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Projecting the concept of sustainability on the mathematical model of the "fold"

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Abstract

In order to discuss the term Sustainability, we will draw from the field of mathematics, especially differential topology and the model of the Fold which the natural philosopher and mathematician R.Thom introduces during the 70's. R. Thom presents this model as a descriptive model of structural stable or Sustainable productive processes. The terms "differential topology", the area which includes this mathematical model, points out the emergence of a reality in continuous variable state which is considered as the central ontological progress of our time. The model of the "fold" indicates the prevalence of the abstract and complex character of the elementary elements it involves. Thus moving away from a deterministic view and attempting to incorporate unpredictability, randomness and improvisation.

Our aim is to contribute to an understanding of the concept of Sustainability and its impact on the general contemporary cultural context. We will acknowledge the interconnections among different scientific and artistic fields that ultimately converge to the notion of landscape through the contemporary ecological sense that points to energetic, metabolic approaches.

The term sustainability envelops the ability of resilient formations and permanence through the transformations of the underlying structure, finally exhibiting multiple and variable formal results, which seems it can be modeled by the differential topological qualitative approach.

Keywords

Sustainability; topology; imagery; landscape; the fold.

Note

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1. Introduction

We will transfer the discussion on Sustainability in the field of mathematics. We will observe that this "rigid" field seems also to be transformed according to the contemporary worldview that – as we will claim – further refers to a landscape model. The term landscape as perceived today concerns a complex cultural construction, and bares meaning attributed to it through epistemological developments concerning an energetic or "ecological" conception of place. Landscape, is considered as a system that is in a continuous state of change due to the exchanges between the subsystems from which is constituted. This view concerns a concept of "resilience" which allows the overall system to maintain through internal and external adjustments. The overall system maintains basic features of its structure while exhibiting alternative formal appearances – the phenotype – through a dynamic time-sensitive systemic conception. The Systemic conception, examines the flexibility to adaptation of complex structures and not simple objects. Those may also include theoretical constructions and design approaches. Systems theory is linked with the development of the mathematical field of Topology and its current use as research and editing tool to different scientific disciplines. Moreover, systems theory underlies the "ecological" aspect of the landscape.

Topology examines relations (functions) or networks of relations between complex objects considered as elementary. Emphasizing on relations is establishing the condition of homeomorphism and further it concerns about the formation of transitional relations as we will see to be expressed though the "Fold" model.

Through the lens of topological mathematics which is providing the methodological approach of this research, the concept of Sustainability is considered projected on an active substrate of distinctive subthemes with which it begins to associate. For this operation we will use the term mapping, drawn from the field of mathematics and particularly functional analysis. In the field of computation another term might also visualize that approach, the terms "projection mapping". More formally, projection mapping is "the display of an image on a non-flat or non-white surface". Thus we will attempt to map these relations arising from the projection of the term Sustainability, therefore we used the determination "mapping" in individual sections of this article.

The term sustainability in the usual sense largely concerns the interactions between man-made and natural environments and indicates a major concern to maintain and preserve resources that will ensure human living comfort and in the worst case scenario the survival of the planet and its ecosystems. However the concept of sustainability seems to have been expanded so that it can determine correlations among different disciplines from mathematics to theoretical formulations and their cultural environment. Finally results in a multiplicity of expressive approaches both in design practices, especially in the landscape design practices and in the rigid areas of "hard" sciences.
In order to provide a definition of the concept of Sustainability we will draw from the theory of complex adaptive systems (Gunderson and Holling, 2002) which seem to correspond to the overall intake of the term throughout different disciplines. According to this theory, Sustainability refers to systems (social, economic, ecological or other) and procedures capable of developing resilient behavior to adapt to an ever - changing environment in which they are embedded while they modify also the internal relationships between their constituent parts. In order for the system to adapt to the changes mentioned above it is considered as evolving. Thus it is considered as if it has a mechanism for self-organization and as it is evolving it can direct the system to new organizations (Forms) which demonstrate some degree of stability. (Holland, 1992; Chan 2001; Gunderson and Pritchard, 2002)

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Figure 1.
Dali, S. (1983) Topological Abduction of Europe – Homage to R. Thom.

