Co-Habited, Co-Lived, Co-Designed and Co-Created Eco-Systemic Responsiveness in Systemic Approach to Architectural Performance:

A Case Study on Interaction of Performative Solid Wood Envelope Ray and Algae

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Abstract. This paper discusses a wider range of agents in responsive wood performance problematique. This is done through an example of prototyped envelope Ray (see Figure 1) that circulates air in dry warm settings and encloses itself in humid and cold micro-climatic conditions (see Figure 2). The envelope is to be applied on semi-interior or unclimatised spaces of a built environment while securing home to various residents (see Figure 3, Figure 7 and Figure 8). The commonly known factors of wood warping are its ambient air relative humidity and temperature. This research claims that the situation can be more complex and that the performance can be co-habited, co-lived, co-designed and co-created with more abiotic and biotic agents. This involves life preferences and social agendas across the species of the biotic part. This co-creative design process that has over-evolving results leads me to ratification of a new design field: **Systemic Approach to Architectural Performance.**

Keywords. systemic approach to architectural performance; responsive wood; co-design; performance oriented architecture; time based design

Figure 1: 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 got inhabited by Blue Stein Fungi, Algae and Lichen. These, namely the algae, are regulating the moisture content of 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 that is affected by material performance and form. Thus it is organised through its moisture and the organism's abundance and distribution interaction (photos: Davidová 2017)

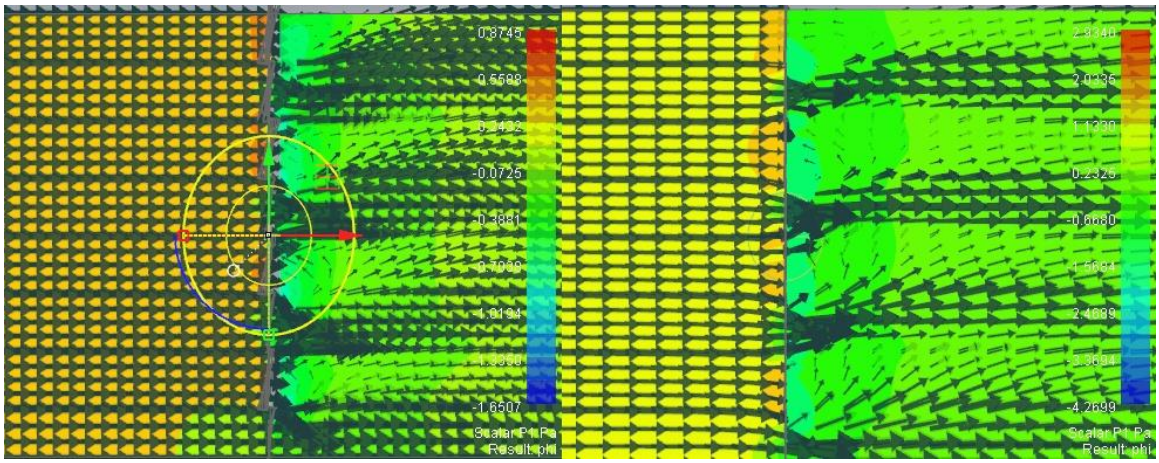

Figure 2: RhinoCFD Fluid Dynamics Simulations Illustrating the Exchange between Exterior and Semi-Interior Spaces through Ray Envelope; a) to the left: situation of dry and hot weather when the screen is open; b) to the right: situation with higher humidity and low temperature (simulation: Davidová 2017)

Introduction

The present research on responsive1 solid pine wood focuses on a wider consideration of material-environment2 interaction. Wood is one of the most important renewable building materials, which has, thanks to its biological basis, specific properties. These include primarily its hygroscopicity, the interaction of the material with relative humidity and temperature for getting into its equilibrium moisture content. This research not only extends the current times of first responsive wood research on laminates and ply-wood founded by Michael Hensel and Achim Menges3 for the solid wood in tangential section exploration, but it also takes into consideration other species that can interact with it. Wood warps, expands and contracts depending on relative humidity, temperature or other moisture suction of the surrounding environment. The warping of the tangential section generates a so-called 'cup' across the grain thanks to the different fibre density on the left and right side of the sample (Knight 1961). This feature can be used for organizations of individual components into systems that respond to such stimuli for our benefit. Therefore, systems are operated through their primary energy use, without the need for electricity. The Environment Responsive Screen Ray (see Figure 1) proposed by the author is to be applied for semi-interior spaces of human dwellings, airing in hot dry weather and enclosing the space in high relative humidity and low temperature. Such a system enables boundary exchange (Addington & Schodek 2005; Addington 2009) between the outdoor and unclimatised indoor environment (see Figure 2) that is further

