Sensponsive Playscapes

A pedagogical design approach to manifest and promote the physical-digital continuum

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Abstract. This paper chronicles an intensive student workshop on sensponsive architecture, from the educators’ point of view, underlying the pedagogical notes on this new design approach that employs digital design tools and electronic assemblies to creatively experiment with human-computer interaction. The workshop presented the theoretical, computational and fabricating frameworks for a human-centered approach to spaces with sensponsive partitions that respond timely with sense, displaying an adaptive behavior through time. The workshop theme was further specialized to direct the design outcome toward sensponsive environments for children that can help them perceive, experience and develop a meaningful understanding of the world around them through play.

Keywords. Sensponsive architecture; student workshop; arduino assemblies; children’s spaces.

INTRODUCTION

This paper reports on the Sens[e-Re]spensive Architecture Workshop that took place at the Technical University of Crete (TUC) Department of Architecture in Chania, Greece, during 22-29.08.2011, co-organized with the Department of Architecture of Aristotle University of Thessaloniki (AUTH). The workshop theme derived from the field of sensponsive architecture, covering the theoretical, design, computational and fabricating frameworks for a human-centered approach to responsive environments that react with sense to the activity of people, displaying an adaptive behavior through time. Moreover, this year’s theme was specifically involved with children’s spaces targeting their learning pathways and their understanding of their own bodies as well as of the world around them through play. The event was sponsored by Materialise, McNeel Europe, the European Association for Architectural Education (EAAE) and the European Network of Heads of School of Architecture (ENHSA).

The paper chronicles the workshop from the educators’ point of view, underlying the pedagogical process related to this new design approach that employs digital design tools and electronic assemblies to creatively experiment with human-computer interaction. Students’ workshops constitute heterotopias that are unique experiences for both students and educators as they promote ultimate
experimentation beyond limitations within multicultural groups from different educational environments. Students participate in workshops by choice beyond their school schedule, a proof of their commitment and engagement with the experience.

The overall workshop theme called for an interdisciplinary approach in the structure of the teaching team. Thirteen educators from six universities in Europe and the USA, teamed in a unique assembly of specializations, from design theory and research to developmental and cognitive psychology, and from computation to digital fabrication. In particular, the workshop was taught by (in alphabetical order): Edith Ackermann [MIT/University of Aix-Marseille], Panagiotis Chatzitsakyris [AUTH], Christian Friedrich [TU Delft], Dimitris Gourdoukis [AUTH], Marianthi Liapi [TUC], Kostis Oungrinis [TUC], Peter Schmitt [MIT], Susanne Seitinger [MIT], Constantin Spiridonidis [AUTH], Kostas Terzidis [Harvard University], Maria Voyatzaki [AUTH], Socratis Yiannoudes [TUC], and Emmanouil Zaroukas [University of East London]. The aim of the teaching team was to help students structure a critical approach to human-centered digital design supporting its continuum with materialization. The diverse backgrounds and research interests of the teachers played a catalytic role to the daily and overall progress of the students’ work.

A call was sent out to a great number of Schools of Architecture across the world, addressed to students of undergraduate and postgraduate (master’s) degrees with an indicated level of computation literacy. A large number of students submitted their portfolios. Thirty of them were selected representing thirteen universities, eleven of them coming with postgraduate competences and the rest of them being on an undergraduate level. Taking all parameters under consideration, the teaching team worked prior to the beginning of the workshop and put together three working groups of students that gathered complementarily skills and capacities necessary for the workshop theme to be tackled creatively and effectively. Each group was assigned a specific working scenario:

- Sensponsive Life-cycles: To create intelligent spatial configurations to help children understand the notions of time and change through play.
- Sensponsive Storytelling: To create intelligent spatial configurations to help children develop their narrative and memory skills through play.
- Sensponsive Traces: To create intelligent spatial configurations to help children understand their body by getting feedback from the movement of its parts through play.

Moreover, prior to the beginning of the workshop, the teaching team invited the students to access a databank with selected readings pertinent to the subjects touched by the workshop theme in order to create a common knowledge base and kick-start productivity from day one.

