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Biodiversity and climate change adaptation through non-discrete architectural spaces and architectures

A systemic approach to traditions for sustainable futures

Abstract

The research claims that traditions are not static. They develop and adapt based on the present situation. Due to the recent climate extremes coming to formerly mild climate locations, their architectures can learn from traditional ones from more extreme climate locations. The present systemic design study on semi-interior, 'non-discrete spaces performances' (Hensel, 2013; Hensel & Turko, 2015) of Norwegian traditional architectures, so-called 'svalgangs' and 'skuts', examines its reuse for today's climate change adaptation and support of biodiversity, which is currently decreasing.

These authors' historical research survey of performance, following similar studies by Hasan Fathy on architectural abiotic agency (Fathy, 1986)*, is motivated by design and co-develops its own systemic process-based methodology: 'Systemic Approach to Architectural Performance' (SAAP). This approach originates from 'Systems Oriented Design'* (Sevaldson, 2013b)*, namely its use of gigamapping* (Sevaldson, 2011, 2015) *and 'Time Based Design' (Sevaldson, 2004). Here, these 'non-anthropocentric architectural' (Hensel, 2012) prototypes are in a process of over-evolving co-design with the ambient environment's abiotic and biotic agency, which also includes human agents.*

***Keywords*:** Biodiversity and climate change adaptation, eco-systemic agency, non-discrete spaces and architectures, Systemic Approach to Architectural Performance, Systems Oriented Design, time-based design, research by design, full scale prototyping.

Introduction

Conclusions based on recent observations confirm a decrease of 80% of flying insects' biomass in Western Europe over the past twenty years. If one thinks of the amount of insects on windscreens twenty years ago, compared to today's situation, the problem becomes obvious to everyone for almost every situation wherever in the world. The most prevalent reason is the use of pesticides in agricultural land (Vogel, 2017). Litter from agricultural fertilisers also can be a source of steroids and other pharmaceutically active chemicals. The introduction of antibiotic chemicals and antibiotic-resistant bacteria to natural waters next to or near farmland can occur, with yet poorly understood consequences (National Centers for Costal Ocean Science, 2012). Czech agricultural landscape was registered to lose about 80% of bird population (Czech Ornithologists Association, 2016). Various specific landscape ecologists' reports conclude that our agricultural land has become so toxic, that recently its species are moving and adapting to life in the cities. The most commonly known observation of such adaptation is the fact that in cities, birds sing louder or use higher frequencies compared to their conspecifics in forests. These habitat-specific differences in song have been interpreted as an adaptation of the city birds to mitigate acoustic masking by low-frequency traffic noise (Nemeth & Brumm, 2009). However, in recent times, architecture and urban design of our cities have evolved into very anthropocentric habitat with alike nutrient opportunities. Therefore, our research posits that our cities also need to adapt for the present situation if we are to avoid even greater biodiversity loss. The bellow-discussed traditional spaces offer various penetrations of the surrounding environment through its boundaries while these are providing mediation of its ambient biotic and abiotic agency. These provide not only benefits for its human users such as light and climate comfort but they also offer opportunities for communication with and among other species or their sheltering or even food resource. For example, birds can nest in semi-interior spaces and eat flies there or algae can be cultivated on a variety of in- and outdoor surfaces.

The eco-systemic perspective of architecture, involving both biotic and abiotic agency[1], has been common throughout the history of human dwellings. Pigeon houses were carved on top of human cave dwellings that were also performing as ventilation streams generator through connecting shafts for above and below spaces in Cappadocia, now Turkey (Davidová & Uygan, 2017). In addition, as an extension to the wider eco-system, the resultant bird droppings were used as fertilising agents for otherwise arid land (Kempe, 1988). This symbiotic co-living situation obviously brought benefits to both species (Davidová & Uygan, 2017). In urban sites, overlapping of roofs and arcade spaces were built to offer nesting spaces for swallows to maintain a healthy environment, free of mosquitos and flies. No matter if planned or not, loft spaces served as opportunities to bats or birds for habitation and their presence in the city generated a healthier environment for people living there. This all requires non-discrete spaces, secured by penetrable boundaries. Such architectures can interact across each other and their settings opens up the possibility of redefining aspects of both – not by way of separation, but as a continuum (Hensel, 2013). Such spaces, their boundaries and therefore their resulting environment, have been adjusted by the generative processes of their users over time, along with its environmental-socio-cultural-political development over generations. Also recent research by design experiments made it evident that approaching non-discrete architecture requires an acute emphasis on designing transitional spaces (Saeidi Derakhshi, 2017).

This complex situation is greatly discussed from a systems perspective. Many systems theorists consider a boundary to consist of the full enclosure of a system. For example Gregory states that in General Systems Theory elements are differentiated upon whether they are in exchange or whether they are bounded (Gregory, 2013). This definition does not seem to be precise. Skyttner states, in contrast, that the boundary surrounds the system in such a way that the intensity of interactions across this line is less than the one occurring within the system. In this discussion, an isolated system is defined as the one with a completely locked boundary closed to any input. However, this concept is very seldomly applicable to the real world (Skyttner, 2006).

When discussing the real world, in this context, we do not question the discussions from the 'Soft Systems Theory' of systems being the mental models. Therefore, so must be its boundaries (Checkland, 2000). However, in reference to this, we state that these boundaries are blurred, multi-layered and cannot be fully closed. This relates to the following discussion on the 'Systemic Approach to Architectural Performance' (SAAP) and its all three presented design-research tools: a) the gigamapping of; b) the observed existing architectures' performances, being in fact physical, observed performing prototypes; and c) the referred example of our own design performing prototypes.

The presented gigamap, which is a mental model relating hard with soft data addressing the real world, has open boundaries for its interpretations and speculations. It also leaves many boundaries open through, for example the use of photographs (see Figure 3 and 4), which are used to reference personal memories and options for new relations and speculations. These speculative performative and habitational opportunities of use as an interpreting tool of the existing prototypes, which were developed and tested over generations, feed our contemporary design prototypes.

For both cases of presented 'prototypes', the boundary exchange is understood in a way similar to that of physics. In that field, a boundary operates as the transitional zone between different states of an energy field (Addington & Schodek, 2005). It is also referred to in this way in 'Performance Oriented Architecture' (Hensel, 2010, 2011, 2012, and 2013) and by other architectural authors such as Michelle Addington (Addington, 2009; Addington & Schodek, 2005). This is important for – and generates – so-called 'non-anthropocentric architectures' (Hensel, 2013). In the discussed cases, boundaries are interacting - means that are in exchange - with an overall biotic and abiotic eco-systemic agency throughout its penetrable and material conditions. This exchange has features not only of biological, but also socio-cultural and psychological performance (Davidová, 2016b). Such a perception and/or interpretation of a boundary has strong references to the past and many cultures (Davidová, 2009).

This discussed condition of an adapted architecture that is in exchange, therefore non-discrete, has evolved for instance through the environmental performance of terrain and light origin in relation to the world axis (O'Hare, 2016) or by the layering of heterogeneous, semi-interior and non-discrete spaces in so-called *onion peel* layers (Davidová, 2016b, 2016a; Davidová, Zatloukal, & Zímová, 2017). Such architectures are therefore to be considered as 'Allopoietic Systems', a special case of autopoiesis when, though the system is autonomous, it requires an exchange with its environment (Dekkers, 2015). They require external interaction through their boundaries and involve local specificity. This seems to be an answer to José Aragüez's discussion on the paradox of architecture's need for autonomy[2] and local specificity (Aragüez, 2016).

However, contemporary building design tends to neglect or fully deflect from this discussion. Today, built architecture tends to increasingly often use highly glassed, fully enclosed facades' surfaces. This implies that these are penetrable only visually, while generating climate discomfort through their material properties. Much of the research has shown that these can generate a problematic atmosphere (Uriarte, Hernández, Zamora, & Isalgue, 2016). Our measures on the presented field study, researching traditional Norwegian architecture, show that the semi-interior space that was rebuilt in this way with closed glassed surfaces also generates the climate comfort of such semi-interior spaces that is even much worse (higher relative humidity, lower temperature) than the outdoor climate in cold and rainy weather.

Traditional Norwegian architecture was originally built with green roofs and without windows. The green roofs not only provide interior insulation but also exterior eco-systemic performance. Though there is an increase of green walls in contemporary architecture and urban design, these are seldom designed from blossoming plants. Urban trees are treated in a similar way. For the most part, plants in the city are perceived as pollution filters (Kessler, 2013; McPherson, van Doorn, & de Goede, 2016), and there is a tendency to reduce their eco-systemic agency that would consider other species.

Within the traditional examples shown in this study, the boundary exchange of light, visual information, micro-climate and biotic agency is given entrance only through tiny slivers within wood and stone structures. Therefore, it offers intimacy and artistic experience while securing climate comfort through natural ventilation. In contemporary designs, however, natural ventilation is still not a prevailing conditioning system. The interaction with light and shadows is redesigned to sterile environments to be maintained as constant as possible. Both biotic and abiotic actors, such as algae, birds or air flow, tend to be rejected from human interiors, dwellings and settlements. The contemporary market has even begun offering benches designed to discourage usage by other species and certain human social groups. People cover their houses in fully enclosed envelopes with needles or nettings to prevent whatever interaction, for example that a bird would sit on a window or ledge. The fully enclosed, insulated envelope focuses on the avoidance of any interaction whatsoever with the environment where it is located. Though the human interiors, dwellings and settlements need to be partially autonomous, there is a necessity to perform exchange with eco-systemic agency through their boundaries with their adjacent environment. This can be done through the gradual multi-layering of heterogeneous environments with varying levels of autonomy. The present case study shows that this has been common, especially in places of extreme conditions. In the search for climate change adaptation and biodiversity support, this study speculates on its co-performance and co-habitation implementations for today's built environment, which is recently experiencing waves of such conditions in formerly mild climates.

Methodology

It is difficult to differentiate the methodology component from our design-research in itself. As explained later, the boundaries of the design processes, registering, prototypes and results are affected by blurring and feedback looping and, in fact, we consider them all as merging within a new proposed field: SAAP. This synergy generates the true performance of the built and landscape environment eco-systemic design practise. With this 'Systemic Design Praxiology in Design Research' (Davidová & Sevaldson, 2016; Gasparski, 1979; Cross, 2001; Sevaldson, 2010), we are no longer solving the 'design problem'. We are interacting with the system, which here means eco-system, through local interventions, therefore co-designing[3] and re-designing it. We state that today's global situation is far too complex to be simply 'solved'. However, our various scale and activating agency interventions may improve the systems' performance. Therefore, we, as well as our interventions, are co-designing the eco-systemic co-performance and co-habitation.

Systems Oriented Design and Research by Design

The methodology of this research originates from Systems Oriented Design (Sevaldson, 2013b, 2017b). SOD is the most designerly and practice-oriented way to deal with systemic relations (Sevaldson, 2017a) (see Figure 1), where, specifically, gigamapping (Davidová, 2014; Romm, Paulsen, & Sevaldson, 2014; Sevaldson, 2011, 2015; Skjelten, 2014) is employed. GIGA-mapping is the visual diagramming of complexity. SOD is used and developed in many design fields, particularly in the very process-based field of Service Design.[4] Therefore, it requires only a very short connection of this well-developed concept to relate to our process-based design of co-performances and co-living.

