

Systemic Approach to Architectural Performance

The Media Mix in the Creative Design Process

Abstract

First-hand experiences in several design projects that were based on media richness and collaboration are described in this article. Although complex design processes are merely considered as socio-technical systems, they are deeply involved with natural systems. My collaborative research in the field of performance-oriented design combines digital and physical conceptual sketches, simulations and prototyping. GIGA-mapping - is applied to organise the data. The design process uses the most suitable tools, for the subtasks at hand, and the use of media is mixed according to particular requirements. These tools include digital and physical GIGA-mapping, parametric computer aided design (CAD), digital simulation of analyses, as well as sampling and 1:1 prototyping. Also discussed in this article are the methodologies used in several design projects to strategize these tools and the developments and trends in the tools employed. The paper argues that the digital tools tend to produce similar results through given pre-sets that often do not correspond to real needs. Thus, there is a significant need for mixed methods including prototyping in the creative design process. Media mixing and cooperation across disciplines is unavoidable in the holistic approach to contemporary design. This includes the consideration of diverse biotic and abiotic agents. I argue that physical and digital GIGA-mapping is a crucial tool to use in coping with this complexity. Furthermore, I propose the integration of physical and digital outputs in one GIGA-map and the participation and co-design of biotic and abiotic agents into one rich design research space, which is resulting in an ever-evolving research-design process-result time-based design.

Keywords: systems-oriented design, rich design research space, GIGA-mapping, prototyping, full-scale, media mix, time-based design, co-design, biotic and abiotic agents.

Introduction

The use of computing in architecture emerged in the nineties. Offices and collaborative networks, such as Ocean (Hensel, 2015a), Nox (NOX, 2016), Asymptote (Asymptote Architecture, 2016), dECOi (dECOi architects, 2015), FOA and others began to submit experimental design research proposals to competitions. These projects used computing in highly artistic and experimental ways. They achieved unprecedented results in their experiments by using different tools, such as animation. Sevaldson, who is at the Ocean network, described his experience in this innovative climate:

The rudimentary traces of an experimental design practice developed further when I slowly became aware of the generative potential in the machine. The machine had the ability to surprise me (Sevaldson, 2005).

Sevaldson (1999) stated that computer technology can help to understand, visualise and design complex systems. However, partially developed digital tools that are specialised for different disciplines included several *bugs*. Several kinds of specialist computer software have been used in exploratory design processes, such as film animation software, sound analysis software, biological system simulations and others. The different disciplinary properties, as well as the so-called bugs, were utilised in design, and they became effective arena in mixing such media in the creative design processes in these offices. Today, design computation is usually discussed

in relation to performance (Peters, 2013). The term *media* is used here as “an intervening agency, means, or instrument by which something is conveyed or accomplished” (Dictionary, 2017). The first processes used systems that were *soft* compared with the currently used parametric design, which is “a process based on algorithmic thinking that enables the expression of parameters and rules that, together, define, encode and clarify the relationship between design intent and design response” (Jabi, 2013, p. 201).

The rise of 3D printing techniques and technologies enabled the prototyping of these design attempts and provided an easier way to mix physical and digital media. Capjon (2004) first explained method of 3D print prototyping for design innovation through trial and error in the field of product design. In 2005, Sevaldson discussed the *hybrid design process* in which many digital and traditional techniques and design strategies were combined. He discussed the mix of media in addition to the different roles of individuals with different responsibilities in the team (Sevaldson, 2005). He then introduced GIGA-mapping, which is a type of visual diagramming that maps complex transdisciplinary data and relations. Currently, GIGA-mapping appears to be the most suitable design tool for handling diverse data and the responsibilities of stakeholders in teamwork in transdisciplinary and transmedia actions.

In 2008, a special issue of *Architectural Design, Protoarchitecture: Analogue and Digital Hybrids*, edited by Bob Sheil called for hybrid modes of experimentation in the post-digital age with a focus on prototyping in architecture (Sheil, 2008). In the same year, Sevaldson published an article that defined the rich design research space:

The concept of the Rich [Design] Research Space includes the physical space of the design studio or research environment, the multiples of digital and analogue design media, the virtual information space, and the social, cultural and aesthetic spaces. The aim is to engage a holistic research approach and to nurture it as a skill rather than a method (Sevaldson, 2008).

In 2011, Neri Oxman demonstrated an integrated approach to design and an additive manufacturing technique (adding material, not subtracting it) by promoting a direct link between virtual performance-based design and the physical prototyping of material systems according to their performative properties (Oxman, 2011). Sevaldson concluded the following about the contemporary state:

Design culture indicates that we are more on the soft, fuzzy and wicked side of that landscape but reality tells us that we more than often work with, e.g., technology. Technological systems at large are ‘hard’ and deterministic. Our lack of grips at the hard side we compensate with interdisciplinary collaborations with, e.g., systems engineers and other experts. This is not limited to the hard end of the scale but it also expands throughout the field involving in any experts and stakeholders (Sevaldson, 2014).

Today’s digital design tools, such as parametric simulations and agent-based simulations, are not sufficiently complex to simulate the performance of the real world, particularly its abiotic and biotic properties, including social behaviour. Moreover, the tools have become too specialised and framed with pre-sets that do not always fit practical needs. The process is dominated by hard systemic approaches in which soft approaches, such as creative and/or complex design processes, are truncated because the two modes are not synchronised. Although contemporary experimental designers compute an enormous amount of data, with regard to physical full-scale prototyping, their output often fails because they cannot include the complexity of an integrated environment.

Furthermore, the experience of materiality is important. The physicality of fabrication is often necessary to develop individual tacit knowledge or intuition on the individual level, especially in transdisciplinary work and co-design, participatory design and physical

prototyping. Regarding prototyping and participatory design, Capjon defined *negotiotypes* as negotiated understandings of materiality in his plant of emerging materiality (POEM) participatory process model. He argued, “physically experienced break downs inspire engaged minds to find new and innovative solutions” (Capjon, 2005a, p. 3). Moreover, “through establishment of shared atmospheres of play and wholeness experiences representing all actors’ contributions, development scenarios can be achieved which resemble the above descriptions of a state of focused awareness which can unite subjective and objective representations” (Capjon, 2005a, p. 3). As positive research tools and gain, he included the following in the participatory design process: “language without words, basic understanding, behind the verbal discussions, shared understanding, catalyst for communication, simultaneous experimentation, iterations, radical solutions, playgrounds and sense feedback” (Capjon, 2005b).

The concept of participatory design or co-design is not new in architecture, particularly in the collaboration with clients. Sanders and Stappers (2008) explained the difference between co-design and participatory design as follows: co-design is co-creation while participation is the involvement of stakeholders in discussion. However, there is a very penetrable boundary between the two. Szebco and Tan (2010) freely mixed the two in their examples of co-design. This flexible boundary is this reason that design is no longer reduced to the proposal of a physical object. Whether the discussion involves designs for health care or architectural, it centres on the performance, not the object. Although previous research has focused on examples of human-centred co-design, true design for complexity must involve all other biotic and abiotic agents. For example, Carole Collet¹ discussed a biological co-design based on the patterns of fungus growth on materials for interior design. Collet uses this creative co-design to generate visual effects. However, she stops the co-design process by baking the fungus for final product. The idea of a biological time-based co-design is not new. Historical examples include living root bridges in Cherrapunji, which are made from the secondary roots of *Ficus elastica* (rubber tree) (Watts, 2011). The work of the Natural Architecture Movement is mainly built from willow trees (Rocca, 2007). Another example are living fences that have long been common already in the traditional architecture i.e. of Central Europe. In the Responsive Wood Project (Hensel, 2012), biologically grown material (wood) used to *participate* through its *active agency* in interaction with abiotic agents (clime) has long been studied for non-discrete design. This participation can be described as co-design within *time-based design*. This field in architecture has mainly been discussed as *weathering* (Kudless, 2009; Mostafavi & Leatherbarrow, 1993), which has gradually opened the discussion to include the *non-anthropocentric perspective* (Hensel, 2013). To the Performance-Oriented Design field, the discussed types of co-design in relation to prototyping, unified into the ever-evolving time-based co-design that is discussed by Sevaldson in his coming publication Systems-Oriented Design (manuscript in preparation) is of particular interest.

