Smartness and Interactiveness in Architecture
The Hybrid Nature of Architecture in the Digital Age

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Abstract
Smart architecture has become a widespread term. In general it relates to computational components in buildings interacting with either the environment or the inhabitants. The term 'smart' itself leads to irritations, because objects can neither be smart by itself nor can a somehow applied smartness make a whole building smart. The presentation of some projects created by means of the Makers' culture shows an alternate pass to handle computational and interactive elements in buildings as part of the concept of empathic architecture.

Keywords: Smart architecture; Maker; Home automation; Empathic architecture

Introduction
Until the 20th century built architecture was considered as real and unbuilt architecture was merely a concept. Bricks and mortar, wood, stone and other materials were assembled to compose enclosures for humans to work, play and dwell. We know these enclosures as shelters, huts, and houses.

As buildings became larger and more complicated, planning was needed to realize them. The configuration of a building's materials required foresight, concept, and a plan. The artifacts of planning were distinct from, but instrumental to, the building itself.

With the advent of the computers, CAD-software and digital spaces planning extended into what we now know as 'Virtual Reality', a concept of interactive spaces with more or less necessary references to the physical world. As representations or symbolic elements in a virtual environment these references provide links to the real world. Modifications made by designers as requirements in a computerized planning process, as they became immediate, were the first mentionable occurrences of interactiveness in architecture, but only in virtual places.

In a same manner our real world environment, the physical space became also affected by the introduction of digital devices. While the first occurrences of interactiveness and smartness, like door lamps sensing motions or regulated thermostats went almost unnoticed, this lingering modification of our every days' life has turned into the presence of the 'Internet of Things' (IoT), a very broad term. In general it stands for both a network of servers as computational clouds of all kinds and connected small devices based on embedded computers. Instead of using the term 'IoT', as it is still subject of discussions beyond the scope of computation in buildings, the more specifying term 'physical computation' will be used here to describe the interacting nature of embedded computers in built architecture.

Hybrid Spaces
The concept of composite images, which places the rendering of a virtual object into a real scene, in architectural design as a projected building into an existing landscape, was the first noticeable appearance of a mixed space. The composition of elements from an imagined digital space, always subject to modifications, and the real world did allow the first interactive presentations of architecture. "Due to the limited processing power of computers at that time, only very simple wireframe drawings could be displayed in real time (Sutherland, 1968)";(Lee,2012). As such the direct interactions of such scenes with its digital elements were limited.

While the computer hosting the digital world was regarded as machine, it was separated from the result and did not interfere with reality. Only the presentation of the composite image as manifest of an idea did, and very often still does. In fact, the role of a single computer controlling the scene on a display is the most prominent feature of computed mixed spaces. "The concept of blending (augmenting) virtual data — information, rich media, and even live action — with what we see in the real world, for the purpose of enhancing the information we can perceive with our senses is a powerful one"(Johnson et al, 2010).

The idea of images composed from different kind of spaces suggested new concepts of hybrid technologies, wherein components of both material and virtual worlds interact. This development leads to the variety of hybrid and interactive spaces and smart technologies that we see today.

Augmented and Mixed Reality
The most prominent of these techniques is Augmented or Mixed Reality (AR and MR respectively). Now well known, applications of this technology started with transparent projection screens for stationary users as see-through devices. Noticeably are the head-up displays (HUDs), "which

have existed in primarily military aviation environments for several years" (Milgram, Colquhoun, 1999). View-through devices provide an effective composition so long as eyes' position remains fixed and lighting is suitable (Foyle, Andre and Hooey, 2005). AR and MR have evolved into a variety of applications that use projections on eyeglasses, windshields, and gaming goggles.

An interactive form of MR arrived once computers could both render three-dimensional objects and capture live video streams in real time. Here the combination of physical and virtual is rendered entirely in computer memory, employing calibrated cameras and fiduciary features (Milgram, Colquhoun, 1999).

The mixed, or hybrid, nature of an AR-systems provides an origin for many theories and concepts of hybrid technologies, combining physical objects with virtual, computational objects, and data (Anders, 1998). Interactive modeling is one of them (Lonsing, 2004).