Source: [Online]. Availiable from: http://www.wikiart.org [last accessed Dec 6, 2015].

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In the context of this theory, Sustainability is incorporating a number of other terms like evolutionary processes, self organization and else that are traversing vertically diverse disciplines yielding the content of the term interdisciplinarity and more generally the view of cross-border conditions for both the development of thought and the design expressions. R. Thom remarks that "the validity of this type of dynamic description exceeds by far the biological realm, and may be applied to all morphological processes whether animate or inanimate" (Thom, 1969, p.313)

The mathematician F. Zalamea generalizes the definition of Sustainability to include scientific disciplines making the following statement: in order to survive, a discipline is adapting to the internal relations of its constituent parts due to the changes in its cultural environment (Zalamea, 2012). We might suggest that Zalamea's formulation is reminding of the earlier one, by J. Cavailles in the field of the philosophy of mathematics. Cavailles argues that "the definition of the theory include incompleteness and evolution" (Webb, 2004, p10). Sustainability finally points to the fact that cultural expression and production is characterized by a vitalistic power which supports spontaneous and expressive creativity. That is why freedom of thought cannot happen within the context of "closed" but of adaptive systems Cavailles further concludes (Webb, 2004).

Another important outcome of the above mentioned it appears to be the correlation of mathematics and science with philosophy, finally yielding the coupling of phenomenology and rationalism. This "paradoxical" composition is marked with the invention and use of terms such as "historical a priori" by M. Foucault in the "Archaeology of Knowledge", "transcendental empiricism" by G. Deleuze in "Pure Immanence, A Life" and to the strict area of mathematics by the terms "mathematical phenomenology" coined by R Thom in "Structural Stability and Morphogenesis". It is typical that R. Thom introduces himself as natural philosopher, restoring a term which had been idle since the 19th century.

1.1 An Outline of the Mathematical Premises of the "Fold"

The contemporary –so called – scientific paradigm attempts to describe the requirement of scientific validity in the areas of philosophy and "soft" human sciences such as sociology, anthropology, history and else (Olkofsky, 2014). Other scholars refers to as the naturalistic paradigm (Dosse, 1998), thus attributing vitalism to the scientific enterprises. But what is considered as "hard" science finally opens up to a space of intuitive approaches – as it is already been reflected in the discovery or invention of non-Euclidean geometries and later on the term «Emergence» will also refer to the production of mathematical objects. The term "soft" transfers from the pliability of the material to the flexibility of the system, thus connecting the term Sustainability with systems theory. Among the characteristics of this change which "softens" the area of mathematics we will note the following as central to the discussion that concern us.

(1) The introduction of the empirical dimension. The mathematician C. F Gauss, driven by his interest in geodesy and cartography, reaches a conclusion concerning the local character of the validity of mathematical structures. Until then mathematical truths had been considered valid as universal laws, now are shifting to what in another formulation

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can be summarized in the concept of "locally true" as the result of the empirical testing of mathematical "truths" in the real world. However mathematics which are concerning formations corresponding to a transcendental order that is controlling the mathematical objects, since then, are referring to an empirical or phenomenological dimension (Webb, 2004). The empirical dimension refers also to the physicomathematical approaches or the procedure of testing the mathematical objects according to the scientific events concerning natural phenomena or the physical real (Lautman, 2011).

(2) The development of topological mathematics. The abstract nature of the objects or phenomena being studied, which moreover can refer to alternative conceptual contents. This approach is supported by the topological mathematics and especially point-wise topology. Therefore the adoption and exploitation of the topological mathematics in the area of philosophy and especially from the philosophical approach of M. Foucault and G. Deleuze (Webb, 2005), emphasizes the spatial theoretical formulation and the synchronic or diachronic aspect of the respective structuralistic approaches. Additionally they are linked to the design research in the field of the architectural practice, and particularly to the construction of architectural imagery.