Because design has crucial effects on our living and non-living environments and vice-versa, time-based co-design together with biotic and abiotic agents as stakeholders needs to be addressed. Co-design is central in systemic design although it was not considered in Peter Jones’ paper (2014) on upgrading systemic design methods. However, this topic was widely discussed at the *Relating Systems Thinking to Design 5 Conference* in Toronto, which was organised by him. In the systemic design field, there is a tradition of participation, such as Pangaro’s (2009) *dialogues* approached from cybernetics field, which mixes digital media and human users. In Prague, one location of the present author’s research, participatory design is practised and supported at the public level based on the working version of the *Manual of Participation by Prague Institute of Planning and Development* (Návrát, Brlík, Macáková, McGarrell Klimentová, & Pelčíková, 2016). Participation is also a major requirement of most calls for projects that are funded by both public and private sectors in the location. Unfortunately, other public community interests, such as non-anthropocentric environments or private business sectors are more or less excluded from the discussion. This lack of

representation of diverse interests has been criticised by the present author who was invited to the working group for the preparation of the manual preparation as a local NGO representative. Hopefully, this critique will have a positive effect in the future.

Systemic Design, as a field of design for complexity, needs to adapt to these trends move toward more complex approaches in design that involve both biotic and abiotic interactors and parameters. The biotic agents include humans, animals, plants and all living nature. These abiotic agents include snowstorms, winds, Relative Humidity, temperature, solar radiation and so on.... The agents, which span from the bacteria to snowstorms, including human activity systems involving various public and private stakeholders who may address and interact within a highly complex context. . Such design processes cannot rely only on underdeveloped digital simulations or on insufficiently complex physical prototypes. The present author and her team experienced this feature in complex full-scale prototyping in opposition to less complex digital and physical simulations (Davidová & Prokop, 2016; Davidová & Sevaldson, 2016). The projects discussed below are not resolving the situation, but they serve as collaborative co-created examples of development in this direction.

Methodology

The methodology research is developed through practice, based on the requirements of a particular project, its agendas, and its further observations and evaluations. The reflections were based on the approach of the *reflective practitioner* (Schön, 1983). This reflexive process was central in the feedback looping processes, where new insight was developed in iterations. For this reason, this paper often refers to my own design-research publications.. This *praxiological* perspective, one could call a *designerly ways of knowing* (Cross, 1999), is grounded in the *development of theory through practical investigations* (Sevaldson, 1999). In the present work, methodology is also seen as a design *result* in its own right. The development of methodology is conducted as evolution over time and it employs co-design to achieve co-creation reaching at unpredictable outputs and performance. None of the case studies discussed in this paper are seen as complete, but they are seen as steps in a continuous process of design research. Therefore, the notions of design and its methodology are not separate and both are discussed as integrated in the following projects.

In each project, media are often changed depending on the suitability of each task. My education started traditionally , beginning with a combination of hand drawing and model making. It continued with combination of physical and digital modelling, animations and physical computing prototypes. I eventually went on to use the GIGA-mapping of complex, environment responsive systems that are sketched, physically modelled, digitally designed and simulated, physically sampled, full-scale prototyped and then observed. These actions are collaborative, and roles of the involved actors differ from project to project. The difference between traditional model making and prototyping meaning is found in the role the different tools play and how they are combined and used in a co-design context. The model tests are used to give form, whereas the prototype are used to tests performance in real life settings while involving diverse agents (Abiotic and biotic as described before) such as the use by people or other living beings as well as the performance in relation to e.g. wind and other weather phenomena.

The Media Mix in Praxis, Development toward Co-Design

In this section, I discuss several examples of my experiences that formed the basis of a media-rich practice in design.

My first experience in using the prototyping method was in the field of physical computing (Figure 1), which uses computation within physical objects. This project was not generating architectures in a traditional sense where architecture is regarded as fairly stable.

The design was generating interactive architectural spaces through reading different digital sensors in scripts that were translating x and y directions into mathematical formulas with an added randomising function. The tools used to create this prototype were the software sketch book *Processing* (Fry & Reas, 2016), connected through Basic programming (Lien, 1986) with a *BasicX* chip (NetMedia, 2012) and a development computing board and various sensors that were tested for their interactive performance.

In 2006, I integrated GIGA-mapping with the physical and digital prototyping conducted in this project. GIGA-mapping is an excellent tool for visually relating all media and transdisciplinary data mix, which is necessary for designers that need to handle complexity. A sufficient and suitable software for this mapping does not exist, so traditional graphics software was used for the GIGA-mapping. The mapping involved only individual work.

