OSIMA

open source interface for modular architecture

1 Introduction

Tools have been used to extend human skills in many design-related disciplines throughout history. In the beginning these were physical objects that represented the finished design but were also used for many other purposes.

Digitalization during the 90´s was considered to be a replacement of physical tools. Eventually these tools evolved into an abstract character based interface and then into graphical interfaces, and this new era made human computer interactions less complex for the user.

At present there is a new trend to use physical objects, which has lead to a phase of bringing users even closer to machines.

The first chapter describes, within a historical context, the first physical tools in the architectural design process. It enumerates the uses of these scale models. The transition between the physical and the digital usage of these tools is marked by the reliance on the "machine" to solve specific and more complex problems.

This is followed by a brief historic approach to the digitalization of drafting and models, which contrasts this development with preview tools. Despite the replacement of scale models with digital methods for some processes of architectural design, other process still benefited from employing physical objects. This is a key element to this project..

While the digitalization of graphical interfaces enabled the user and computer to better communicate, the next step is to improve the cognitive user experience by developing new physical interfaces.

2 The model as physical structure

2.1 The early scale models

The word “model” is borrowed from Middle French *modele,* from Italian *modello,* and from the vulgar Latin *modellus. Modellus* is a diminutive of the Latin *modulus,* a diminutive of *modus*, which means **to measure** (Smith, 62). A model is typically a small object, that represents another object. It can be considered a preliminary pattern, serving as a plan, from which an item not yet constructed will be produced. A model can also offer a tentative description of a theory or system that accounts for all its known properties. It can be stated that measurement is the process used to answer the questions: How many? How much? (63).

The scale model as we know it presently is a very complex structure of information that supports the design process in terms of scale, materialization, relations to other parts, process complexities and so on. Throughout history it was used for many different purposes.

Ancient Egypt

Egyptian tombs and pyramids contained hundred of wooden models inside every chamber. Egyptian small-scale models were believed by their creators to take on magical qualities that could control nature by representing it. (Smith, p. 5).

- to represent nature

Classical Greece

The Greeks' aim was to develop eternally valid standards of form and proportion. At that time, architects were not considered as important as, for example, philosophers. Thus, architectural tools (like small-scale models) were of little importance. Buildings were replicated from older buildings and change took place only within small details.

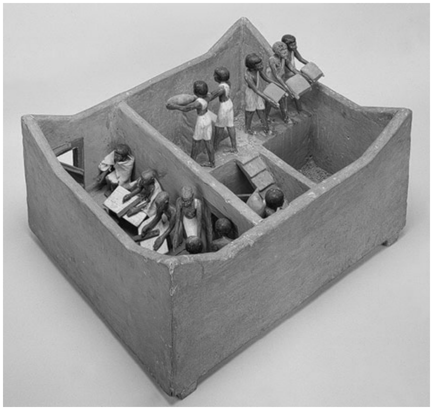


Figure 1, Egyptian funerary wooden model

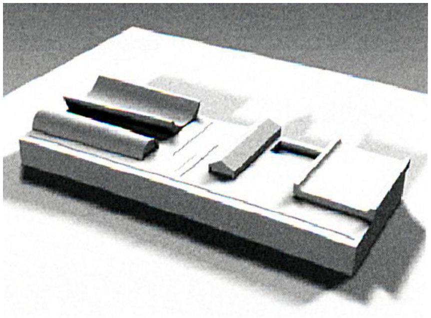


Figure 2, Greek paradeigma

Figure 3, facade of Santa Maria del Fiore

The only important type of architectural scale model was the *paradeima*.
A paradeima was used to study specific architectural elements, such as triglyphs or capitals, which required a three-dimensional design. It was also useful in cases where carved or painted decorations had to be shown.(8)

-to design ornament
-to present ornament

Imperial Rome

Roman architects seemed to be well aware of the persuasive application of the scale model. In the tenth book written by Vitruvius, there is a passage in which an architect named Callius presents a model of a wall. In this passage, the model enabled the architect to explain to the people the possibilities of a full-scale mechanism. (14)

-to study complex mechanisms
-to persuade other people

The Renaissance

There were a vast number of small-scale models built during this period. These models served the builders when it came to the execution of a building. Designs for decorative details were often modeled in wax, a practice continued from Roman architects. Brunelleschi's small-scale models for his cupola were used to solve problems not usually encountered by designers. Another kind of scale model was used to discuss details between designers and those responsible for the execution. To study three-dimensional effects, Michelangelo made small clay models. He rarely made perspective sketches, because he thought of the observer as being in motion and was therefore reluctant to visualize buildings from a fixed point. Alberti also stated that these models made possible the examination of the relationship between the site and the surrounding district. (25)

-as a guide during execution
-to design small details
-as support to solve problems
-to explain and discuss details
-to study 3-dimensional effects
-to study different points of view of the object
-to study relationships between objects

Bauhaus

The architecture school, as we know it today, is a creation of the nineteenth century. However, model making was included in formal education only in the twentieth century as an official curriculum emerged. Students of the Bauhaus University took part in a foundation course, in which they had to craft their designs as models. After 1923, Bauhaus innovation included partnership with industry, providing research and development as a means to offset costs. Product design at the Bauhaus centered on prototype development and much of this work was done in models. This was applied also to architecture. (Mark Morris, p.20)

Figure 4, model for the memorial for the "March Heroes" by Walter Gropius

-as a design tool
-to try materials
-to check proportions

2.2 The model as machine

Measurement aids the human brain and senses in estimating distances, dimensions, temperatures, and weights. In general, man's capabilities need to be both extended and refined by instruments. These instruments for measuring are typically **manufactured*** by machines.