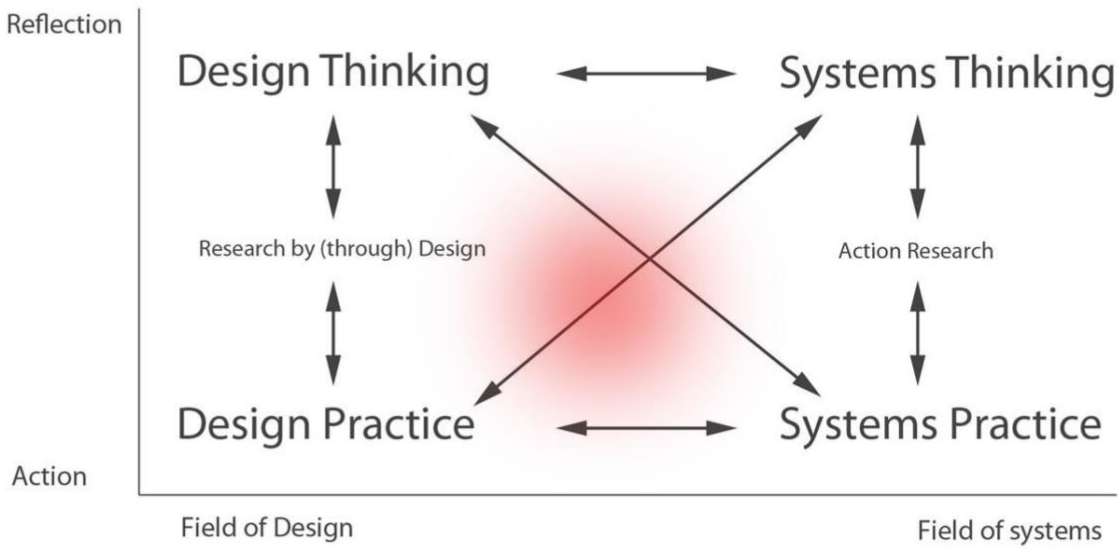

Figure 1: Field of possibilities in Systemic Design. Systems Oriented Design is located at the red dot. (Sevaldson, 2013a).

In this study, gigamapping serves as an analysing tool for registered traditional architecture's performance and opportunities of use. The study took place as a reflection of the previously speculated application of bottom-up research by design prototypes in the field of 'responsive wood'[7] (Hensel & Menges, 2006). In this case, gigamapping engages photographic documentation as one of the research tools. These are helpful for examining soft and hard data and thus generating tacit knowledge of the *first person practitioner researcher*,[8] relating registered environmental and performance items with her/his memories of atmospheres when registering, thus also generating new speculative interpretations. The images cover spatial development and light/shadow penetration analysis. These are related to micro- and macro-climatic data, today's world axis orientations (this means environmental: such as sun in time, prevailing winds, storms, etc. orientation), geographical position of the buildings' origin, spatial distribution of the semi-interior, 'non-discrete', spaces and opportunities for their use.

Though this following discussed mapping journey was updating a previous study, many of the parameters were defined through first-person experience in the context of new conditions and many after the journey at the time of the gigamap creation, while the gigamap was also updated as a different way of 'reflection in action' (Schön, 1983) when writing this text. Such a first-person, process-based learning tool that is processing first-person experience from registering generates both tacit and hard data relations skills and knowledge of architectures' eco-systemic performance in the practising designer.

Systemic Approach to Architectural Performance

The present study of the architectures that were developed and prototyped over generations has been developed in support of recent speculative design research on responsive wooden screens. These full scale, prototyped 'breathing walls' (Leatherbarrow, 2009) are meant to be installed on semi-interior spaces and as facades similar to how the technique has evolved in traditional Norwegian architecture and elsewhere in extreme climatic conditions. Therefore, the otherwise full-scale prototype that was developed by the first author's (Davidová) research has transformed into an architectural heritage study in combination with her Research by Design. However, the heritage study here is performed as an observation of complex prototypes. Michael Hensel and Søren Sørensen state that each design research case needs to develop its own methodologies (Hensel & Sørensen, 2014). This seems to be true. We would add, that these methodologies need to relate soft and hard data, while employing first-person, tacit knowledge and her/his experience of the memories of specific atmospheres. The same way as Terje Planke justifies the necessity of the restaurateur cooperating with the carpenter in heritage preservation (Planke, 2016), we believe that our reading of researched traditional architectures as researchers by design, prototypes and practitioners may bring a valuable insight to architectural practice. This approach of the 'reflective practitioner' (Schön, 1983) on long-time environmentally and socially tested knowledge will generate a special case of 'reflection in action' (Schön, 1983) through experience. However, we state that this real-life experience of co-performance and co-design is the eco-systemic re-design (which means also the design result of using the traditional vocabulary). This first author's long time span approach to design–research practicing has led her to ratify a new design field: SAAP.

SAAP is the fusion of process-based fields formerly initiated by the integration of Systems Oriented Design and Performance Oriented Architecture (see Figure 2). SAAP involves Time Based Eco-Systemic Co-Design and Co-Living, which is performed by both biotic and abiotic agents, including humans. It is 'Time Based Design'[9] (Sevaldson, 2004, 2005), which merges and develops methodological processes and the result's performance evolving in time. While doing that, it generates theory through experimental practice. It is based in (eco-) systemic interventions that therefore co- and re-design the initial system by its co-performance and co-living. These interventions are fusing the natural, edible, social and cultural environments of a variety of species, including humans, with abiotic agency.[10]

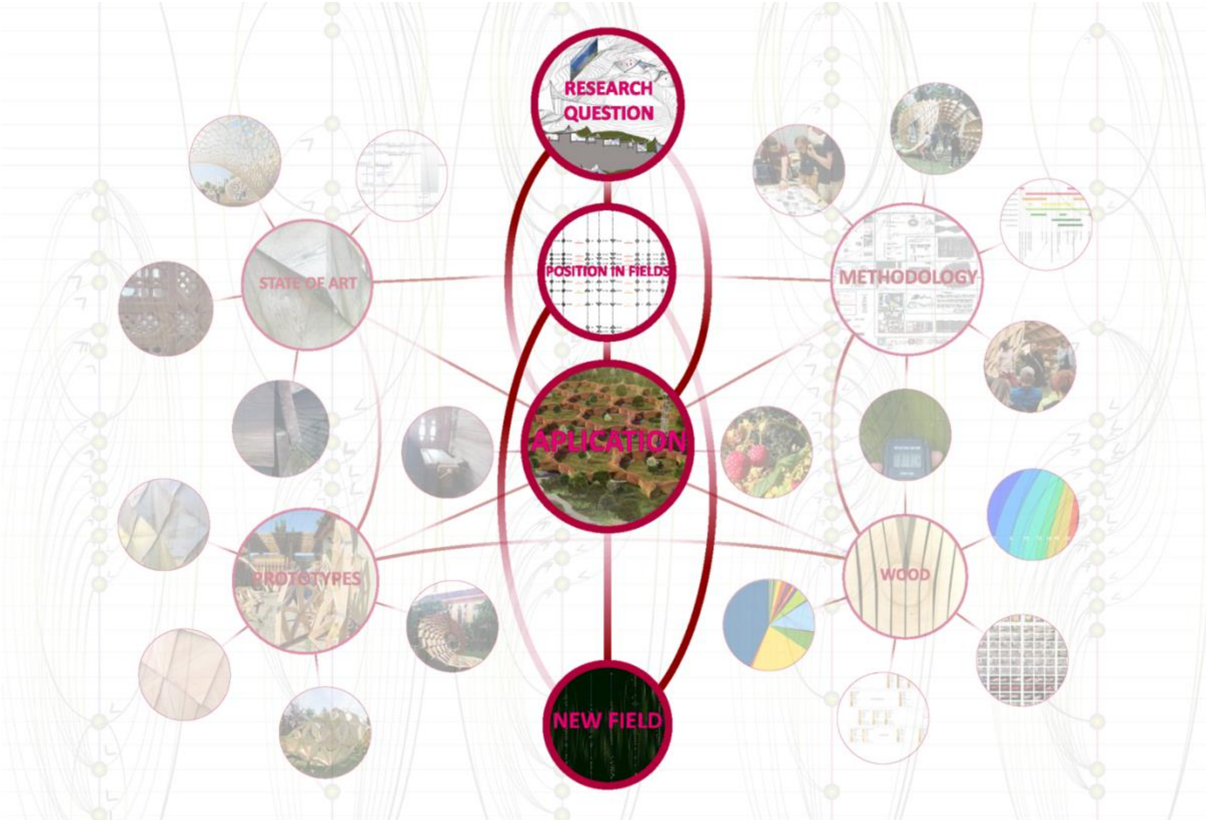

Figure 2: The diagram of the previous complex study that lead to ratification of the Systemic Approach to Systemic Performance design field: The study first asks the research question of what is responsive in the solid pine wood's environmental interaction and how it can be applied in Performance Oriented Architecture in a Czech location when approached through Systems Oriented Design. The study follows by defining its position in these fields, while for application, it has to further develop the methodology and the wood material science and to build and observe its own full-scale prototypes. Through fusion of these studies into one ever-evolving performative eco-system (the application), it concludes with the ratification of a new design field: Systemic Approach to Architectural Performance (illustration: Davidová 2018).

The systemic relations of these processes, their agency and perceptions were the study field of the presented gigamaps, when the first one from the initial study informed and updated the second one (see Figure 3 and Figure 4). The first study of these semi-interior spaces was performed by the first author after she registered these on a friend's visit when they immediately aroused her sense of curiosity. After finding out there is not much written literature on this topic but there is spoken knowledge of the historical heritage experts when it comes to the uses of these spaces, she arranged a journey to measure their climatic performance. All the other parameters were defined on site, enriched by local expert's knowledge (please, see the acknowledgements section). This journey was arranged in winter and it was immediately clear that mappings in other seasons would be necessary as well. The collected knowledge and experience enriched the planning of the second summer journey, which also mapped the performance of these architectures from the more extreme climates of the Norwegian West Coast. This journey updated the first gigamap not only with new data, but also with new parameters that appeared as relevant through a second, deeper study that was to be compared with the first parameters. This leads to the following discussion in the next section that the more extreme environments, the more material-environment performances and opportunities for co-habitation across the eco-system appear. This registered and experienced knowledge serves as a future design generator for architectural, landscape and urban design practice when dealing with biodiversity loss and climate extremes.

The parameters for the mapping also resulted from similar studies, the first author's full observations and speculations regarding the prototypes, and design research practice curiosity. The researchers thus wonder about not only hard data, but also their relations with phenomenological observations and speculations regarding their potentials. It shows that the sound–material relational phenomenological property of live performed sound called *timber*,[11] which has never been successfully simulated, appears not only in sounds but also, for example in perceptual spiritual, visual, touch and climate comfort in relation to material and spatial organisation. The synergies of such properties generate atmospheres. These seem to be reached by the material–environmental performance of both biotic and abiotic interactors within – and across – the systems' penetrable boundaries.

