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Multifractal Geometry Role's in Historic Urban Morphogenesis

Topic: (Architecture, Design Approach)

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Main References:

[1] Charles Jencks, "The architecture of the Jumping universe, a polemic: how complexity science is changing architecture and culture", A john Wiley & sons, Inc. Singapore, 1997

[2] Eleonora Bilotta & Pietro Pantano, "Structural and functional growth in self-reproducing cellular automata". A john Wiley & sons, Inc. 2006

Abstract:

Urban intervention processes in the historical cities demands a thorough comprehension of the urban morphogenesis approaches in these complex structures. It took hundreds or even thousands of years urban structures to emerge and evolve till the current morphology co-evolving with the human bio-functional interrelations evolution. The focus of this research is on fractal geometry role's in emerging urban morphogenesis, by analyzing two main rules (**Multifractality** and **Sensitive Adaptability**) capable of achieving comprehensive homogeneity at all Urban and Architecture levels. To understand these new approach and to create a new epistemological framework for urban morphology, evolutionary techniques could be used in order to have a set of rules for building different genotypes of Architecture and urban forms which, by using computational processes, develop as output 3D models of urban processes, more suitable with complex adaptive systems such as historical contexts.

- The interrelation between forms and functions is one of the crucial deterministic should guiding morphogenesis approach. Fractal geometry utilized various levels of Mono-fractal and Multi-fractal scaling for reconciling between the function needs (social agents contribution) and the architectural typologies in the historical context. The ability of fractal geometry of emerging **Self-Similar** structures is the secret behind achieving homogeneity at spatial and functional relations.
- Sensitive Adaptability of Fractals manifested through high capacity of responsiveness to different environment situations and changes by changing their structure, behavior and function through manipulating in their "**Genetic Code**".

The research hypothesis based on considering historical urban structures as complex as living bio-organic species has similar attributes, advantages and characteristics, behaves in the same way towards adopting and adapting with different environmental conditions by changing their "genetic code". These complex structures took hundreds or even thousands of years to emerge and evolve till the current morphology, co-evolving with the human bio-functional interrelations evolution. Therefore, the core questions that research will investigates are How, Why and What:

- **How** living organisms could reconcile between their functional needs (reproductive behavior) and their form (produced pattern)?
- **Why** they are using specific rules for evolution or mutation?
- **What** are the secrets/learned lessons that urban morphogenesis and Architecture typologies should be aware of?

Verification of research hypotheses and responding the core questions requires adopting creative architecture and urban concept depending on convergence between Scientific Complexity approach and Artificial Intelligence on one hand, with Complexity approach of Architecture and Urban Morphology, on the other hand.

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Keywords: Genetic Code, Urban Morphogenesis, Scaling Behavior, Multifractality

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Abstract

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– 1. Introduction

Urban interventions in historical cities contexts have ever been considered as an important topic at different urban and social levels, as well as a major vector of economic development. Till now it was not possible to make a clear prevision of these interventions because urban morphology processes which are applied in most of the historical structures lack of finding harmonies configurations [1]. But with the use of computational urban generative approach that moves the creative acts from static events to dynamic transformations (This dynamic process could be easily represented and managed with a set of algorithms [2]), it is possible to achieve harmony, coherence and homogeneity by involving the scientific complexity approach's, based on the role of Complexity and Connectivity factors as essential orientation for the growth of historical urban contexts [3].

Traditional technology (Top-down) of urban systems which used on historical urban ontology has been considered as an obstacle, confronting to the emerging creative processes of urban morphogenesis, because it could only study semi–liner urban structure, but it is unable to analyze the biological-like (Self-Organizing) development of organic urban forms. While the traditional urban analyses have utilized linear and standard statistical techniques to study urban phenomena from the 'top down', techniques of scientific complexity such as Chaos theory and other 'new' methods of analysis such as cellular automata, agent based modeling, spatial metrics, artificial intelligence, neural networks, non-linear simulation and fractal generation represent means to study urban phenomena from the 'bottom up' [4].

According to Jenkins, a new language of form based on fractal design is beginning to permeate our landscape - and skies [5]. The embodiment of fractal characteristics in the urban context relates to the mechanisms involved in the bio-functional evolution process and to the urban context's morphological characterization using fractal analysis [6]. Fractal analysis(1) challenges the traditional methods of analyses such as linear and standard statistical techniques, and presents an innovative Mechanism to analyze and generate Urban Structure/Form corresponding with two interrelated relations: **Spatial Relation** and **Functional Relation**.

The research will highlights on the main obstacles coming from reconciling between techniques of scientific complexity and techniques of complexity of Architecture, especially the fractal technique in both complexities theories', due to the ability of fractals to analyze and emerge coherence, hierarchy and complex self-similar structures from simple rules as biological and organism ones.

1.1. Research General and Specific Problematic

Most of Urban design studies in the historical context associated with a lot of architectural, economic and social interventions are lacking to development a new mechanism/process and an innovative spatial analysis tool for Urban Forms and Architecture Typologies, As a result of these studies and

interventions many cases considered as cancerous cells in the historical city, appeared within the urban fabric and contributed in isolating cells surrounding areas inside the historical context as well as destroying adaptability of reuse and infill development in these contexts.