Physical Computing

With the increasing use of miniaturized computers - especially micro-controllers – and cloud networks a new form of computation, Physical Computing, has emerged. Based on the cybernetic principle (Wiener, 1961) of action and reaction, sensors, motors, and lights are interconnected through customized software. Almost all common devices with a digital display have a data processing unit to help the device (and user) interact with the physical world.

"Personal computers have evolved in an office environment in which you sit on your butt, moving only your fingers, entering and receiving information censored by your conscious mind. That is not your whole life, and probably not even the best part. We need to think about computers that sense more of your body, serve you in more places, and convey physical expression in addition to information" (Igoe, O'Sullivan, 2004).

Micro-Controller

At the smallest end of the scale, low-cost, tiny computers allow interactions between physical objects in various ways. "Microcontrollers (MCUs) are typically manufactured with memory and some digital and analog peripherals integrated with a processor core on one chip" (Malinowski, Yu, 2011). Micro-controllers were developed as part of embedded systems. As consequence their programming is still unique, Although higher level programming languages have become available, some limitations, especially computational power and limited memory capacity are still constraining their usage.

Cloud Networking

At the other end of the scale, vast information warehouses like tile-servers for mapping applications or big data reservoirs as online storage and file-servers enable the creation of cloud networking, cloud services, or short clouds. A cloud is a service or a set of services for computational devices that are always on and connected to their servers without direct user control. The location of the server is usually unknown and often cannot be determined, because it consists of rented digital space on some data farm.

Clouds were first mentioned in the mid 1990's: "The beauty of Telescript ... is that now, instead of just having a device to program, we now have the entire Cloud out there, where a single program can go and travel to many different sources of information and create sort of a virtual service"(Hertzfeld, 1994). Clouds augment small computers beyond their innate capabilities by tying into uses and data otherwise unavailable.

Internet of Things

The unique relation between clouds and micro-controllers made an Internet of Things (IoT) possible. "The Internet of Things represents a vision in which the Internet extends into the real world embracing everyday objects" (Friedemann, Floerkemeier, 2010). IoT is a fairly recent term and one of the labels coined to describe this evolving technology. Whether the label sticks is yet another question. By comparison a network between micro-controllers and a cloud is a simple many-to-one relation, meaning that a micro-controller simply can not switch or swap clouds, while the Internet as we all know it is a very flexible many-to-many relationship between computers. As consequence the labeling is misleading and probably makes false promises.

Home Automation

A similar label is Home-automation. It refers only to all devices in a designated home or space ultimately under supervision of a central remote control, practically a smart phone. Major supplier of operating systems have already formulated software packages for their smart-phones, namely Apple's HomeKit and Google's nest.

A naming convention does not interfere with the technology itself. So called smart devices melded with ubiquitous computing will define the next generation of hybrid spaces with new forms of interavity. They will bridge the gap between the virtual and real world.

It should be noted that companies formerly known for selling only software products are now developing industrial products like lamps or cars (Google, elgato). Right now it seems to be easier to add physical objects to an already existing cloud network than to enhance physical products with computational interfaces.

Maker Culture

Another form of development is making. Derived from the DIY (Do-it-yourself) culture it combines physical objects with the beneficial effects of programmable computers.

Dale Dougherty's manifesto "The Maker Mindset" describes it as follows: "Maker Movement is spurred by the introduction of new technologies such as 3D printing and the Arduino micro-controller; new opportunities created by faster prototyping and fabrication tools as well as easier sourcing of parts and direct distribution of physical products online; and the increasing participation of all kinds of people in interconnected communities, defined by interests and skills online as well as hyper-local efforts to convene those who share common goals.”(Dougherty, 2013) It is one of the most comprehensive descriptions of the Maker Culture.

Like similar movements, Maker Culture has its own vocabulary and claims that open it to academic dispute. It has two consequences. Maker Cultures priority on production makes theoretical discussion almost impossible. Secondly, because of its general avoidance of established rules - even formal education! - some of their own labels undermine their cause. While appealing, expressions like ‘experimental play’ or ’basic democracy’ compromise the movement and cast an unprofessional light on their results.