THE PEDAGOGICAL UNDERPINNINGS OF A “DESIGN-PROGRAM-FABRICATE IN A CONTINUUM” WORKSHOP

The teaching team wanted to demarcate a pedagogy relevant to our digital times in a critical way and to contemplate the criticism that accompanies digital design in the last 15 years. Looking back at international student workshops in architecture that have taken place in the recent past one can pinpoint two distinct tendencies:

- The first one involves top-down approaches to formal complexity, which in turn alludes to manneristic manipulations toward the establishment of a new style that could be seen as “digital baroque” (Picon 2010).
- The second one targets material explorations with the exhaustive use of CNC equipment. The task of this approach is often the fine-tuning and compatibility resolution between design and fabrication software. Another premise is the experimentation with emergent properties of known materials and building components through the use and exploitation of the respective machines.

Along these lines, one can also remark the absence of extended and systematic references on the
conception of the human being, detecting only implicit references that try to simulate architectural productions as ‘creatures’ revealing this way a certain conception of the word ‘alive’ (Voyatzaki 2009).

The Sens[e-Re]sponsive Architecture Workshop organised its educational objectives and creative work focusing on the two following pillars of technology-driven architecture simultaneously:

• The relationship between idea and its materiality.
• The reconsideration of the human being, and in this case specifically of children between the ages of 4-8, as permanent reference of architectural creation.

Throughout the workshop, the students were guided to explore the user-oriented ‘why-factor’ along with the design-oriented ‘how-factor.’

During the initial conceptual phase all teams were asked to figure out an intriguing way to play out the assigned scenarios. This included the development of a design scheme with the appropriate functional, aesthetic and symbolic value that could creatively facilitate the activity and enhance the experience of the children involved. It was crucial from this point to agree upon the intensity of the activity as well as the basic design parameters. A bottom-up approach was adopted with certain key-points that guaranteed a smooth process. The teams were encouraged to adopt small-scale proposals with little complexity that could be manageable for the limited time and in order to reach completion from idea to operational prototypes. Drawings and small conceptual mock-ups were necessary for each team to communicate the prevailing ideas. The notion of physicality was very important from the outset.

After getting feedback on the conceptual phase, each team had to shift gears and begin to work on two distinct parallel explorations, one related to the actual form and the structural details of the sensitive spatial configurations and the other to the development of the code for their behavioral patterns. The proposed steps were to:

• Define the exact parameters for each activity (spatial and behavioral design) and evaluate the time frame in which the spatial elements could act discretely and beneficially.
• Choose the appropriate type of sensors to capture the quantitative and qualitative features of the set parameters.
• Set up a crude neural network to process these data.
• Synchronize this information with the design environment.
• Test the process of “identifying activity (sensor input) - exhibiting response (mechanism output) - getting feedback and fine tune - loop”.

The final phase involved the assembly of the basic electronic infrastructure and the fabrication of the necessary parts to create working prototypes, scaled or 1:1, with character and intentions. The physical models were made out of simple materials, like fabric, paper, plastic and plywood using the Department’s fabrication laboratory which is equipped with 2 laser cutters, a CNC router and a 3d printer. The kinetic parts were controlled via Arduino assemblies.

The proposed working method was construction under continuous scrutiny and re-adjustment, on a continuous feedback loop with definitive relationship between cause and effect, fine-tuning to the best possible extend the properties, capacities and multiplicities of the objects created. The workshop workflow was enhanced with daily presentations from the teaching team targeted on the issues that were deemed necessary for the continuation of the projects. Every two days students had public presentations on the work in progress.

THE CONCEPT OF ‘SENSPONSIVENESS’

During the past ten years, the spearhead of architectural research has been gravitating toward the integration of Information Technology (IT) systems into the production of space, extending that way the scope of architectural inquiry beyond the Vitruvian triptych, to the design of responsive environments with automated spatial behaviors. The next logical step was to add ‘sense’ to this response and create a context for the way space performs and the way
it ‘learns’ from the past: a sensponsive architecture (Oungrinis 2006). The know-how to perform such a feature is already available from other scientific disciplines as well as from the industry. The potential for architecture is significant as embedded interactivity in places that were long regarded inert can exhibit new possibilities for the human experience. Intelligent control systems are able to enhance the functionality of space, create provocative aesthetics and instigate radical changes in everyday life as we know it. Moreover, contemporary social conditions seem to be addressed better through the acquired spatial connectivity.