Although many Urbanists and Specialists such as Batty (1994), Longley (1994), Salingaros (2001), Alexander (2004), Jeffrey West (1999), Frankhauser (1998), McAdams (2007) and others had studied fractal Technology and used it in urban analysis, also had recommended to develop this creative technique; and many of pioneer Architects utilized Fractal Architecture such as Libeskind, Zaha Hadid, Rogers, Otto, Jenkins, Celestino Soddu and Renzo Piano. But fractal technology since its discovery by Mandelbrot in 1979 has so far suffered in the application field, and continues to suffer from serious problems especially at the Macro level of urban analysis; and Micro level of evolving adaptive architectural geometrics, due to a set of problems that will address in detail:

Three impediment factors have prevented of Building Genotype[2] and Phenotype[3] Definition and Optimization of new Architectural typologies and urban morphologies for filling urban gaps in the historical context coherently and adaptively, which could be considered as the main significant problematic topics at the Emerging Level. The research will highlight on these factors:

A) Ignoring the spatial and functional relations with historical environment surrounding the Urban gaps and thus reducing the significant and crucial impact to these relationships on formulating and determine the Genetic Code[4] of architectural types/patterns and urban forms, as well as the omission of the historical development of this relationships and its effect and their role in the emergence of new forms and patterns were able to adapt with the variable functional and spatial requirements over time.
B) Imbalance process and misleading Architectural language utilized to identify buildings Genotype, because of absence an integrated mechanism for studying the inherited characteristics derived from the building genetic code's, which reflected negatively on the Phenotype of the building because of giving priority to one factors in forming the genetic code and neglecting the rest of environmental or spatial or functional factors, which led to a serious disruption in the physical and behavioral properties that constitute the building phenotype; and emerging abnormal architectural models contributed largely in fragmenting the complex urban structure in the historical context.
C) Follow destructive mechanism for generating architectural forms based on the cancellation of all spatial and functional links with the historical context surrounding the urban gaps, and destroying the focal points at all levels, which led to disengagement the impact of the Field Effect and to reduce its role for emerging the Seed of architectural and urban forms. Resulted to creating exotic 'cancerous cells' on the historic context, instead of being able to achieve desired optimization.

– 2. Methods

– The research[4] methodology adopted a Morphological Approach (consisting of three main phases). A new Adaptive Dynamical Model **ADM** for Parametric design written in Python and combined with visual programming of Grasshopper[5] as a plug-in to "Rhinoceros 5"[6] software, will be presented in this paper. Incorporation ADM with optimization algorithm is under investigation to develop a modelling software tool called Morphogenetic Fractal Architecture **MoFA** as final research output's.
– The First Phase[7] has developed a novel technology for A) Assessment both urban connectivity & complexity; B) Thresholding urban interactions and self-similarity structure dimensions' by Local Connected Fractal and Lacunarity Algorithms'. This technology represents a paradigm shift for the very first time in architectural and urban design toward transformation urban network analysis from qualitative to quantitative measurements, and establishes a solid basis for the evolutionary

process of network interactions (Swaid, Lucente, Bilotta, & Pantano, 2015). This value of urban connectivity and complexity threshold forms a phase transition of the dynamical urban behaviour, and forms a P_c Critical Percolation Threshold that guarantees the historical sites Continuity's, Homogeneity's and Coherence's.

This paper will describe the latest Second Phase results' of an ongoing research project that aims at using the power of Multifractal Geometry (based on Field Effect, Point Attractor and Power Law Scaling Models') for designing and optimizing Building Genotype and Phenotype as a first step of the Seed Emergence for developing a modelling software tool which has been called **MoFA** (Morphogenetic Fractal Architecture) and contains an **Efficient Algorithm for Evolving Fractal Architecture** (Figure 1). The second (Generator Techniques) and third steps (Optimization Algorithm) will be investigated in the research Third Phase's.