Three Projects

Even with these qualifications, Maker Culture has much to offer inspirationally and technically. The projects presented in the following pages were created with tools and techniques from the Makers’ scene. Without that approach they may not have been created at all and, more likely, the accompanying concepts and techniques would not have evolved. Working directly with these tools can become an enlightening source of creativity and innovative design.

Empathic Lighting

This project is an attempt to combine the three common concepts of light sources, ambient, scenic, and personal lighting. These concepts are taken from lighting virtual models with CAD visualizing software, especially the knowledge that all three types are needed to get acceptable results.

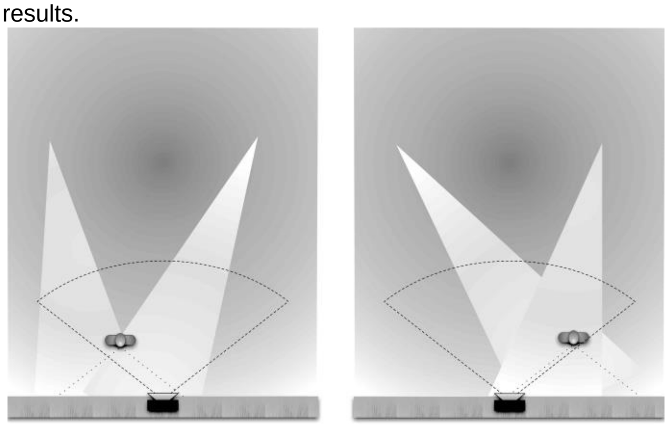

Figure 1: Principle of Empathic Lighting

Ambient lighting is usually simple daylight, no device at all. If floodlights are used, their common task is to simulate daylight. Scenic lighting relates to one single scene, regardless of whether observers are present or not. An arrangement of light sources illuminates a designated space as a scene. It can be as simple as lighting a public place with a street light or as complex as illuminating a stage. Personal lighting is best described by the devices in use. These are head-mounted lights, flashlights, and lights attached to vehicles and vessels. They are often in motion and usually point in the same direction as their user.

In the material world an arranged composition of all sources is rarely possible because daylight and most other light sources are not under the control of a single user. Neither the sun nor a street light nor a moving car with headlights can be directly influenced. The only remaining option an observer has is reducing the light intake by shading.

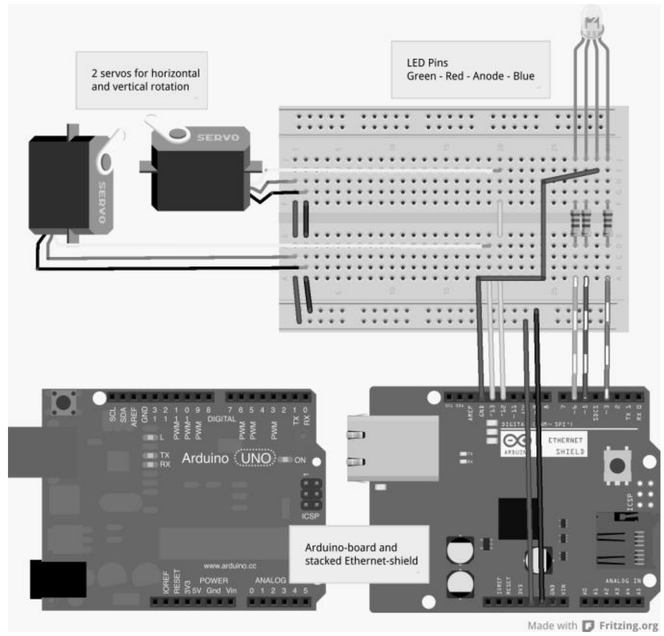

Figure 2: Schematic drawing of a lighting unit

Empathic lighting tries to overcome this situation - at least a bit. The system is based on the assumption that there is an ideal state of lighting, which can be defined for a designated scene. By comparing it with a current situation additional light sources can change the lighting of the chosen scene. Therefor the system employs several spot-lights with RGB-LEDs mounted on pan-tilt brackets (Figure 3) and arranged around the scene. They are individually controllable: color, brightness and the direction can be changed on demand. A camera is used to determine the present illumination requirements. At first it detects if an observer is present or not. If no observer is present all lamps are off. Otherwise the lamps are on. If the viewer’s direction is known, e.g. like in front of a painting on a wall, his or her eye- direction is detected as well and the lamps are directed accordingly.