(3) The global (universal) dimension attributed to the field of mathematics refers to an ever-expanding outline enveloping the a posteriori production of new mathematical objects. The a posteriori or retrospective classification of mathematical objects considered to develop in an evolutionary process and according to a productive logic which refers to the limits of that subject area. This third observation - as general and simplified it might be as offered in this limited presentation - refers to an "ecological" conception of the field of mathematics with the content that corresponds to it today. This framework as it is configured in mathematical interactions with physics and biology, ultimately characterized by terms of vitality (Webb, 2005).

We are attempting to define the terms "cultural landscape" in the context of the scientific / naturalistic paradigm, attributing to it an ecological dimension and its connection with the concept of the "fold" that summarizes the correlative character between different disciplines. We mention the "ecological" dimensions here as a metaphor for systems theory exhibiting the interrelations and exchanges of theoretical constructions with their cultural environment.

The interdisciplinarity as a condition referring to exchanges between different disciplines and which through the concept of the "fold" could be represented as relational figure / ground formation, meaning the interrelation between environment and design or theoretical object. The relational figure/ground formation refers to forms of temporal material nature which emerge from an active background. We will note here that the temporal nature of the model of the "fold", in the field of epistemology, refers to a "return of history" (Dosse, 1998), that is, the perception of retrospective reflection updated within the conditions of understanding of the present era. Thus, it is intertwined with the technological possibilities that extending the limits of human cognition. The perception of physical space in energy flow terms – that is the ecological dimension with the metabolic contemporary notion – intangible and physical networks, all focuses on the transitional dynamic relations as active interfaces. With the contribution of new technologies, are finally blurring the perception of virtual and real (Shelden and Witt, 2011).

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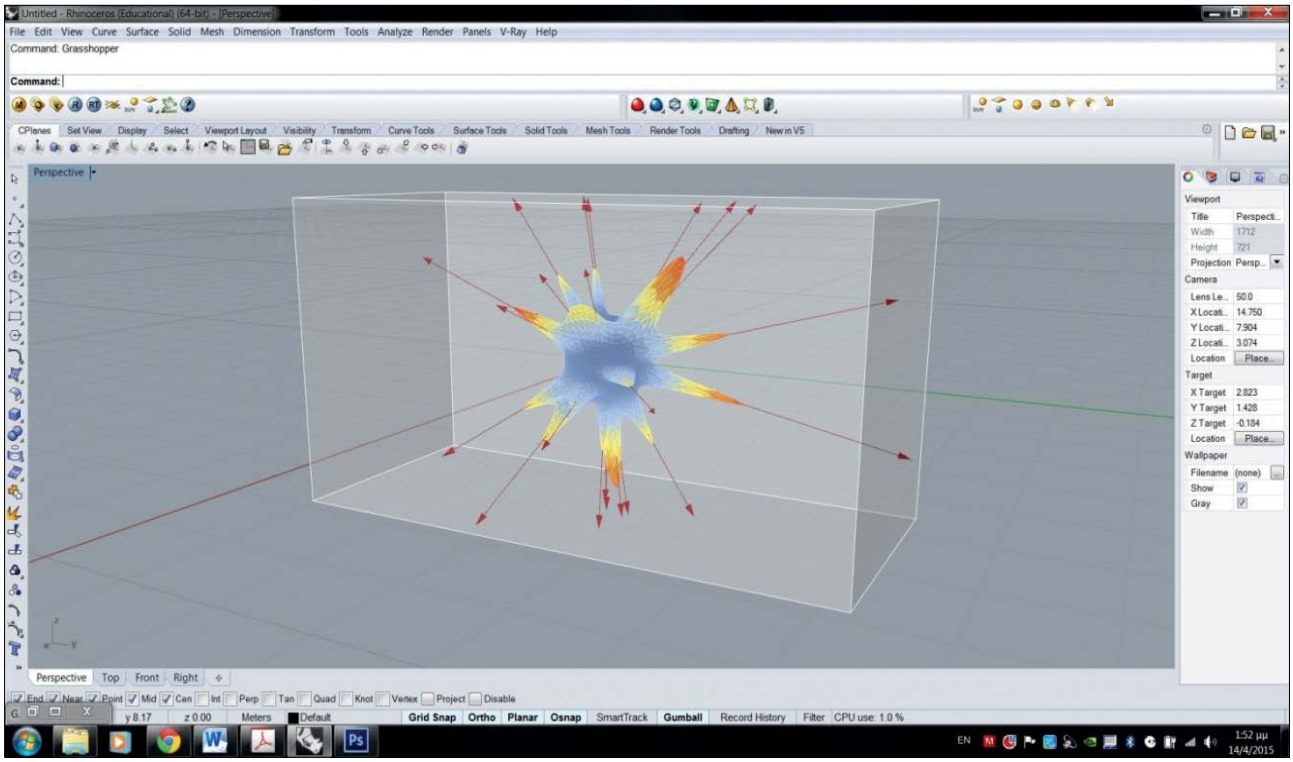