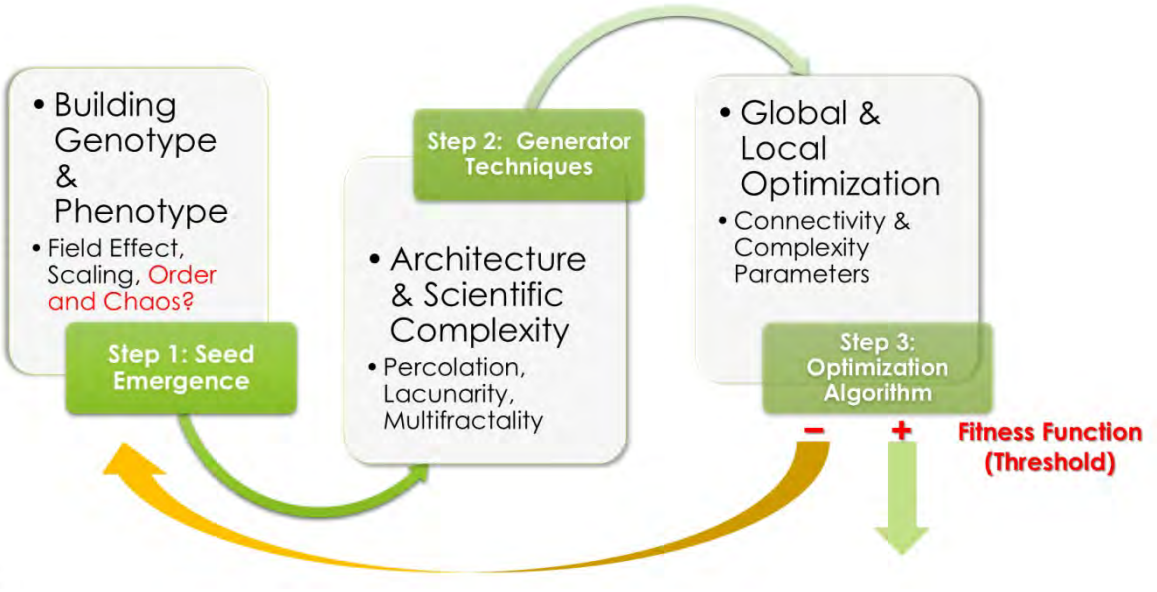

Figure 1: Developing an Efficient Algorithm for Evolving Fractal Architecture

The implemented methodology was applied to Cosenza city as a pilot project and involved two consecutive stages: Maps Generation and Designing Adaptive Dynamical Model.

2.1 Maps Generation

The city maps' were generated by "ELK" Technology combined with visual programming of Grasshopper as a plug-in to "Rhinoceros 5" software. Where data of Streets, Railways. Waterways, Buildings, and various facilities maps collected from OpenStreetMap.org and Shuttle Radar Topography Mission (SRTM) data from NASA/Jet Propulsion Laboratory, and were fed to the Mapping component OSM location to generate digital maps "baked" in Rhinoceros multilayers' (Figure 2).

Figure 2: Cosenza Digital Maps Generation's

2.2 Designing Adaptive Dynamical Model (ADM)

An Adaptive Dynamical Model for Parametric design is written in Python and incorporated with Grasshopper as a plug-in to Rhinoceros 5. The significant motivation with ADM is to model the optimization of Building Genotype and Phenotype for seed emergence in complex adaptive system[(8)]. In this context a number of computational approaches (**Field Effect, Point Attractor and Power Law Scaling Models'**) to modelling morphogenesis are compiling to study an integration. These approaches collectively form the Multifractal geometry skeleton's.

Developing a set of rules for building different genotypes of Architecture and Urban forms requires specifying precisely the relationship between the main systems that constitutes these forms genetic code. Hiller considered the question every theory must address is: What, if any, is the relationship between the two systems (Spatial and Functional)? [7]. Fractals mechanism which control this correlated relationship characterized by high Sensitive Adaptability through capacity of responsiveness to different environment situations and changes by mutating their structure, behavior and function through manipulating in their Genetic Code. Which interprets how Multifractal geometry emerged, where the last one utilizes various levels of Mono-fractal and Multi-fractal scaling for reconciling between the function needs and the architectural and urban forms.

This Multifractal geometry abilities' of emerging **Self-Similar** structures is the secret behind achieving homogeneity at spatial and functional relations. Where scaling and self-similar configuration, create complex patterns lying in planes with different orientations in a multidimensional space and subject to the approach **Power Law Scaling** model [8]. Which is the most successful approach at achieving morphogenetic outcomes that are faithful to complex adaptive systems such as historical reality.

The surprising regularities in the way in which all city networks are constructed, covering both the geometry and configuration of spatial networks, and functional as well as spatial phenomena were emphasized by what Hacking [9] has called "created phenomena". On the basis of these structures Hillier proposed a new universal definition of a city as a network of **linked centers** at all scales set into a background network of residential space [7]. Hillier showed that universal pattern comes from two interlinked but conceptually separable phases: a spatial process through which simple spatial

laws govern the emergence of characteristically urban patterns of space from the aggregations of buildings; and a functional process through which equally simple spatio-functional laws govern the way in which aggregates of buildings become living cities.

Another Approach is Field Effect model's. The main functions of this model are: defining the local criteria for emerging the Multifractal geometry interlinked centers'; and distributing these centers coherently. Interlinked centers form a crucial condition for achieving universal distribution harmony's. According to Christopher Alexander theory of centers, Harmony seeking computation in terms the identity of each center scale become blue because (of achieving) the coherence is a field effect, so no longer possible to identify individual centers. In universal distribution emergence become a field effect. The model to watch out for is the fractal, since the fractal every little piece belongs to the larger whole, so it is not possible to take out any small piece form fractal because there are an emergence unity.

The local criteria which has responsibility for emerging Multifractal geometry interlinked centers' based on generic relation between spatial and function structures. This relation lies in two key new phenomena, explained by Hillier: the first called **Spatial Emergence:** the network of space that links the buildings together into a single system acquires emergent structure from the ways in which objects are placed and shaped within it. The second is **Spatial Agency:** the emergent spatial structure in itself has lawful effects on the functional patterns of the city by, in the first instance, shaping movement flows, and, through this, emergent land use patterns, since these in their nature either seek or avoid movement flows [7]. These two key new phenomena of spatial emergence and spatial agency forms together the self-organizing processes which grant the urban structure universal spatial form. Adopting the approach of Field effect model for emerging the Multifractal geometry interlinked centers' represents a realistic and practical model for applying the self-organizing processes. According to Jencks In the new sciences and architectures the fundamental idea relates to feedback, self-organizing change, "which the computer is well-adapted to portray [5].

Point Attractor model of Multifractal geometry morphogenesis is yet another approach. Since the whole simulation is a non-linear dynamic system, but the result should be static the crucial objective is to bring the system to a stable state. In the theory of dynamic systems this is called a point attractor in the phase space of the system [10]. Indeed all organisms appear to be organized by internal attractors. Where it's a truism for Jencks that all organism and Architecture must show some self-similarity and the influence of attractors.