A machine is generally considered to be something with a practical purpose, a device that substitutes for or extends mankind's own force. Vitruvius, in the *Ten Books of Architecture*, devotes the entire last book to the study of machines. It is within this last book that Vitruvius discusses scale models.

Gaudi

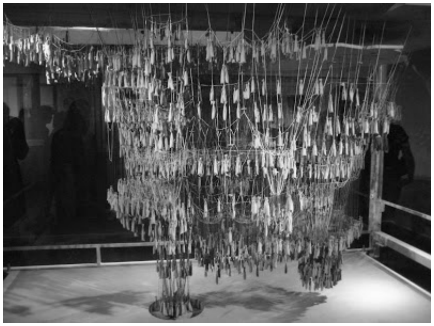


Figure 5, Gaudi's model for arches and building stresses

It is well documented that Antonio Gaudi relied on his small-scale model machines in his design process. These models were white plaster devices, hanging wire, or chain models used to study complex geometric shapes (Smith, 90). These models were a way to geometrically represent measurements of compression forces.

-to represent natural forces
-to study material resistance

3 The model as digital structure

"A digital computer is, essentially, the same as a huge army of clerks, equipped with rule books, pencil and paper, all stupid and entirely without initiative, but able to follow exactly millions of precisely defined operations… In asking how the computer might be applied to architectural design, we must, therefore, ask ourselves what problems we know of in design that could be solved by such an army of clerks… At the moment, there are very few such problems.“
Christopher Alexander in "An Evolutionary Architecture" (comp. Frazer, p. 17)

By the end of 1970, Nicolas Negroponte wrote "Architecture Machine". Smart assistants and context-sensitive help in CAD and office programs from today are practical applications of this work. (comp. Maia Engeli, p.6)

First-generation CAD software was a pure drawing tool with the same possibilities pen and paper offer. Data input was two-dimensional and the information relayed was simple lines and basic geometrical figures. (comp. Marco Hemmerling and Anke Tiggeman, p. 18).

At the end of the 80´s, computer-supported plotting and model making moved away from service bureaus into the architectural office. (6).

The second generation of CAD saw the first attempts to work with simple three-dimensional objects. (18)
The first important change that CAD underwent was the transition from analog to digital drafting. (comp. Morris, 159). This changed the drafting into multiple dimensions and turned it into a very complex data-structure. "A digital model that not only describes the form of a building (comp. Negroponte, p. 21) but also can be linked together with others data structure", by using for example "Building Information Modeling" (BIM). Moreover, these systems offered the possibility to link non-graphic information such as material and mass properties to the drawing.

The use of CAD systems has evolved from a digital tool that merely copies traditional design and representation methods into a

Figure 6, drafting departament before cad

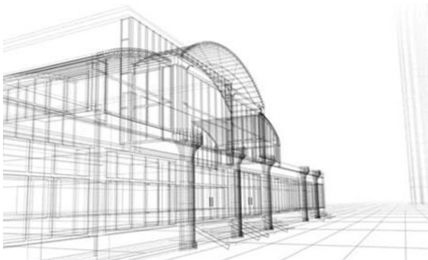


Figure 7, cad perspective example

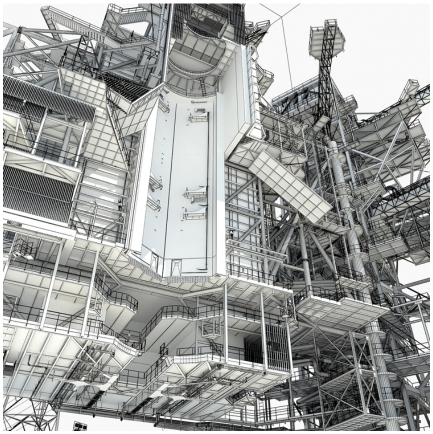


Figure 8, cad 3d model example

medium with new possibilities. People could generate designs that previously were almost impossible from a technical and formative standpoint because of excessive time requirements and lack of technical means. (comp. Marco Hemmerling and Anke Tiggeman, p. 18).

Digital models replaced physical models in many areas, mainly in fine details and the more precise phases of the design process. However, physical and digital tools work in conjunction in architectural practice.
Scale models are used for the first steps because of their tolerance, while digital ones are used to define the more complex details in the last steps of the process because they are more precise. Another important feature of physical models is that they can be a very handy medium for team work. Moreover, to present ideas and projects, physical models have a greater impact and a closer link to spatial expression, while digital models are more efficient in allowing the designer to save, erase, modify and share faster and easier due to the digital data structures in which they are organized.

4 The model as interface for digital structures

“The technical impact of computers is not simply its capacity to reduce everything to ones and zeros, but also its equally powerful ability to expand those ones and zeros to analog appearances. The computer does not represent a “victory of the digital” but a new mechanism for coordinating the digital and the analog. And it is crucial to stress this point at the level of tactility as well as visuality”. (comp. Mitchell, p.14)

4.1 Introduction to human-computer interaction

Interactive approaches conceptualize computation as the interplay between different components, rather than the fixed and pre-specified paths that a single and monolithic computational engine might follow. These models of computation emphasize diversity and specialization rather than unity and generality.
Interactivity between humans and computers has been changing from a direct interaction with electronics in the beginning to an interaction with contemporary user-friendly interfaces. A historical introduction is necessary to understand the contemporary tendency of making easier and more efficient interactions with computers.

Early analog computers relied on electronic components (resistors, a transistor, capacitors), and were used for scientific simulations. To set up a new experiment, the machine would have to be reconfigured through the incorporation of new circuits. ().