Figure 2.
Morphing: Mesh Volume Deform
Source: formDEcode, 2014

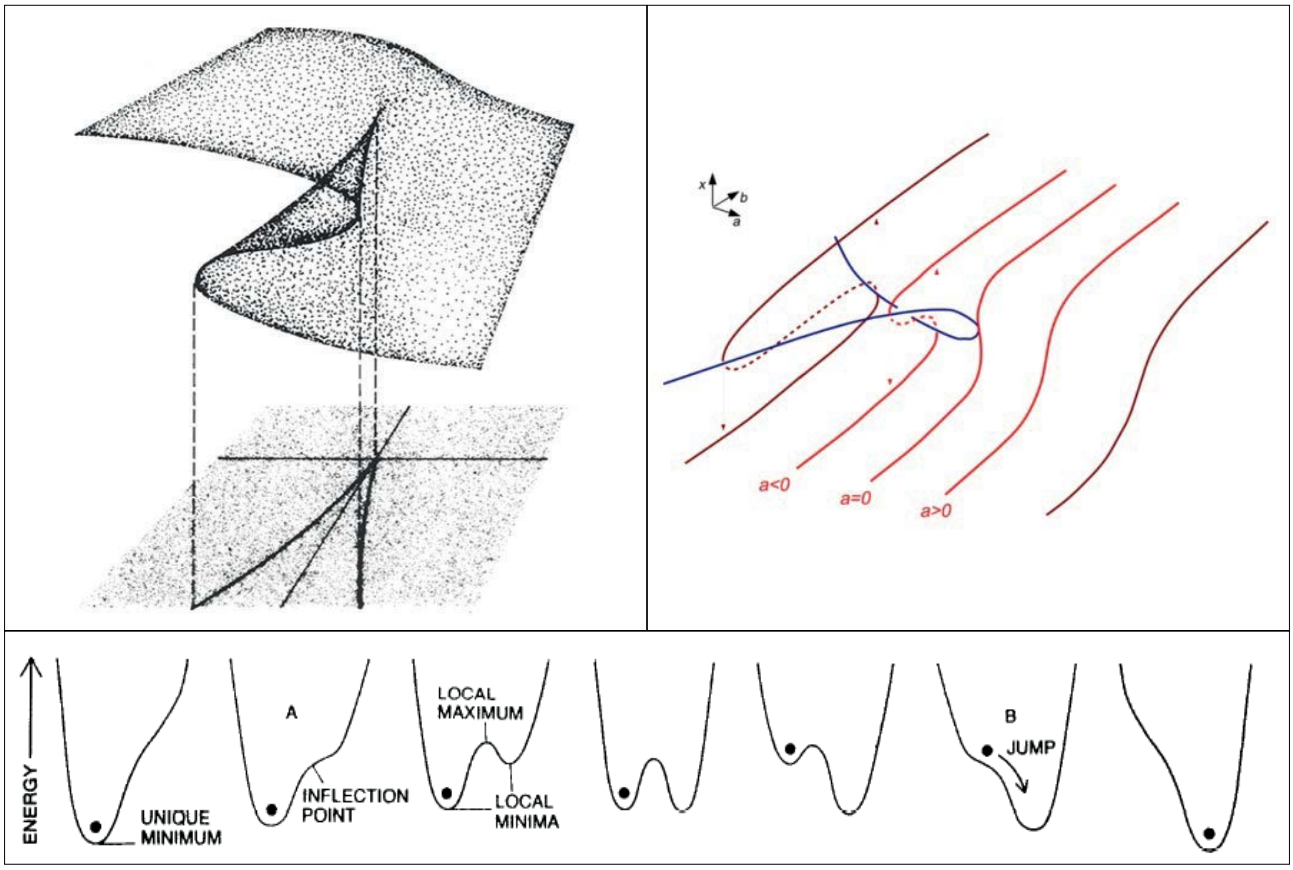

Figure 3.
Fold or Cusp Catastrophe model

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The energetic perception of the natural space within the mentally conceived model of landscape, the relational figure / ground formations yields boundaries as active interfaces affecting and providing gradient relations as opposed to a previously valid Euclidean approach. Through the "biological" paradigm leads us to the perception of a real genesis, a real production and constitutes a methodological contribution which will attribute the boundary conditions in terms of continuity in a topological sense. And that topological sense constitute a geometric order.

In order to provide an example – a schematic representation of these relational formations and the local aspect within the universal outline within which the former is confined, we will refer to the area of visualized programming and specifically in the area of algorithmic design and to a procedure that is called "Morphing" [Figure 1]. Morphing is a term initially referring to the smooth transition of forms elaborated from the field of animation. "Morphing" (Khabazi, 2012) as a tool available in the software of associative design, can be contribute to the understanding of the universal as an outline -- a border which refer to the transcendental or universal plane – which is elastic and which encloses spontaneous formation activity or formation processes, within its disciplinary boundaries. The local condition refers to events which are considered uncontrollable and unpredictable and that are able of producing new objects, after traversing an energy threshold. This might conclude to the transition to a new organization of the whole system, thus summarizing the energetic conception of landscape.

We cannot further develop these comments in the context of this limited presentation, but we will move directly to the concept of the "fold" as it is perceived within the area of mathematics that is called differential topology.

2. Mapping the virtual: Catastrophe theory

Catastrophe theory – we will not outstretch its technical description here – and the differential topology approach in general, is an intuitive mathematical approach. By including ruptures in a perception of continuity is contrasting to topology which persists to the "integrity" of a "plastic or rubber" surface. Moreover, the differential topological approach refers to time-sensitive procedures, therefore they can include transformations and transitions or even disasters in a time span – yielding to these geometrical or spatial articulation – summarized by the term "fold". In this paper we will focus on some features of the theory considered as interesting for the subject under consideration:

(1) Catastrophe theory provides interpretative descriptive models, that is, describing observed phenomena , and not proof or solution-finding models. As R. Thom notes it is no longer possible, due to the indeterminacy of the phenomena to provide a global theory so to envelope the universe (Thom, 1989). Thus, R. Thom is renouncing "dogmatic" scientific approaches, privileging the creative expressing production of interpretative models, he considers as a form of art. This has been a main target of the criticism against the theory.