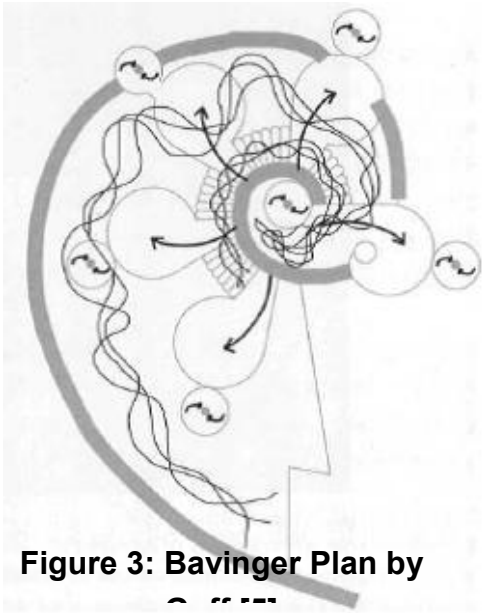

Figure 3: Bavinger Plan by Goff [7]

One of the most leading example of utilizing point attractor model for geometry morphogenesis done by Goff with the Bavinger and Garvey Houses 1952, when Goff uses a strange attractor to organize a force-field of movement around and up a ramp. Bavinger plan (Figure 3) shows

strange attractor of spiral movement. In the center it oscillates chaotically around the stairway and on the edges within limit cycles of walls. Five larger and six smaller point-attractors are suspended pods [5].

This example shows how much extent the Point Attractor combined with Power law models' plays a significant role for emerging what Jencks had called **Cosmogenic Architecture** made by fractal language, exactly at the edge between chaos and order, started with chaotic behavior by evolving the point attractor (attracts motion and visual direction) but it does so differently at each ascent and descent, thus ended with deterministic chaos behavior mixture. This fractal language could absorb such heterogeneous material from nature and culture is a lesson to all practicing architects, even that great bricoleur Frank Gehry [5].

– 3. Results

– Following the concept of Power Law, Field Effect and Point Attractor Models, the basic idea for the solution of the pilot project was to 1) generate the interlinked centres; 2) create a simulation that takes every center as an autonomous agent that tries to find its "optimum" place within a focal points set, competing with the other agents and governed by the **local criteria** mentioned above to evolve point attractor.

3.1 Generation the Interlinked Centers

The interlinked centers were generated by applying Python model integrated with visual programming of Grasshopper as a plug-in to "Rhinoceros 5" software. Where three consecutive Adaptive Algorithms had implemented: **1)** the first algorithm is responsible for spatial emergence to generate the network of space that links the buildings together, through select 2D grid with square cells (A) which is consistent with the city spatial structure, also have two input parameters (size of grid cells and number of grid cells in both directions X and Y), after choosing the project boundary (B) both (A and B) would be encoded as inputs into region intersection component, the result outlines of intersection A and B (Figure 4). This emergent spatial structure represent the first chromosome for population genesis.

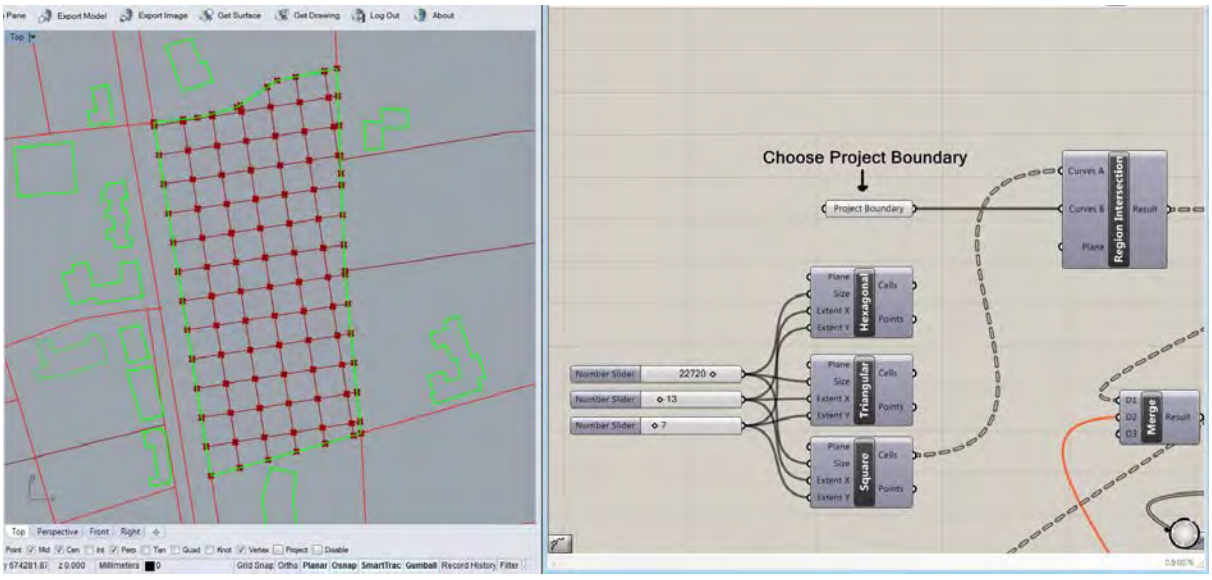

Figure 4: Spatial Emergence Algorithm of Cosenza Project

2) The second algorithm is responsible for spatial agency to stimulate all probable movement flows, through extending these flows resources (green color) by a specified distance (Input parameter: extension amount), which generate points intersection at Project boundary, then by python script component all intersection of movement flows will be taken and draws one line between every pair of points, this will generate 119 centers forms all possible “centers” caused by the movement flows intersections (Figure 5). The centers represents the second chromosome for population genesis.