Early digital computers were also special-purpose devices. Nevertheless, these computers brought a very important innovation: computer-stored programs. Operations were no longer encoded in circuits, but rather in memory. However, every machine was a prototype and every program was designed for a specific processor. Thus, interactions with systems relied on an understanding of the electronic device.

With the transition from an electrical approach to a symbolic one, users began to require less understanding of the electronic part of the machine, which made it more accessible.

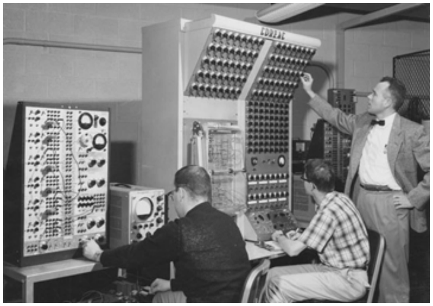


Figure 9, first Cornell Electronic Analog Computer

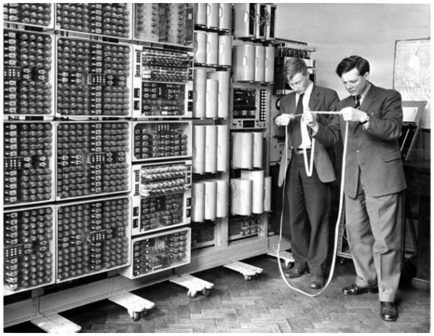


Figure 10, first digital 1951

Figure 11, first system with all the elements of Graphical User Interface.

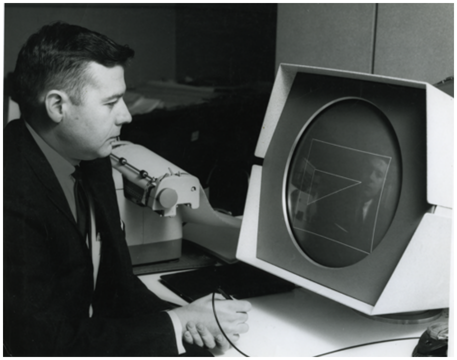


Figure 12, sketchpad by Sutherland

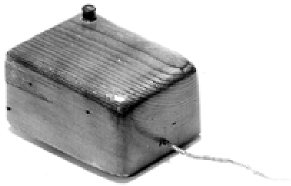


Figure 13, first mouse by Englebart

Symbolic interaction with computers naturally turned into textual interaction due to the concept of the "interactive loop.“ This brought an endless cycle of instruction and response, and the user started to "interact“ with computers for the first time in a more human way.

The transition from textual to graphical interaction changed the idea of interactivity from a one-dimensional stream of characters to two-dimensional space. According to Paul Dourish in the book “Where the action is”, this change made it possible to exploit further areas of human ability, such as peripheral attention, pattern recognition and spatial reasoning, information density, visual metaphors, progress, new models for interactive system design.

4.2 Tangible user interfaces (TUI)

Like other human-computer interaction (HCI) technologies, TUI strives to increase human productivity by making their digital tools easier to use. They achieve this by exploiting human spatiality, our innate ability to act in physical space and interact with physical objects. The desktop mouse is a powerful and early example of the impact this approach can have on HCI and productivity.
George Fitzmaurice was the first to distinguish TUI from other interfaces—though he called them ‘‘graspable’’ user interfaces. Fitzmaurice defined a graspable user interface as ‘‘a physical handle to a virtual function where the physical handle serves as a dedicated functional manipulator.’’ Ishii and Ullmer, who suggested and established the term ‘‘tangible user interfaces,’’ defined them as ‘‘devices that give physical form to digital information, employing physical artifacts as representations and controls of the computational data.’’ Both of these definitions highlight the mapping between the physical object and the digital information or function it embodies as the essence of a TUI. (comp. Sharlin, p. 9)

According to the article “On Tangible User Interfaces, Humans and Spatiality,” successful TUI will follow three heuristics.

-Physical/digital mappings must be successful spatial mappings.
-Physical/digital mappings must unify input and output space.
-Physical/digital mappings must enable trial-and-error activity.
(8)

Also, Sharlin states that highly specialized TUI will prove to be more valuable than generalized TUI in the long run, and that today's PCs are complex devices that are difficult to master. The unspecialized PC interface leaves many applications and user groups poorly served. (345)

4.2.1 Early architectural experiments

The first working model was called "Intelligent mats" and was presented in 1980. This involved mapping the two-dimensional relationship between standard square mats in order to plan relationships of different proportions. Polling for an identifying code caused a mat to wake up and pass back a message by prompting neighbors. (comp. Frazer, 37)

A cube version demonstrated that it was possible to operate in three dimensions by employing a different electronic technique. Each cube, in turn, explored each face to see if it had a neighbor; it sent back a message to say what it had found and where, and control was then transferred to that cube, and so on.(37)

After that, a more complex version was constructed which featured blocks in a variety of shapes and sizes. The last step was to miniaturize the system to the level of bricks smaller than two sugar cubes. This was possible by vertically stacking eight-bit coded units in combination with a board. (39)

In 1990, the most ambitious of these intelligent models was designed and constructed. It was a three-dimensional array of identical cubes that was called the "Universal Constructor." Cubes, rather than a more realistic representation of an element, were chosen for their universality and they could model at any scale. Each cube could have 256 different states expressed through