Figure 3: Complete installation of Empathic Lighting

Lighting color can also be corrected. Responding to the observer, the light is ever changing, even in an otherwise complete artificial illuminated scene. Any person in the scene provides both shading and color modifications. If a person is wearing red clothes, the overall color value is detected and the green and blue color components of the lamps may be raised for correction.

The project is still on a model scale and the working model is under continuous development. The number of light sources will be increased and an additional ambient light source, an OLED panel, will be added. The sensing part of the system, the camera with subsequent image processing, is also under investigation.

Outlet Spider

The outlet spider is a smart remote switch which is built around a micro-controller mounted on a power shield. The shield including AC/DC converter is inserted inside a typical junction box from a hardware store in order to simulate a typical building situation, where the installations are sunk into walls (Figure 4). The concept avoids any unnecessary devices, like smart power bars or smart outlets, which are plugged into a conventional outlet.

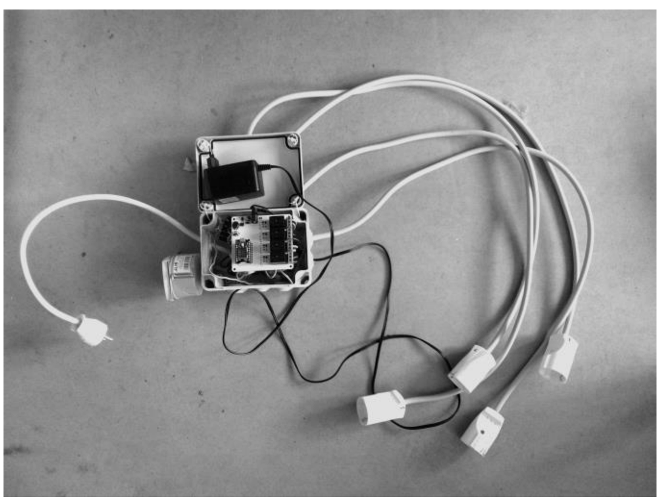

Figure 4: Outlet Spider with junction box.

With the micro-controller sensors like a thermometer, motion detectors, a microphone and so on can be easily added. The related logic will be executed directly inside the junction box.

In addition the controller has wirelessly access to the local network, which in most cases is already in place. With this connection several options are available, accessing a local cloud residing on a server directly connected to the network, a connection to a global cloud providing all kind of Internet access (Twitter notifications, etc), or simply a small network connection to a smart-phone on a table.

As proof of concept all three mentioned scenarios were tested with an application on an iPhone by simply turning on and off some lights. A motion detector was installed to turn on a switch once a motion was detected, and a tweet was sent as well. This project is ready to go, presently awaiting a concrete implementation in a real home.

Smart Street Light

The colorful street light, as demonstrated (Figure 5), is a project that enters the realm of urban planning. The project is a prototype of a street light made from a common mushroom shaped enclosure, wherein different types of light sources and sensors are integrated. It combines ambient and directed lighting as result of environmental stimuli detection and an animated installation.

Figure 5: Smart street light.

Lighting systems to illuminate public open spaces are categorized in two distinctive groups based on their appearances: The vast majority are functional lighting systems with blanket coverage comprised of white light sources as substitute for daylight. The typical case is a permanent public street light system build of stationery luminaries on an underlying regional grid.

The other group consists of colorful light installations, sometimes labeled as sculptural, artistic or theatrical lighting. They are usually temporary, site specific, and designed for special events. The intersection between both groups is, for a variety of reasons, rather marginal and the subject of this project.