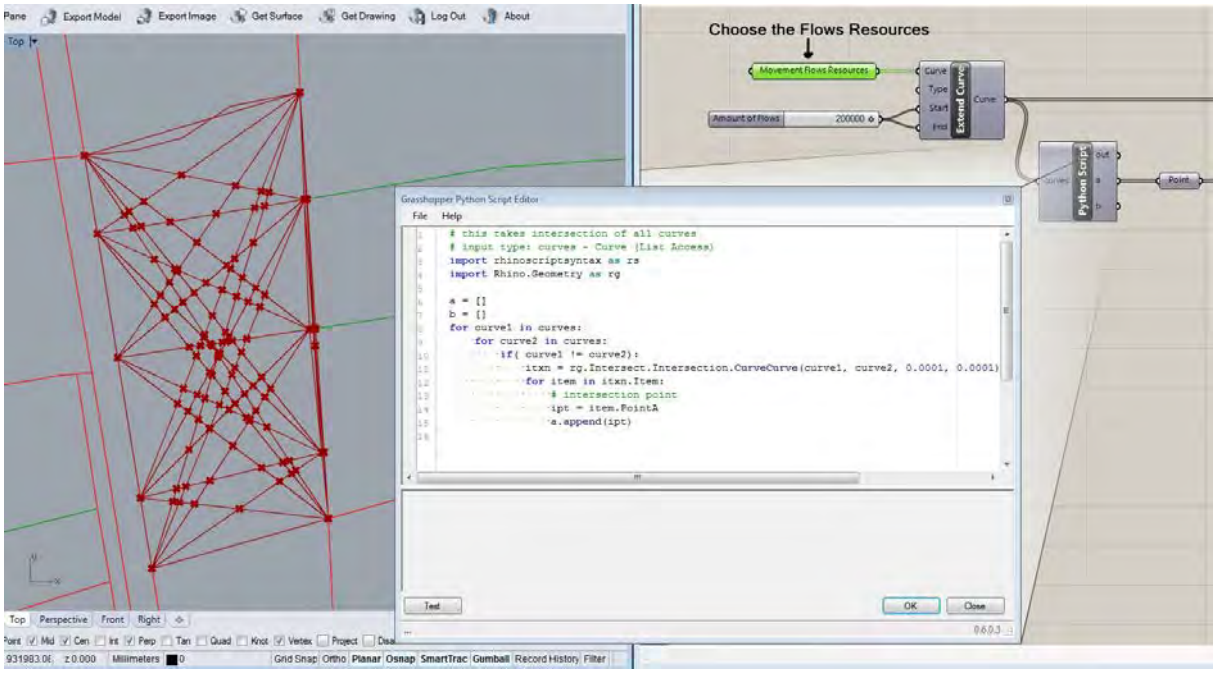

Figure 5: Spatial Agency Algorithm of Cosenza Project

3) The third algorithm is responsible for govern the way of distributing these centers on the spatial emerged structure coherently, by reconciling between the emergent spatial structure and generated centers, through select chaotic thee centers from the 119 then searching for the Closest Points **CP** (red color) of each center to the spatial structure intersections point’s and merging the CP into the field effect of this center, finally adapting (mutation) the spatial structure (cyan color) with the field effect center’s power (Field Effect power specified by dynamic input parameter) (Figure 6).