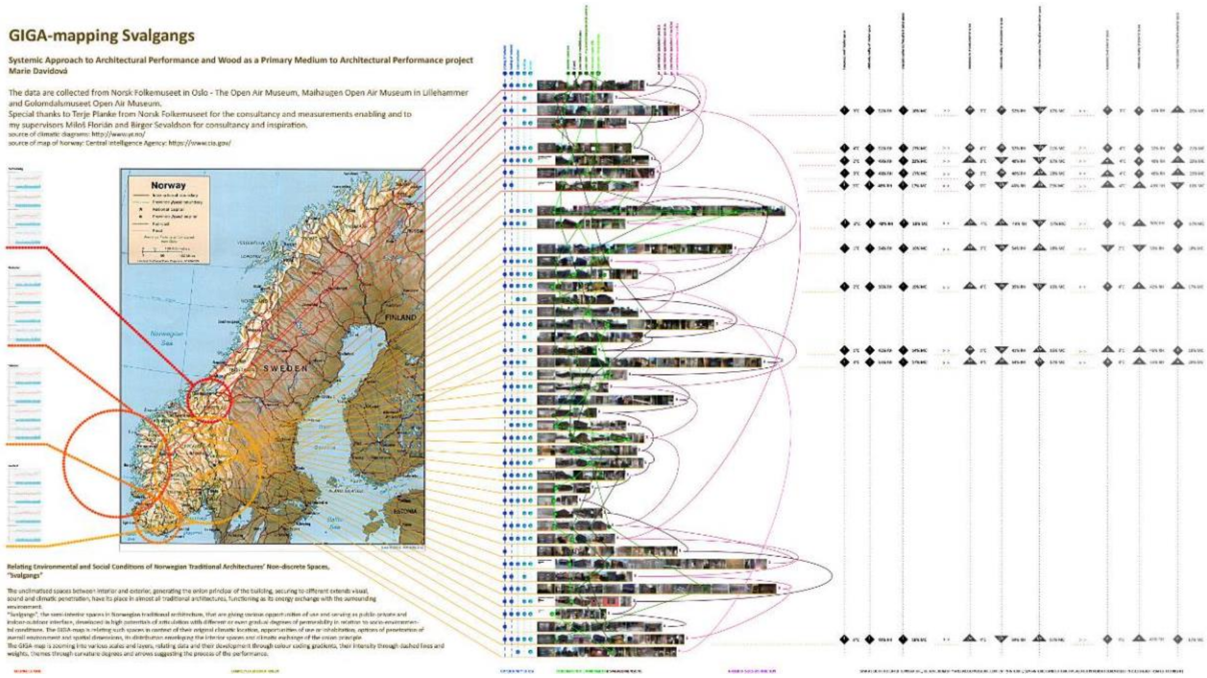

Figure 3: gigamapping Svalgangs (Davidová 2016) The gigamap relates such spaces in the context of their original climatic location, opportunities for human use or inhabitation, options of penetration of the overall environment and spatial dimensions, its distribution enveloping the interior spaces and measurements of micro-climatic exchange and moisture content of the material within the onion principle. The gigamap is zooming into various scales, relating data and their development through colour-coded gradients, their intensity through dashed lines and weights and themes through curvature degrees and arrows suggesting the process of the performance. The map of Norway is a public source from: Central Intelligence Agency (Central Intelligence Agency, 1998); the macro climatic diagrams (yr, 2016) are used with the courtesy of yr.no

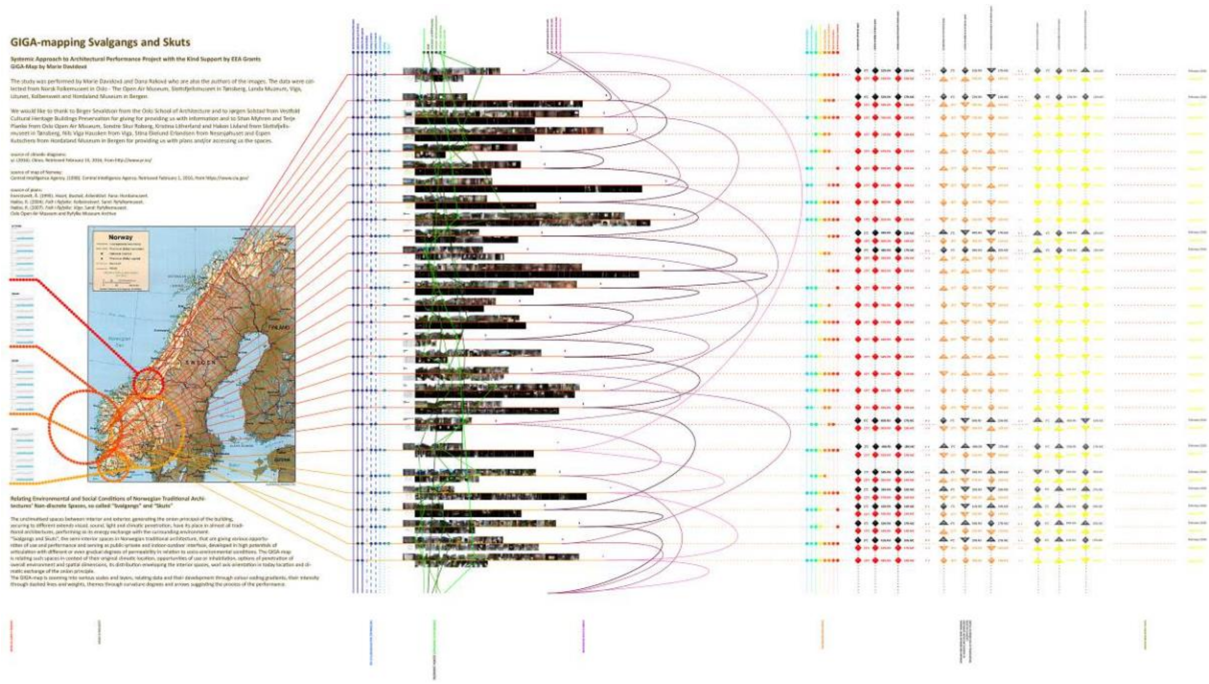

Figure 4: Gigamapping Svalgangs and Skuts: gigamap is relating such spaces in context of their original climatic location, opportunities of use or inhabitation, options of penetration of overall environment and spatial dimensions, its distribution enveloping the interior spaces, world axis orientation in today location and climatic Exchange of the onion principle. The gigamap is zooming into various scales and layers, relating data and their development through colour coding gradients, their intensity through dashed lines and weights, themes through curvature degrees and arrows suggesting the process of the performance.(main author 2017) - the map of Norway is a public source from: Central Intelligence Agency (Central Intelligence Agency, 1998); the macro climatic diagrams (yr, 2016) are used with the courtesy of yr.no

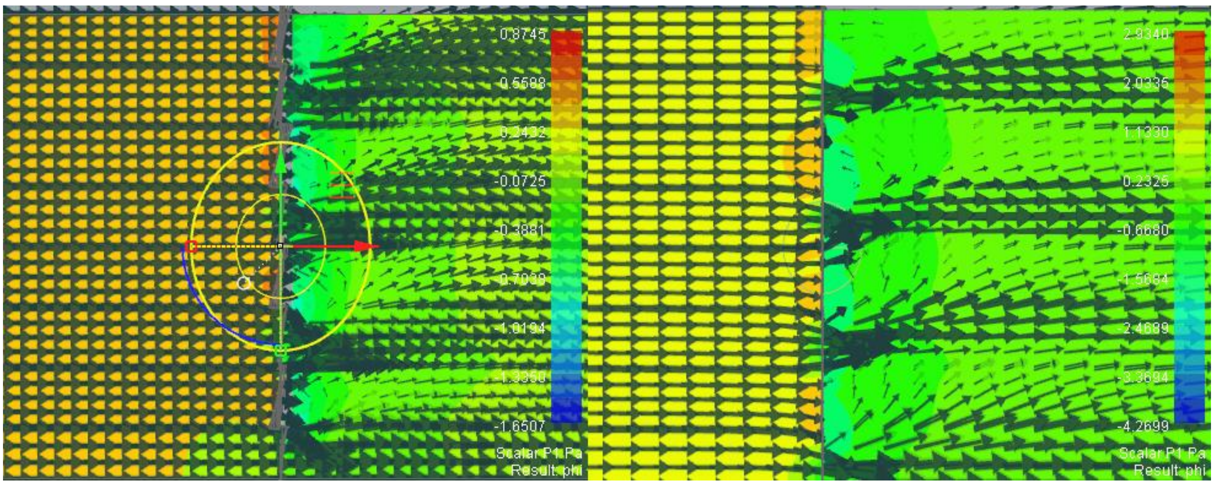

Figure 5: RhinoCFD Fluid Dynamics Simulations Illustrating the Exchange between Exterior and Semi-Interior Spaces through 'Ray' Envelope; a) to the left: situation of dry and hot weather when the screen is open; b) to the right: situation with higher humidity and lower temperature when the envelope slowly closes (illustration: Davidová 2017).

The complex phenomena of boundaries penetration is difficult to express visually through gigamaps. Though we can visualise the airflow through design of screen 'Ray' (see Figure 18) just by simulation (see Figure 5), the light-shadow photography much better visualises these multi-layered conditions and atmospheres (see Figure 6 and Figure 7).

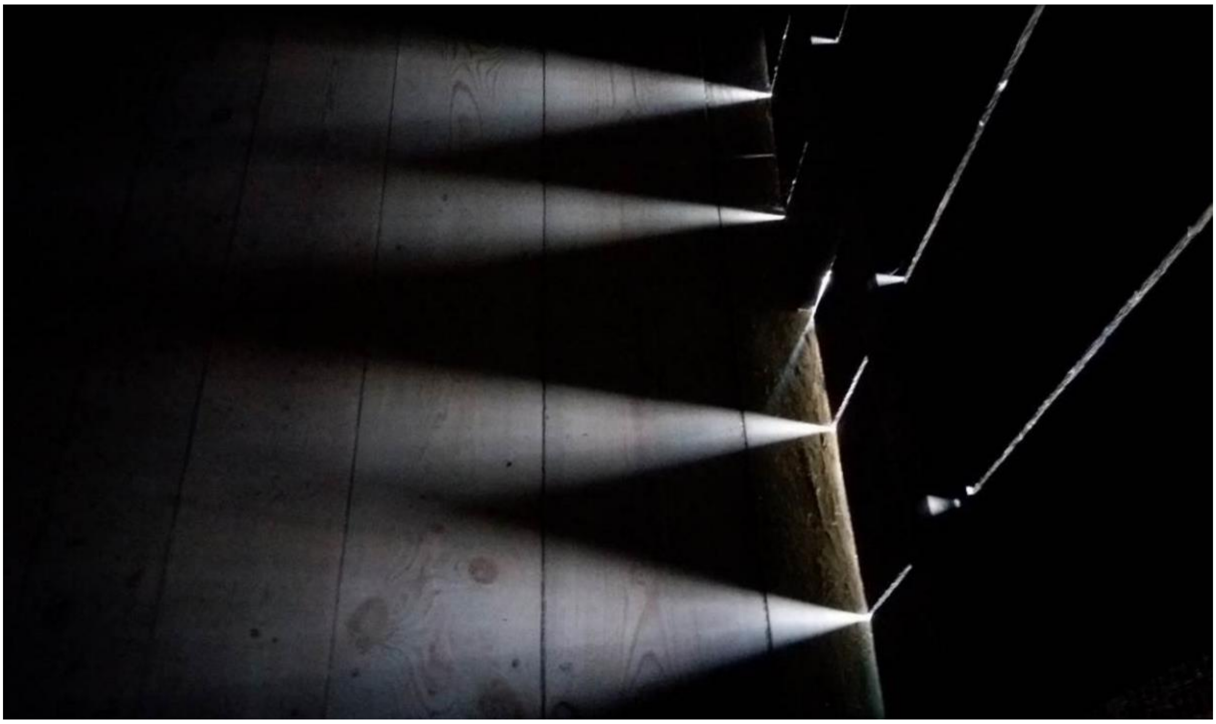

Figure 6: Light penetration into the svalgang of a farmhouse from Trogstad in Østfold from 1769, Photographed at the Oslo Open Air Museum (photo: Raková 2017).

