Computation in Architecture

Subtitle: The Handling of Computational Devices in Buildings

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The common point of view in architectural design regarding computation states, that in architecture computational aspects of a building's design are ignored once a building's design is finalized. Computation beyond the completion of a building does not belong into the realm of architectural practice.The undeniable existence of computers in buildings should not only be regarded as addition to a building's design. Architects have to deal with computational devices and their functionality in buildings and they have to design both form and function of them. An integrated design approach as part of the holistic concept of designing buildings needs to be established, because computation will become an essential component in the architectural design process.

Keywords: *Programming, Computational architecture, smart buildings, cloud computing*

TOPIC(S)

- Design Concepts &Strategies
- Human-Computer Interaction
- Smart & Responsive Design
- Spatial Reasoning & Ontologies
- VR, AR & Visualisation

INTRODUCTION

Computation in architecture, as it is well described in the conference's theme, "spans from the virtual representation of space to its physical making" [Spaeth & Jabi 2016]. This common point of view in architectural design inherently states, that in architecture computational aspects of a building's design are ignored once a building's design is finalized and the building is erected. The finding correspondences with the typical job profile of an architect that after the architectural production has ended the work including the work the engagement of computers is done. It looks like a perfect fit.

The shortsighted assumption that computation in architecture is only part of the process to enhance and ease the design introduces the limitation that after fulfilling the promise of a design the computational elements therein are not any longer part of its architecture, if they have ever been. Computers inside the finished and established building are usually not regarded as part of architecture, because computation beyond the completion of a building does not belong into the realm of architectural practice.

This is reflected by the naive attitudes of not handling computation by simply ignoring computers in buildings, like as the conference's theme, refusing

them, neglecting, denying and even fighting it in a sense, that buildings cannot be 'smart' (Koolhaas 2015).

It is obvious that these strategies are leading to a dead-end. Theoretical and practical computational applications in architecture cannot be left out at will. They are everywhere and buildings are no exception. Instead computers as part of buildings should be considered as valid parts of the architectural design and taken as chance to the ongoing quest of improving architecture.

COMPUTERS IN ARCHITECTURE

Computational machines and applications can be essentially divided into two groups, computers in the hand of a user within a building running specific software, like mobile device with a navigational software or an AR-system (Augmented Reality) and computers as part of the building itself, usually small embedded computers with limited capabilities and especially no dedicated user interface, commonly assigned to home automation or 'smart buildings'.

Mobile devices

For a decade now mobile devices with their touchscreens have silently infiltrated the perception of our reality, meaning that the sole focus on our world is vanishing in favor of a more connected and networked surrounding. Any activity like a simple tweet or an SMS on a smart-phone is related to a location, the place where the users gets distracted and shifts the focus from the environment to a small display.

Designated applications on mobile devices for certain buildings or locations are already known, like apps for museums or exhibitions, often based on augmented-reality technologies, or specifically designed navigational applications for particular localities.

What is lacking is an integrated design of both the application and the building. By pretending that programmers are not designers and designers can not write code a building's environment delivers only the static context where the app is fitted in. The usage of the app should not interfere with the architectural design, even though apps are already doing it all the time by mixing realities and changing the architectural appearance. This ostensible arguing becomes more and more outdated.

Computers mounted in building

Unlike walls, doors, windows, handles, locks or else computers are not considered as part of a building. Instead they have become part of them as accessories. Computers merged inside building parts, typically some electrical and mechanical items, as embedded systems are regarded as component of that part of the building. Computerized outlets deploy an integrated relay as switch, locks are motorized and so on. The upcoming question here is, if e.g. an automated door is still a door with a lock and some mechanism or a temporarily opening which appears to be permanent, because only the absence of users made it close. Hence in theory nobody never will notice that particular spatial separation. Just an aspect here, which will not be discussed any further.

The point is that while the relation between mobile devices and buildings are only established through the simultaneous perception of their users the relation between computers mounted in buildings and the building itself are even more tight, and hence is the design.