1 'responsive suggests mutual reaction and exchange, with adjustments occurring continually on both sides of the use equation.' (Hookway & Perry 2006)

2 'Environment is physical and biological surroundings of an organism. The environment covers non-living (abiotic) factors such as temperature, soil, atmosphere and radiation, and also living (biotic) organisms such as plants, microorganisms and animals.' (Oxford University Press 2004)

3 First current times responsive wood prototype was built by Asif Amir Khan at AA School of Architecture in 2005 under the leadership of Michael Hensel and Achim Menges. This work has been first published in Morpho-Ecologies publication in 2006 (Hensel & Menges 2006).

moderated by climatic heterogeneity of other ambient spaces (Hensel et al. 2009)4. It performs in its over-evolving co-design5 with its surrounding micro-climatic and biotic environment. Unlike the bioLogic, which discusses synthetic biology for hygromorphic transformation actuation that is to be fully programmed by humans for human-computer interaction (Yao et al. 2015), this exploratory paper discusses co-living, co-design and lived co-creation with other species and abiotic agents within eco-system6. This also means that the research is not focusing on synthetic biological fabrication such as Araya et al. (Araya et al. 2012) but on generating ground that is further inhabited and lived by biotic organisms on their own will based on their local specificity.

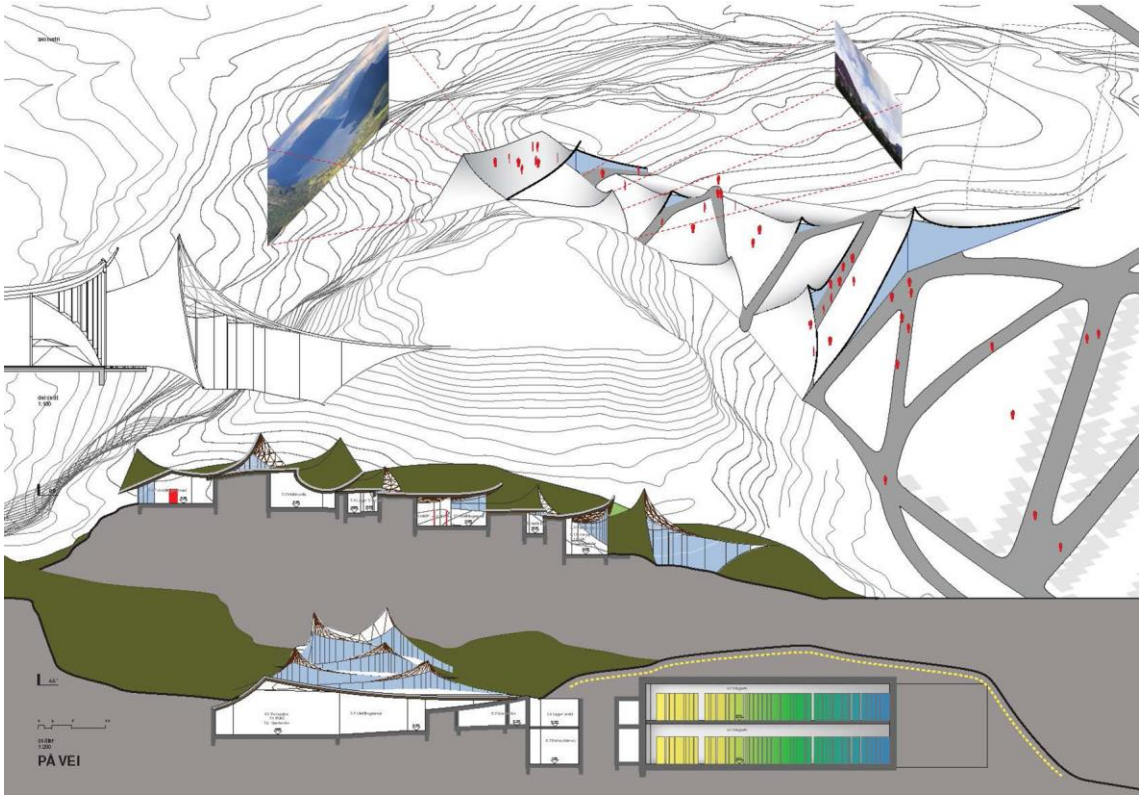

Figure 3: På Vei Competition Entry for Vernacular Craft Museum and Gallery Complex by Collaborative Collective exhibits heterogeneity of different climates of the building proposal. These vary from climatised office and archive spaces insulated by ground and green roof, semi-interiorto a non-climatised gallery path to be moderated by ambient heat leakage from the offices, and an exterior climate through responsive envelope Ray with the outdoor gallery path to see the exhibits through Ray in pleasant weather. (Collaborative Collective 2011)

4 Please, see the architectural project På Vei by Collaborative Collective at Figure 3 as a simple example of such spaces, layered in the onion principle (Davidová 2016a; Davidová et al. 2017; Davidová 2016b).