(2) Secondly it refers to events which are incidents that are unknown in nature, occur-

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ring in unknown time. We might say that this way catastrophe theory includes parts of empirical reality as such, that are considered irreducible to mathematical control. As R. Thom formulates "they form kinds of islands of determinism, separated by zones of instability or indeterminacy". (Thom, 1969, p.321). These "islands" concerning also a straight reference to the intuition of real physical space as indicated by the use of terms such as "hills", "valleys", (attractor's) "basins", we will risk to mention them as a "picturesque" reference. The "Fold" being a surface sensitive to external perturbations as it is embedded in a multidimensional environment, for which Catastrophe theory presents algebraic-geometrical description. [Figure 2] The fusion of the "picturesque" and the mathematical description provided it yields the coupling of mental and phenomenal. "The latter attributes with content R. Thom's terms "mathematical phenomenology". We would say that this last phrase best describes the condition of the "Fold". To take a step further we will suggest that is also providing a certain relation among science and philosophy. The same mathematical terms are used and guide the philosophy of Deleuze as indicated by his scholar Manuel Delanda in the book "Intensive Science and Virtual Philosophy" (Delanda, 2002).

(3) Thirdly if the nature and the time of action of perturbations or events to a system it is unknown then equally unpredictable are the effects upon the system, so final results reported here are referring to the term bifurcation. Catastrophe model is a surface upon which the behavior of a singularity is unfolding. In another formulation, singularity is considered as a local unpredictable event and equally unpredictable is the nature of the final results as assigned to the corresponding mathematical model, that is what the term bifurcation introduces. (Thom, 1990).

Another observation concerns the fact that the elementary catastrophe models refer to a limited number of parameters and it is worth mentioning that from the third model on, no visualization possibility is provided. But with the introduction of a larger number of parameters, catastrophe theory purports to describe the whole reality. A "vivid" reality in constant transformation, in which man is understood as an active agent. If this is considered as a cognitive activity, it "curves" the surfaces of knowledge producing mental landscapes, as meaningful places. Places of "orgiastic meaning" that encloses all the knowledge past and current - this is the point that "fold" refers to history - referring to their retrospective reflection and their adaptation to the present context of understanding.

Clearly, mathematics which are providing models (Thom, 1969), constitutes a reductive delimitation of reality but which ever widens its outline for example in the topological abstract approaches to include and classify a posteriori the creative production of new mathematical objects (Buhlmann, 2014).

3. Landscape projections: the image of thought

In Catastrophe Theory the perception of relational figure / ground formations is mathematically associated with the change of the kinetic energy of a body as the terrain is also altered. (Thom, 1990). Respectively landscape can be considered as a

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projection space where our conceptions emerge as a reational figure / ground formation. This is also suggested through the post-structuralistic theoretical approaches. Also by the mathematical notion of product spaces (Shelden and Witt, 2011).

The perception of the "fold" also summarizes the historical approaches and projecting them in place or the perception of landscape. So in conclusion we can say that landscape-meaning and historical «substratum» coincide in the interpretation and the display of both in the real place or site. Relations that emerging from a retrospective reflective approach. Further it is associated with developments concerning the sustainability of the mathematical objects, and the expansion of their specific field so to include new objects considered to be as the result of an autonomous productive process.

This intermediate interstice reflection, the image of thought is introducing the concept of "soft" or weightless and the perception of matter as a matter of expression. As this mental structure is then folded and displayed/projected or mapped as we have seen in the real physical space, it refers to what R. Thom calls "mental landscapes" (Thom, 1990). "Mental landscapes" constitute a model where the real and the mental are folded one onto the other.

The reference to landscape as a model or the fundamental metaphor -or projection -- represents a simplistic abstract approach that enables the understanding of complex phenomena considered as elementary for this abstract mathematical approach (Kosona, 2012). When referring to the landscape, the degrees of freedom are increasing, complexity and diversity becoming key words. The abstract mathematical representations or models are performing a variety of connections with different fields of knowledge. So the term metaphor in the context of an ethos that is shaped within the boundaries of the scientific paradigm – marking the removal of the linguistic model --should be attributed to corresponding mathematical terms such as projection or mapping of a real phenomenon on a model. And if the term model, seems to be teleological or deterministic it may be argued that it is not static but evolving. Due to this observation we may eventually lift the teleology inherent in the mathematical approaches, because they are constantly broadens their disciplinary boundaries in order to include new mathematical objects emerging - through a creative intuitive production (Buhlmann, 2014). That ultimately allows this rigorous discipline to share the terms sustainability, self-organization processes, evolutionary development and else, with the ecological approach - dominant in the naturalistic example - in which it seems to fit.
Finally our approach attempts to explain how the concept of 'identity' of a place is constructed in the context of the contemporary scientific paradigm and that the terms active interface are inherent in the concept of sustainability and generally the creative, productive expressive approach.