TERMS AND DEFINITIONS

The utilization of embedded computers in buildings has lead to some interesting wordings like 'home automation', 'smart devices' and IoT (Internet of things). Before discussing them in detail at first these terms have to be acknowledged as technical terms. Otherwise philosophical issues and similar will become overwhelming. Neither can a device be taken as smart, nor a complete home automated (What does it do?) nor reality be augmented and so on.

Smart Devices

Adding an embedded computer, eventual some network interface and commonly some sensors and

some actuators to some part of a building assumably makes them 'smart'. A window with a computer is a 'smart window', an outlet with a computer a 'smart outlet' etc. Usually such computerized entities act to some degree on their own without direct user control, hence sensors and actuators are usually integrated.

Besides the inflationary usage of 'smart' which causes a lot of irritations (Koolhaas, 2015; Lonsing, Smartness and Interactiveness, 2016) the real functionality of the computer is disguised. It is not about smartness or intelligence, it is about control. Modern embedded systems establish controlling, timing, supervision, regulations etc. in a quality that have been unthinkable only a few years ago. With servos, colorful lighting and modern networking technologies attached to it new types of installations can be created inside computerized buildings making them interactive, responsive and more flexible.

Home Automation

Home automation slightly differs from smart devices as it includes more sophisticated machines like a coffee-maker or a dish-washer. Already computerized those machines have become interconnected and may now are messaging their status and also accepting orders from authorized users elsewhere, although strictly an Internet connections according to the concept is not mandatory.

Surprisingly one special consideration in home automation is the wide variety of technologies, platforms and protocols. Some of them are standardized, some of them are open and a lot of them are still proprietary. However, essentially the usage of different protocols and frequencies is simply an implementation detail.

IoT

The 'Internet of Things' is defined by its status, where all devices are expected as connected through the Internet regardless of their functionality. It can be literally everything.

One point to mention is the ubiquitous usage of speech recognition, which depends on the Internet. All major provider, Apple with Siri, Amazon with Alexa, Microsoft with Cortana, and Google with its refreshed Assistant are performing cloud-assisted speech recognition as their services.

Common Pattern

Needless to state that the terms and definitions and their related technologies are not a major concern. The main problem is that in architecture a kind of yet unknown flexibility and control of the built environment has been established. With the introduction of computation in buildings, this may include networked access, new concepts are requested to integrate computers into a building's design process. The apparent sprawling installations more than indicate this as a consequence.

A look at the simple example of smart outlets from the supermarket, which can be triggered wirelessly, may demonstrate the issue. There are a lot of different vendors, each of them uses specific technologies and probably different frequencies, each of them has its own cloud and its own app. These device are not designed for integration and their users' experience is less than optimal. But what really matters, even for otherwise technology-resistant architects, is their appearance. Although the look of common outlets is not always pleasant, these kind of extensions are distinguishable well designed in all different forms. Plugged into a normal outlet on a wall they look like pimples, just ugly.

Then there may be different types of outlets, because they were once on sale, with different protocols of course. In addition there maybe are those typical cylindric sometimes blinking devices for speech recognition, dominating a room because they should always listening, and there maybe other devices to come.

If as architects we otherwise do not care about computers and have no opinion regarding computation whatsoever, this is a point we have to address.

THE TASK

To prevent a building's design from electrical clutter has become the challenge in modern architecture. The related task is to do it by design. It implies rethinking the concept of buildings like it has been done before when new technologies were introduced like e.g. the usage of steel or glass.

Therefor the computational infrastructure as part of buildings should be laid out during the design process. A special type of installations are central computers or a network thereof in buildings. They establish an informational grid and a local cloud bound to the location eventually effecting the ownership of data, reliability, security and other issues of modern computation. A holistic view of a network as integrated part and as a specific element of the construction of a building, when a building provides connectivity like shelter, is the focal point of this task. Designing a layout for computation needs special consideration on its own during the design process.

Computers in public spaces

Architecture is not limited to buildings and therefor computation not bound to their physical presence. Public spaces as part of urban planning are also about to be computerized. One example are much more flexible public lighting concepts based on smart street lights.