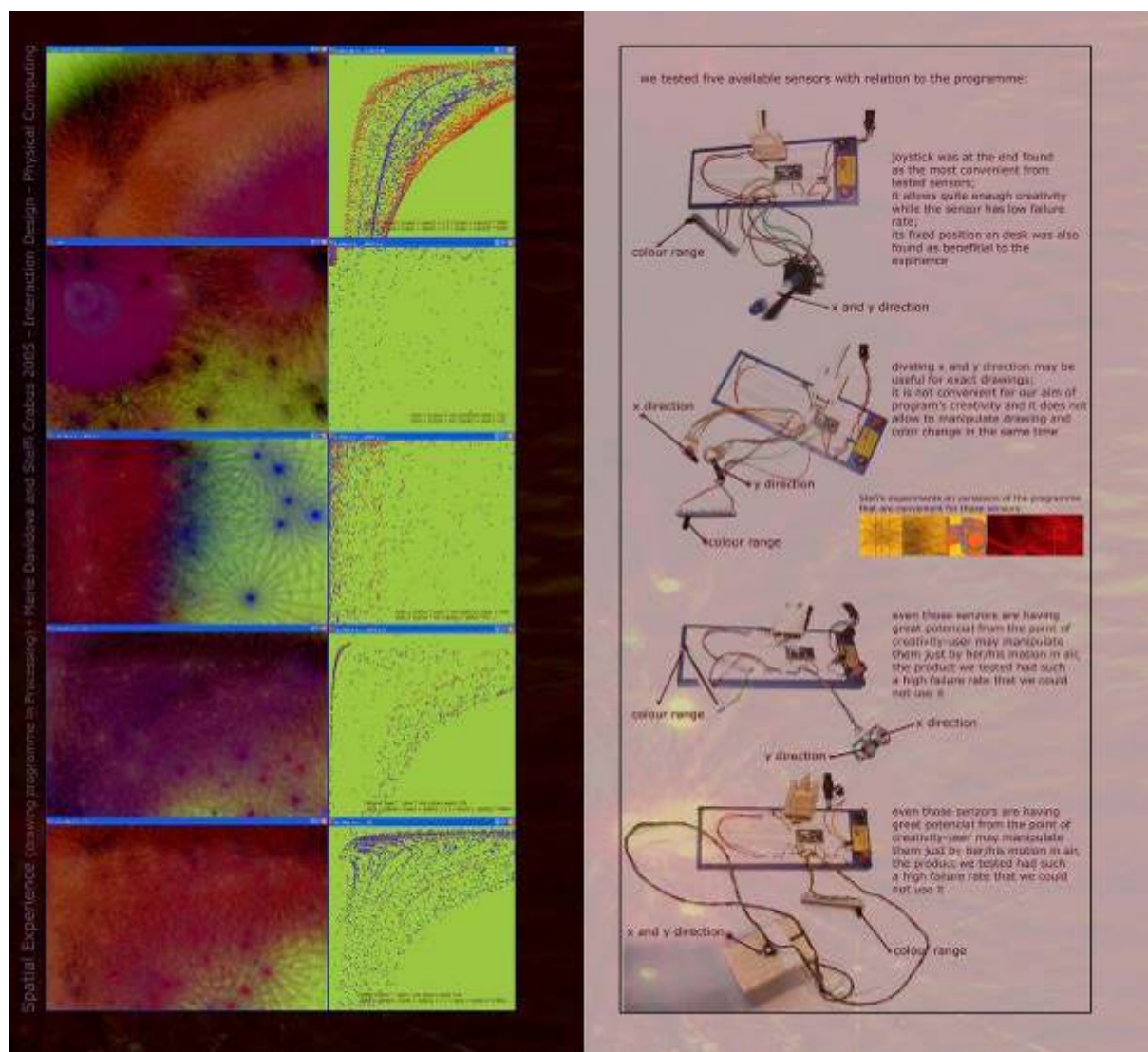


Figure 1: Spatial experience: A drawing program for architectural spaces (Davidová & Crabus, 2005).

My first mapping involved phenomenological *conversations* and their *iterative process* (Pangaro, 2008), which were compiled from observations made during one day in the city of Istanbul. The goal was to explore the complexity of this field by focussing on multiple historical development and cultural mixtures. This mapping was inspired by the situationist concept of

dérive, which means mapping the atmosphere of a city (Debord, 1956). This *dérive* case study involved both biotic and abiotic factors. The phenomenological journey was composed of unintended pathways based on intuitive walking and stepping into random public traffic devices. The pathways were moderated by interactions and conversations with locals. The GIGA-map was a mixed media format comprising photography, written reports of experiences of interacting with locals in different places, city soundscape and personal conversations recordings on MP3 players and physical objects/souvenirs—mainly music instruments—connected to the board by wires in order to interact. This map served as a tool for both analysing and memorising. It also was an exhibition artefact that was used for reporting this study trip.² The multi-media and interactive character of the map involved physical performative objects that helped to communicate and generate the experience of the multi-layered phenomena of the city. The resulting GIGA-map was displayed in an exhibition at The Oslo School of Architecture and Design. It raised curiosity that was followed by discussions and *conversations* with the exhibition audience of the passing students and academic staff of the school.



Figure 2: Davidová. *Holoslo: The Penetrating Of Latent*. Diploma thesis at the Oslo School of Architecture and Design. (Supervisors: Sevaldson and Kartvedt, 2007.)

The following example is the GIGA-mapping of the project *HOLOSLO: The Penetrating of Latent* (Davidová, 2007, 2009) (Figure 2). This example demonstrates a mixed media GIGA-map also including a description of the conceptual prototypes with performative capacities, interacting with sound, light and radio waves. The prototype was meant to operate through material-temperature interaction to generate movements of the designed installation through *nano-wires: shape memory alloys* (Kumar & Lagoudas, 2012). I used only computer-generated graphic images and diagrams, and I physically added the relations by different colour-coding using fishing lines (Figure 3) and attaching sound and radio scanned recordings played on MP3 players. The map was constantly used in relation to the prototypes of these proposed environmental performative installations, that were meant to be spread over the city of Oslo. I also produced speculative animation of the performance, demonstrating how the dynamic installations could work. Within the design-research process, this was to relate computer generated models, processes analyses and recordings, mapping the paths of different data

sources that were parameters for the proposed design sound, light and radio waves responsive city urban design operated by local micro-climate temperature.

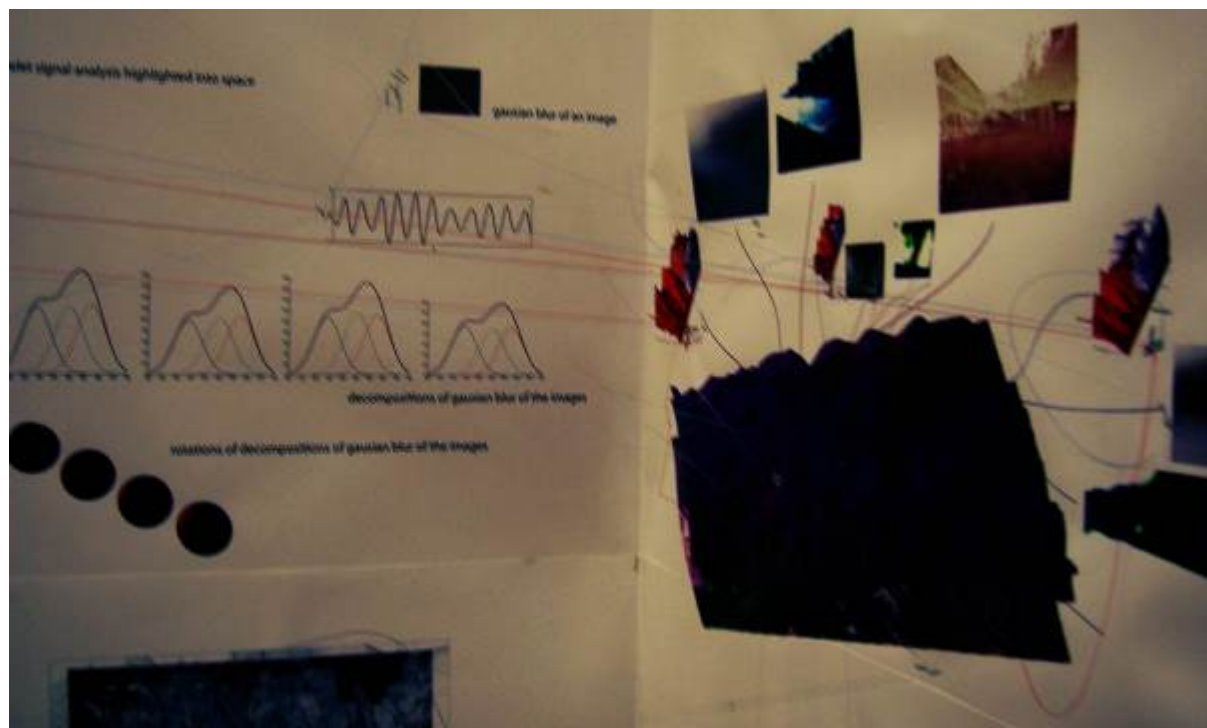


Figure 3: Davidová: Colour-coding with fishing lines in a GIGA-map in *HOLOSLO: The Penetrating of Latent*. Diploma thesis at the Oslo School of Architecture and Design, Supervisors: Sevaldson & Kartvedt 2006. Photo: Žilinek, 2006.