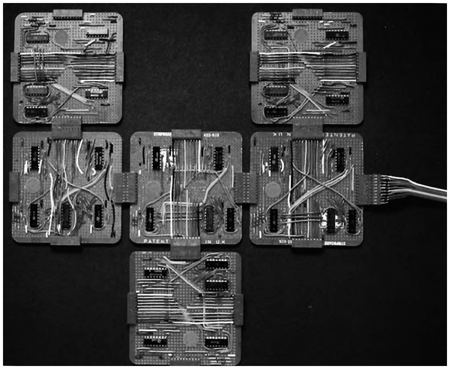


Figure 14, Intelligent mats

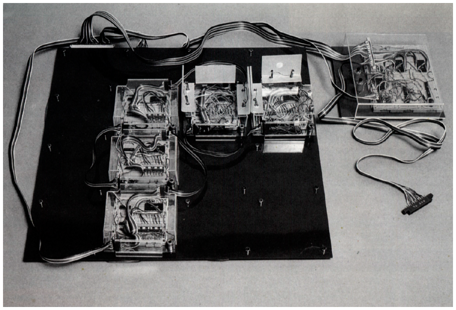


Figure 15, cube version

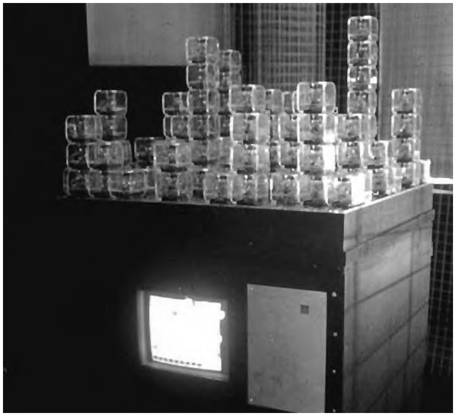


Figure 16, Universal Constructor

LEDS colors. There was a 12 x 12 cell baseboard. (44)

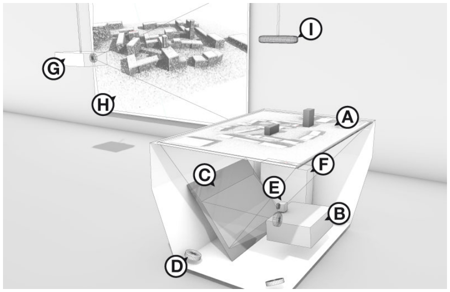


Figure 17, CDP components

4.2.2 Collaborative design platform

The basis of the CDP is a custom-built multi-touch table.

A special aspect of the TUI is the ability to automatically capture 3D objects. This is what facilitates the seamless interface between the digital tool and the architect's familiar way of working by making it possible for a physical working model, as commonly used by architects, to interact directly with interactive design by supporting simulations and analysis in real time.
A working model made of rigid styrodur foam is automatically scanned in three dimensions and incorporated into the 3D city model. Using this newly created digital model, various analysis and simulations can be calculated and the results displayed.

Changes to the form of the styrodur blocks -- such as when they are trimmed or shaped -- or changes to their position are updated directly in the scene, and the simulation updates accordingly in real time.
The automatic 3D object recognition is achieved using an IR camera (E) in combination with a Microsoft Kinect Camera (I). Parallel to this, a second beamer (G) that projects onto the screen (H) makes it possible to display further contextual information for the design process such as perspectives or functional diagrams. To provide a better indication of the spatial characteristics, it is also possible to produce true three-dimensional representations of the design.

4.2.3 Cognitive Cubes

Cognitive Cubes is a system for the cognitive assessment of human constructional ability.
Cognitive Cubes follows a very simple assessment paradigm: show participants a prototype and ask them to reconstruct it. In Cognitive Cubes, the prototype is an abstract 3D shape

constructed of simple blocks and displayed visually, while participants attempt the reconstruct it using physical versions of the same blocks. During this attempt, each rearrangment is automatically recorded and scored for assessment.
Cognitive Cubes does not seem to offer strong I/O unification because the virtual prototype is displayed separately from the participant's current physical approximation. However, the prototype is merely an unchanging representation of the constructional goal, and is, therefore, external to the interaction.
Cognitive Cubes' representation of the user's approximation is completely unified—so unified, in fact, that it is not necessary to ‘‘output'' a representation of that approximation. It offers excellent support for trial-and-error exploration of the problem domain.

Figure 18, Cognitive cubes

5.1 Objectives

The aim of the project is to re-design the “block interface” typology by improving its technical and design properties with the purpose of a better 3D cognitive user experience and a more efficient trial-and-error capacity of problem solving during the architectural design process. Specific improvements targeted were: actualization of technologies, portability, affordability and constructability in order to develop an interface builded by the user.

5.2 Concept

OSIMA is reminiscent of “Intelligent Mats," “Universal Constructor,” and “Cognitive Cubes.” However, it is not a tool to improve 3D modeling skills. It is a tool that supports the user by providing information to better understand configurational properties of the buildings and to apply this knowledge in the design process.

It decodes building information in a 3D space and enables the user, through trial-and-error, to change the building configuration and intuitively check for better solutions in real time. It is restricted to simple parallelepipeds of various proportions. In this case, 3 cm x 3 cm x 3 cm prisms are used due to the 3m average height per building level.

By improving upon some technical and design issues that earlier modular interfaces had presented, OSIMA targets a group of people with at least a basic knowledge of programing. The electronics inside the cubes were selected taking into consideration the necessities for proper building analyzation, such as an accelerometer and magnetometer for 3D positioning and piezometer and RGB LED for function selections.

The project was built with prefabricated shields in order to make it easy to reproduce and it was coded in Processing, which is a user-friendly and open-source programming language with a very active community. This platform design enables users with basic

knowledge of programming and electronics to collaborate
with the improvement of the software and the parallelepipeds by adding code or shields.