Some Projects

Instead of theoretically elaborating on design issues some projects are introduced. They have in common that they are all deploying a micro-controller based on the Arduino-platform. While the genuine Arduino does not provide connectivity the specific type of controller from Particle here in use are connected. Their different types of boards are interchangeable and can offer connection either through WiFi, GSM or Bluetooth with the same code-base. In addition they can access either the company's global cloud or a cloud locally installed on a small server, typically a Raspberry Pi.

Figure 1
Lighting with a color changing lamp.

The project related to deliver some new computational supported functionality in buildings are more or less all related to lighting. As technology artificial lighting simply provides the best cost-benefits ratio. User interfaces on the other hand may already cut costs and do provide some savings. By substituting wall switches and their really expensive high-current power lines with connected and programmable custom made switches the switch panels on walls could be elimanated altogether with something like e.g. integrated touch areas made from concrete.

Empathic Lighting. Empathic lighting as project (Lonsing 2016, Empathic Lighting) explores the usage of computers, sensors and actors to illuminate a scene. With moving RGB-LEDs a fast responding lighting system is developed to not only defy the impact of changing daylight conditions but to answer the environmental light intake on the fly and even anticipate a viewer's acting. Still at a model scale the working system comprises two specially designed lighting units and a smart phone as both as camera input and user interface.

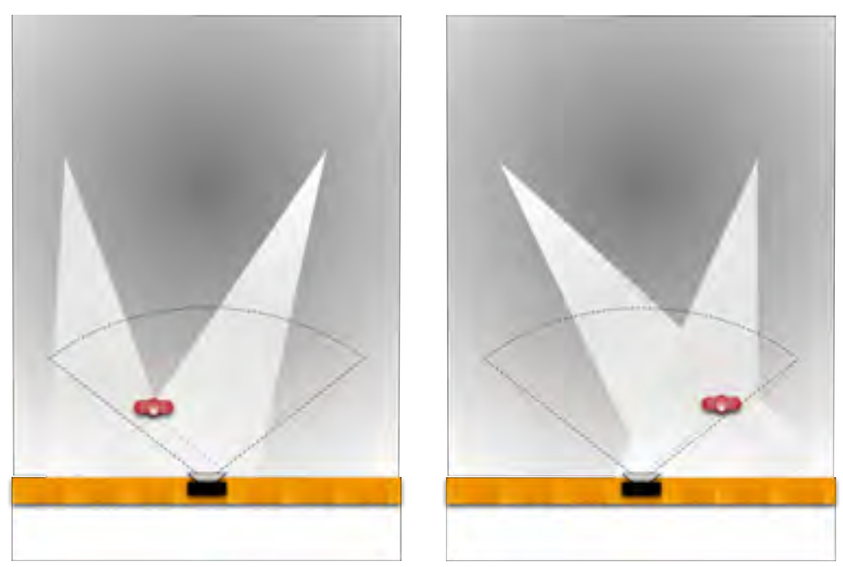


Figure 2
Concept of empathic lighting, the lamps are moving according to the position of a user.

Figure 3
User-interface on a smart-phone to control a single lighting unit.