The development of more powerful and intuitive software as well as the ability to experiment with ‘approachable’ electronic assemblies facilitated an ever-growing tendency for responsive environments. Virtual, actual or hybrid, they are the new exciting thing, becoming widespread and common globally through art installations and architectural applications. Particularly in architecture, the design tools aim to respond to users’ needs, fabrication methods are developed to respond to design idiosyncrasies and space is designed to respond to human behavior and environmental conditions.

Compared to responsive systems that react repeatedly with certain programmed actions, a sensponsive system is able to choose the location and the type of the response, with time and timing being the most crucial factors in its operation. Control is governed by a neural network programming approach, while the validating and decision making actions are based on fuzzy logic, in order to avoid determinism. Overall, the creation of a sensensive system, embedded within architectural space, must take five factors into consideration:

- It must support human activities by taking informed decisions and acting on them.
- It must maintain a relatively low profile in its operation (regarding programming and behavioral patterns) and act only when required.
- It must be non-invasive, exhibiting mild reactions. It must also be equipped with some level of control, like a log-off switch.
- It must exhibit a seamless connection between the design environment and its smart assemblies that operate with a simple control interface. Along these lines, maintenance should be reduced.
- Last, but most important of all, it must be capable of meaningful communication. If the embedded system exhibits sense in the way it understands and reacts, then it will gain people’s trust more quickly.

These goals can be best achieved through a human-centered approach in order to provide patterns of human behavior in relation to space. These patterns can be analyzed to indicate the critical parameters that must be monitored and addressed in a timely manner to achieve a spatially efficient, comfortable, aesthetically intriguing and symbolically rich outcome.

**SENSPONSIVE PLAYSCAPES FOR CHILDREN**

As mentioned earlier, the workshop theme was further specialized to direct the design outcome toward sensponsive environments for children between the ages 4-8. Why this particular user group? To begin with, there is a plethora of scientific data to support detailed design explorations for children’s spaces. From the developmental psychologists’ point of view, children are experts in exploring as well as composing, driven mainly by necessity and not by design, to better place themselves in a grown-up world. They ceaselessly imagine and create alternatives of things that already exist, pushing the boundaries of known concepts like creativity and simulation, imagination and knowledge. Moreover, they are “digital natives” (The Library of Congress, 2008) exhibiting an amazing capability to self-directed learning and to authoring diverse media.

Each one of the three student teams was assigned a specific working scenario related to how children perceive, experience and develop a meaningful understanding of the world around them. There was a very distinctive behavior required from the produced ‘intelligent’ structures, that of acting
as a tutor and providing continuously new stimuli for the children to re-ignite the game process while keeping the educational value high. In this sense, the goal was to create sensponsive environments that could be integrated in educational and/or recreational spaces as playfully learning mediums, able to engage children with their programmed activities through fun. There were not any children actually involved in the design process. The students were guided by selected bibliographical data, cross-checking their findings with the expertise of the teaching team.

Scenario 1: sensponsive life-cycles
The first scenario addressed the concept of life-cycles, touching upon the notions of time, change, speed and duration in a child’s world (Ackermann, 2004). During the conceptual phase, the students identified the key concepts that would help them spatialize those temporal notions and motivate the design of their final artifact: the looped life-cycle vs. the spiral life-cycle, the notion of real time vs. relative time as well as the distinction between short and long periods of (real) time.

The proposal relied on both analog and digital features in order to capture creatively the multiplicity incorporated into this scenario. The project is an autonomous unit with its form emerging from the repetition and the axial rotation of one main element that also incorporates within its shape the electronics necessary to exhibit sensponsiveness. The overall form was inspired by the natural process of blooming and the metamorphosis of a bud into a flower. All parts are held together with a basis, which is also used to ‘hide’ the supporting digital assemblies. The size of the unit is such so as to accommodate three children in the area designated as the interior space. The form of the unit exhibits the characteristics of a sun-clock, a feature that helps in accentuating the passage of time throughout the day as well as during the year, with the occurring shadows being the visual results caused by the sun movement.