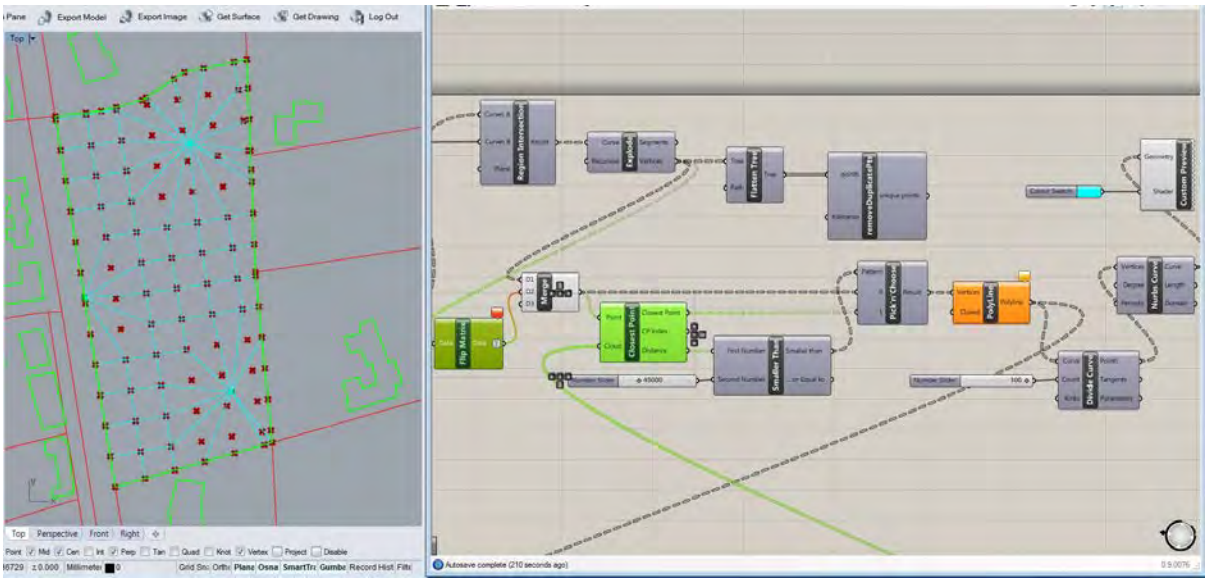

Figure 6: Field Effect Algorithm of Cosenza Project

For each three centers chaotic selections a new mutant spatial structure will be generated in self-organizing process. But for more than 350 interlinked centers scenarios, there is only one optimum solution achieving universal distribution harmony's. This algorithm represent the second step of the evolutionary process "Genesis" by merging two chromosomes to mate selection for creating the first population of solutions. These population will be differentiated in terms of achieving high level of bond percolation (urban structure continuity).

3.2 Creation the Interlinked Centers Simulation's and Optimization's

Looking for the optimum solution of interlinked centers were done by "Shortest walk" Technology combined with visual programming of Grasshopper as a plug-in to "Rhinoceros 5 software. The shortest walk technology is based on a topology calculator and the A* search[9] algorithm [11]. The simulation takes every center as an autonomous agent that tries to find its optimum (in terms of its proximity to the next center, where the closest achieves faster percolation) place within interlinked centers (focal points set), competing with the other agents. Where every agent of the interlinked centers encoded into the shortest walk component, and for each scenario the shortest polyline (yellow color) was generated (Figure 7).

This competition between centers governed by the **local criteria** mentioned above (to evolve point attractor) and governed also by the fitness function (**global criteria**) for the objective Multifractal geometry, in this sense an Evolutionary Multi-criteria Optimization (EMO) will be performed (at the third phase of the research approach) to achieve more than one objective in parallel.

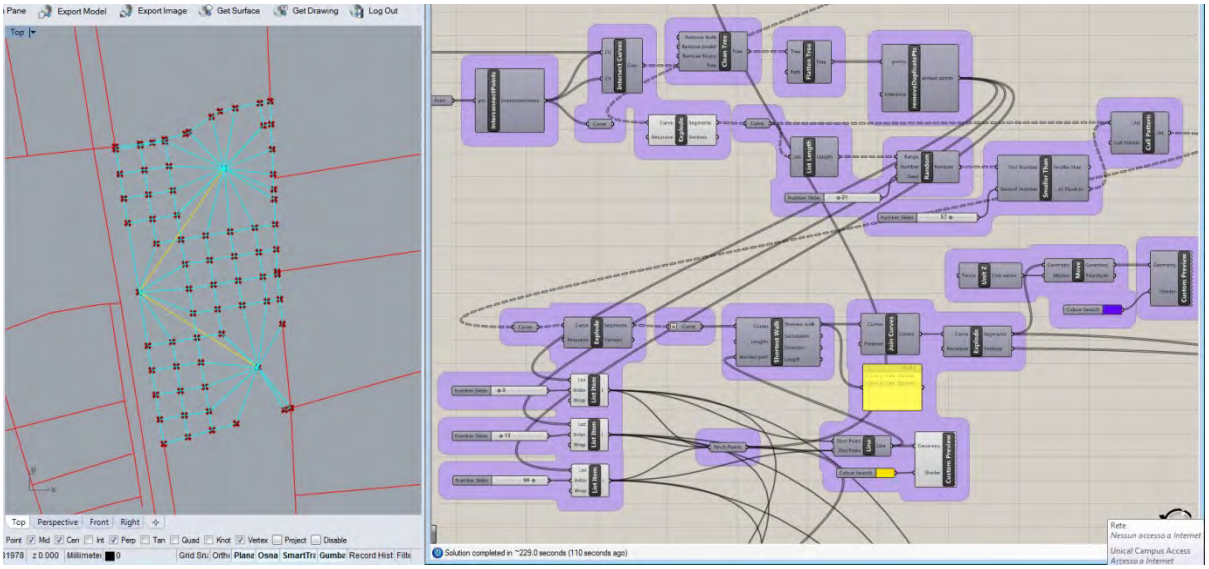

Figure 7: Shortest Walk Algorithm of Cosenza Project

But this yellow polyline does not fit with the mutant spatial structure (erected by algorithm 3) therefore a new algorithm of Filed line was applied to compute the field line through selected centers and to enforce the shortest polyline of respecting the mutant spatial structure shape's. Generating the field line requires utilize merge field component to merge all the fields created due to a centers (as attractors or repeller) charge (Figure 8). Where an attractor or repeller is defined as a point in 3D space. Around this point movement is warped to force the movement closer to the attractor or farther from the repeller. The amount of warping depends on distance from the attractor or repeller and the force of the attractor or repeller. This force is parameterized for the user to set. Attractors and

repellers significantly alter the generated fields from its specification in axiom and production rule terms [12].