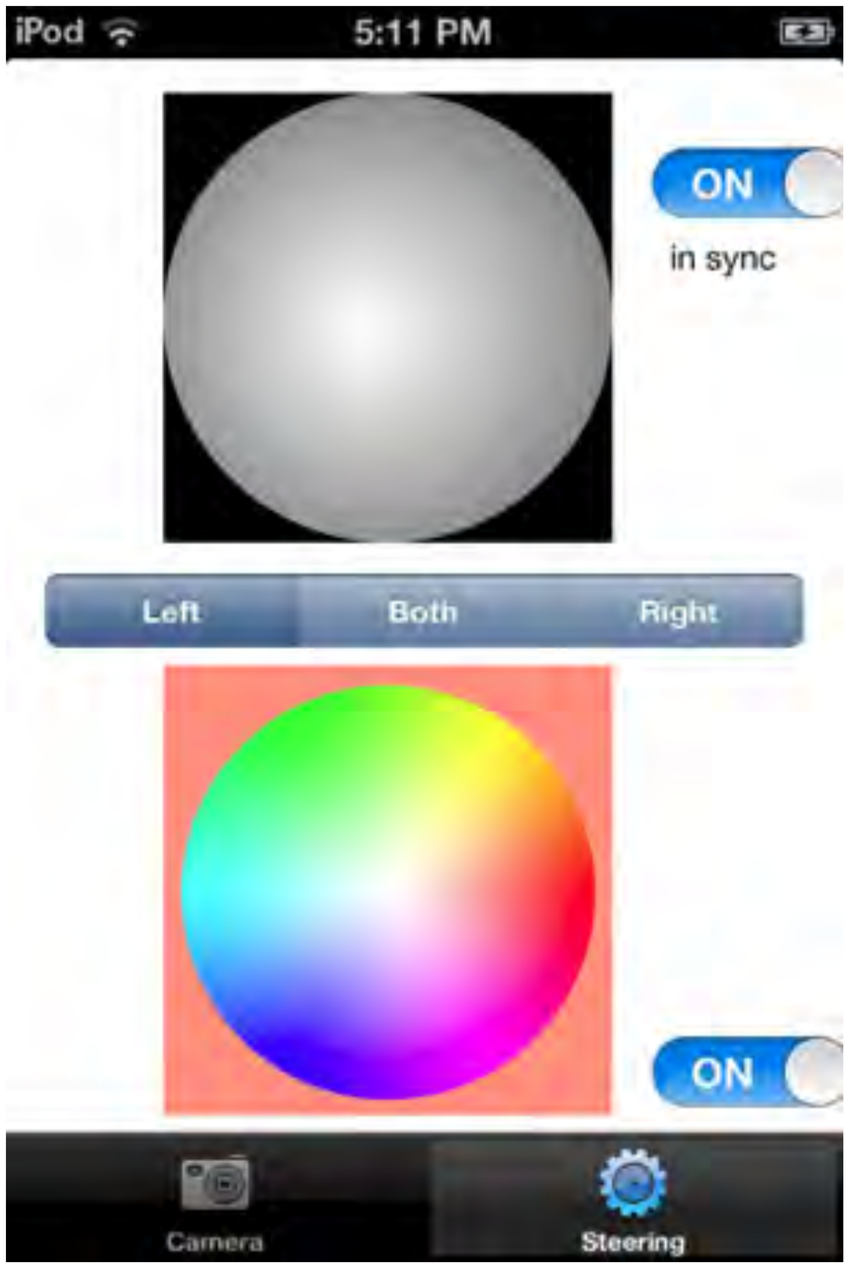


Figure 4
Complete system, colored LEDs mounted on pan-tilt-brackets with servos and micro-controllers.

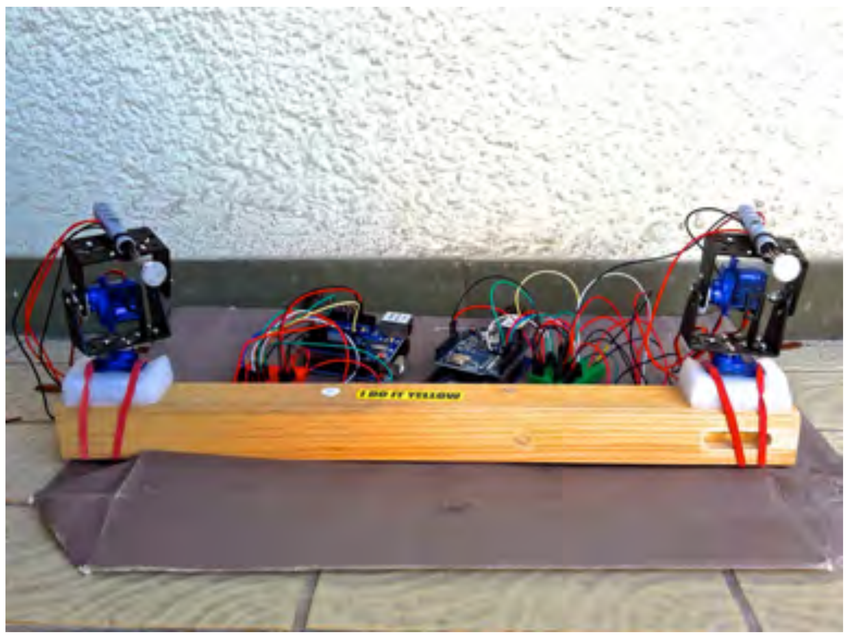
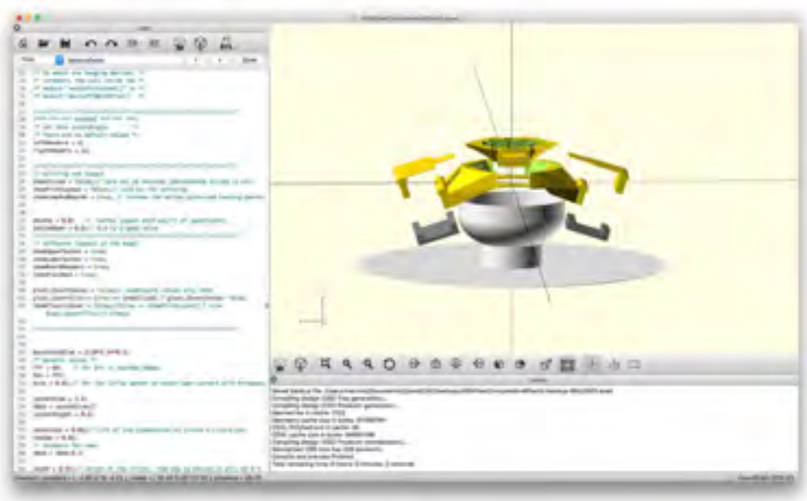