The final design for the conceptual installations was illustrated with computer graphics (Figure 4). Some features of these environmentally responsive installations such as the acoustic responsiveness of geometrically complex moving objects, combining flat and hyperbolic reflective surfaces, would be almost impossible or very difficult to handle in computer simulations, whereas they were physically prototyped with ease. The media output of the dynamic installations included sound, radio waves and visual video recordings resulting in synesthetic synchronised stimuli of diverse senses (Pallasmaa, 2005; Stower, 2006) in the form of visualisations of recorded sounds.

The sources and samples mentioned above were wavelet analysed (The MathWorks, 2016b). This data was decomposed into basic colours similar to the `imColorSep` command in the MATLAB tool for analysing data, developing algorithms and creating models from datasets (The MathWorks, 2016a). The difference was that the data were represented in a composition graph analysed in MATLAB. These data were read from a 2D colour-coded vector field to 3D surfaces using Rhino 3D a 3D NURBS modelling software (Robert McNeel & Associates, 2016) that was originally developed for use in boat design. Similarly, several MATLAB wavelet analyses were conducted to examine the Oslo city landscape and demographic data plans, which were interpreted using the *voronoi* (Okabe, 2000) plug-in for Rhino 3D. The results served as the background of the Rhino scripted³ model and the physical prototyping and rapid prototyping development of the installation from the material-systems performance to the detailing of movable joints. The recorded local environmental data informed the physical properties of the installation in order to be responsive to it. In this project, GIGA-mapping and prototyping were used in the design process, which involved synchronising media-mix

database, analysis, speculation, all of this feedback looping within an evolving design research process development and its registering. The META-mapping of the registering process within the process played a crucial role especially because the data had to be reduced as little as possible. This enabled the previous less-focused options to be relevant in the later stages of the process. Hence, the discussed feedback looping was composed of several layers and the time-base of the design was not linear but layered and iterative.

The following description of how the media output was produced is highly technical and difficult to follow for readers who do not have the required insight into the computational tools. I apologize for this inconvenience, which is a frequent phenomenon in highly interdisciplinary work. I still hope it gives an impression of the built up and logics of the project.

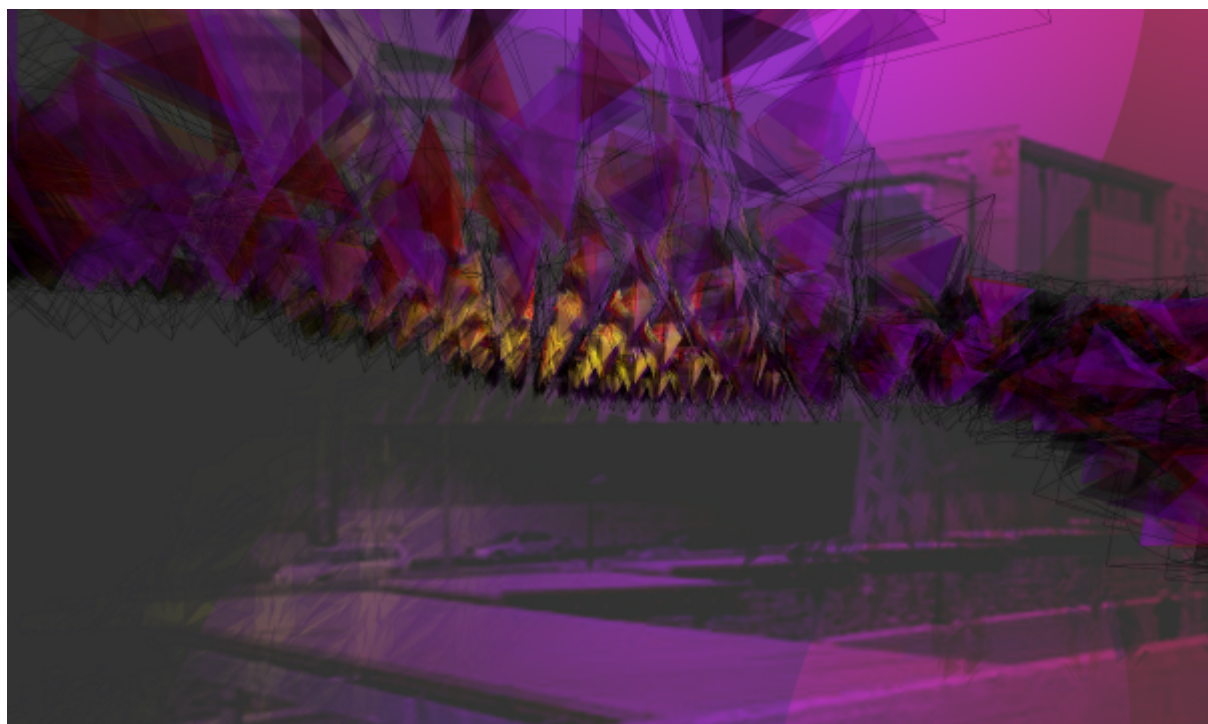


Figure 4: Davidová. *HOLOSLO - The Penetrating of Latent*. Installation in Lysaker, Oslo, 2007.

Media Mix in a Time-Based Co-Design

The project SpiralTreeHouse (Davidová, 2013c, 2014d, 2016b) is a design for a treehouse built of natural materials harvested on the site and equipped with a temporary textile tentlike structure, a cocoon surrounding a open fireplace (Figure 5). This project demonstrates how mixed media and timebased processes came in play in a co-design setting. The treehouse was co-designed with the client, geologist Prokop Závada, volunteering co-building friends and the surrounding natural environment. This means the surrounding environment was not just taken into consideration, serving as input for the design, but it was allowed to influence the result in a substantial way.

In this situation, the computing tools used in design were not sufficient to handle the complexity involved in interacting with a biotic and abiotic environment. The house was built in a public forest using tree trunks harvested from a dying, unnatural, densely seeded pine forest, which was a monoculture planted during the communist period. The project was built with the verbal agreement of the forest keeper based on the understanding that the project would improve the conditions of the forest through harvesting and thinning the forest providing conditions for

increased biodiversity. Its self-standing, climbing dynamic helix structure is based on joint-system geometry. It does not rely on the trees as traditional support but circumscribing them as spring that synchronically joins them in the symbiosis, dancing together in the winds. It serves as a spiral ramp access in the form of a climbing structure and as a frame for its removable fabric cocoon.



Figure 5: Davidová & Závada: SpiralTreeHouse. Project start in 2010. Photos: Davidová, 2010 and 2012.

No drawing was made before we started to build it. However, an abstract physical stick mock-up of the structural system geometry was sketched (Figure 5 left). Throughout the process of building, the thickness and the angle of the logs were tested at full scale (1:1). When the structure was built, it was measured on site in order to produce a digital model of the fabric for the removable cocoon using Rhino3D. At that time, the Rhino Nest plug-in (TDM Solutions SLU, 2016) for nesting the surfaces of 3D model in a 2D canvas was not yet capable of organising the orientation of the parts. Therefore, the sewing drawings had to be adjusted physically on canvas in order to ensure that the folds in the canvas would be protected from the rain. This process demonstrates how planning and building simultaneously allows for dealing with more complex geometries in interplay with dynamic surroundings. Computer tools and traditional planning strategies are not able to cope with such designs.