5.3 Graphical Interface

The graphical part supports the physical interface by displaying the parallelepipeds in three dimensions on a computer screen. This is necessary to show the different analysis results in parallel with the changes made on the physical interface.
It is important to mention that the user can also rotate a camera around the cubes to reach every side of the objects.

5.4 Physical Interface

The physical interface is a collection of laser-cut parallelepipeds with embedded electronics that detect position and connections. These objects communicate with a computer wirelessly.

An ordered graphical description of the physical interface is divided into the following parts:

-components

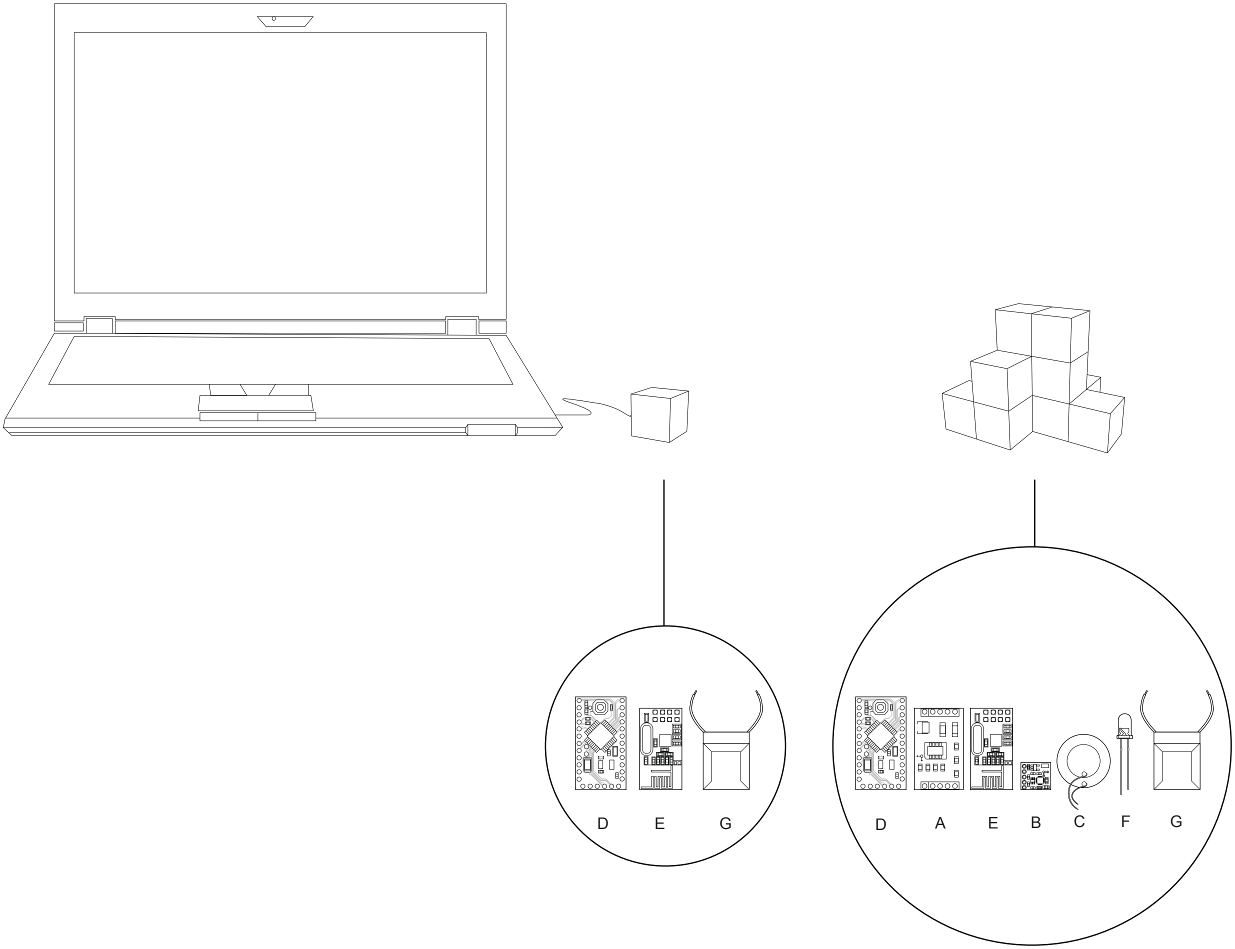
-communication

-connections

-shells

-shield

Components
The components are divided in four parts according to functionality:
-data sensing: (A) accelerometer (position), (B) magnetometer (position), (C) piezometer (knocking)
-data handling:(D) arduino (computing) and (E) NRF24L01(comunication) wireless module
-data output: (F) RGB led is used to display the color of the architectural function of the cube (kitchen, bath-room, room, living-room, dinning-room and circulation
-powering: (G) mini battery



OSIMA: Open source Interface for Modular Architecture.

Thesis project of the Post-graduate master Program in Media Architecture
of the Bauhaus University Weimar during the 2012/2013 winter semester.