Figure 5
Projected socket with designed parts.



The lighting units are spot-lights with RGB-LEDs mounted on pan-tilt brackets. They are individually controllable: color, brightness and the direction can be changed on demand. Each lighting unit deploys its own computational controller, a common Arduino-board with an Ethernet-shield for connections.

To determine the actual illumination a camera is used, which is already part of a mobile device. By means of image processing the immediate visual appearance is analyzed like the presence of users and the ambient lighting. An overall color value is detected by summarizing all pixels and calculate a mean value thereof which is used for corrections. Then the detected color components of the LED are lowered and the opposite color components are raised. As result the scene should always appear in a constant light regardless of environmental inputs whatsoever.

An additional feature is the usage of the built-in face detection to anticipate the viewing direction of a user in order to illuminate only the area of interests the user is looking at.

Fado Lamp. The Fado-lamp is a simple self-made RGB-lamp similar to common mood lamps. It utilizes 3D-printed parts to mount the LEDs and the micro-controller on top of the socket of the then removed light bulb. The chosen Pixie-LEDs have the advantage, that they can be daisy-changed, hence a variant with three LEDs is already projected.

Figure 6
Printed parts and the real lamp.

To create the printed parts the socket was measured and virtually rebuilt to design the mounts. The micro-controller then were virtually placed as winglets and mounted using the physical pin layout of the boards. Due to the small size of the pins the fitting of the winglets still has to be worked out.

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.

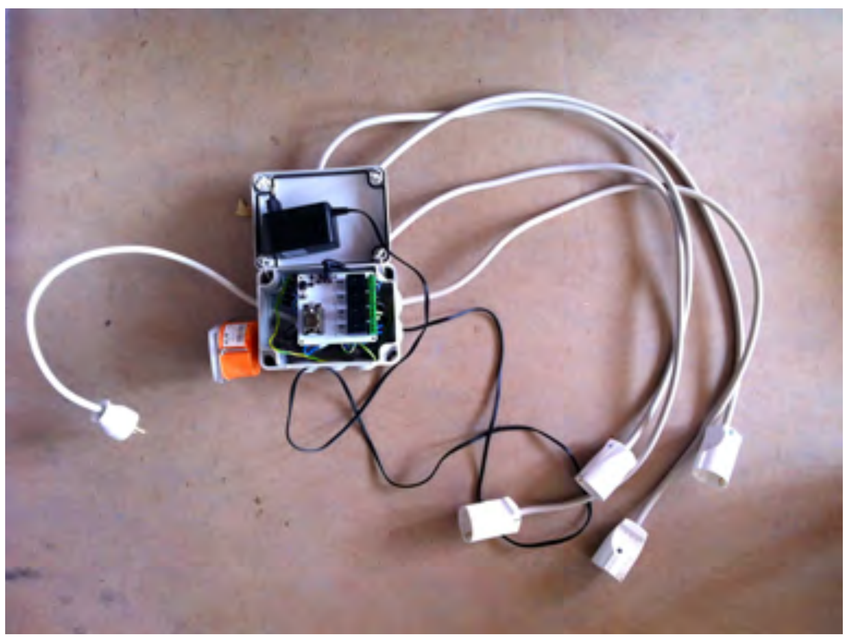


Figure 7
Outlet spider with micro-controller and relais inside a junction box.