Alternatively, if we had modelled the project using the traditional method of solving all design issues before starting to build, we would have to make a 3D scan of each log. The thickness of the logs would define the angle between them (Figure 5). We also would have had to conduct a structural analysis, which, at that time, would not have considered the direction of the fibre in the wood. In addition, the cocoon's natural ventilation with its central fireplace performs similarly to a Native American tepee. All these properties were analysed physically through the experimental building and co-designed with naturally growing biological materials, such as the trees in the surrounding physical environment. We used our experience and tacit knowledge instead of a simulation, which would have required much more work but less useful and less holistic output. Also the correctness of the analyses would be highly uncertain.

The Time Based Design process (Sevaldson, 2004, 2017b) implicates that the process does not have an end but that the product would be modified over time by natural processes and interventions by biotic and abiotic users. This also implies that the treehouse is literally co-designed with other species of the forest (Figure 6). We helped this natural agents by seeding and preparing conditions. E.g. we “planted” the moss on the platform. We regarded the moss as co-habitants and co-designers together with us and other species. For example, the structure

of the tree house will be structurally changed and supported by climbing ivy in the future. Figure 6 shows that the structural organisation of the logs defines the moss's habitation. The moss also co-creates the platform, which provides a comfortable surface for humans who camp and overnight. For this reason, the project's design develops over time in relation to its environment. It will gradually be co-created and taken over by the natural world, which is the original generator of material. These biotic processes would be very hard to simulate because there is not empirical evidence of such complex conditions. Therefore, the SpiralTreeHouse serves as a symbiotic prototype for observing the performance of the environment. Because it was built in a public forest near Prague, the structure is accessible, and it can be co-inhabited, co-lived and co-designed by a variety of species, including humans.



Figure 6: Davidová & Závada: Local moss inhabiting the platform after one year of seeding. Note the habitation based on the structural direction of the logs. Photo: Davidová, 2012.

I conducted further investigations of time-based co-design in my PhD project, with the title: *Wood as a Primary Medium to Eco-Systemic Performance*⁴. The focus of the thesis is climate-material interaction, and it covers the designing and construction of prototypes of two pavilions (Davidová, 2013a, 2014a, 2014b; Davidová & Prokop, 2016; Davidová, Šichman, & Gsandtner, 2013; Nam, 2013; Slavičková, 2014) (Figure 11), one responsive screen (Davidová, 2013b, 2014e) (Figure 10) and one responsive envelope (Davidová, 2016a). Data collected from observations of the samples were mixed using Grasshopper, a graphical algorithm editor that is integrated with Rhino 3D (Davidson, 2016) and is used in parametric design. The climatic conditions were measured using data collected from a digital weather station. The response of the material to the changing weather, especially to relative humidity and temperature resulting

in warping of the material was measured. For the peak of the cup warping distance, slat with a hole through and calliper was used (Figure 7). In addition, I used an electric moisture metre to register the moisture of the wood samples over time. This way, this observation combined physical and empirical data with a simple geometry, which could be used as input to the geometry-based code in Grasshopper for performance design simulation and further concept development (Figure 8). Discussions with programmers who were specialised in complex environmental simulations revealed that writing a code that would be considering complex environmental data with a material-responsive system, such as the discussed prototypes, which are defined by the trunk's moisture content at the time it is cut as well as by its spatial position in the log, would be very difficult.

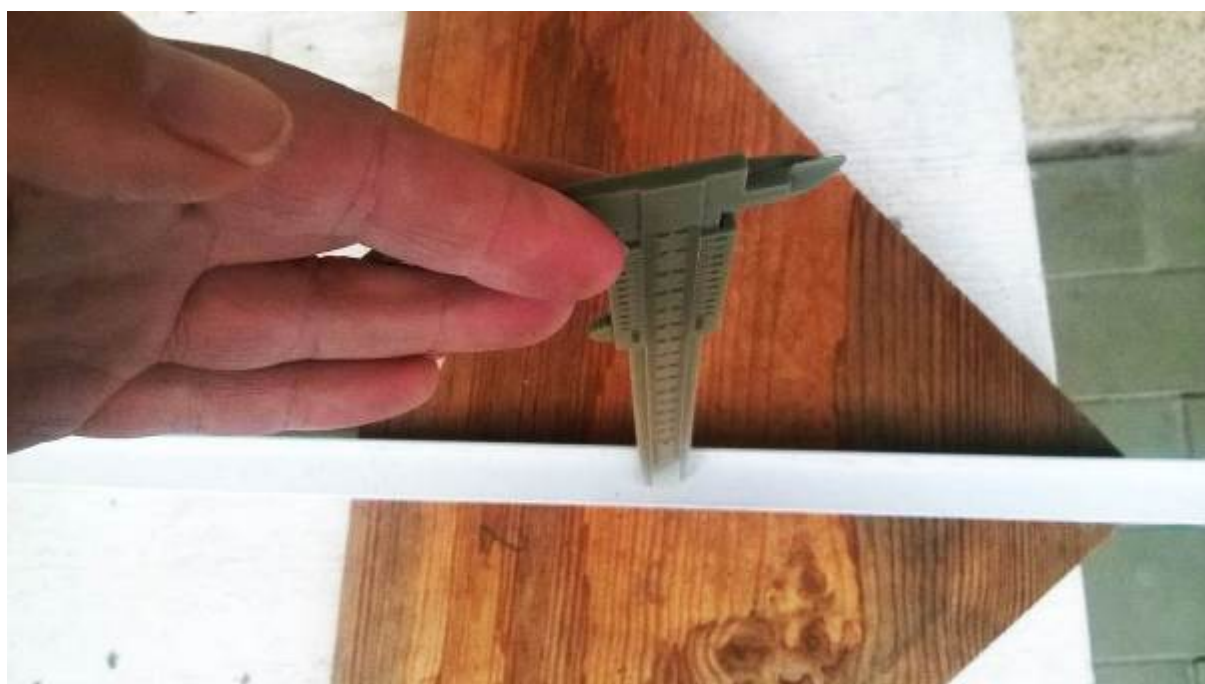


Figure 7: Samples measured by a slat with a hole and callipers. Photo: Davidová, 2016.

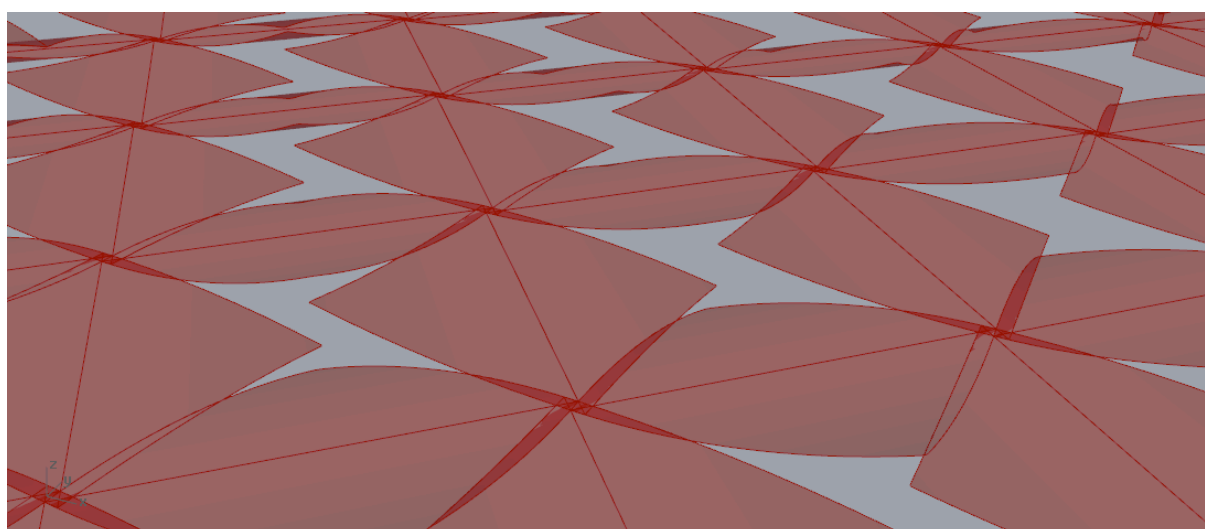


Figure 8: Davidová, 2013: Grasshopper Simulation of Warping of Performative Screen Ray 2.