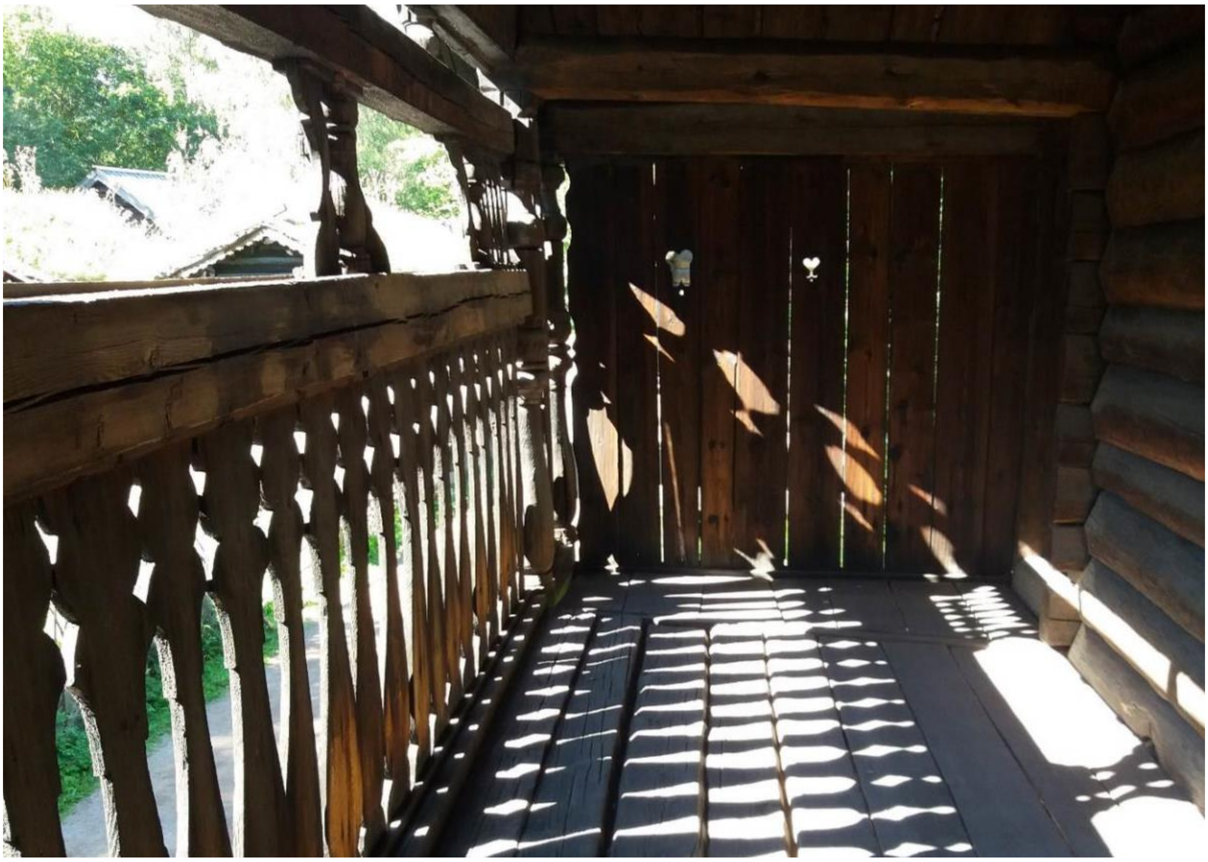

Figure 7: Light penetration into the svalgang of a *Loft* storehouse from Nes, Hallingdal from 1700–1797. Photographed at the Oslo Open Air Museum (photo: Raková 2017).

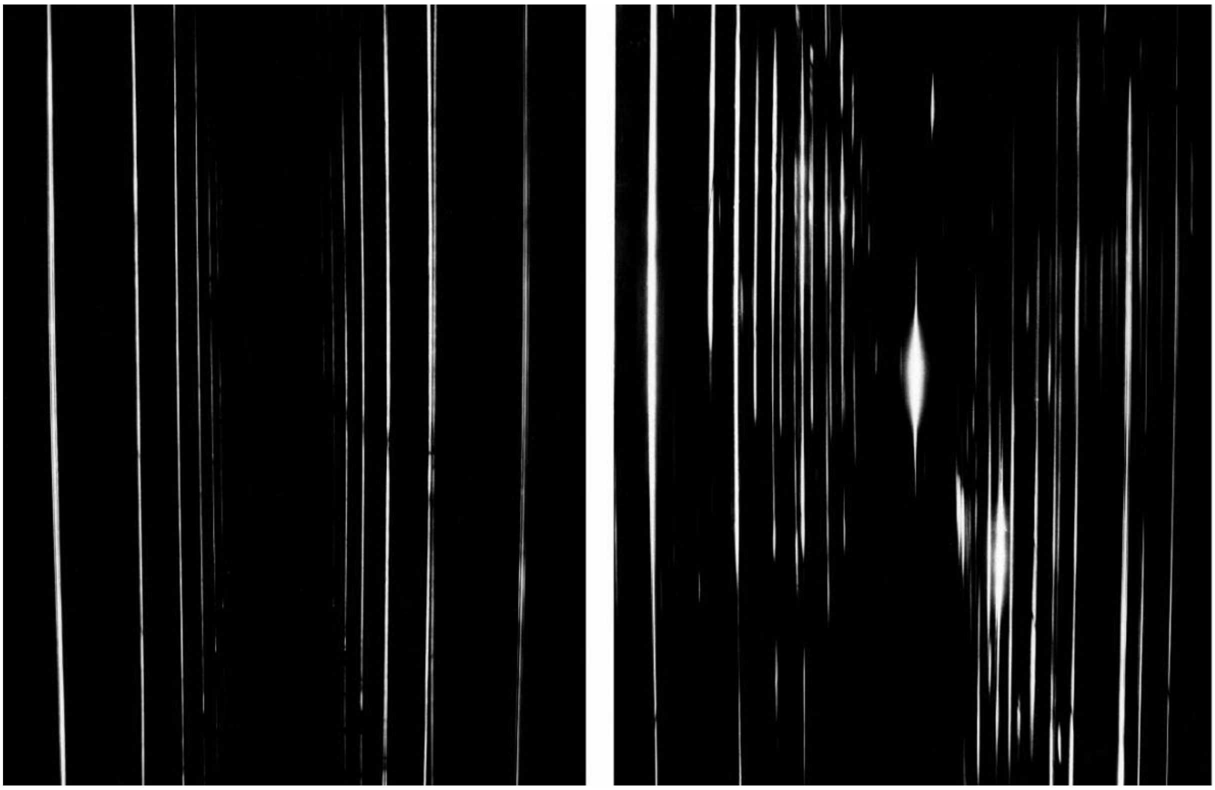

Figure 8: Zuzana Füsterová: Journey – light object, 1997 from (Centrum pro současné umění Praha / Centre for Contemporary Art Prague, 2006) used with the permission of Zuzana Füsterová.

This light penetration analysis therefore also covers other boundary crossing conditions. This method of analysis through the photographs of light atmospheres was inspired by the artwork of Zuzana Füsterova (see Figure8). She experimented with a model of ‘negative perception’ when the darkness penetrates through us (this induces a synergy of physical and psychological conditions) and causes those experiencing the effect to start questioning the conditions (Zemánek, 2003). Also, psychologist and artist James Turrell has experimented with light projection through darkened scratched windows with reference to Plato’s cave shadows in his earliest work ‘Mendota Stopages’ (Govan et al., 2013). Thus, while assessing hard data through the more or less artistic analysis tools of the use of memories, psychology and personal experience, overall it is the preference of this research to address the ‘phenomenology of eco-systems’[12] so it can be applied in architecture, landscape, urban design and built environment.

In contrast, the use of eco-systemic co-design, co-creation and co-habitation in the latest architecture has been, up to now, mainly discussed as ‘weathering’ (Mostafavi & Leatherbarrow, 1993). However, this has been done mostly from an anthropocentric perspective. The present study and the other studies of the first author show that an eco-systemic perspective has been common in traditional architectures, namely in extreme climates, where this could perform as a survival necessity for both humans and other species. Today, we are experiencing similar kinds of extremes in mild and other climates in waves of different intensity, such as droughts, floods, heat waves, cold waves, varieties of storms and so forth (Czech Republic Ministry of the Environment & Czech Hydrometeorological Institute, 2015; Flæte et al., 2010; Republic of Turkey Ministry of Environment and Urbanisation, 2012; Richardson, 2010; U.S. Department of State, 2014). This research aims to involve related agency within the equality in eco-systemic co-performance and co-living for recent biodiversity support and climate change adaptation.

Non-discrete Spaces in Norwegian Traditional Architecture: Svalgangs and Skuts

The semi-interior spaces in Norwegian traditional architecture were often developed some hundreds of years later after the main structure (Berg et al., 2011; Enerstvedt, 1995; Hauglid, Hosar, Krekling, Mathisen, & Songli, 2005; Sveen, 2016). Most common are multifunctional *svalgangs*, which also cover communication to the main, at least climatised by material mass, structure, and *skuts*, which serve as storage area without creating entries to the main structure. Houses from the west coast islands, facing the ocean, developed this climatic protection hundreds of years earlier than the less-exposed locations. Thanks to this performance, their climatic and world axis orientation relation is also preserved in all open air museums. These houses usually host a skut with a stone storm wall towards the south, which generates airflow in the spaces between the wooden envelope and the main structure. The main structural rooms are often built as several entities from different time periods, covered by an envelope of panelling that also gathers semi-interior spaces such as svalgangs and skuts. In these houses, the panelling has a mainly responsive wood performance. These consist of airing in dry and closing in humid weather (Larsen & Marstein, 2000). This recalls Christopher Alexander’s notion that architects ‘ought to design with a number of nested, overlapped form-context boundaries in mind’ (Alexander, 1964). However, these ‘heterogeneous spatial organisations’ (Hensel, Hight, & Menges, 2009) have been performed as the Time Based Design of inhabited full scale prototypes through generations as adaptations to the current situation. An even more open transition was present in the Viking times, where a screen of woven willow branches was inserted by the enclosed part, often built in different times (Bakkevig, Komber, & Løken, 1999), and these were attached without a boundary (see Figure 9).

Figure 9: The Woven Part of a Smithy for Climate Exchange, Reducing Extreme Heat, Landa, 350–600 (photo: Raková 2017).

Many of the svalgangs have a transformable character. Their semi-interior spaces can fully or partly unfold based on the current climatic or use performance need. In a similar way, the houses themselves were capable of being unfolded and moved from farm to farm (Berg et al., 2011; Høibo, 2004, 2007). It is not clear if the inhabitants respected the previous world axis or climatic orientation of these structures, but it is obvious that they adapted to the new situation.

This section is therefore divided into two fully interrelated sub-sections: a) the boundary conditions, discussing the exchange across different levels of the openness and closeness of the studied envelopes of the semi-interior spaces and b) the onion peel aspect of these semi-interior spaces generating a heterogeneity for the environment through its co-performative and co-habitational opportunities of use.

Boundary conditions

We mapped the types of boundary conditions of these semi-interior spaces, such as their openness, its variation, light penetration, spatial distribution and world axis orientation to relate it with its climatic and co-living co-performance and the opportunities of use and habitation of these enveloped spaces.

The enveloping systems of either the entirety of these traditional houses or just of their semi-interior spaces have highly varying degrees of penetrability of the boundaries. We differentiated these categories: a) transformable openings; b) closed; c) semi-closed – ventilation openings; d) semi-open – lace-like semi-transparent; e) semi-open – large openings; and f) semi-open – open side. It is noticeable that especially the buildings from places with greater weather extremes and the older ones offer also shelter to other species from fauna to flora (see Figure 10).

