resinance 2.0 was designed specifically for display
over an extended period of time at a remote location, its material
complexity was intentionally simplified and in cases substituted
with established, mechanical solutions. This decision ensured
the necessary stability and continuous performance of the parts,
allowed the pieces to be transported and assembled on-site, and
liberated the team to focus on other essential aspects of the proj-
et, such as software and logistics. Reviewing the project from an
educational point of view, it can be considered a great success.
The student team not only managed to produce a (mostly) func-
tioning installation within a very short timeframe, limited financial
resources, and on a different continent but also strived in develop-
ing their very own material system. While thermochromic plastics
already exist in various ways, the particular use of polyester resin
in combination with the applied rotational molding technique to
make hollow forms as well as the creation of a controllable inter-
nal microclimate to induce the color-change are true novelties.
Examining the project further, the major technical problems oc-
curred in embedding the sensor mesh into the resin body, since
if the mesh wasn’t covered completely, the internal liquid would
result in a short circuit, continuously triggering the sensor input.
Considering the project’s larger impact and potential for the field
of architecture, it needs to be emphasized that the focus of the
materiability research is not on developing practical or useful ap-
plications to solve certain problems or substitute existing technol-
gies. The emphasis is on trying to understand the composition of
the respective Smart Materials, their working principle and assem-
bigly, and acquire a basic knowledge to communicate, collaborate
and provoke cross-disciplinary development. In this context, none
of the projects that emerge from the research are designed with particular uses in mind, since imposing functionalities on the outcome would both restrict the open exploratory approach and dictate certain associations upon the materials. Thus making sense of the displayed materials remains a matter of interpretation and imagination in the eye of the beholder.

CONCLUSION

As Philip Beesley points out in the introduction to the 2013 Acadia Conference Proceedings, “Architecture has always been inventive and adaptable. Our current era, however, is unique in its technical potential and in the formidable challenges that society and environments face today” (Beesley et al. 2013, 1). People are becoming educationally and vocationally more flexible but yet specific; less geographically and domestically committed but at the same time increasingly addicted to continuous media input, social connectivity and an abundance of information. With architecture being omnipresent and permanent during every stage of life, it carries a great responsibility to address and respond to such challenges. This not only means the incorporation and adaptation of new technologies, among which Smart Materials will certainly play a lead role, but also the effort to collaborate and exchange across various disciplines and professional levels in a much less hierarchical manner.

Such changes are hard to implement since they have to arise from genuine ambitions and not imposed sanctions; thus new models for education and intellectual empowerment are necessary. The proposed approach suggests a viable method to reveal innovation in an open way and develop a common language for open exchange based on emerging techno-social phenomena.

NOTES

REFERENCES


IMAGE CREDITS

Figure 1. Kretzer, Manuel (2014) Computing Power, adapted from [1]

Figure 2. Kretzer, Manuel (2014) World Population, adapted from [5]

Figure 3. Kretzer, Manuel (2014) Life Expectancy

Figure 4. Conrad, Dennis (2010) Fassade MKG mit “Oase Nr. 7” von Haus-Rucker-Co im Rahmen der Ausstellung Kli kapseln 2010, via Wikimedia Commons.

Figure 5. Pomeroy, Ashley (2010) The Barcelona Pavilion, Barcelona, 14 October 2010, via Wikimedia Commons


Figure 7. Kretzer, Manuel (2012) MediaTic Barcelona

Figure 8. Kretzer, Manuel (2010) Protocells Venice Biennale

Figure 9. Kretzer, Manuel (2014) Smart Materials Market Forecast, adapted from [14]

Figure 10. Xydis, Achilles (2013) Resinance 2.0

Figure 11. Shammas, Demetris, and Xydis, Achilles (2013) Topology

Figure 12. Shammas, Demetris, and Xydis, Achilles (2013) Section

Figure 13. Shammas, Demetris, and Xydis, Achilles (2013) Parts

Figure 14. Xydis, Achilles (2013) Resinance 2.0

Figure 15. Xydis, Achilles (2013) Resinance 2.0

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