Student: Augusto Gandia, Matr.-Nr:101270
Presented: 16th of May

1. Examiner: Prof. Dr. Jens Geelhaar
2. Examiner: Dipl. Ing. Sven Schneider
3. Examiner: Dipl. Ing. Martin Scheid

Comunication

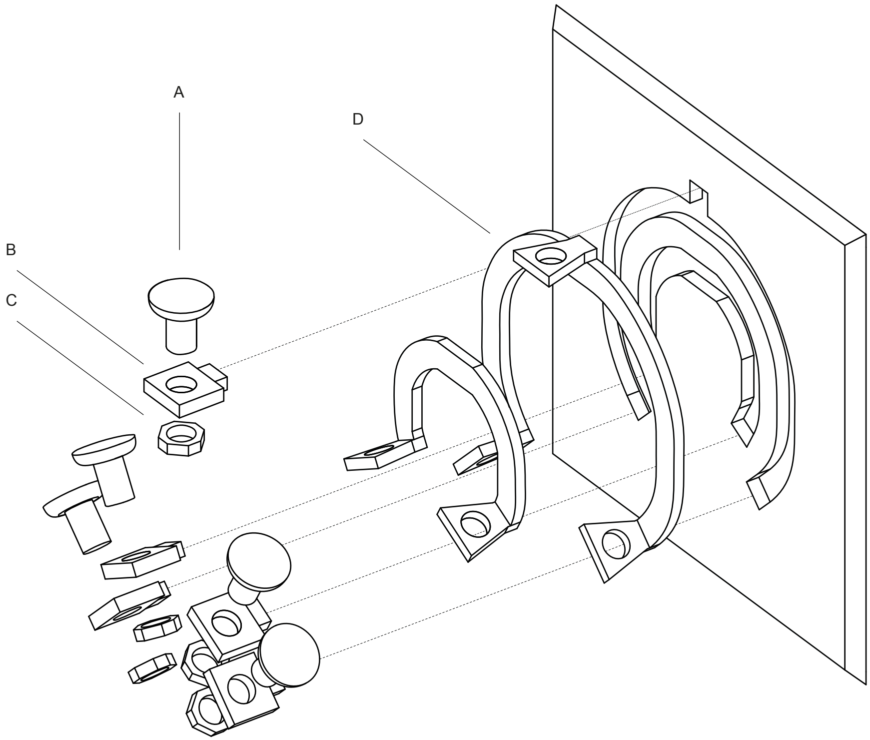
The process is divided in two parts: data collection and data sending.

-data collection: the coordinator assign one cube to be the receiver and the rest act as senders. (A) The senders send continuesly through each face the proper cube and face number (B) while the receiver check each face to receive the number of cube and face in case there is a connection. (C) After that the receiver make a packet of data ready to be send to the coordinator.

-data sending: once the packet is ready, the receiver sends through wireless comunication the packet to the cordinator (D), which via serial comunnication delivers the packet to the computer. (E)

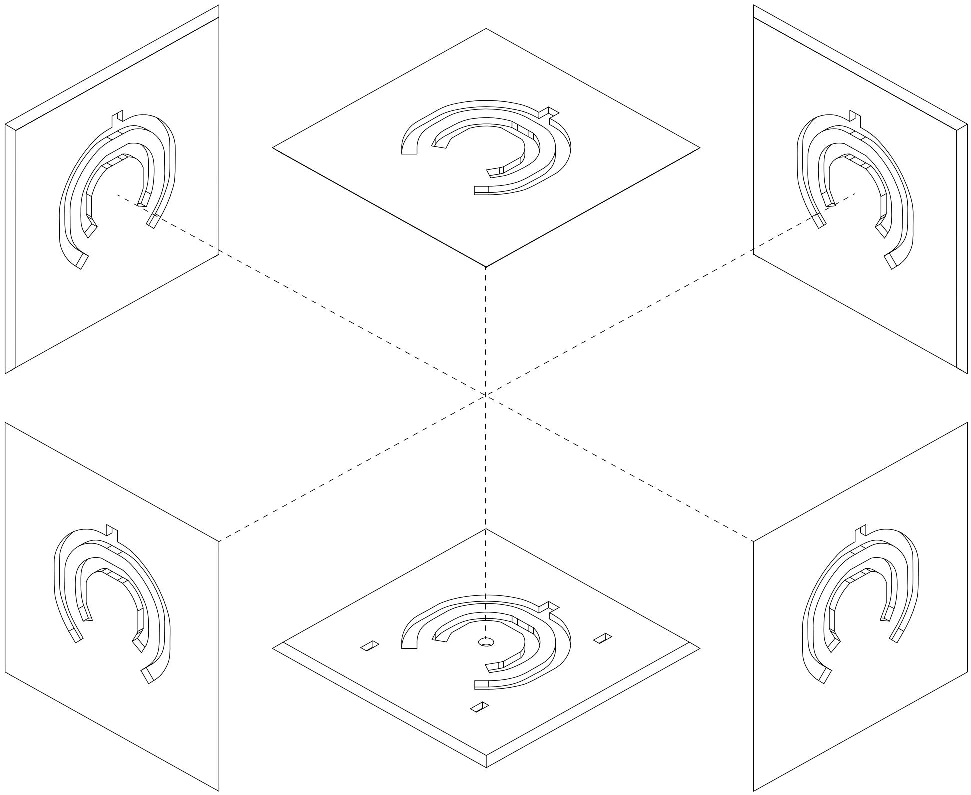
Connections

The connections (A) are aluminium plates cutted with laser. To join them to the wooden faces an small wooden piece (B) is glued to the face and finally with mini screws and nuts the metalic plates are attached.