5 Co-design and participatory design was explained by Sanders and Stappers, considering only humans. Co-design means co-creation of stakeholders while participation their involvement into the discussion of the design with the possibility of considering their comments (Sanders & Stappers 2008).

6 Ecosystem was described by Allen and Roberts as an ecological system inside the system that includes the geophysical part (Allen & Roberts 1993).

Explorations

Figure 4: Samples of Artificial Growth of Apatococcus and Klebsormidium (from up to down) on a) Ash; b) False Acacia and c) Pine Wood from - Left to Right, Respectively (photo: Davidová 2013)

The original synthetic tests performed on growing algae on wood samples (see Figure 4) were not as successful as exposing the prototypes to a living environment with its local natural inhabitants. The results were obtained by giving a completely free hand to the ambient eco-system. The habitation of other species was speculated but not programmed. Through my speculative observations, algae habitation on wood affects its moisture content approximately by two to four percent in average relative humidity (see Figure 5). In high relative humidity and low temperatures after light rain it can differ by up to ten procent (see Figure 6). Its habitation in a wooden environment responsive screen Ray 2 seems to distribute along the grain at its moistest areas (see Figure 1). This seems to have an effect on the material's warping as its edge part across the grain, where the algae distribution appears, is more sucked out of its moisture. The warping on Ray 2 prototype, with its 30cm height of the panel's triangle, differs by one centimetre in 15°C and 50% relative humidity with higher deformation for the panels with algae. This performance is namely important at the moments with very high moisture, when the algae regulate the warping in the opposite direction. Also, the support of positive warping in arid conditions is very relevant. At the same time, it has been stated by consulting algologists that no local algae will live in the environment under 30% of air relative humidity when exposed to solar radiation. This is very often the case of the placement of prototype Ray, often even being exposed to direct sun. It seems that through the wood's moisture content distribution with its sorption over humid nights and its evaporation over arid summer afternoons, the algae receives sufficient humidity. This concept of performance is common in human settlements from arid regions through so called Oriental wood lattice screens called *mashrabīyas* (Fathy 1986) and is applicable to diverse species. Thus, the algae co-designs and co-creates the human pre-concept and speculation of prototype's environmental interaction as well as its outlook through its co-living and co-habitation. While Carole Collet discusses co-design with fungus when the organism creates a design pattern and the design process is ended by humans by baking the material thus killing the fungus7, this design-research is a 'non-anthropocentric' (Hensel 2013) ever-evolving eco-systemic responsive 'Time Based Design' (Sevaldson 2004; Sevaldson 2017).

7 Carole Collet's public lecture at the Academy of Art, Architecture and Design in Prague 28.11. 2016

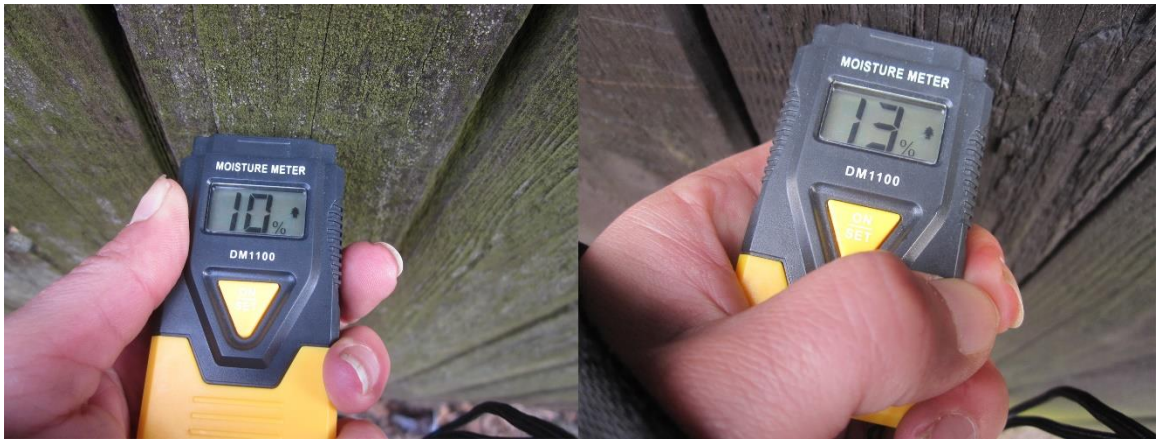

Figure 5: Initial speculation proof on fence with and without Algae Measured with Moisture Meter in Nové Město nad Metují (photo: Davidová 2013)