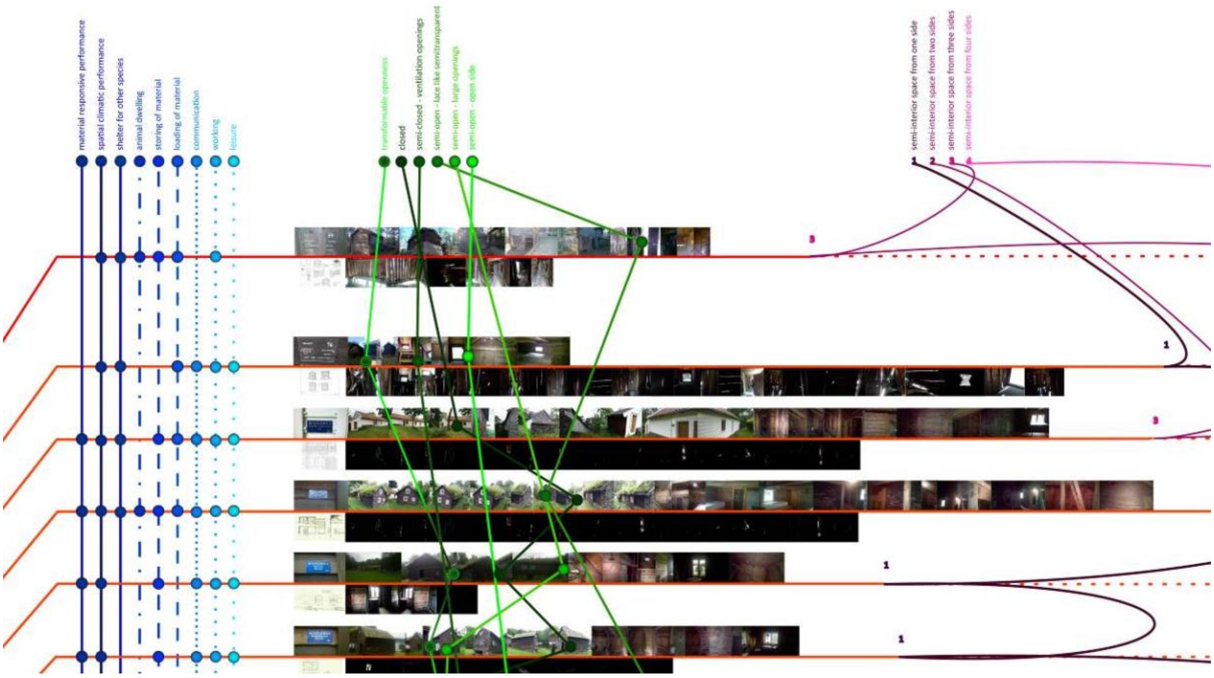

Figure 10: Detail of gigamap showing from left to right: a) performance and opportunity of use and its intensity: material responsive performance; climatic performance; shelter for other species; animal dwelling; storing of material; loading of materials; communication; working; leisure; b) penetration of environment (green gradient) & spatial dimensions (photography): transformable openness; closed; semi-closed – ventilation openings; semi-open – lace-like semi-transparent; semi-open – large openings; semi-open – open side & walk path spatial development and its boundaries' penetrations; c) spatial distribution along the main structure (gigamap: Davidová; photography: Davidová & Raková, 2016 & 2017).

The transformable envelopes (see Figure 11) can be unfolded, therefore their boundary penetration is operated by the climatic or use preferences of their users. The more or less fully enclosed envelopes are from modern times. It is clear that even the spaces with open sides perform as micro-climatic moderators. These however do not generate airflow due to their orientation and distribution. The lace-like micro-openings seem to perform the best in this sense. They generate both climate comfort and ventilation. The 'breathing' envelopes of responsive wood (see Figure 12) even increase the moderation for that. It often appears that several of the categories are applied along the variety of distributed spaces of the building (see Figure 10). This seems to have a clear climatic (at the unchanged environmental settings), social and usage differentiation.

Figure 11: Transformative Envelope on the Loft from Raundal, Voss 1600–1700 – Oslo Open Air Museum. The envelope of svalgang (on the right) can be fully or partly removed or fully be closed again (photo: Raková 2017).

Thus, the building is heterogeneous not only by climatic and light penetration, but also by interaction with – and distribution of – biotic agents (see Figure 13). These also moderate the environment. For example, the growth of algae is dependent on and changes the relative humidity of the space and the moisture content of the wood it grows on. With the first one, it creates climate comfort for humans and a majority of other species. With the second one, it serves as a preservation agent against decaying species. When the wood's responsivity is applied, it moderates its material-climatic interaction. In high relative humidity, the moisture content has been measured even 10% lower at the samples with the algae than without it. In low relative humidity, it is about two to four percent (Davidová, 2017). This has a reasonable effect on warping, and due to that, a reasonable effect on the envelope's performance (see Figure 18). Therefore, the space generates a variety of opportunities of use, cross-species' social situations, climates and atmospheres.

Figure 12: Responsive Wood Envelope of Loft from Dale, Fusa 1700 – Hordaland Museum. The envelopes here have the left side of the plank oriented towards the inside and are attached on the lower side of the panel. Thus in dry weather the plank warps towards the interior and in wet weather generates enclosure together with the upper panel (photo: Davidová 2017).

Figure 13: One side of an opened skut inhabited by algae of barn at Kolbenstveit from 1850. The algae is lowering the moisture content of the panelling from the interior side and thus the relative humidity of the space (photo: Davidová 2017).

Co-Performative and Co-Habitational Opportunities of Use

The co-performative and co-habitational opportunities of use and the so-called 'opportunistic use'[13] (Sevaldson, 2005) are closely related to spatial organisation and performance (see Figure 3, Figure 4 and Figure 10). The heterogeneity of space generates specific opportunities as discussed below. Therefore, it seems, within this collaborative design that is offering a second person's perspective (Sevaldson, 2010), in this case happening as time-based prototyping over generations, there was a larger focus on the heterogeneity of properties of spaces and environments than on their functional definition.

The gigamap studied these co-performance and co-living opportunities and engagements for opportunistic use: climate-material responsive performance (responsive wood); climatic performance; shelter for other species; animal dwelling; storing of material; loading of material; communication; working; leisure in their relation to their periodicity (see Figure 9). Among all the investigated buildings, it is common that the envelope has climatic performance (see Figure 14).

The semi-interior spaces serve as a part of an 'onion principle' generating moderate penetration of climate and light between exterior and interior. This can be supported by the material responsive envelope, in this case responsive wood (see Figure 12, Figure 18, Figure 20 and Figure 22) and by the 'transformers'.

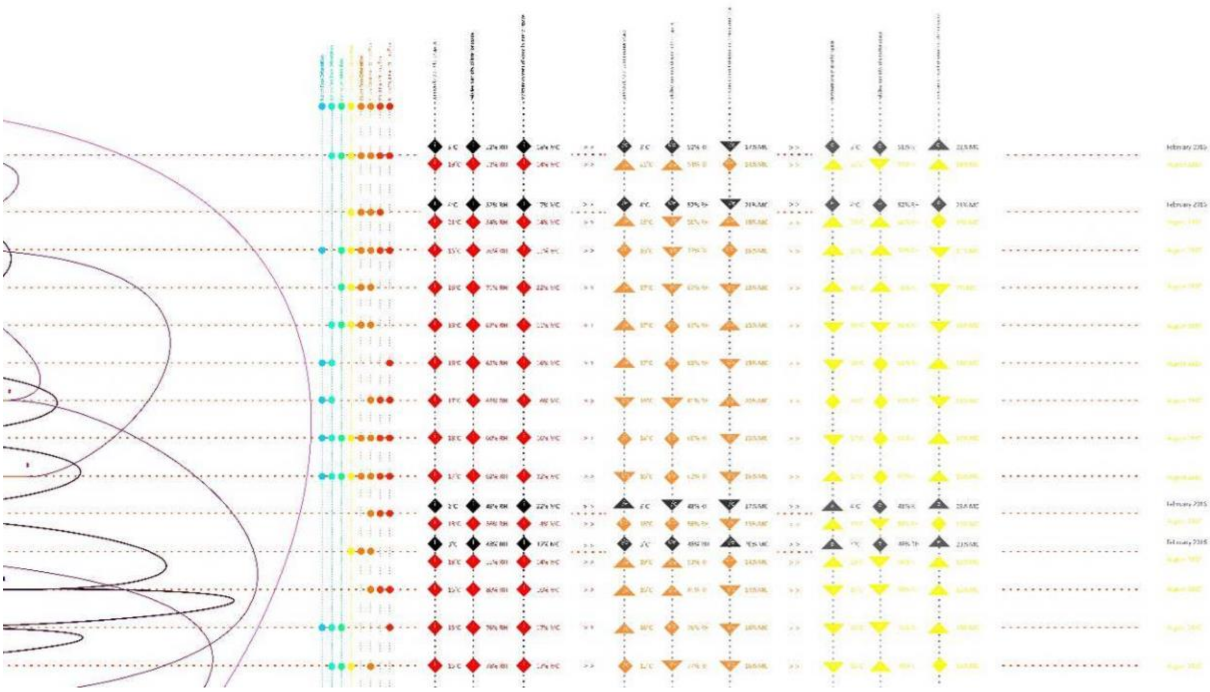

Figure 14: Detail of a gigamap, showing from left to right: a) world axis orientation; b) temperature, relative humidity and moisture content of wood in interior; c) temperature, relative humidity and moisture content of wood in semi-interior; d) temperature, relative humidity and moisture content of wood in exterior (see further detail at Figure 15). The b, c and d show increase and decrease by arrows from left to right and are differentiated by colour for summer (red to yellow) and winter (black to light grey) measures, defined by dates from the right (illustration: Davidová 2017).

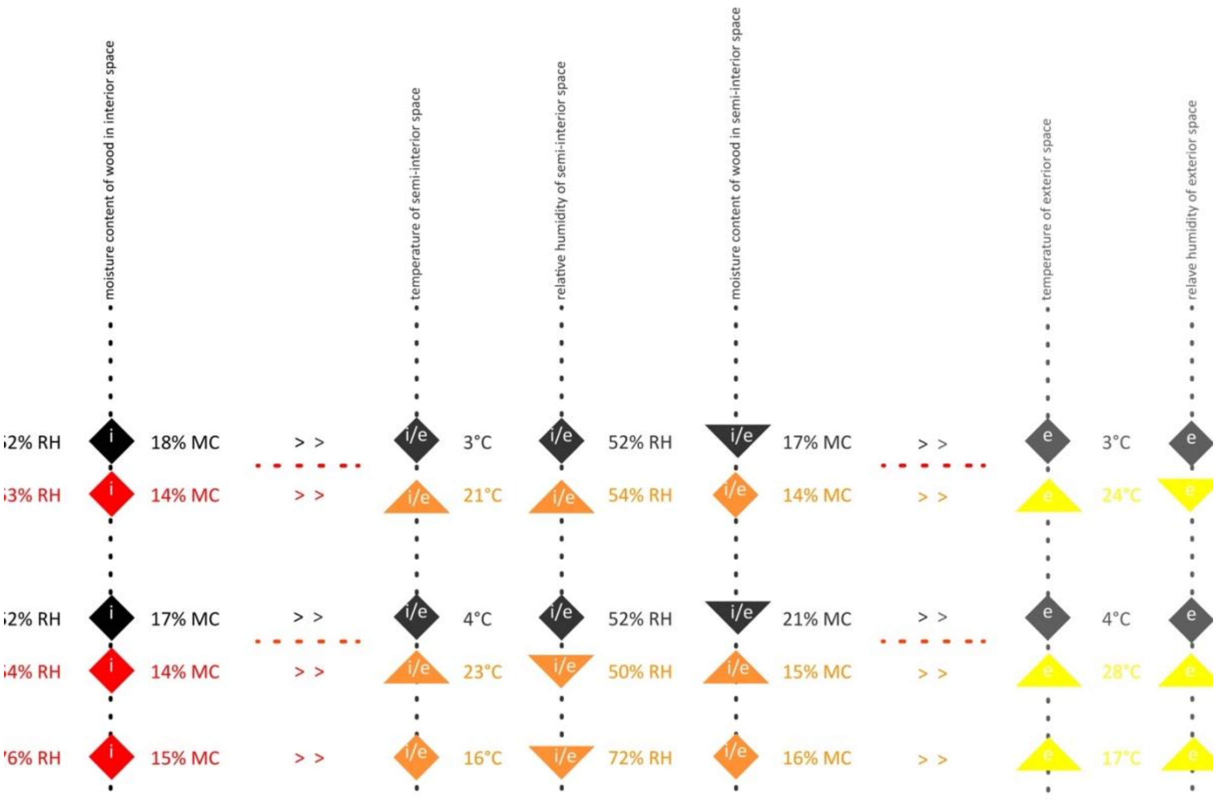

Figure 15: Detail of gigamap, showing from left to right distribution (increase and decrease by arrows from left to right) of: a) moisture content of wood in interior; b) temperature, relative humidity and moisture content of wood in semi-interior; c) temperature in exterior. The a, b and c points are differentiated by colour for summer (red to yellow) and winter (black to light grey) (illustration: Davidová 2017).