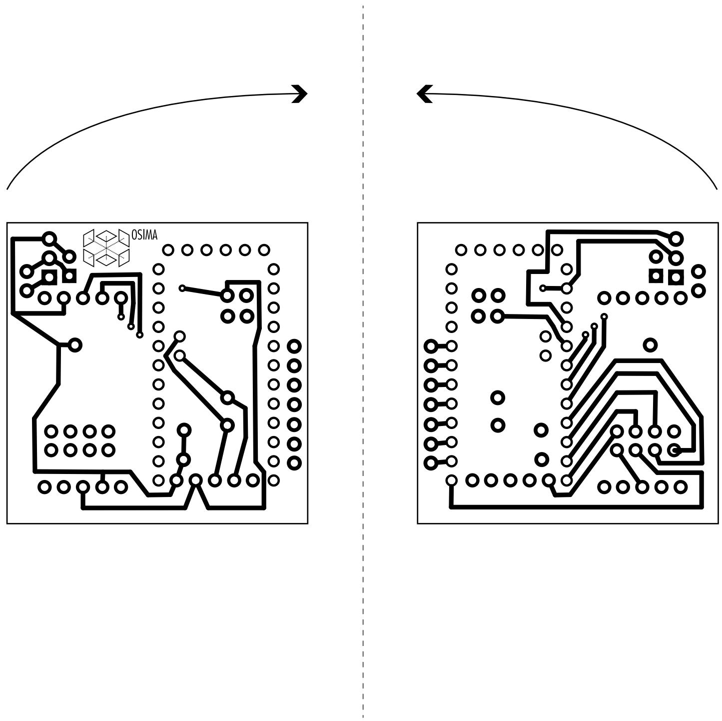
Boxes

The boxes are simple wooden faces cutted with laser. The sides are sanded in 45°. In the middle the shield hold the electronics parts. The four lateral faces are glued together while top and bottom faces are fixed to the structure through inserts and an elastic band keeps them together. They can be pulled to access the interior of the cubes.



Shields

The shield is a double side copper shield self made in Fritzing. Male headers are soldered to que shield to connect the components together. Resistors, voltage regulator and the battery are also connected to the shield, saving cable and as a consequence space inside the parallelepipeds. The shield can be produced in a laboratory or ordered online.



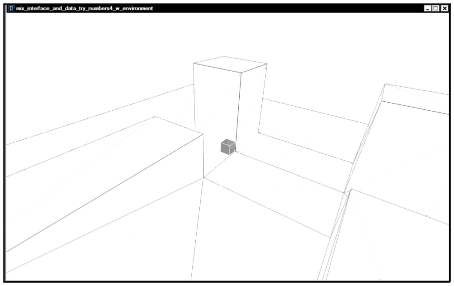


Figure 24, graphical interface with sourrounding buildings

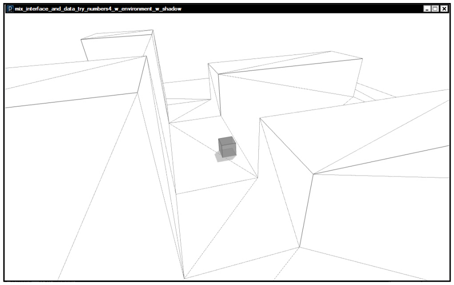


Figure 25, graphical interface with shadows

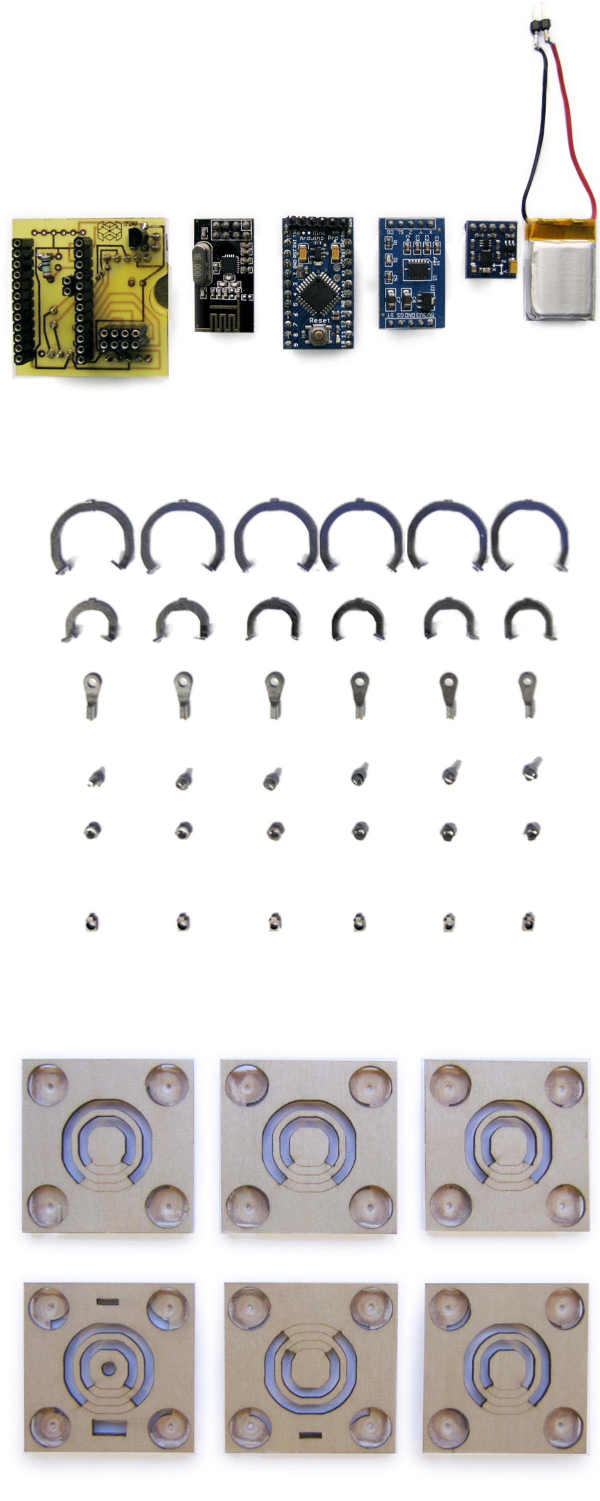
5.5 Extra features

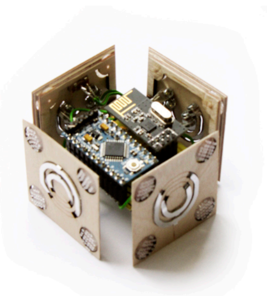
-importing surrounding areas:

An important extra feature of the graphical interface is the possibility to import 3D geometry. By modeling the surrounding area in a 3D program, the user can import it in obj format. Once in the graphical interface the imported file can be re-located.