Figure 6: Moisture Content of Panels of Prototype Ray 2 with and without Algae in 8°C and 66% Relative Humidity after light April Rain (photo: Davidová 2017)

This means that this work does not have the ambition to be fully pre-programmed. The non-living biological material of pine wood attracts the habitation of living non-decaying species whose habitation distributes according to weather-material morphology interaction. The more solar radiation, air humidity and CO2 are absorbed and also released by these organisms, the more they distribute. This also generates an increase in their abundance. The decaying species are not attracted to pine wood for its highly acidic composition with high amounts of resin. However, the prototype Ray 3 went through salt water soaking of the material. This process removes sugar and amyl from it, thus it does not attract decaying organisms that subsist from these nutrients. This prototype is quite new and is in waiting to be inhabited by biotic agents. Until now, it has mainly performed on its abiotic basis. Therefore, these screens develop over time, not only serving for human settlements.

Visions of Application

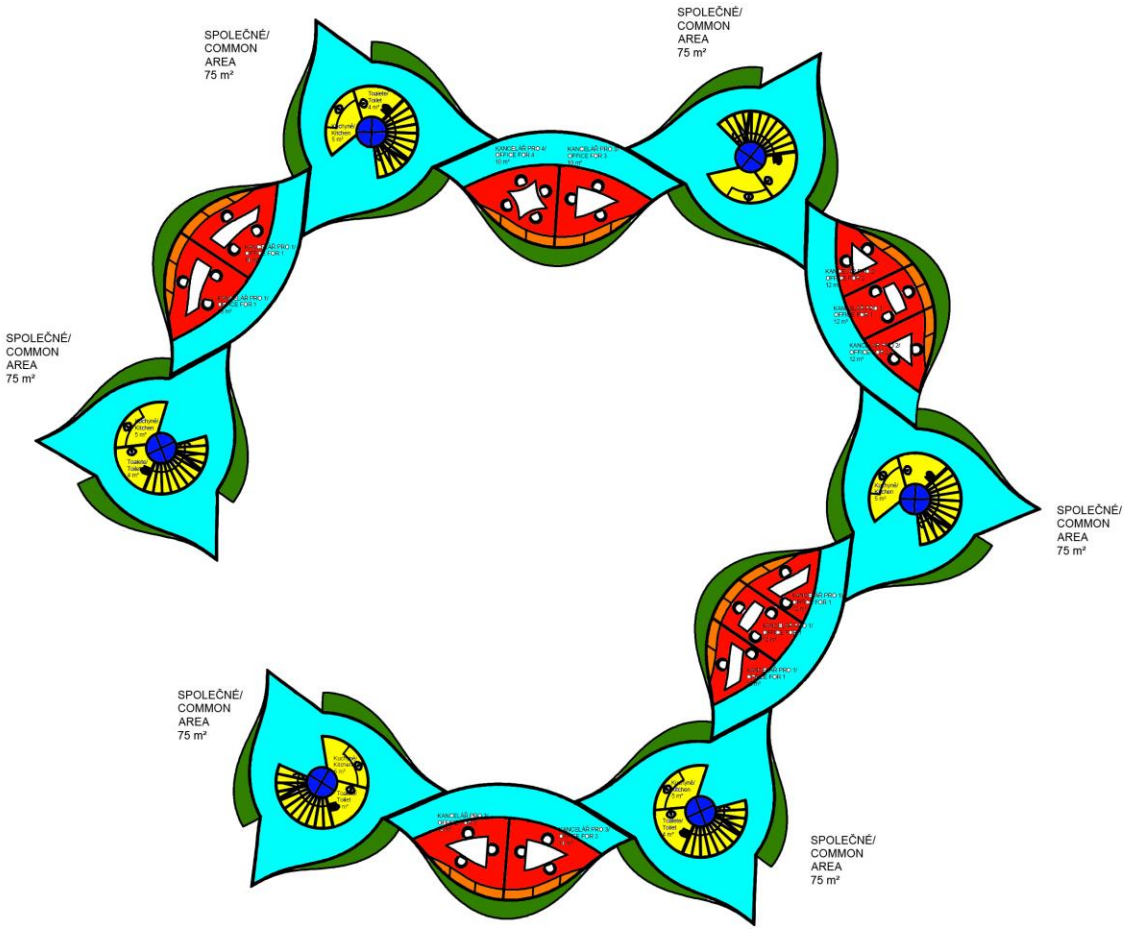

Figure 7: Example of Bio-Climatic Layers of Certain Part of Cells Composition within Small Urbanism in Responsive Transformer Competition Entry for Administration Complex of the Forests of the Czech Republic. The layers in the cells show green surface roofing, tempering storage space, climatised office space and blue semi-interior space, moderated by Ray envelope. The joints are equipped with natural ventilation system from the underground layers of a water reservoir and tempered unfrequently used rooms (Davidová et al. 2017)*. (Collaborative Collective 2016)*

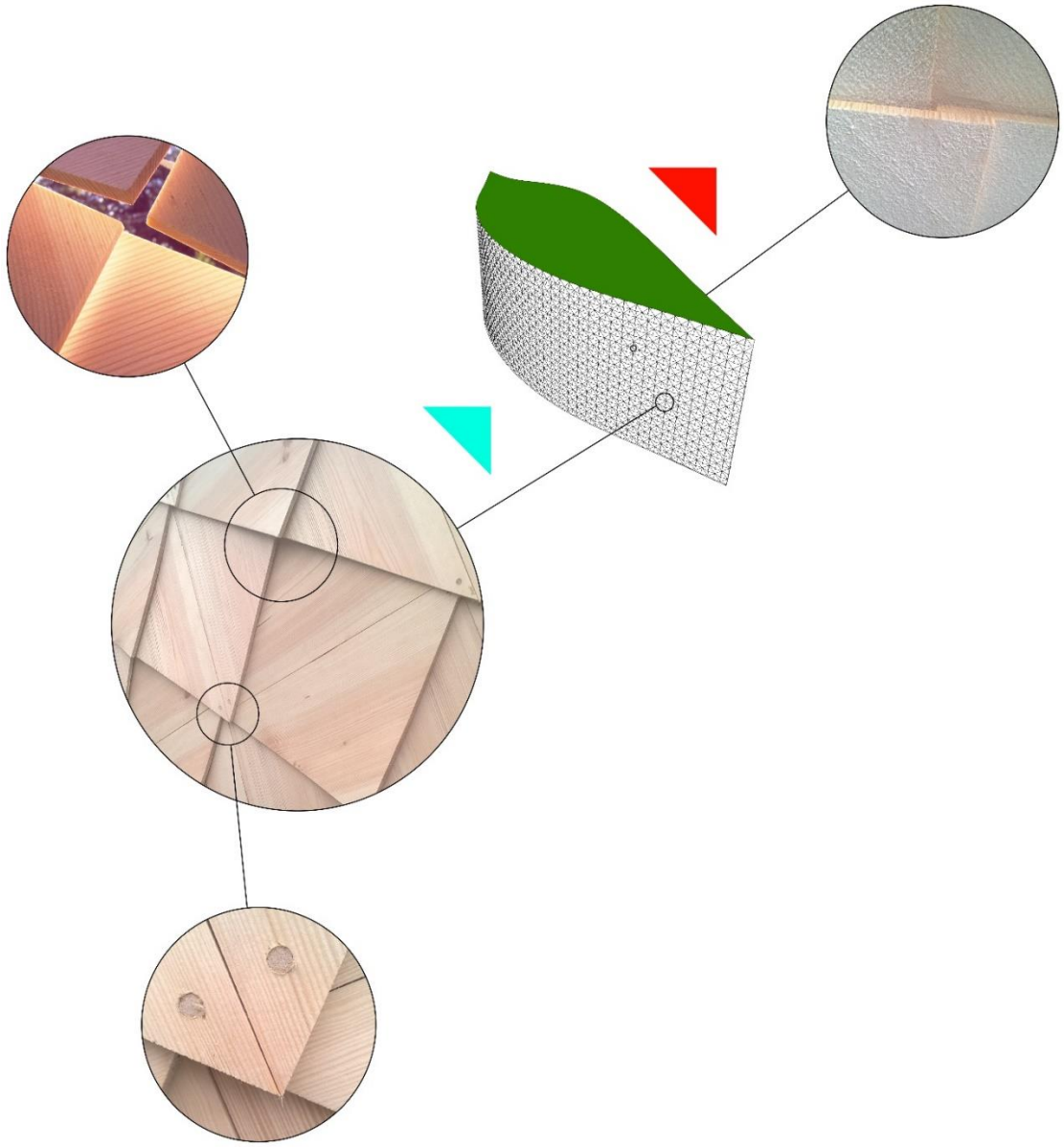

Figure 8: One Cell within Responsive Transformer Competition Entry Showing the Placement of Ray Envelope and Green surface of Local Species that Produce Edible Goods for Other Species (Collaborative Collective 2016)