The approach to the project was very inclusive as the intention was to cover for as many parameters as possible. This resulted in the project being informed by different transdisciplinary data and knowledge domains, spanning from forestry, meteorology, wood science, craftsmanship to different types of wood fungi. In addition came my own observations of experimental samples of the material-environment performance, resulting modification of microclimate and the growth of natural species on the samples, such as algae. Together with the meta-observation of the design process this formed a complex knowledge system in its own right. It is obvious that such a complex and wicked process is hard to plan and follow with traditional methods. GIGA-mapping was used to keep an overview of the process from the early literature review until the realisation of the full-scale prototype (Figure 9 and Figure 10).

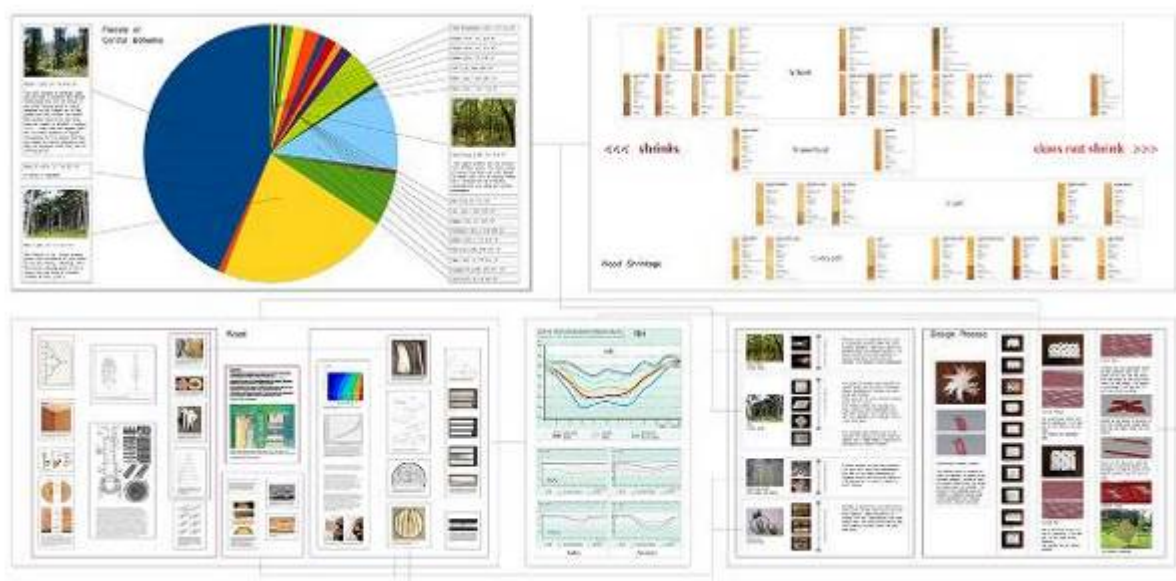


Figure 9: Davidová: Environment responsive screen GIGA-map showing transdisciplinary relations within the project. Research by Design GIGA-Map (Davidová, 2013). Images are from the Forest Products Laboratory (2010; Hoadley, 1980; Menges, 2009; Němec, 2005; Tolasz & Coll., 2007) or by the author. The first are used with the courtesy of USDA Forest Products Laboratory, Taunton Pres, Achim, Menges, Grada, and Tolasz. For a high-resolution image go to the systems-oriented design website (Sevaldson, 2017a).

In the following, I will go through the different prototypes:

The prototype Ray 2 is a full scale screen made of wood panels testing a dynamic envelope covering system. The purpose of Ray 2 was to investigate how such a system could react to climatic variations through the natural material warping. The panels would open and close according to the moisture in the environment. In addition, the intention was to investigate how this screen wall would react over time and how it would be inhabited by and interact with natural algae and fungi.

The prototype Ray 2 is placed beneath a forest hillside near Prague. Therefore, rich biotic and abiotic environmental interaction takes place at the site. The performance is co-designed and co-created with blue stain fungi, algae and lichen. This is a still ongoing process, that changes the prototype over time. Combined with the microclimate, these elements regulate the moisture content of the material and thus its warping. The material also moderates the microclimatic environment when change occurs, returning it to a state of equilibrium. The habitation of algae is organised according to the direction of fibre in the wood (Figure 11).

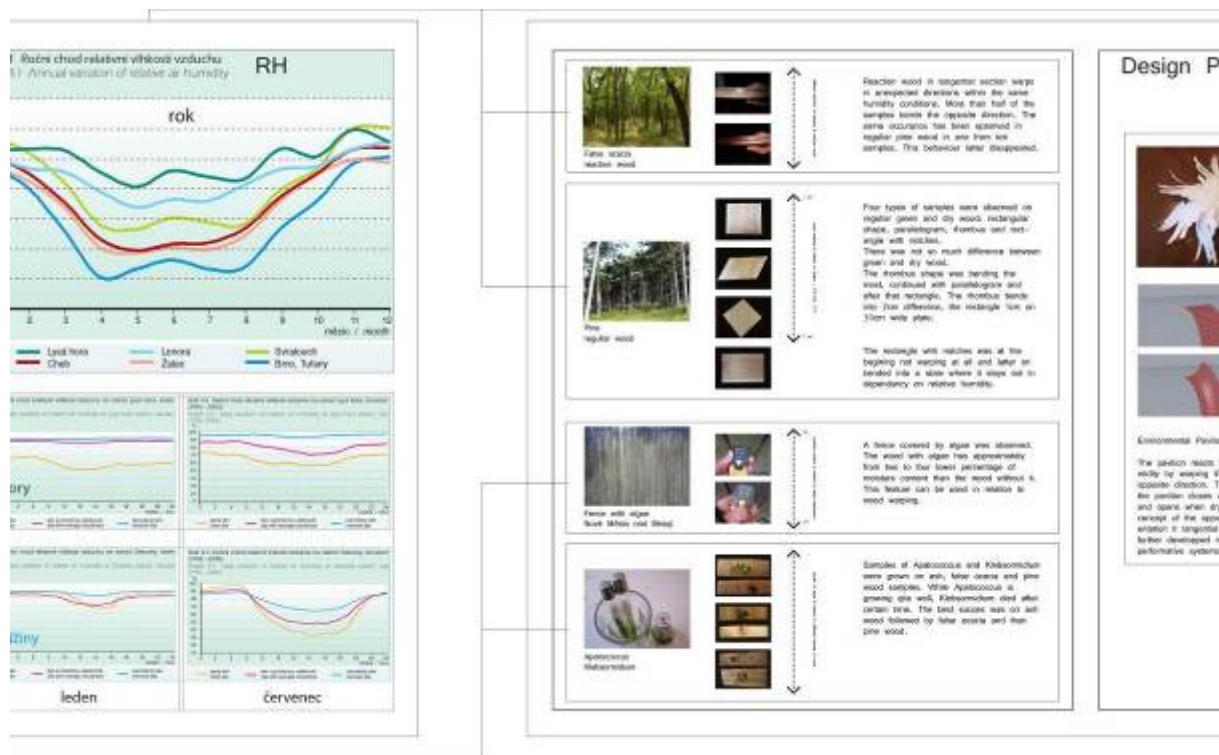


Figure 10: Davidová: Detail of environment responsive screen GIGA-map showing climatic-forest-tree species. Wooden material relations and/or summaries of samples observations evaluations in reference to design (Davidová, 2013). Climatic diagrams from Tolasz and Coll (2007) were used with the courtesy of Tolasz.



