Managing complexity in Bio-design practice

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Abstract. Bio-design is a field where design and biology work together: Bio-designers can take inspirational sources, principles and strategies from the environment to imagine new products or find ways to connect people. This approach is suitable in fragile environments, providing innovation independent of location and technology level, given its foundations on self-evolving nature. Innovation is introduced through the detection of local peculiarities, even in the absence of a structured socio-technical system. Bio-designers borrow strategies and solutions that provide multidisciplinary innovation and network diffusion. This is usually necessary because designers build their works within complexity and sort complex information. In this paper, we explore how complex information management evolves in the field of Bio-design. Complexity originates mainly from human and socio-cultural aspects. In case studies regarding the emerging countries, we show that a practical approach derived from Participatory Design can develop new solutions to include marginalized people and invigorate economy, supporting development. Each application field is an experience of its own, being the feasibility of collaboration practices extremely variable: certain customs and religious beliefs can limit people's willingness to share opinions, whereas different local ethics can promote a participatory approach to development. Here, communication tools are crucial to make every stakeholder properly understand his role. We take into account communication strategies for involving users and other kinds of stakeholders into Participatory Design projects within the Bio-design approach. Other case studies concern a product space analysis within complex economic systems, translational tools to share information between scientists and designers, and divulgative approaches to explain Bio-design to the people. The goal of the paper is to determine how complexity is faced within bio-design, combining strategies from scientists and designers.

Keywords: Bio-design / transdisciplinarity / ecosystems

1 Introduction

In this paper, we define the concept of Bio-design, a novel approach to design whose aim is to embrace, and not to fight, complexity.

Design specifies objects, intended to accomplish goals, in a particular environment, using a set of primitive components, satisfying a set of requirements, subject to constraints. By its very definition, design is a process that has to deal with a large amount of factors: goals, environments, communities, components, requirements and constraints. Human progress has greatly enlarged each of these factors: technology gives us more goals and components; we have access to more diverse and evolving environments and constraints; requirements are continuously pushed to the edge.

In this present scenario complexity arises. Complexity is the fundamental property of complex systems, systems for which the global behavior cannot be understood by the behavior of the single parts composing it [1]. We unveiled the presence of complex systems in many aspects of our world. Complexity theory [2] now percolates throughout many disciplines. Examples are ecosystem analysis, where patterns like nested structures of species and ecosystems [3] and food webs [4] show the huge repercussions of small changes in the nexus of interacting biological elements. This causes a paradigm shift in contemporary natural sciences [5], together with a new conception of nature-culture relationships, acknowledging the human dependency on a healthy biosphere [6] and the vision of "nature as culture", aiming to re-establish an intrinsic human connection with nature [7]. The same paradigm shift happens across other disciplines: equivalent nested pattern of ecosystem can be found in the ecology of international trade [8] and in the micro-behavior of supermarket customers [9].

Design cannot be considered immune to this paramount paradigm shift. It has to morph into the Bio-design concept that we present here. By its very definition we have presented, design is intrinsically a process characterized by complexity. According to Ken Friedman, *"design is not central but is part of a network that can regulate the network itself"* [10]. Designers often act in a parasitic way: design solutions emerge and give results when working together with other disciplines. Mediating these disciplines is complex, and it is much more so when these disciplines are marked by complexity themselves.

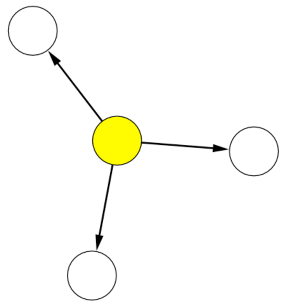

Fig. 1. A small directed graph representing a network

Mentioning networks is not by accident. Complex networks are one of the principal tools used to tame complexity [11], and one of the central aspects of Bio-design. Networks are used to map the interactions between entities, even many interactions at the same time [12], and they have been used to demonstrate the emergence of ubiquitous complexity in many fields: social relationships, technological networks and biological networks all show the same patterns of scale free connections and bursts of activity. In Fig. 1 we provide a small example of a network, where we can see how entities are represented as nodes (circles) and they are connected with edges if they are interacting. Rich information like the direction of an asymmetrical relationship and node attributes can be included in the model (in this example, with arrow heads and colors).