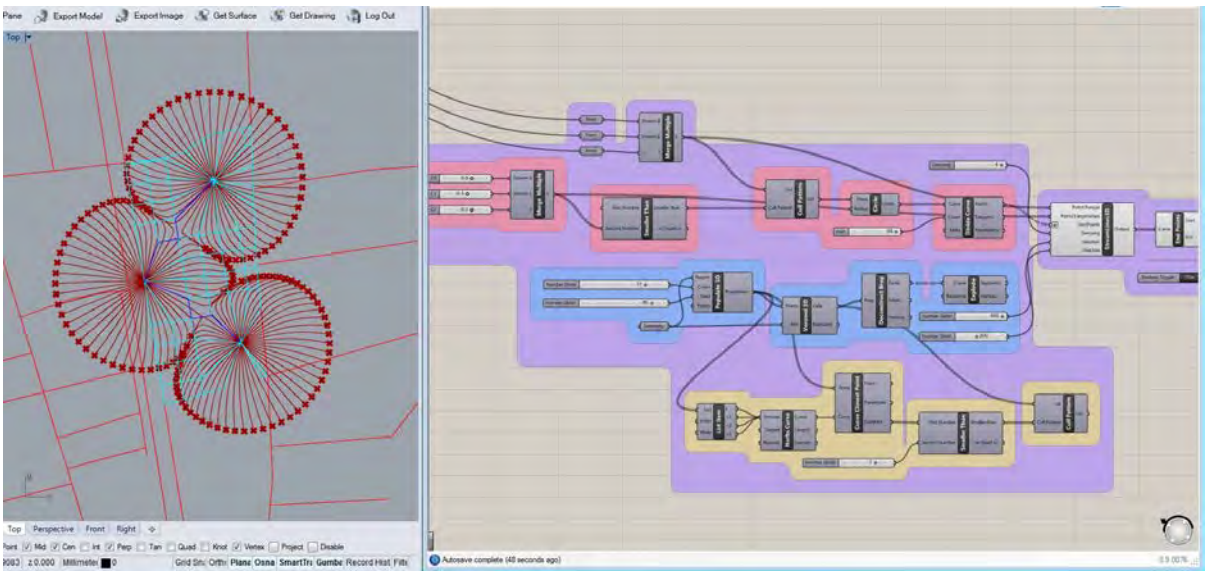

Figure 8: Filed Line and Attractors Algorithms' of Cosenza Project

The new generated shortest line (Blue color) represents the generator polyline that will be subject to the approach **Power Law Scaling** model for Multifractal geometry morphogenesis. Optimizing this polyline will be investigated in the third phase of the research approach considering local and global criteria as Stopping Criterion.

4. Discussion

– Before discussing the core questions of the research, it's really worth to emphasize the crucial inherited instructions of the new generated shortest line. These instructions were derived from spatial emergence and spatial agency processes. Therefore constituting together self-organizing process for building different genotypes and phenotypes of Architecture and urban forms. The second phase of the research methodology is credited to transfer the self-organizing processes form theoretical to the implementation realm by applying multiple correlated algorithms.

Where consecutive Adaptive Algorithms (Spatial, Emergence, Spatial Agency, Field Effect, Shortest walk, *Filed Line and Attractors*) generated and optimized the Interlinked Centers, that gives living Organisms (cities) the capacity to reconcile between their functional needs and their form through adopting and adapting with different environmental conditions (Local and Global Criteria's') by Manipulating their genetic code for mutating their genotype and phenotype.
Living Organisms (cities) are using specific rules for evolution or mutation, due to the fact that all organisms appear to be organized by internal attractors. Therefore all Organism and Architecture must show some self-similarity and subject to the influence of Point attractor model, because it brings the system to a stable state, thus living organism which started their evolutionary chaotically ended with deterministic chaos behavior mixture.
The secrets/learned lessons that urban morphogenesis and Architecture typologies should be aware of: approaching **Power Law Scaling** model is the most successful approach at achieving morphogenetic outcomes that are faithful to complex adaptive systems such as historical reality. Particularly when accompanied with fractal language, which could absorb such heterogeneous material from nature and culture.

– 5. Conclusion

– Applying the new computational urban generative approach on Cosenza pilot project has proven that is a valuable method for creating and optimising genotype and phenotype of Multifractal geometries within the architectural process. Where developing an Adaptive Dynamic Models (**ADM**) for Parametric Design based on number of artificial intelligence computational approaches' (Field Effect, Point Attractor and Power Law Scaling Models') played a crucial role in discover and model an infinity Multifractal geometries, then optimize it, to correspondence with the local and global criteria's' of a complex adaptive system such as historical cities.

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– This ADM represents a tipping point in computational and parametric Architecture design, towards achieving practical application and unifying the scientific complexity with Architecture approaches' for addressing the problematic and creating a new epistemological framework of urban morphogenesis. The powerful emergence ability of this creative model derived from the critical role of Multifractal self-organizing process in achieving harmony, coherence and homogeneity in the historical context.

Verification of research hypotheses and responding the core questions verified due to adopting creative architecture and urban concept depending on convergence between Scientific Complexity approach and Artificial Intelligence on one hand, with Complexity approach of Architecture and Urban Morphology, on the other hand. This interrelationship between various approaches presented the crucial motive for renaissance and progress of various scientific fields, it is the time for post-modern architecture to follow suit.

Notes

1- Fractal analysis is a contemporary method of applying non-traditional mathematics to patterns that defy understanding with traditional Euclidean concepts. In essence, it measures complexity using the fractal dimension [13].