The Ray envelope is to be applied within larger complexity of *bio-climatic layers* (Davidová & Uygan 2017) of a built environment. This concept employs biotic and abiotic agents within heterogeneous environments serving for co-habitation and co-living interaction. The transdisciplinary competition entry by Collaborative Collective /architects (Collaborative Collective 2012; Collaborative Collective 2016), Experis DSKM /structural and mechanical engineers (Experis DSKM 2012; Experis DSKM 2016)and CooLAND /landscape ecologists (CooLAND 2016a; CooLAND 2016b): Responsive Transformer introduced such layers to today's architectural practices (see Figure 7 and Figure 8). This involved the concept of heterogeneous micro-climates, distributing from an underground water reservoir, through large gradients of layers with semi-interior space being penetrable for biotic and abiotic agents through envelope Ray.

Extending to its exterior while being inhabited by edible plants and adjacent animals and providing an edible landscape for a variety of species, including humans and social co-designing interaction for the overall eco-system (Davidová et al. 2017). One more layer of algae, being a layer as well as habitant and designer, can serve as a climatic and pollution moderator within the system, generating a liveable environment for other species.

Discussion and Conclusions

Overall, such an environment also generates rich human personal and social situations for co-living and another co-creation through its psychological and climate comfort, and understanding of one's belonging to biosphere8. Such non-anthropocentric, process based co-design is always beneficial to all, including humans (Davidová 2016b). This can be observed in recent history that through human centrism, focused on short term results, a substantial part of our living environment was destroyed, which leads us to discuss this current crisis. To co-live and co-habitate with other species and the entire eco-system while co-generating our living environment introduces a new vision to co-creation of architectural design, when the design also gives life and involves social-systems to support suitable, interactive and edible environment. After all, this also involves fauna-generated CO2 pollution, produced by human activity and agriculture that can be consumed namely by algae and also by other flora. However, algae's operative living conditions offer more than that. Its moderation of the ambient environment can co-create speculative architectural performance together with the human based design, micro-climate and other factors. This case studied algae specie is a full member and co-habitant of such processes, which involve its distribution and abundance. This means that the algae are reproduced thanks to the design, material and its ambient environmental factors, such as climate and other species. In addition, the specie is purely local specific, being proposed and applied by the present eco-system that takes part in the co-designing game. Thus, these ‘performance-oriented design’9 processes are feedback10 looping, when the result is unprogrammable and not really predictable. The initial designer's intention here to be claimed is only the speculation of systemic performance. This collective eco-systemic responsive co-design, where the result is an ongoing process, led me to ratification of new design field: **Systemic Approach to Architectural Performance**.
Co-design in a certain sense has been always involved in the architectural design process as architects often have to co-create with their clients. At the moment, architecture slowly opens itself for a bit more extended transdisciplinarity and participation, unfortunately focusing on biomimicry systems rather than on life biological creations themselves. This

8 Biosphere is ‘irregularly shaped envelope of the earth's air, water, and land encompassing the heights and depths at which living things exist. The biosphere is a closed and self-regulating system (see ecology), sustained by grand-scale cycles of energy and of materials—in particular, carbon, oxygen, nitrogen, certain minerals, and water. The fundamental recycling processes are photosynthesis, respiration, and the fixing of nitrogen by certain bacteria. Disruption of basic ecological activities in the biosphere can result from pollution.’ (Lagasse & Columbia University 2016)

9 ‘Performance-oriented Design is a research area dedicated to the formulation of an inclusive to design design based on the interaction between the different domains of agency that make up the human environment.‘ (Hensel 2015)

10 ‘The feedback principle: The result of behaviour is always scanned and its successes or failure modifies future behaviour.’ (Skyttner 2005)

exploratory paper states that this is not enough. We need to co-design the performance in real time with the overall eco-system and its biotic and abiotic agents. This involves various disciplines, living species and climatic agents.

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