The concept avoids any unnecessary devices, like smart power bars or smart outlets to be plugged into conventional outlets.

Smart Street Light. The Smart Street Light project (Lonsing 2016, Smart Street Light) was designed as a common street lamp with added colored lighting allowing for new concepts of public spaces with integrated lighting installations.

Figure 8
Concept of a smart street light.

As project it enters the realm of urban planning. The prototype of a street light is made from a common mushroom shaped enclosure, wherein different types of light sources as high power LEDs, one RGB- and three white LEDs, sensors and the electronic devices, micro controller, shields and a power converter are integrated. It combines ambient and directed lighting as result of environmental stimuli detection and an animated installation as well.

Figure 9
Inside of the street light.

Figure 10
Projected switch to control a complex lamp with a rotary button and a small display as UI.

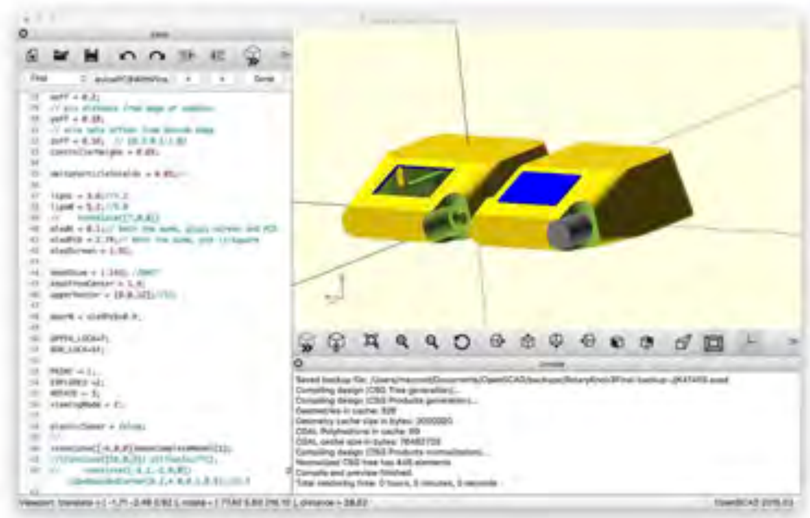
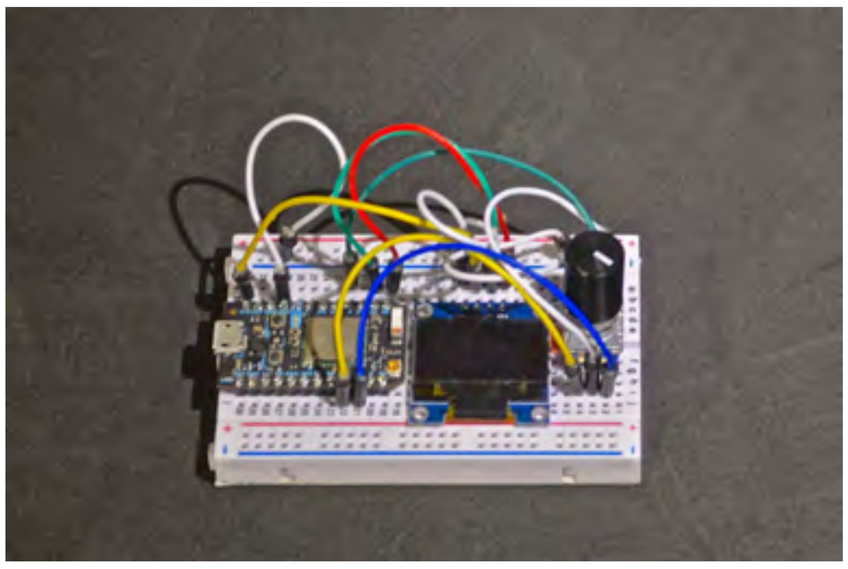


Figure 11
The same functional switch with micro-controller on a breadboard.