A paradigmatic example of complex network usage is in networks of scientific collaborations. An objective inter-textual analysis based on the papers presented to the SEAD Network was used to build project networks involving scientists, engineers, artists and designers. In these networks, scientists-engineers are not recognizable from artists, whereas designers are. *"[Designers] overcome the non-separation, acting as hybrids and standing out as network hubs: they reveal to have more connections than expected by chance alone [...] they are probably better at collaborating with each other, [...] they could also collaborate with artists and scientists at the same time, bridging the gap between the two cultures"* [13].

We now present in detail what Bio-design is, and how it represents a promising way to overcome the resistance to complexity.

2 The Bio-design methodology

2.1 Approach

As hubs and connectors, designers deal with complex project networks and environmental complexity around the design goals, including socio-technological factors. It has been proved that these issues can be faced with laws coming from the biological field, such as metabolic laws and tools for ecosystem analysis.

The Bio-design approach emerges as a design methodology based on nature, whose expertise can be used for design purposes. It can be defined as a project philosophy and strategy that poses its basis on a participatory relationship with nature, as environment and the design object are part of the same complex system. Both in individual designs and complex systems, growth, effective settlement and long-term stability have to be driven by collaborative networks [14] along with competition. The connection is then approached in a collaborative perspective: nature can provide design solutions as well as design material. According to Bio-design, nature and design should have a mutual connection and a tight grade of coexistence, thus design goals can be part of natural phenomena and natural processes can support design.

Its methodology allows projects to be set up and sustained by the ecosystem where they take place, integrating into its metabolic balance. Metabolic qualities of homeostasis and system coexistence can become design criteria and generate tools to improve participatory design by adding a complete environment awareness.

2.2 Solution space

The Bio-design approach aims to overcome the difference between man-made and natural designs, by exploring a solution space drawn by multiple axes of symbiotic qualities and integrating principles of evolution, metabolism and stable conditions within ecosystems. According to the “bio-thinking” approach, meeting values of safety, cyclicality and “solar” sources of energy[1] means to reach bio-compatibility. When having to meet complexity, the solution coordinates have to be set within a more articulate, trans-dimensional space, where different goals unify to set an optimal area of transdisciplinary bio-compatibiliy, constantly repositioning itself over time and over change.

The dynamics of optimal Bio-design require project goals to undergo continuous variations. The goals move from reaching stability through constancy, within a set of changing parameters in a constant environment; to reach stability through change, within changing parameters in a transdisciplinary evolving space. This model is deeply based on the idea of fitness constraining adaptation and the allostatic model, as an alternative to homeostatic regulation under stable environmental laws [15] and allows to improve the definition of the design goals coordinates by enriching their space definitions, thus enclosing the focus in a more contextualized space.

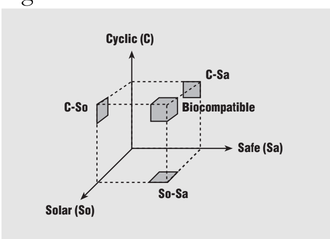

Fig. 2. The ‘bio-thinking’ Bio-design solution space (Datschefski, 1999)

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[1] Energy sources can be defined 'solar' only when all the energy and materials flows are powered by photosynthesis, muscles or renewable energy [16].

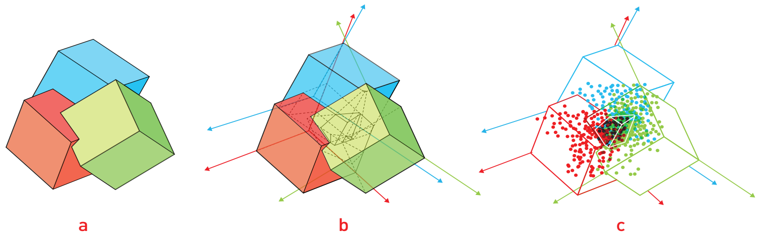

Fig. 3. Transdimensional solution space model:
different disciplinary values are involved (a), identifying a common space (b); the more complex is the space, the more precise is the solution level of definition (c)