-shadow detection:

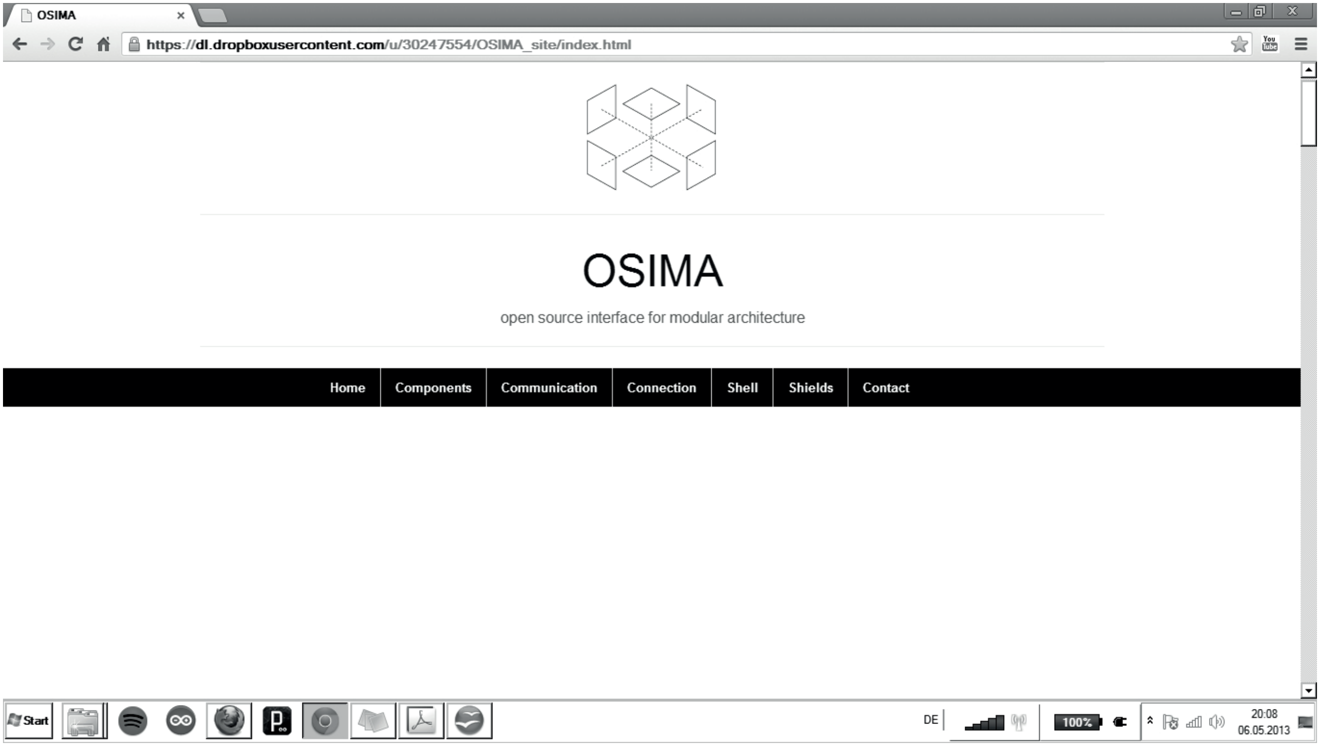
Shadows of the cubes are also tracked as part of the graphical interface program, enabling the user to
understand the impact the projected would have in different configurational possibilities.





6 Future developments

-Web site:
In order to share the project, a web site provides details of components, communication, connections and plans. The code can be download from github.com and also a contact formular is available to report problems and suggestions.



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Collaborative design platform web site
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Figure 13, first mouse by Englebart (resonancepub.com)

Figure 14, Intelligent mats (**Frazer, J. (1995).** An Evolutionary Architecture. London: Architectural Association. p.37)

Figure 15, cube version (**Frazer, J. (1995).** An Evolutionary Architecture. London: Architectural Association. p.37)

Figure 16, Universal Constructor (**Frazer, J. (1995).** An Evolutionary Architecture. London: Architectural Association. p.39)

Figure 17, Collaborative design platform components (cdp.ai.ar.tum.de)

Figure 18, Cognitive cubes (Cognitive Cubes: A Tangible User Interface for Cognitive Assessment Ehud Sharlin, Yuichi Itoh, Benjamin Watson, Yoshifumi Kitamura, Steve Sutphen, Lili Liuo)

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.
Weimar, 16th may 2013
Augusto Francisco Gandía

Abstract

This project is a redesign of the block interface typology. The purpose is to develop a tool to experiment with the configuration of a building and to receive feedback through analysis techniques. In contrast to other similar interfaces this physical/graphical interface, intends to improve real time capabilities and spatial cognition of the architectural design process. As result, a self-buildable physical interface with a graphical interface is designed. It is restricted to modules. These modules are identical parallelepipeds.

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