Figure 1
Scenario 1. Visual documentation of the working process, which resulted in a 1:5 scaled working prototype.
Moreover, the unit is equipped with a ‘sentient’ system that develops its personality according to the stimuli of its environment. By employing Arduino assemblies with light, proximity, acoustic, and touch/pressure sensors along with LEDs, the unit uses colors (red-blue-green) and motion to communicate with children. There are two levels of communication. The first one is manifested immediately, triggered by the actions of the children (haptic, somatic or verbal) inside the structure, feeding them with short-term changes and rewards. The second level is designed to assess the actions taking place and react in time, helping this way children to develop the hardest skill, which is to understand long term changes and effects. The notion of real time, for example, is passively addressed by the visual cues created from the changes in the daily and the seasonal cycles. The inability to affect these cycles also points out their looped character. On the other hand, the notion of relative time is unveiled by the type and the duration of the children’s activity within the unit, evoking diverse experiences like curiosity, anticipation, surprise and fun.

The unit is also designed to form a network with other similar units creating a digital playscape within the urban setting, that allows for a variety of responses by letting the units act alone, in a cluster or as a whole exhibiting collective behavior. The exterior surface has a long-term memory capacity while as the interior one has a short memory depending on the activity that takes place. Children are introduced to a staged playtime watching the cumulative effects of their actions proportionally affect the network, grasping this way the sense of the spiral cycle. In the long run, entertainment, urban landscaping and in-depth stimulation are the project’s aims and desires.

**Scenario 2: sensponsive storytelling**

The second scenario involved the concept of storytelling as an essential tool for children to practice and develop their narrative and memory skills, facilitating role-playing and stage-setting activities (Ryokai and Cassell, 1999). After researching their options during the conceptual phase, the students realized that they needed a medium that would be able to trigger storytelling activities in order to help the children play them out as well as to provide an unanticipated feature for the sake of open-endedness. Moreover, that medium needed to be regarded as a toy.

Design-wise, the students elaborated on different types of forms and scales before they concluded to the archetypical form of the cube, sized 25x25x25cm, keeping in mind the simple analogy of one cube per child. They based their project upon an interesting mixture of analog digitality employing also...
two levels of communication. The conventional level is based on variations of the cube's surface, exploring additionally the effect of materiality in the storytelling process, while the high-tech one is supported by sensor-actuator assemblies. As a result, the cube can be regarded and used both as a passive toy, offering the traditional repertoire of such playthings, as well as an active toy, able to behave as a sensponsive playmate. Regarding the latter, the students came up with an additional programmed feature, related to time in a wider sense, which allowed for processes of reflection and understanding to take place, apart from the cube's immediate responses to the children's actions.

The cubic form of the produced object offered a variety of advantages, ranging from the simplicity and the recognizability of the form to the potential visual and spatial complexity of having multiple such cubes connected, creating spatial settings for their stories that can involve a number of physical actions such as climbing, sitting, hiding and other. The materiality of the surfaces could be combined to produce homogenous or heterogeneous displays as well as playful patterns. Moreover, each cube is penetrated on two of its sides, either opposite or adjacent, encouraging a 'connect the dots' type of play that can easily drive to the creation of three-dimensional complex structures. This structural connection is achieved with the use of magnets.

A cube can react to a variety of stimuli coming from the children, other neighboring cubes as well as from changes in the environmental conditions. The tutoring method used by the cubes is the introduction of a 'new element', meaning that at certain points an attribute changes challenging children to adapt the new feature to their stories. Acting as an instigator, it helps children constantly reinvent their own physical and sensorial space, both on an individual and a collective level.

Regarding the intelligence embedded in the cubes, the students concentrated on the definition of simple rules. Each cube is programmed to respond to light, sound, temperature and pressure, producing light, color and sound effects. Whenever a change in temperature takes place, and follows a certain pattern for a period of time, the cube gives out an appropriate colored light, ranging between blue and red, and it may enhance this output with tones of green according to the surrounding soundscape. Moreover, each cube is programmed to express extreme emotions, such as boredom and over-stimulation, by emanating a set of clicking sounds. A feeling of 'happiness' is also programmed to be communicated when a lot of cubes assemble together through the blinking of their lights. There are multiple possible reconfigurations that create twists and unexpected events, urging children to adapt to the new conditions and evolve their story.