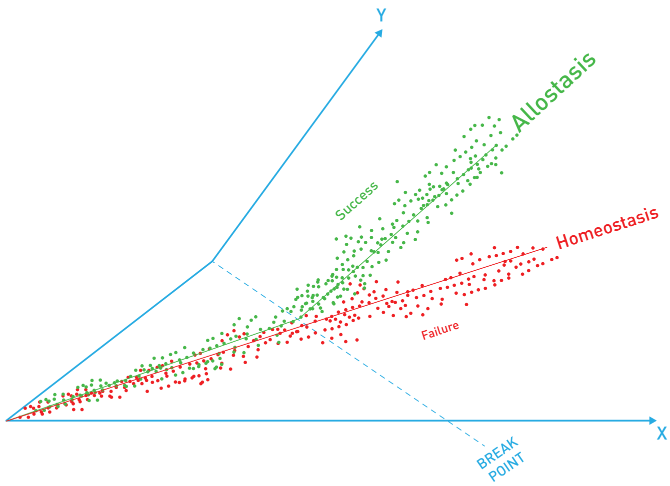

Fig. 4. The allostatic model: stability through change

2.3 Environmental factors

In socio-eco-systems, multiple factors intervene at the same time, often unpredictably. Environmental factors are complex to gather and express, and their relationship with the final effects involving single artifacts and people is difficult to find. However, social factors do influence complex behaviors, such as citizenry health. Social disruption causes afflictions such as stroke and heart disease [17]. This can only be understood by overcoming complexity with a systematic approach, as Bio-design does. With the same approach, it has been possible to explain phenomena of apparently overwhelming complexity, such as synesthesia: brain paths rewiring towards a different sensory ability has still to be explained in neuroscientific terms [18] but if we include the external environment as part of a unique experiential process [19] it is clear to understand.

Coincidences are often serendipitous, events linked beyond complexity [20], explainable with an integrated theory of complexity. Bio-design is based upon a comprehension of complex systems derived from the analysis of nature, therefore examples reflecting its methodology can be found even before its theoretical introduction as expressions of success adaptation to complexity and change.

3 Origins and early adopters

The rules of 'good design' have been anticipated by collective design and improvement of archetypal domestic objects. The result was an experience that both design historians and critics call "anonymous design" [21]. This experience has been successful lately, especially with the project and exhibition "Super Normal" by N. Fukasawa and J. Morrison (since 2005). In the same way, the Bio-design methodology has been anticipated by popular wisdom in integrating man-made objects, systems and landscapes into the natural environment as parts of a stable, collaborative system. Many of these projects still exist or find place in the shared memory.

A very early example of successful Bio-design principles implementation can be found in the traditional cave houses in Cappadocia, now protected by Unesco. Constructed by carving rooms into the soft stones of basalt and tufa at the feet of the local mountains, shaped by wind, sand and rain into, letting the rock harden after contact with air, they are still providing a space dynamically integrated into the changing natural environment. Besides reflecting the evolving aesthetics of the local inhabitants, they have been made to protect from harsh climate conditions, ranging from -20°C to nearly 40°C, while keeping the internal temperature almost constant, usually from 7°C to 15°C [22]. Albeit having issues related with the limits of this building technique, such as acoustical comfort and space rigidity, they offer an optimal temperature and air quality and reflect many among the Bio-design principles:

– integrated instead of additive construction
– optimization of the whole instead of maximizing individual parts
– energy saving [23]

– can be recolonized
– mimic and integrates nature's materials (rock and wood)
– have been planned in advance of future, resisting to variations [16]

Along with structures, other examples of an early Bio-design vision can be found in artifacts and functional infrastructures. In Mediterranean countries, especially Syria, Morocco, Spain, Portugal and Italy, the design of water-wheels is almost unchanged since the introduction of the *saqiya* and *noria* archetypes in Egypt from the I century BC. Water-wheels successfully combine nature and technology, optimizing the human gathering of natural resources and setting a dynamic relationship with the environment [24].

Whereas water-wheels have been successful in integrating technical activities with the social life of people, to introduce a socially sustainable water pumping device in the arid regions of Zimbabwe has proven to be a slower process. The so-called "Zimbabwe Bush Pump" has been introduced in the 90s and is a remarkable example of visionary system thinking.

The pump design is successful because entirely thought for the African environment, and not just in terms of climate and soil. It is not the result of any adaptation: it is a device that works well by mechanical adaptability and social participation. It produces innovation by meeting society and promoting local networking forms, by encouraging village level participation while respecting the natural equilibrium.

"Village women push the iron crossbar to drive the auger into the ground, while village men sit on the bar to weigh it down and children dance around" [25].