4. Transitional atmospheric mappings and the architectural imagery

We will provide an example from the field of landscape architectural practice, in order to exemplify how the notions we have previously presented are incorporating in the design practices. The selection being made for this approach, which is an expressive one,

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seems to share certain characteristics with Catastrophe Theory. Also because of the interdisciplinarity involved and because it demonstrates the fusion of phenomenal that is the picturesque (textures) and engineering controlled design aspects concluding to environmental sensitivity of producing energy among other features.

We are referring to the example of the LCLA's project "Energy Park Weatherfield" in Abu Dhabi and we will argue that the architecture of "atmospherics" of the LCLA office (Callejas, 2012) presents an analogy with catastrophe theory and moreover we will observe that we are no longer obliged to the depiction of folded surfaces as our understanding evolves while we move forward into the "naturalistic" paradigm.

We will very briefly mention what we find interesting in the design of the energy park: the capture of fleeting / intangible wind and its utilization for energy production through the patented invention of parakites. The above highlighting the cooperation between experts of many fields of expertise, the management both of the intangible and the material environment and ultimately the opening in the area of architectural design of a new research field that refers also to the renewal of imagery construction methods [Figure 3].

As we have already mentioned the relational figure / ground approach in the perception of the "fold" is no longer bounded to the visual representation of the folded surface. That is, it does not refer to direct transcription of the corresponding mathematical model. Rather, trying to find new ways of representation in the practice of landscape architecture. The digital assisted design facilitates the possible blending or folding of the layers referring to multiple alternative readings of the site. But the construction of architectural imagery, has as main characteristic the gradient or scalar field relations - relations that we can understand through painting and mostly through the term "texture". The application of colors and the volatility of their perception, the transformation that occurs in their vicinity are a good example of diffusion in order to describe the movement from the clear demarcations in relational transitions marked by their provisional character. If the correlations with art are so clear and the digital tools offers the ability to "spread" their understanding in a much wider community –this may also refer to the visualization of complex conceptual constructions.

5. Mapping the real

If the folds of thought concerning a real-time mapping, someone could further claim that describes our wandering in a foggy landscape. In the area of computational approaches, the representation of mapping cognitive processes, ultimately yielding with creative emphasis as "landscape geometries", in the example of the landscape analogy of generic problem – solving algorithms. This being suggested by the famous software designer and architect D. Rutten (Rutten, 2014). [Figure 4]
Such an approach of the expressive possibility already inherently registered as a potential, ultimately transforms every material into material of expression, provides determination of soft or "weightless" perception of materiality, that is, the possibility of opening a space in which we can think or a space of thought (Deleuze, 1990). In other words, to Problematize, that is formulating a problem and its conditions That space is multidimensional, plastic and adaptive. Emphasizing the terms interstitial, transitional and through

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Figure 4.
Source: Callejas, L. with Lateral Office (2008).
Project: Abu-Dhabi-Weatherfield.