As a street light the power can be supplied through the pole. A remote control is not yet installed. The usage of higher voltages here simply requires more attention and extra care.

User Interfaces in Buildings

Regardless of the functionality of their corresponding computational devices common user interfaces in buildings are following only two patterns, and both are relying on the Internet comprising remote data processing and storage.

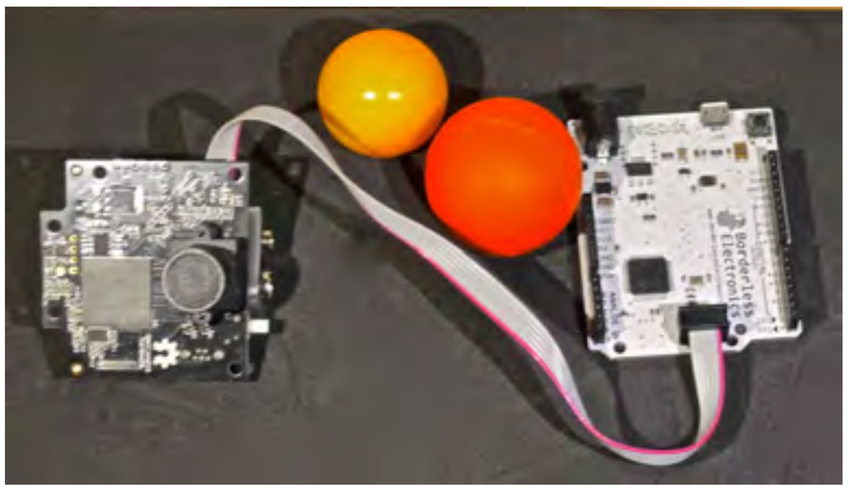
Either connected embedded computers are controlled through mobile devices or by speech recognition. Both use cases are not as intuitive as they could be. Focussing on some small display and wiping through screens is always distracting and almost as cumbersome as the time consuming verbal communication is .

Flexible Switch Pad. The switch pad combines an OLED-display, a push-rotary-button and a micro-controller. The button provides the input to display a little menu on the the display, walk through it and select some functions, while the push-button is an on-off switch. One application is to control the colors of the LED of the Fado-Lamp and simply switch it on or off.

The provisional implementation is hard coded, but it is contemplated, that all devices, once connected, may deliver their menus and related functions, hence this small pad (Weiser 1991) is capable of controlling more than one and different types of devices.

Wand. The wand is a colored ball on a stick, which can be visually traced. A camera with integrated image processing detects the ball and its color and sends the detected features as values to the controller like e.g. what color has been chosen, is the ball raised or lowered and so on. Various colors may invoke differ-

ent functions.



The controller then acts according to the installed functionality.

Push Button. The push button is a simple all-purpose button with a big push button, a rotary switch to select a specific functionality and the micro-controller. Based on the idea to create a simple and easy to use emergency button the actual implementation is mounted inside an off-the-shelf button, which has been produced to some office entertainment application making random comments.

The button itself offers little degree of freedom. Once the up to twelve different functions are assigned, the button can be placed anywhere, and it can be pressed by hand or foot.

Touchable Pad from Concrete. The concrete pad is still highly experimental. Goal is to establish a touchable surface made out of concrete without any mechanical components. Using concrete as material with some electrically conductive additive and probably some reinforcement permits almost any form and kind of integration in buildings made from concrete.

Right now the pad can execute only one function, because there is only one single touch area. It is connected to the micro-controller by only one single wire.

It is contemplated that more touchable surfaces can provide more functionality. Then every touchable area is connected by a dedicated wire., increasing their number significantly.

Other parameters may be arranged similar to other usages of concrete, it can be colored by using pigments, the surface can be to some degree structured and so on, as long as the electrically functionality is maintatined.