The successful adaptation of these devices has been expressed with the term *fluidity*, which is not only a stable system network model but a model for dynamic, complex networks and a key value for an allostatic coexistence of technologies in emerging countries. In all the examples shown, the effectiveness of a Bio-design-like methodology is proven by a good, changing relationship with a specific local environment. This has happened also at wider scale after the Industrial Revolution. We witnessed the growth of manufacturing districts as forms of auto-organization [26] towards a symbiotic coexistence of various stakeholders. Another example is Todmorden, a town where in 2008 the inhabitants spontaneously started to work for a viral urban gardening project based on self initiative and cooperation. Like in the case of Italian districts, that have not been able to find a proper spreading strategy worldwide, the main issue to their survival is the scale passage from the local to the global.

4 Local scale

When taking into account the Bio-design methodology application in local contexts, the most insightful case studies come from the emerging countries, where socio-technical systems are less structured and the cultural environment is often different from the common reference model. There, designers can contribute from the first analysis to the development of a stable network. Firstly, society is analyzed as an ecosystem and innovation is foreseen as a metabolic improvement of the whole. Design practice has to set itself the goal of improving the environment it stands in, working in a context of metamorphosis, dealing with change. Society is expected to undergo continuous change, as ecosystems do. Designers should then recognize existing attitudes towards collaboration, like in the case of Ubuntu, a widespread African ethic valorizing the power of communities, collaboration and interdependence [27].

Starting from the local experience of communities, they can start to build networks, to make people collectively participate to innovation processes that they will develop without the necessity of external guidance. Community building can start from local resources, coming from the natural and socio-cultural environment. The Bio-design approach allows these communities to act as networks and to be shaped according to natural laws of collaboration. Social networks are built as allostatic systems, promoting a stable coexistence together with transformation. Network building and management permits innovation by fluidity: in emerging countries, design constraints have to keep flexible limits. Designers should preserve flexibility, as well as nature does.

An example of this can be found in the Shack/Slum Dwellers International[2], where local communities are empowered with technological and organization tools to improve the quality of their lives.

A relevant field study is the one lately conducted in the context of developing a context-based device for enabling children who use prosthetic legs to walk in mud in the rural areas of Cambodia [28]. This research project aims to test Participatory Design methodologies on field, involving marginalized people of different social position, together with doctors and technicians. Whereas they find a structured set of barriers, that they mapped and tried to overcome with the tools of psychological empowerment, the prototypes developed by the participant groups reveal the extreme need for more advanced designs and the big potentialities of emerging countries.

5 Global perspectives

The scale passage from local contexts to global perspectives, along with the origination of complexity from transdisciplinary issues and connections, bring out a critical complexity. Bio-design methodology aims to solve it with an integration of natural strategies and system view. The socio-cultural context is viewed as "natural environment" of the project to be developed. The focus is on making connections and building networks for communication, fostering innovation by removing requirements that would be bonds. This approach puts socio-technical and socio-ecological systems on the same level, with user participation intended as a natural process and not an option, according to a systemic thinking. The quality of design and communication depend on heterogeneous skills, therefore participation is essential and the contribution of Participatory Design tools is an advantage.

There are some limitations. For instance, there are no user participation strategies applicable to specific, local contexts. Also, Bio-designers do not have a clear profile as regulators of transdisciplinary networks yet. Their role is often confused with that of "bio-makers", emerging skilled professionals that can merge nature and design but do not have the disciplinary abilities to deal with different contexts, scale passages and long-term planning. The field of healthcare research is especially relevant because of a critical information flow between designers and doctors/biomedical engineers [29]. Nevertheless, it is promising when taking into account regenerative medicine, where smart materials are being conceived thanks to a Bio-design methodology for applications in devices such as scaffolds [30] and placing designers in the initial phase of research can expand market opportunities [31].

6 Conclusions

In this paper, we presented a new design process called Bio-design: a new design methodology aiming to embrace complexity, rather than fighting it. Bio-design is needed due to the deep level of complexity we currently face.

2 http://www.sdinet.org/

Complex issues have to be solved by transdisciplinary teams and these teams need new paradigm with which operate, and Bio-design is one of them. It is based on the relationship among complexity theory and ecosystems behavior. According to the Bio-design approach, designers can take inspirational sources from nature and its laws, such as the collaborative networks supporting coexistence and the allostatic model, to solve complexity. We presented ancient predecessors of Bio-design, namely anonymous design, environmental architecture and fluid socio-technical structures. We detected in each of these examples the main issue of moving from a local to a global scale, meaning increased complexity. We finally provided the example of Participatory Design, that teaches what are the social barriers to overcome and provides hints to do it through participation, whereas the transdisciplinarity model refines the solution space, helping to clarify the goals.

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