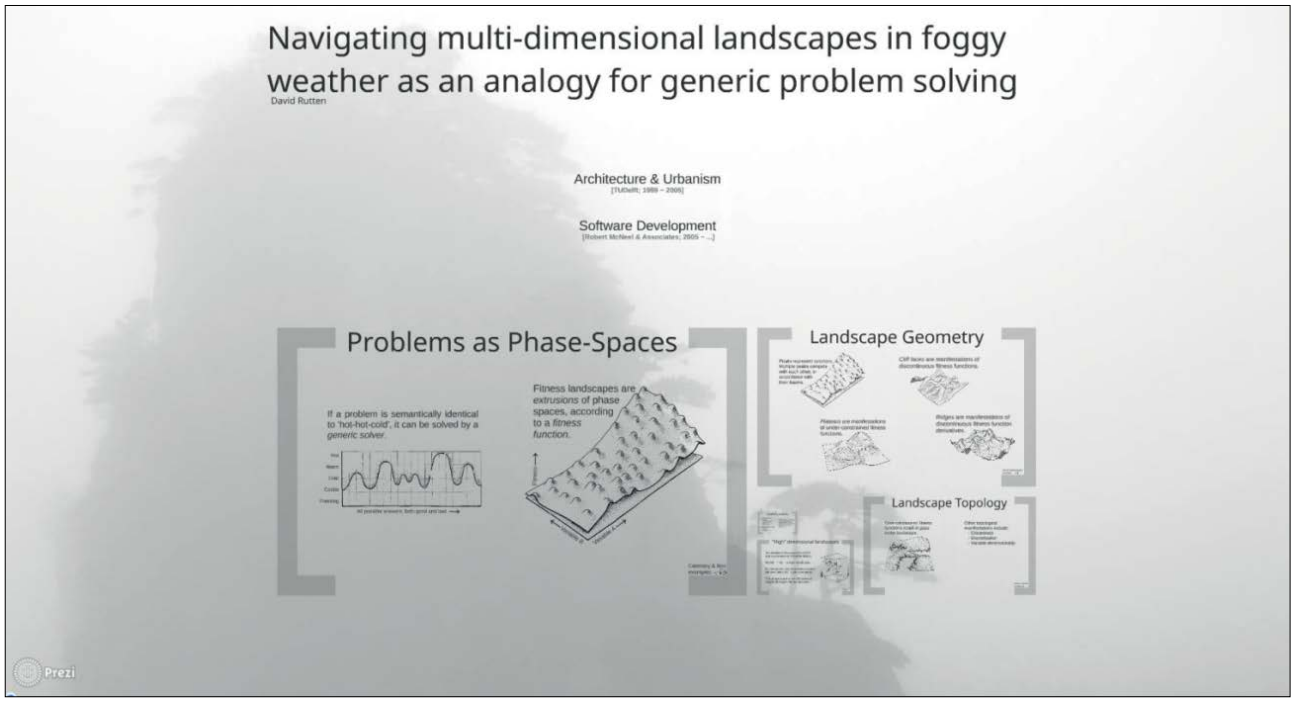

Figure 5.
Landscape geometries

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the notion of the "fold" we can extend this transitional conditions to interdisciplinary exchanges, and provide the construction of diverse and expressive identity of sites. Providing alternative enfolding of the term Sustainability. And we might further suggest an alternative term which we consider as interwoven with our previous observations, to the notion of landscape as ecologically evolving process, that is the term seeding. The latter enfolds all the possibilities of creative cultivated expressions.

Another important final observation is that landscape as cultural identification of place (Moraitis, 2005) exemplifies both theoretical and mathematical processing. Attempting to approach an ecologically coherent perception, transverses all the different areas of human knowledge, reflecting the content of the term interdisciplinarity. This term refers to methodological approaches that allow the import and geometric translation of data from many different areas, as we have already mentioned. It is also intersecting with architectural design and meets the contemporary construction of site imagery.

All previous concludes to the promotion of open negotiating boundary conditions, whether relating to real places - that refer to local vicinity conditions - or due to a quasi-- deterministic mathematical (Zalamea, 2012) treatment that can be applied to places geographically remote. Thus trying to imply consistency condition as the deepest content of the concept of topos, emphasizing on its specific features or singularities and intensities in terms of a topological approach. They ultimately produce approximated representations of reality which does not cease to be expressive approaches of the imaginary.

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