Figure 11: Ray 2 Prototype exposed to time-based co-design with its microclimatic conditions and blue stein fungi, algae and lichen that inhabit it. All is regulating the moisture content of wood, thus causing warping. Note the organisation of the algae habitation caused by the material's fibre direction and thus moisture distribution. Photo: Davidová, 2016.

This interdependency shows that transdisciplinary relations are crucial in Performance-Oriented Design because the agents in game are trans-related regardless of the knowledge and skills in human disciplines. This finding corresponds to the use of non-singular issue focused images in the mappings conducted individually and in co-designing. The work is focused on mapping with images instead of representative nodes and abstract icons for two reasons. The images correspond with the media used in my research field. Furthermore, in my experience, the image provides in-depth background information, even on a subliminal level, which might not be of much interest in mapping but may be of great interest later in the design process. By referring to the commonly used architectural slogan, *one image says all*, I am avoiding any loss of data even from an emotional perspective. Different impasses that remained on the board were unexpectedly used to resolve particular design issues. You cannot know at an early stage of a design process dealing with complexity, what information becomes important at a later stage. Because of this multiple use of mapped items, the GIGA-map had several layers reflecting though not fully representing the real life complexity. It mapped the performances of image comprising the whole as well as the relations inside and among the images. This multi-layered mapping, covering larger complexities of relations and data, is impossible to quantify in direct way. Thus, tacit knowledge was generated in a way that was similar to use of prototyping. This knowledge was generated through reflective doing, which means in this case systemic design practise. Therefore, across the discussion board and prototypes, some phenomena are often emerging and are made explicit that could not be named because no terminology is sufficient. Another effect of this is that it bridges language problems in the international teams where nuances and advanced issues are lost in translation .

While working in transdisciplinary teams with the material-clime-responsive wooden pavilions (Figure 12), the project teams focused on moderating “urban heat islands” (Meteorology, 2009). Handling, processing and sharing the data became crucial. Here GIGA-mapping, in this case the image-based type mentioned above proved valuable in the generation of the design process (Figure 13). This was analysed and discussed in a separate paper (Davidová, 2014c). Connected with threads and pins, representing relations and connections, the physical collage of printed computer-generated data, images and site photographs provided a holistic overview for the team work and external co-operations in relation to the design of the performance features of the installation and the construction of the physical prototyp. The GIGA-map was organised as a timeline according to the responsibilities of the team members. The earlier GIGA-map designed in the responsive screen project Ray 2 was used as a starting point and a scientific background for the complex project (Figure 9).

Several media were used, such as digital 3D scanning, Rhino, Grasshopper for Rhino, Lady Bug⁵ (Sadeghipour Roudsari, Pak, & Smith, 2013) and Donkey⁶ (Svoboda, Novák, Kurilla, & Zeman, 2014), plug-ins for environmental performance simulation, physical prototyping and testing of joints, CAD/CAM and digital fabrication, V-ray rendering plug-in (Visual Dynamics, 2016) and Photoshop image processing (Adobe, 2016) for visualising public spaces socio-environmental relations and atmospheres were involved. Simultaneously, social media and cloud sharing media were used to support the teams and their dynamics. Facebook group discussion and cloud file sharing at Copy (Barracuda Networks, 2016) was a crucial part of the team’s organisation and collaboration. The media richness was an important element in generating the social network of the project, its development and the pavilion itself. As opposed to hard planning, in such collaborations it is easy for individuals to plug in their expertise and find their position and a way to be useful and contribute to the emerging social system that the project generates. The collage in the GIGA-map (Figure 13) was reorganised several times by the team so it was very useful for generating collective creativity by addressing the visual relations of the discussed topics. It also helped to maintain a shared sensibility towards the project, its systems and relations among and within its subsystems.



Figure 12: LOOP Pavilion. Photo: Exner, 2014 with the courtesy of City Council of Prague.

Unfortunately, the tools used in the digital analysis and in the physical joints tests did not produce successful results in the full-scale (1:1) prototype. The build pavilion had to be structurally secured by add on plating and permanent structural checks were necessary. Also the solar radiation analysis in combination with shrinkage samples data was not sufficient. In heavy storms, some panels were expanding more than predicted, thus cracking. This result was clear evidence of the need for integrated holistic mapping, prototyping and simulations. However, design tools have not been developed for use in *hybrid processes* (Sevaldson, 2005). In a discussion of this situation, Sevaldson suggested switching the media across the board:

Start with simple, low-threshold media like big paper rolls and markers but switch to other media later. Redraw the mapping on your computer and plot it out in large formats to continue working manually. Then repeat the process with new iterations (Sevaldson, 2012b).

In this case, the iterative process was done by reorganising the existing mapping. Thus, new relations were found, and redrawn on the map over time. For the presentation purpose, a digital GIGA-map was designed to show the complexity of the project at the multi-genre EnviroCity festival (Davidová & Kernová, 2016) (Figure 14 and Figure 15) ex post. The map was not organised as a timeline but according to different topic areas and their relations, which saved white space on the board and reduced the budget for printing. The next time, it would be interesting to leave that white space as an interaction field for the festival's visitors. A similar method of participation and co-design in public space has been used by the activist group Uličník (2016). They use aboard and yellow stickers] to engage local neighbours in commenting on issues in the local community and local public space on site.



Figure 13: LOOP Pavilion design research process GIGA-map resulting from the transdisciplinary studio course.⁹ The administrator of the map and photo was Pokorný (2014). For a high-resolution image, see the Systems-Oriented Design website (Sevaldson, 2016a).