Technically high power LEDs, one RGB- and three white LEDs are mounted inside the enclosure with the micro controller, some shield and power converter. As a street light the power is supplied through the pole. A remote control is not yet installed. The usage of higher voltages simply requires more attention and extra care.

While the concepts of smart street lights are evolving, the single purpose of all lighting installations being a piece of art is mostly neglected. Commonly, installations as pieces of art are not regarded as part of a public street light system. If such a system is installed and presents itself, it is usually temporary and isolated. On the other hand the public street light system has no means to present itself as an installation. Here its single purpose is the illumination of public spaces.

Neither limited to simple public illumination nor to a piece of art the'smart' streetlight combines both a unique new concept and the enhancement of an existing technology. The presented prototype made with techniques obtained from the Makers' culture shows a new type of streetlight and some ideas that can enhance our urban environment with interactiveness.

Other Projects

Some other projects are already in the pipeline. They include the use of GPS-receivers for locative applications, an informative wall switch with an integrated display, and a modified weight scale to be used as step sensor.

Findings of the Projects

In some sense all projects are, because micro-controller and electrical power are involved, related to home automation. At present this field of expertise is not usually regarded as an essential part of architecture, it is just better appliances. While the latter is at least disputable the more important observation is, that although all projects can be regarded as home automation they are in fact Making.

If any of these projects would have been presented separately, they would have been very soon trapped in a lack of theoretical background, Empathic Lighting might have been compared to other projects of adaptive lighting, the Outlet Spider would have been placed in the context of remote controlled housing and the Smart Street Light, because of its dual nature, would have been vulnerable to criticism as lighting installation and concerns about the nature of dark public spaces as consequence of sensing passers-by.

Pulled onto a hot seat in the need of valuable theoretical arguments any of these project would be at a loss. If theoretical arguments would be arranged, any theory that fits be referenced the presentations reduced to explanations then it would discard the major advantage all these projects have: They have been made.

The main goal of making is the success of the project itself. If afterwards maybe a discussion arises it is all about the project. By coincidence it is very similar to built architecture, when criticism and discussion takes place once after a project is finished.

Discussion

As all projects are in an early stage and nothing has been part of a real construction there is plenty of room for discussion. A superficial examination of theory and practice in computational architecture very soon reveals, that obviously concrete physical results are at a minority. The majority of papers are referring to theory or virtual architecure. Even if built a lot of the demonstrated projects are not more than proof of concepts, as the buildings are simple pavillions or huts without the necesssary infrastructure. Besides some few exceptions computation in architecture is about virtual architecture and derivats, not about computers in buildings.

Rem Koolhaas on intelligent Architecture

Rem Koolhaas wrote a well-observed essay, where he reflects on new technologies in architecture. His article, worthwhile an in-deep discussion on its own, will here be discussed as a representative opinion regarding computational elements in architecture. He (Koolhaas, 2015) wrote: "Now digital technology is no longer restricted to merely enabling design; it is rapidly integrating with architecture's essential physical components.[…] Looking at the traditional elements of architecture through a microscope, we saw the extent to which they had been penetrated, if not completely transformed, by new kinds of 'intelligence.'" It is evident, that he regards digital technologies only as serving techniques being a part of the design process in architecture, but not a part of architecture itself. This preconception might explain some of his following statements, when he wrote: "For thousands of years, the elements of architecture were deaf and mute—they could be trusted. Now, many of them are listening, thinking, and talking back, collecting information and performing accordingly." Besides his undeclared Romanticism there is the mistake, that he personalize architectural elements in a simplifying manner. To avoid the term 'smart', the interactive and responsive elements in architecture he is referring to are only reacting or performing. They are not 'thinking' or 'listening' and they have no intelligence on their own. Such an assumption is a complete disregard of the contextual nature of connected digital devices. In a technical discussion without further information such arguments can only be rejected.