Many of these offer shelter or habitation to various species (see Figure 13). This depends on the option of penetration (size) and climatic/world axis orientation of such. No matter if planned or not, the other uses, such as material storing, human communication (different levels of privacy), work or relaxation, call for the same performance. However, it is possible to speculate that the cultures in extreme climates that were attached to nature, might even plan this pattern of eco-systemic co-living and co-habitation. In many of the cultures from extreme climates it is an obvious fact, such as the pigeon houses in Cappadocia where there is evidence of symbiosis (Davidová & Uygan, 2017).

Opposed to animal shelter, the category of animal dwelling cannot be considered as symbiosis. It is the humans taking advantage of other species, though the border is a bit blurred. The differences in tectonics between the two categories are however very clear. One is to invite and keep open and the other is to lock.

When discussing material storing, it is important to differentiate that the prevailing types, svalgangs and skuts, differ in that sense. Svalgang has by its preference motion (loading, communication, etc.) performance, while skut is meant to be static for storing. The stability in this context also seems to generate better dwellings for other species. On the other hand, svalgangs offer better options for communication not only among interior spaces, but across the species and environments. Therefore, the heterogeneity of these spaces provides better options for co-living.

This also applies to the options for working environments in certain climates and afterwards relaxation. These uses require light and climate comfort and public–private space social balance. Darkness, deep-shadow and shade in an architectural space influences biotic (and human) neurological conditioning. Petrus et al. state that for humans, spending two weeks in darkness enhances hearing and visual deprivation, which leads to improved frequency selectivity (Petrus et al., 2014). Architect Peter Zumthor asked how much light and darkness do we need for our life (Zumthor, 2006). All human beings spent prenatal life in darkness. However, light condition comfort is very individual and often relates to geographical origin. While neglecting this context, the darkness is slowly disappearing from contemporary life. The increased and widespread light pollution is not only impairing our view of the stars, it is adversely affecting our co-living eco-systemic environment and the health of most of us.

Contemporary Application Speculations

Within the following section on contemporary application speculations, we will discuss how the above study focuses on non-discrete spaces in Norwegian Traditional Architecture: Svalgangs and skuts can be applied in SAAP. The first discussion is on the extreme light and sound parameter closeness of the boundary for its deprivation therapy with semi-interior space that serves as an exchange with the 'real world'. The special section for this discussion consists of the transformers (see Figure 11, Figure 19 and Figure 21) and responsive wood (see Figure 12, Figure 18, Figure 20, and Figure 22) surfaces, which can adapt to the current situation. These perform based on climatic and/or social settings, generating preferred situations across the discussed parameters. However, even the stable material complexes are not static. The light, wind, seeds, birds and other agents generate a time-based interactive performance. This research seeks to apply such eco-systemic principles to a contemporary trans-disciplinary practice.

Though the application of such heterogeneous spaces does not have support in current building laws and construction businesses, we argue that with today's climate change and decrease of biodiversity, such spaces are relevant. Instead of extensive energy-consuming building insulations, we need to develop onion principles of varieties of spaces with penetrable boundaries that perform exchange and parallel the heterogeneous moderation of its spaces. This is to be applied to a variety of abiotic and biotic agents that may pass through, settle and interact with the boundary.

Darkness Therapy Application Speculation

Darkness therapy is a variation of a sensory deprivation method used in several places in Europe, especially in the Czech Republic (Kupka, Malůš, Kavková, & Němčík, 2014). Its practitioners are seeking novel experiences or self-exploration during periods of stressful life situations. The therapy offers an opportunity for relaxation and regeneration. It enables the client to explore her/his mental landscape and resolve her/his personal or professional life situations. Each facility is a small, isolated cabin divided into at least two rooms with a sound-reducing and light-proof wall separating each room from the other (see Figure 16). The first room, though fairly insulated, serves as an exchange with the outer world such as provision of food (Suedfeld, Rank, & Malůš, 2017). This can be compared to sensory deprivation research in the artistic work of James Turrell. Turrell and his colleagues Robert Irwin and Ed Wortz were searching for spiritual dimensions of the interiors of anechoic dark chambers. Their study focused on affecting the perception of everyday reality in a way that might open up a view to the 'inner light' (Govan et al., 2013).

Though the phenomenon of light deprivation has been extensively studied, the moments of adaptation to daylight conditions are rather neglected. James Turrell in his artwork Mendota Stoppages slowly opened and closed the small holes in the walls of a space for viewers standing inside the space beginning in complete blackness. He compared this experience with opening and closing the apertures to the accompaniment of music compositions (Govan et al., 2013). In relaxation and meditation techniques, especially in yoga, there is a technique of placing one's fingers over the eyes and slowly letting the light pass through the resulting vertical slivers for adaptation to the light and reality. It seems that the non-discrete and responsive spaces in

Norwegian traditional architecture, such as svalgangs and skuts, offer this performance, generating an environmental gradient for comfortable adaptation.

Figure 16: Contemporary Darkness Therapy Cabin in 'Place in Hearth' by Kobylnička by Prostějov (photo: Martin and Katka 2017, with the courtesy of Vladimír Böhm).

The På vei project

På Vei (see Figure 17) is a museum and gallery space for vernacular culture competition entry by Collaborative Collective, the first author's design research NGO. The building design employs the onion principle of penetrability of bio-climatic layers. The exhibition space of the museum is designed as an unclimatised walking path, or svalgang, which is tempered by adjacent climatised office spaces carved into rock with a green roof and exposed to the outdoor environment. This project served as a motivation for the development of an environment-responsive screen 'Ray' (see Figure 18). Due to the biological basis of wood, which is cut in tangential section, the screen's panels warp in dry hot weather and become narrow in cold, high humidity conditions. Thus, the envelope allows for the presence of air flow and evaporates moisture from the wood when the generation of a comfortable climate is desired. In this case, the climate moderation is specifically for preservation purposes of wooden vernacular objects. However, the screen is also intended to generate specific comfort and spiritual atmospheres for visitors. The light-visual penetration that is in motion in relation to climate creates enigmatic internal light conditions and surrounding landscape views. The screen is pervious to other smaller species for some of which it generates grounds for habitation (see Figure 18). In this case, algae together with climatic agents affects the moisture content of the wood. Thus, the screen offers an eco-systemic performance that is co-designed with other species and abiotic agents. The outdoor green roof generates an eco-systemic landscape of the previous slope that had a harsh environment and walkable landscape for visitors.

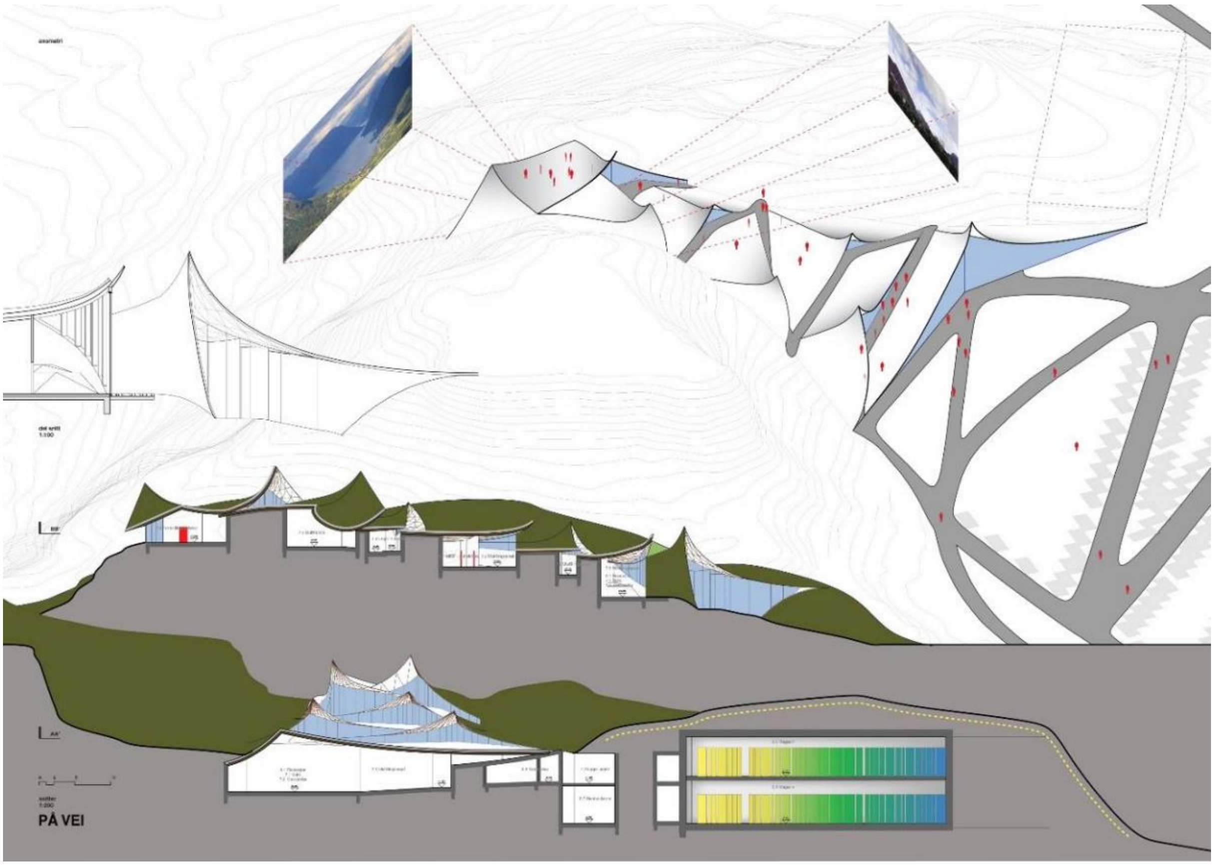

Figure 17: The På vei project, from up to down: axonometry, detail and sections. Please notice the onion principle of bio-climatic layers in detail in the upper sections (Davidová, 2016a; Davidová & Uygan, 2017) (competition entry by Collaborative Collective 2011).

Figure 18: Ray 2 Responsive Wood Envelope Prototype a) in Semi-Dry April Weather When the Screen is Partly Open for Boundary Exchange between Exterior and Semi-Interior; b) After April Light Rain When the System is Closed, Not Allowing the Humid and Cold Air to Pass through the Boundary; Both after Four Years of Being Exposed to Weather and Biotic Conditions. The prototype became inhabited by blue stain fungi, algae and lichen. These, especially the algae, are regulating the moisture content of the wood, thus co-causing its warping. Notice also the organisation of algae habitation caused by the material's fibre direction and position within the design, which is affected by material performance and form. Thus, it is organised through its moisture and the organism's abundance and distribution interaction (Davidová, 2017) (photo: Davidová 2017).

Responsive Transformer Project

A Responsive Transformer competition entry by Collaborative Collective (architecture), Experis DSKM (engineering) and CooLAND (landscape ecology) is a bio-robotic architectural project for the administrative centre of the Forests of the Czech Republic. It is a small landscape urbanism project, which consists of responsive bio-robotic cells. These organise themselves based on environmental or social conditions or other preferences by the position or opening (see Figure 19, Figure 20 and Figure 21). The project follows the concept of *edible landscape* (Adams & Lindsey, 2016; Creasy, 2004), serving a variety of local species, including people. The cells are designed according to the onion principle of bio-climatic layers (see Figure 21). These cover a semi-interior space enveloped with a Ray screen (see Figure 20), climatised space, layer of storage space and green roof with local edible species. Through the joints between them, they can even connect to underground spaces of an underground water reservoir for its use and cooling.