2- The genotype of the Building is the inherited instructions (derived from functional and spatial relations) it carries within its genetic code. Not all buildings with the same genotype look or behave the same way because morphology/typology and behavior are modified by environmental and developmental conditions. Likewise not all the buildings that look alike necessarily have the same genotype.

3- A building phenotype (from Greek *phainein*, meaning "to show", and *typos*, meaning "type") is the composite of building observable characteristics, such as its morphology, development, physical properties, behavior, and products of behavior. A phenotype results from the expression of a building's genes as well as the influence of environmental factors and the interactions between the two. When two or more clearly different phenotypes exist in the same urban context, the urban is called polymorph.

4- This paper represent an interdisciplinary collaborative work, done as a part of PhD research in the University of Calabria. The research chooses six cities (London, Paris, Rome, Milan, Aleppo and Cosenza) which represent diverse patterns in terms of their morphological urban networks and structures.

5- Grasshopper is a graphical algorithm editor that is integrated with Rhino3D's modelling tools. Grasshopper's visual "plug-and-play" style gives designers the ability to combine creative problem solving with novel rule systems through the use of a fluid graphical interface [14].

6- Rhinoceros 5 is a commercial 3D computer graphics and computer-aided design (CAD) application software. Rhino geometry is based on the NURBS mathematical model, which

focuses on producing mathematically precise representation of curves and freeform surfaces in computer graphics [15].

7- Final results of the research first phase's had been published and presented in the "European Conference on Artificial life, ECAL 2015", York, UK, https://www.cs.york.ac.uk/nature/ecal2015/paper-158.html

8- According to Gershenson (2008) A complex system is one in which elements interact and affect each other so that it is difficult to separate the behaviour of individual elements [16].

9- "A star" is a computer algorithm that is widely used in pathfinding and graph traversal, the process of plotting an efficiently traversable path between multiple points, called nodes.

– References

- [1] ALEXANDER, C. (2015, November 05). Harmony-Seeking Computations: a Science of Non-Classical Dynamics based on the Progressive Evolution of the Larger Whole. Retrieved from http://www.livingneighborhoods.org/library/harmony-seeking-computations-v29.pdf
- [2] Soddu, C., & Colabella, E. (2013). Why Generative Art? GA2013 - 16th International Conference (pp. 4-5). Milan, Italy: Domus Argenia Publisher.
- [3] Swaid, B. (2015). Fractal Evolutionary Technique for Filling Urban Gaps in 3D Models Applied in Historical Context of Aleppo. Cosenza, (PhD Thesis Not puplished): University of Calabria.
- [4] McAdams, M. A. (2009). The application of fractal analysis and spatial technologies for urban analysis. JOURNAL OF APPLIED FUNCTIONAL ANALYSIS, VOL.4,NO.4,569-579.
- [5] Jencks, C. (1997). THE ARCHITECTURE OE THE JUMPING UNIVERSE, A POLEMIC: HOW COMPLEXITY SCIENCE IS CHANGING ARCHITECTURE AND CULTURE. Singapore: JOHN WILEY & SONS.
- [6] Swaid, B., Lucente, R., Bilotta, E., & Pantano, P. (2015). Thresholding Urban Connectivity by Local Connected Fractal Dimensions and Lacunarity Analyses. European Conference on Artificial Life 2015, (pp. 15-16). York, England.
- [7] Hillier, B. (2012). The Genetic Code for Cities: Is It Simpler than We Think? In J. Portugali, H. Meyer, E. Stolk, & E. Tan, Complexity Theories of Cities Have Come of Age (An Overview with Implications to Urban Planning and Design) (pp. 129-152). Heidelberg Dordrecht London New York: Springer.
- [8] Bilotta, E., & Pantano, P. (2006). Structural and Functional Growth in Self-Reproducing Cellular Automata. Complexity. A john Wiley & sons, Inc.nc., 12-29.
- [9] Hacking, I. (1983). Representing and Intervening Introductory Topics in the Philosophy of Natural Science. Cambridge: Cambridge University Press.
- [10] SCHEURER, F. (2005). Turning the design process downside-up Self-organization in real-world architecture. In B. Martens, & A. Brown, Computer Aided Architectural Design Futures 2005 (pp. 269-278). Netherlands: Springer.
- [11] Europe, M. (2015, November 03). shortest walk gh. Retrieved from Food 4 Rhino: http://www.food4rhino.com/project/shortestwalkgh?etx
- [12] Testa, P., O'Reilly, U.-M., Kangas, M., & Kilian, A. (2000). MoSS: Morphogenetic Surface Structure A Software Tool for Design Exploration. In proceeding of Greenwich 2000 Digital Crativity Symposium (pp. 71-80). London, UK: University of Greenwich.
- [13] Karperien, A. (2015, September 01). Fractals and Complexity. Retrieved from FracLac for ImageJ: http://rsb.info.nih.gov/ij/plugins/fraclac/FLHelp/Fractals.htm#fractalanalysisinpractice
- [14]Akos, G., & Parsons, R. (2014). FOUNDATIONS, THE GRASSHOPPER PRIMER THIRD EDITION. Modelab.
- [15] Wikipedia. (2015, November 01). Rhinoceros 3D. Retrieved from Wikipedia the Free Encyclopedia: https://en.wikipedia.org/wiki/Rhinoceros_3D
- [16] Gershenson, C. (2008). Complexity: 5 questions. Automatic Press.