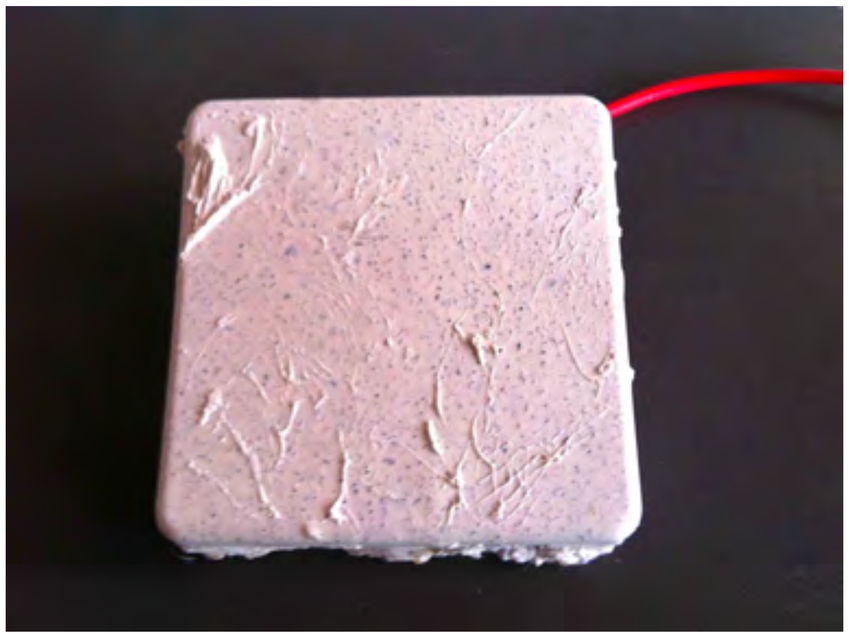


Figure 12
Camera with micro-controller and two colored balls

Figure 14
Pad made from concrete with wire.

Figure 13
Simple push-button with integrated rotary switch.

COMPUTATION AS PART OF THE DESIGN

In architecture computers are already bound to the design process: whatever kind of building and construction is imagined, it is developed as data, at first a virtual model, than as integrated building model. This widely accepted approach ignores the computational statements done within a building. In other words, handling the undeniable existence of computers in buildings is not the task of an architect. This

has to be changed.

At first, it has to be acknowledged that architects have to deal with computational devices and their functionality in buildings. As consequence they should secondly design both form and function of those computational devices and finally their should be an integrated design of them as part of a holistic concept of computation in buildings.

The role of programming

The question is, how and to what degree architect should and can handle computers in buildings. There is no answer yet except that some programming skills are required, because programming is an essential part of computation and no computer is running without software. Programming will become part of the design process the one way or the other.

Then a question remains: Can architects acquire and maintain an in-depth knowledge of some specifically designed architectural SDK (software development kit), programming language included?

This question is not simple to answer, but there are some aspects worthwhile to mention:

- Architects are already programming. They are writing C-sharp or Python scripts as executable code for computers to enhance their drawing software-packages.
- Programming itself is changing dramatically and has become diversified. The old model of a desktop-computer running some software now competes with mobile-, cloud- and embedded computation and even more.
- New technologies are evolving. Tools like visual programming or cloud-compilation detach the programmer from a specific platform and its IDE.

Other issues, like if there will be any support for a standardization from an industry or a major supporting governmental entity like ANSI (American National Standards Institute) or ISO (International Organization for Standardization) then will be resolved almost automatically based on needs.

CONCLUSION, KIND OF

Computation will become an essential component of architecture, there is no question about it. By closer looking at buildings it becomes evident, that the upcoming task here, if taken seriously, is nothing less than injecting a nervous system into pre-existing structures, like the modernization of buildings, or historic concepts as building designs.

The standard phrase, that the introduction of new technologies will sooner or later lead to new forms of design applies here, too. It has happened before. The difference to those events from the past with the introduction of new materials and structures is only, that structures and materials are already in place as static elements. With computation the next kind of architectural style will become dynamic, flexible and responsive. Buildings will change from an almost immutable state to a collection of mutable objects in control by the buildings' inhabitants.

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