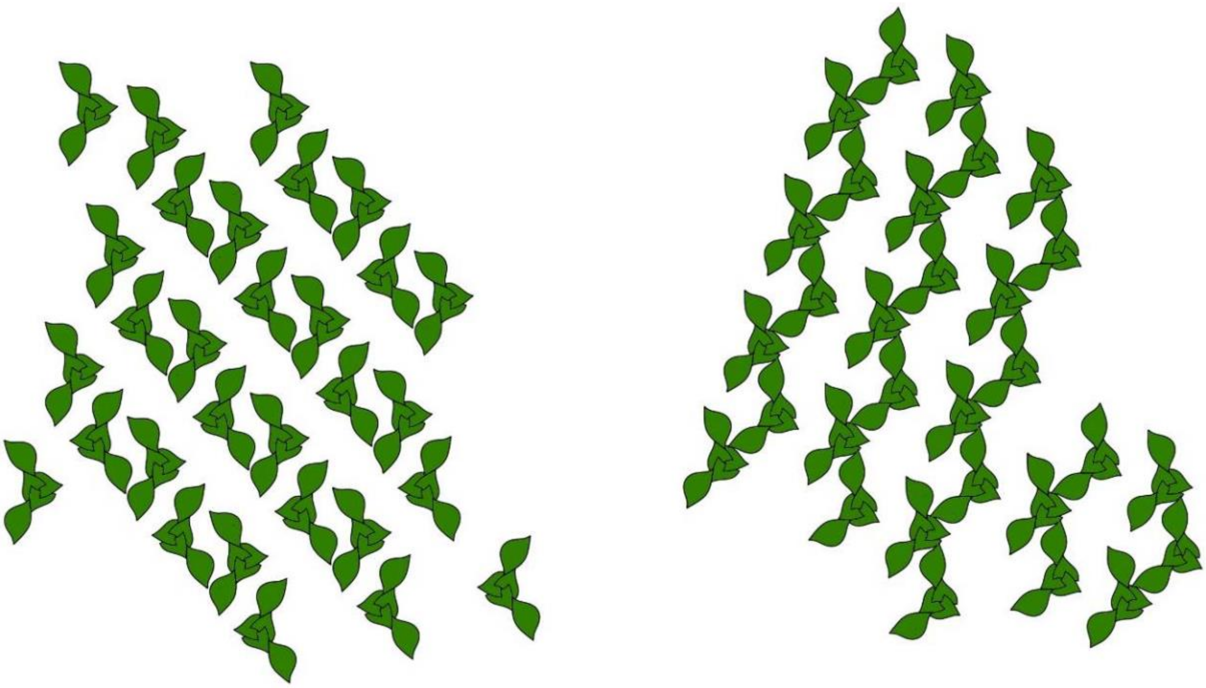

Figure 19: Responsive Transformer: Different Variations of Cell Organisation with Green Roofs (Davidová et al., 2017) (drawing: Collaborative Collective 2016).

The bio-robotic architecture, urbanism and landscape design with bio-climatic layers is thus co-designed with both abiotic and biotic agents, including people. The responsive envelope and green roof also offer shelter to a variety of other species. The aim of this trans-disciplinary design proposal is to turn a designated area into a site of co-design, co-creation and edible co-habitation throughout the eco-system within its use –habitation process, consequently, the targeted zone will turn into a local 'biotope'.[14]

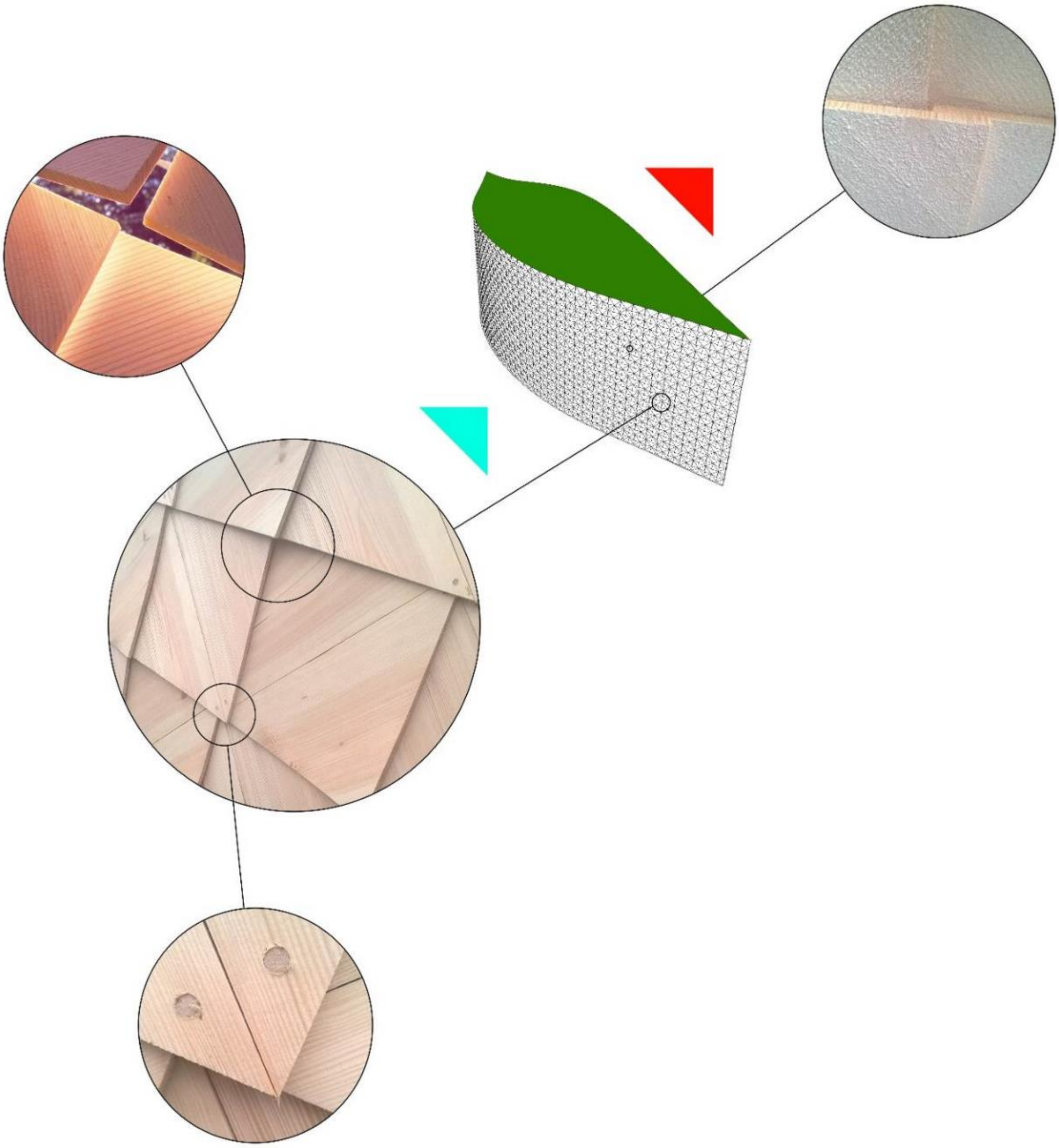

Figure 20: One Cell within Responsive Transformer Competition Entry Showing the Placement of Ray Envelope and Green Surface of Local Species That Produce Edible Goods for Other Species (Davidová, 2017; Davidová et al., 2017) (drawing: Collaborative Collective 2016).

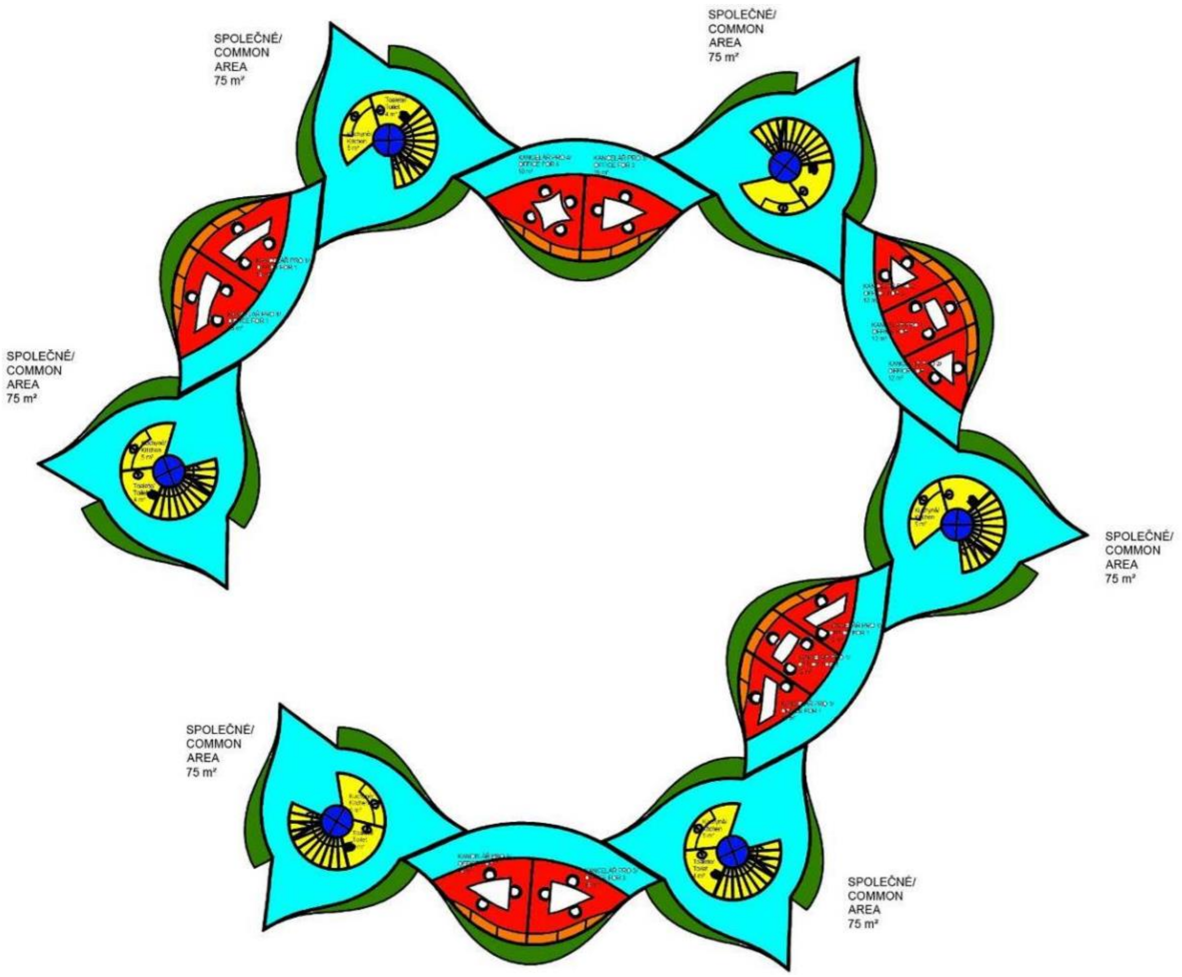

Figure 21: Example of Bio-Climatic Layers of Certain Parts of Cells Composition within Small Urbanism in Responsive Transformer Competition Entry for Administration Complex of the Forests of the Czech Republic. The layers in the cells show green surface roofing, tempering storage space, climatised office space and blue semi-interior space, moderated by a Ray envelope. The joints are equipped with a natural ventilation system from the underground layers of a water reservoir and tempered, infrequently used rooms (Davidová, 2017; Davidová et al., 2017) (drawing: Collaborative Collective 2016).