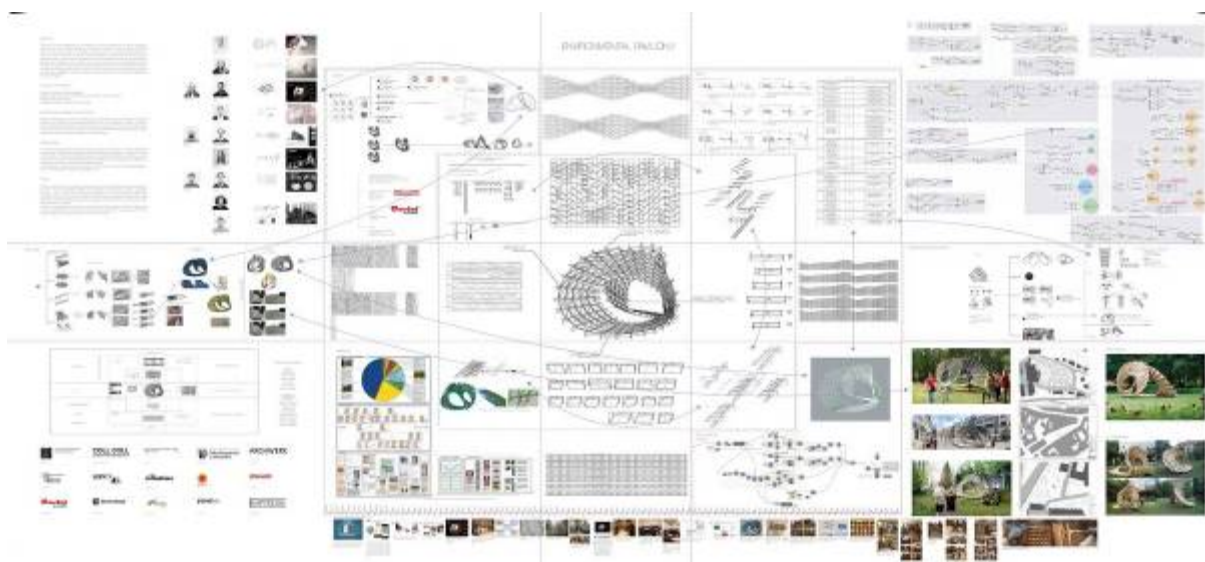


Figure 14: LOOP Pavilion GIGA-map designed in the transdisciplinary studio course.¹ The administrators of the map were Hrušová and Pokorný (2014). For a high-resolution image, see the Systems Oriented Design website (Sevaldson, 2016b).

In their discussion of *Showrooms*, Koskinen et al. (2011) described it as an arena that provides a *script* that people are assumed to follow, as in the concept of *making people think* borrowed from art (Koskinen et al., 2011). In contrast to this, this design research is driven by opportunistic interaction in a similar way as it is common i.e. in service design. There is no script to follow, or one could say it's a very open script. The installation is partly reinvented and redesigned through use. Such interactive participatory and co-designing exhibition events might serve as a research tool in time-based co-design research. In this case, this methodology was supported by the performative prototypes of pavilions, which were *enacted* and *embodied* (Merleau-Ponty, 2002) by local audiences (Figure 16), performers at multi-genre festival events (Figure 16 and Figure 17) and even birds (Figure 18) that did not have another place to rest in the built-up urban environment. In the adjacency to the pavilion, we exhibited the GIGA-map of the design and construction process (Figure 14). We found the exhibition, describing the

complexity of the design process, to be very successful. The GIGA-map in the exhibition was partly interactive, encouraging participation. In addition the team had a public lecture about the project at the pavilion (Figure 15). The exhibition was very useful and informative for the discussion following the lecture. Exhibiting the physical full-scale performative prototype next to the GIGA-map was very informative and engaging. Hence, it served as a co-design tool that engaged the participants through the public events held in the festival. The participants included the locals as well as the city festival audience and the performers were engaged within the urban environmental city perspective topic as well as the research on it.



Figure 15: Opening of EnviroCity Festival with a public lecture and discussion of design research. Photo: Dvořák 2014.



Figure 16: Landscape Architect Jolana Říhová discussing the design research from her discipline's perspective. Photo: Novotná, 2014.



Figure 17: *Pavilion's Embodiment* by Dancer Kateřina Dietzová. Photo: Novotná, 2014.



Figure 18: *Pavilion's Embodiment by Black Bird*. Photo: Škuta, 2014.

Discussion and Conclusion

This project demonstrated how the need for open-ended responsive and flexible design solutions require similarly complex open-ended, transdisciplinary, participatory and flexible processes. Issues of agency, partnership, discipline, collaboration become immensely intertwined and we need new approaches to planning for such processes. The teams engaging in such processes are open-ended social systems on their own right and the results are partly emergent.

Today's digital technology is not well suited for such complex and deeply layered design processes. This also goes for creative artistic processes which are lacking appropriate new tools. Many tools and methodologies are getting expanded through today's collaborative, physical, digital and real time-based processes but there are still large synchronisation issues. When it comes to generative design computing a few pre-sets and predefined codes are often repeated without any in-depth considerations or understanding regarding the current practice and education. The newly emerging technical digital tools often fail to predict the performance or engage the designer's cognition compared to the full-scale prototyping and physical GIGA-mapping practised, enacted, embodied and observed in the time-based co-design process. The single-field targeted tests, such as FEA, and partial physical prototypes in general lack the overall complexity of the design and its ambient local environmental data. Therefore, the mixture of media and agents is a necessary approach in the creative design research process, which also better addresses full-scale physical prototypes. The working with a great amount of mixed transdisciplinary data, multi-media GIGA-mapping was the most suitable tool in the projects described here although they could be merged in future development. This development would require a large interactive space with different agents, such as a public space. This research fuses mixed media with a generative time-based endless co-design.. Today, the creative design tools of participation and co-design often fail because they do not

communicate to actors who do not have the skills and confidence of professional designers. Therefore, the research proposes improvisational opportunistic interactions of biotic and abiotic environment, which is in contrast to *making people follow a script*. My observations revealed that although the human participants seemed to do well in GIGA-mapping, all agents were engaged in addressing physical objects when they had opportunities of the *enactment* and *embodiment* of their performative capacities. Therefore, the research searches for GIGA-mapping in the physical space of performative objects by involving all biotic and abiotic participants. This methodology is basing on Allen's (2011) discussion of *what architecture can do opposed to its meaning*: Research by Design implies joining the media mix with physicality, being the real builder and constructor and, most essentially, crossing the disciplines' borders while interdisciplinary working through participation and co-design as well as co-reflection, involving, developing and generating the theory. Hence the GIGA-mapping, prototyping and participation in co-design generated a fully environmentally engaged *rich design research space* (Sevaldson, 2008, 2012c) in an ever-evolving *time-based design* (Sevaldson, 2004, 2017b) in a public space.

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¹ Carole Collet's public lecture at the Academy of Art, Architecture and Design in Prague 28 November 2016.

² Study trip of Birger Sevaldson's, Per Kartvedt's and Geir Øxseth's Complexity and Systems Thinking studio at the Oslo School of Architecture and Design.

³ According to McNeel (2017), RhinoScript is a scripting tool based on Microsoft's VBScript language. With RhinoScript, you can quickly add functionality to Rhino, or automate repetitive tasks.

⁴ The thesis was supervised by doc. Ing. arch. Miloš Florián, Ph.D. and Prof. Birger Sevaldson, dipl NCAD, , PhD

⁵ Lady Bug is solar radiation parametric plug in for Grasshopper.

⁶ Donkey is Finite Element Analysis parametric plug in for Grasshopper.

⁹ Tutors in 2014: Marie Davidová, Šimon Prokop, Martin Kloda. Students in 2014: Alena Novotná, Anna Hrušová, Antonín Hůla, Barbora Slavičková, Jakub Kopecký, Jiří Fáber, Jiří Pokorný, Petr Tůma, Tereza Jílková, Radim Sýkora, Eliška Antonyová, Tereza Lišková, Filip Janata, Tomáš Kytka, Marie Kortanová, Vojtěch Holeček, Martin Vaníček, Jakub Hlaváček and Petr Havelka.