To conclude with him: "A Faraday cage will be a necessary component of any home—an electromagnetic shield offering a retreat from digital surveillance and preemption." Such a suggestion can not be serious. Avoidance is no solution. This attitude blocks any discussion about the subject itself. Koolhaas' conclusion reveals only fear and anxiety. The real problem, how to deal with new technologies and how to maintain ownership of an architectural design even in the digital age is masked away.

Finally the question remains, how to deal with an opinion suggesting an almost paranoid exit strategy only. As emotions are involved there is a simple general solution: With knowledge and practice. Knowledge means, that, as example, different types of clouds, based either on messaging or storage, either as local or global cloud based on the type of server in use and so on. Practice means, that it has to be done. In case of the Faraday cage the solution would be a local cloud on a server inside the building that serves all directly connected devices. A global cloud might be available as a fallback or for really remote access. Koolhaas might be right in cases, where smart phones control homes through internet connections by using some global clouds on alien server farms, but he is not capable of formulating it this way, and has no information of alternate solutions. Yet it has to be acknowledged that he made a clear statement. His essay can be argued with. Very often technophobe opinions remain both general and vague.

Practical Approach

Another point of discussion is the practical approach makers show. Theorist in architecture already found a name for buildings fulfilling the needs: Vernacular architecture. Other labels are traditional or popular architecture. Buildings that fall into this category were just build without requirements to some theory. or special design. The main reason for their existence is their practical usefulness.

The same applies to the projects of makers. They are made because of their obvious usefulness. The difference is that computers are involved, both as micro-controllers and as clouds, and to not forget it, as normal desktop or laptop computers in order to develop the software. But their usage remains still solely practical. Once it works, it works. If it can be enhanced, next time it will. That's it.

The Problem of Data

Another point is, whether there are side effects. Dealing with physical computing, clouds and other form of computation might suspect that there can be more, especially another form of handling the data and the understanding thereof.

The increasing pressure of computer-delivered data into our haptic world injects various elements of virtuality, from simple information like from a navigational unit to complex interactions like the interfaces for personal training applications. To examine these virtual injections, they should be observed without regard to the concrete devices executing them. It does not make any difference, if a smart phone, a watch or a dedicated standalone device inserts some elements of virtuality. Computers are already elsewhere in the cloud or wrist. What matters is that those injections or insertions are changing the lifestyle noticeably. Because computers are elsewhere virtual elements are everywhere.

This includes architecture, and while some architects refuse to acknowledge it (Koolhaas, 2015), makers already have an understanding how to deal with it. Again referring to the presented projects technical details have been executed in several forms. Obtaining and evaluating personal data is done in Empathic Lighting. The Outlet Spider handles data from a cloud and the Smart Street Light can inflict space from the outside or automatically.

Correspondingly, because all projects are self-made, a decent understanding of the handling of various form of data has been gained. There can be an encrypted path of data through the cloud as with the Outlet Spider, a direct path from a mobile device to a lighting source of Empathic Lighting by controlling the system with a graphical interface (Figure 6), and a simple automated control with a Smart Street Light.

The increasing application of computers in different places of a building, home automation being only a part of it, the handling of data and its understanding will become an important portion in the work of an architect. By adapting tools and techniques from Makers architects can easily master that task. In this sense the Makers' Culture has an educational component.