**Scenario 3: sensponsive traces**

The third scenario addressed the theme of traces. A variety of activities are connected to this theme, like creating and leaving traces over time, knowingly or by chance, following them, changing them or just observing their temporary existence (Lund, Klitbo and Jessen, 2005). For children, the act of incorporating traces into play constitutes a principle means in their way of learning. Initially the students researched ways to guide children into understanding that an activity they are involved with affects not only the surrounding environment with the traces it produces but also the play parameters and the decisions of another player. The proposal designed to respond to this scenario was the largest of the three in scale and the only one that needs more than one children in order to unfold its potential in a series of chained reactions. It involves the creation of an intelligent surface that separates two otherwise isolated spaces, of the same dimensions placed one above the other, comprising their floor and ceiling respectively.

Children playing with this project are split into two groups. The first group is invited to enter the upper level, which initially seems like an empty space, and after a while the second one is guided to the lower level. As soon as the children on the upper level begin to move, pressure forces on this level's floor turn on one or more lights on the lower
level floor, mapping and revealing their position and direction. The children on the lower level begin to chase those lights, driven by an overwhelming urge to ‘catch’ them. However, their activity immediately affects the topology of both the upper level floor and the lower level ceiling, spatializing the children’s movement as bumps with various degrees of deformation. The changed terrains affect in turn the children’s movement on both levels. After a certain period of inactivity, the traces begin to diminish, and the surfaces are gradually restored mechanically to their original state, reflecting nature’s reclaiming process. The whole system urges children to experiment with this type of interactions. With time and through a ‘cause and effect’ narrative they will begin to understand the way those traces are made and the way their actions affect a wider system, refining eventually their playing skills.

The project is heavily dependent on technology in order to control the quality of the environment and ensure the inscribing effect of the activity in space. Both sides of the intelligent surface consist of sensor-actuator assemblies with piezo-electric tiles, flexible fabrics and positioning related LEDs. Both layers of the surface are producing a tactile landscape that changes its relative altitude through nodes using an automated scissors mechanism. Technology helped this team evade the barriers of synchronized presence and locality. In other words, technology was able to render the trace-producing activity visible for a longer period of time, in a different place from where it initially took place, providing children with additional feedback and opportunities for reflection.

CONCLUSIONS
The entire process provided a fertile ground for the evaluation of the pedagogic process while allowing for constructive feedback on the overall research framework of the sensponsive approach. For the first part, in the aftermath of the workshop one can clearly acknowledge the fact that a large team of...
educators with a combination of matching and diverse specializations and skills worked complementary in a very productive way throughout the duration of the workshop. Even though the distribution of the selected participants created three working groups with even competences, the dissemination of the reading material prior to the beginning of the workshop brought everyone on the same knowledge level providing the impetus for a dynamic start. The workshop begun with presentations on its key-concepts and from there on the teachers would form and re-form smaller groups, based on their specialization, to deal promptly with the problems each team was encountering by giving targeted presentations and guidance.

Regarding the evaluation of the chosen research framework, as soon as students grasped the notion of 'sensponsiveness' they begun to focus more on the activity-based design process rather than following a formalistic path. They investigated the design of 'spatial augmented reality' aiming at the design of experiences and a discreet digital layer that compliments the abilities of spatial arrangements than overpowering them. Contemplating on the workshop's results, it is evident that in order for architecture to overcome the established borders and achieve an augmented new state of being useful and collaborative it requires a multi-disciplinary approach along with an in-depth, trial-and-error analysis of the optimum way to integrate IT in people's living space. Even though there is no immediate visible difference in the integration of senssponsible logic into responsive systems (technically speaking), the difference lies in the context that emerges from the use of such spaces through time. In this sense, the senssponsive approach requires time in order to become beneficial through a discreet presence and be truly evaluated by its users.

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