COLridor and TreeHugger project

The TreeHugger insect hotel (see Figure 22) is an eco-systemic ‘prototypical urban intervention’ (Doherty, 2005) to support a local biotope project called COLridor in the city centre of Prague. It generates micro-climatically heterogeneous spaces for different kinds of insects’ dwellings. This is done due to the different warping of the panels coming from different positions of the tree trunk. The wood, which is cut in tangential sections from the centre of the tree trunk, warps much more than the samples of its edge (Hoadley, 1980). The different kinds of insects choose their specific environmental preference chambers, distributed under the diverse petals along the tree. These are opened to all world axis climates and therefore they offer a better variety of climatic preferences. Behind that space, there is a vegetation layer of the tree as a living insulator and moderator.

The project of COLridor (Davidová & Zímová, 2017), and specifically this insect hotel, is to support the concept of an edible landscape, generating food namely for local bats and birds. We also expect the algae habitation to enrich the site’s performance. Together with the intervention of specially planted seed bombs, which generate honey food for insects, this project interacts with the urban eco-system as a small intervention with a larger impact. This trans-disciplinary community ‘co-design’ is engaging a whole eco-system for the co-creation as well as for co-habitation across biotic and abiotic agents, including human societies of a wide spectrum. This first dwelling application of responsive wood research and Ray project is a part of 'non-anthropocentric architecture', generating urban ecologies.

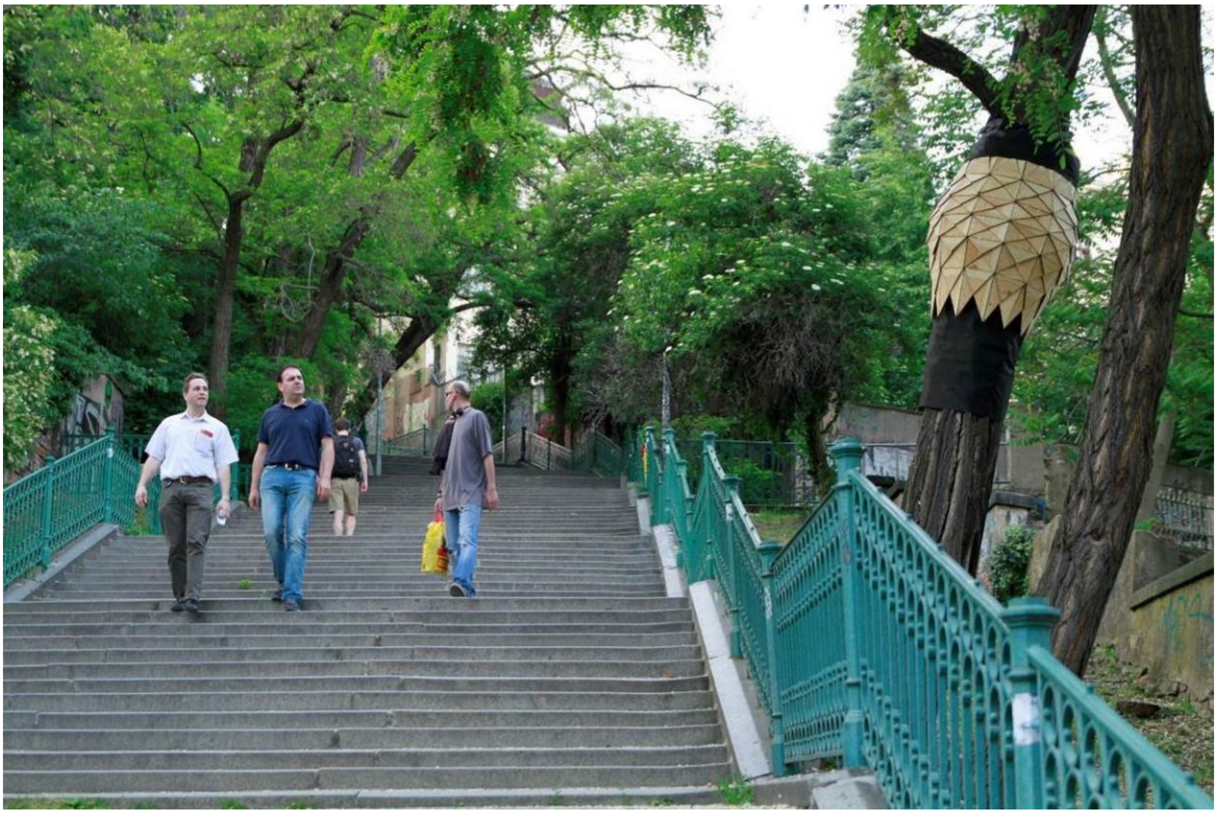

Figure 22: TreeHugger: Responsive Wood Insect Hotel. Please, notice the social communication engagement of people and the insect habitation architecture (Collaborative Collective, CooLAND, FUA TUL, FLD CZU and the Community 2017) (photo: Carrithers 2017).

Discussion and conclusions

From the registering of traditional dwellings from extreme climates, it is apparent that buildings have long been used to adapt to local environmental change, including climate, biodiversity, societies, fashions, politics, and so forth. These final products and prototypes were tested and developed over generations. This same technique seems to be applied in today's Time Based Design (Sevaldson, 2001) field for designers. As of now, Systems Oriented Design (Sevaldson, 2013b) is the most advanced method for developing the synergy of such complex thinking and design concepts. We argue for the architectural ecologies and environment extension and fusion into an eco-systemic, time-based co-design that involves all-environmental agency over time through full-scale prototyping/production interventions. This methodology, which takes place during the same time process and over the evolving result, we call SAAP.

Facing the ongoing decrease of biodiversity and natural resources and climate change, we conclude that our contemporary practises have to adapt their design processes and the existing dwellings need to be rebuild, not demolished and built again. When facing another eco-systemic shift of species from overly toxic agricultural land to the cities, only the engagement of the overall eco-system, which means to make a shift from the anthropo-centric perspective, can lead to the flourishing of a sustainable environment for all. The 2030 UN Agenda for Sustainable Development (United Nations, 2015) defines its goals as being for a) sustainable cities and communities and b) life on land – without cross-referencing (United Nations, 2016a, 2016b). However, we cannot agree with this proposal. In the view of the emerging ecological studies, the existing barriers within the land are seriously degrading and perhaps ruining the eco-system (Begon, Harper, & Townsend, 2006). Our research investigations show that at one time, especially communities with weather extremes would co-create and co-habit their dwellings and land, either in symbiosis or as an exploitation of other species and other environmental agents.

The first of the proposals described below, a more single-focused system, engaging its participants on the personal phenomenological psychological level, seems to perform in even broader relations and scale. It can employ architectural, urban and landscape design for eco-systemic co-design, co-creation and co-habitation. This eco-systemic interaction involves also food and shelter resources. The examples cover psychological treatment, cultural buildings, administration buildings and dwellings. All of these proposals discuss the necessity of boundary exchange and interaction with the biotic and abiotic environment.

From the detailed human adaptation to a phenomenological and psychological perspective, equally, as the artist Zuzana Füsterová captures from the resonance of the darkness and the light in her photographs, the in-between situations, it is possible to interpret the atmospheres of semi-interior spaces such as svalgangs and skuts. The user is indoor and outdoor at the same time, experiencing the space in such conditions as sunrise after deep night. The consciousness that such an experience can generate in a person can be represented by anechoic space that focuses on sensory deprivation. James Turrell explores sensory deprivation in his installations by increasing the intensity of reaction of the viewer. In its current form, however, darkness therapy does not focus on such transitions. As described in their study, Malůš, Kupka and Dostál mention only the use of sunglasses for adapting to a different environmental complexity (Malůš, Kupka, & Dostál, 2016). As shown in the work of the mentioned artists as well as the second author's first-person phenomenological experience, this seems to be a very weak point of such treatment. Therefore, we propose the extension of these enclosed spaces into an onion principle by non-discrete spaces with environmental penetration for personal psychological as well as physical environment and climate change adaptation.

The På vei project proposes climatic, social, phenomenological and artefacts preserving performance, while offering space and ground for habitation for several species. In fact, it is a landscape design, layering the landscape and the ground, opening penetration to the rest of the environment. The Responsive Transformer concept fuses the interaction of the social, engineering and biodiversity aspects. It is based on the bionics and biodiversity concept, which has an extension into the eco-system (Barthlott, Rafiqpoor, & Erdelen, 2016) and eco-social-systems. The TreeHugger project supports a weak biotope on the transition path of a local bio-corridor system within the city centre. The project claims that we have to generate penetration within the ecological boundaries of the city's built environment.

In a similar setting in which tools were stored and working, social, spiritual, communication and sheltering environments in svalgangs and/or skuts were generated by earlier generations, we claim that the environments of eco-systems have a need for such synergies. Thus, we claim that research by design has to be trans-disciplinary and across many fields from the humanities and natural sciences in the same way these exemplified projects were created. The disciplines ranged from environmental humanities, psychology and psychiatry, art and art preservation, service design, robotics and civil engineering, meteorology and climate studies, material sciences, architecture, landscape architecture and landscape ecology to agriculture. We consider this 'Rich Design Research Space' (Sevaldson, 2008) involving 'Bio-Climatic Layers of Built Environment' engaged in the SAAP processes/results-based field as a true participation within our environment. Therefore, we believe, we can generate conditions that can perform as boundaries, but those can be penetrable and engaging the eco-systemic agency, while offering co-performative and co-habitational opportunities of use; in other words, the Allopoietic Interventions.

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[1] The word agency is in this text used in the meaning defined by the Oxford Dictionary as an 'Action or intervention producing a particular effect.' Example: 'canals carved by the agency of running water' (Oxford University Press, 2018)

[2] Previously, there has been a large discussion and promotion, largely lead by Patrik Schumacher, of architecture's autonomy, the 'autopoietic system' (Schumacher, 2002).

[3] The difference between *participatory design* and *co-design* was discussed by Sanders and Stappers: The participation is meant as such that the related stakeholders are invited to the discussion board, while co-design means co-creation where the stakeholders play a creative active role within the design process as co-authors (Sanders & Stappers, 2008).

[4] 'Service design as a practice generally results in the design of systems and processes aimed at providing a holistic service to the user. This cross-disciplinary practice combines numerous skills in design, management and process engineering. Services have existed and have been organised in various forms since time immemorial. However, consciously designed services that incorporate new business models are empathetic to user needs and attempt to create new socio-economic value in society. Service design is essential in a knowledge driven economy.' (Copenhagen Institute of Interaction Design, 2008; Stickdorn & Schneider, 2011)

[7] Responsive Wood: Wood that moves based on its hygroscopicity, occurring due to change of moisture and temperature in its surrounding environment.

[8] 'The conditions for practice-based research to be successful are embedded in the individual experience of the practitioner, hence the term "first-person practitioner research".' (Sevaldson, 2005)

[9] 'The time-based approach leads towards understanding action, performance and life cycles.' (Sevaldson, 2005)

[10] Note: Performance in architecture (therefore Performance Oriented Architecture) was reformulated by Hensel in 2010 as a *'reconsolidation of form and function into synergy of dynamics of natural, cultural and social environments'*. (Hensel, 2010)

[11] Timber: a sound property of materials and their spatial organization. (Erickson, 1975)

[12] Eco-systems Phenomenology is contrasting analytical processes that are dissecting that which is whole, probing that which is small, and looking for causes in component parts (Ulanowicz, 1988).

[13] Items with an undefined function can be created so that they generate a variety of opportunities of use. As opposed to a chair – an object with a predefined function for sitting – a landscape gives you many more undefined opportunities of use: sitting, lying, walking, etc. (Sevaldson, 2017)

[14] 'Biotope: A region that has a characteristic set of environmental conditions and consequently a particular type of fauna and flora (biota).' (Oxford University Press, 2004)

'Biotope: An environmental region characterized by certain conditions and populated by a characteristic *biota.' (Allaby, 1998)