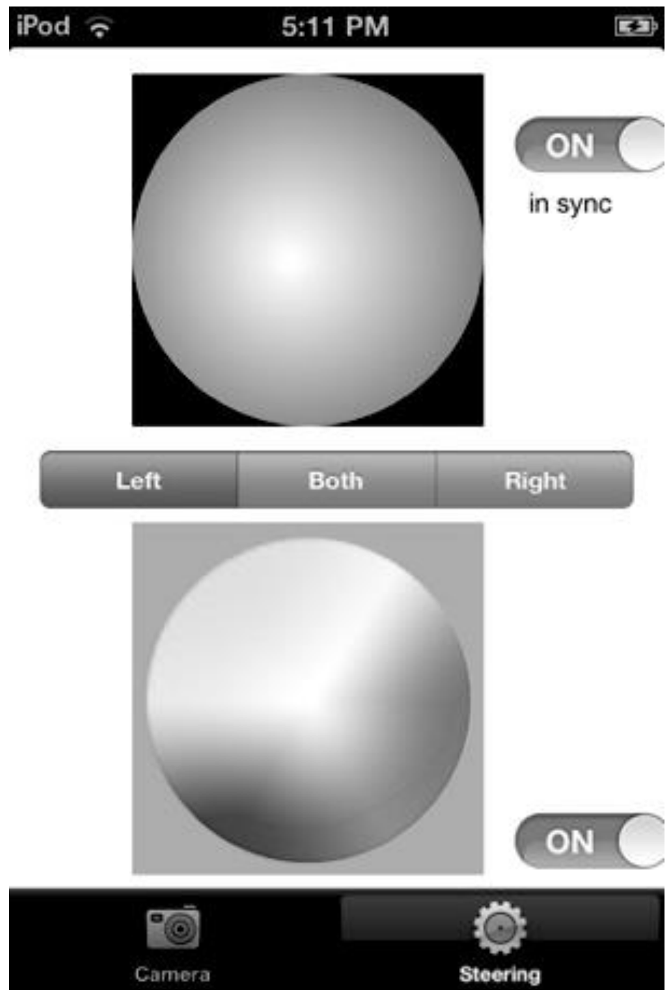

Figure 6: Graphical interface on a smart phone.

Makers' Culture

What in fact renders the Makers' Culture a special case are two factors. At first it does not only combine different types of computers like e.g. in Digital Fabrication, it combines computers that are not accessible as such. Neither a cloud nor a micro-controller employs a dedicated universal graphical user-interface similar to a common desktop computer. If interfaces are provided they are designed for only single purposes and hence they are constrained and limited. Otherwise access to both kinds of computers is only indirect by the means of using other computers.

The other factor is that the combination of digital clouds and physical computation bridges a wide gap between an abstract virtual layer, the cloud, and the most concrete computers available, those that are directly manipulating our reality. It is then a glimpse of what can be expected as possible future of smartness and interactiveness in architecture.

Computational machines as so called smart devices all around us will define flexible spaces through interaction or otherwise, while the visible machines occupying hands and eyes are vanishing. Making would be one of only few ways to define and create spaces in such hybrid environments.

Empathic Architecture

The last point of the discussion here is the question, whether the existing naming conventions like 'home-automation', 'Internet of Things' and so on are sufficient. Obviously at present the simple wording has become an issue.

In general the compound terms in use to describe yet unknown devices and techniques are misleading. An example is 'Augmented Reality'. Reality cannot be augmented, because it is a singularity in space and time. Otherwise it is not real anymore. Given the philosophical implications of what is real or not discussions will be endless and finally fruitless. As compound term it is in fact solely a label to name a specific technology. Koolhaas did hit this trap, when he complained about smartness in architecture and did not acknowledge it as a technical term with a certain and limited meaning.

Nevertheless there is still no term that describes smartness and interactiveness in architecture sufficiently. Derived from the project 'Empathic Lighting' the suggestion here is 'Empathic Architecture'. The term reflects the overall responsiveness of smart devices in buildings as well as it refers to a general sensing component of the technology. Sensing the behavior of the inhabitants of buildings is as much important as monitoring and manipulating the actual devices. Otherwise smart architecture depends solely, as the concept of home automation suggests, on the direct manipulation of electronic devices inside a home with dedicated controlling devices like remotes, cellular phones, voice control or else. Without adequate sensing smart or interactive buildings require and demand explicit active actions from its users.

Conclusion, kind of

There is no real conclusion yet. By accepting the influence of digital technology at all as first step, and secondly the desire as architect to keep the ownership of the design process of complete buildings as a whole, not only as configuring their shapes, the next steps will become visible. One promising is utilizing tools and techniques from the Makers' culture to create yet unknown interactive and smart elements of architecture, like the lamps of 'Empathic lighting'.

As both the described projects are in a very infant state and the subject of smart and interactive architecture is almost non-existent in the field, compared to information technologies or similar disciplines, there is only one mentionable result: There is plenty of room for future research.

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