A Strategic Approach to Smart Cities through CA and Shape Grammars

Fakiri Ioanna[a] and Tsoumpri Dimitra[b]
School of Architecture, NTUA, Athens, Greece

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Abstract: In recent years we have seen a gradually increasing concern for the urban landscape and the way it is designed and evaluated. This concern, a result of the emergence of digital technologies and convergence of different scientific disciplines, is based on the ability of design tools to support and reinforce the discussion on urban landscape as an open process for action. But, how do we design a new urban space employing these design tools? So far the discussion on the design and form of the city placed emphasis on the creation of a communication platform that functions either through the development of interpersonal and interactive relationships of the users, or as an entity for configuring and displaying visual messages and communication to society. The term "smart city", has been linked with digital applications, sensors, and software to produce the city of the future. However, the real challenge is to develop a "smart city," that starts from the city of today and enables the combination of these smart practices by activating infrastructure that may reform the spatial structure of the urban morphology. This paper will introduce a "reformer," the *natural landscape*, based on which a new methodological approach shall be established, in order to manage the urban landscape. The paper presumes that the execution of the cell automata demonstrates, loose coupled with Shape Grammar, provides a robust and useful application of this reformer in metropolitan planning. The connected techniques shift locally as a component of the points of interest concerning specific examples and procedures to be advanced. This will help create a "smarter city," which may find applications in various fields that start from today's city, instead of trying to compose an ideal image of the city of tomorrow, that can bridge the gap between digital, natural and urban environment. The main theme of this paper is part of the extended scope of *Landscape Urbanism*, according to which the urban landscape can be redefined / designed through the remedial procedures of the urban landscape.

1 INTRODUCTION

Before tackling the main issue of the research presented in this paper, it is necessary to present the broader context of this research, as this constitutes the basis, which feeds the research interests, produces general questions and directs research methods. This research is being conducted at a time when the focus of architectural activity shifts from its perception as a form or (and) operational organization, which responds to a given architectural program, to its perception as composition of elements, their properties and relationships. At the dawn of our late capitalist era, we are witnessing a paradigm shift that encourages a new relationship between design and object, which, according to Michael Hays (Hays, 1998) is nothing other than the passage from a "critical history" to a "theory" of architecture.

To this end, the term "smart city" was introduced, which covers a wide spectrum of research and development applications. The concept of smart city involves an emerging market, therefore identifying and examining the term "smart" is still going on. Consideration of the particular characteristics of the smart city is best understood by interpreting its main conceptual features (Vianna et al., 2004; Hollands, 2008). Accordingly, "Smart cities" are created by the convergence of two major currents: on the one hand, the redefinition of the city through its communication technologies, digital networking and representation, and, on the other hand, through the understanding of the city as an environment of creativity and

[a] https://orcid.org/0000-1111-2222-3333
[b] https://orcid.org/1111-2222-3333-4444

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innovation. Despite the clear link between *society of creativity* and *information society*, the concept of "smart city" is still controversial. This occurred because term "smart" is often associated with digital functions, and the terms "digital city" and "cyber city" (Mitchell, 2006) are used alternatively and equivalently. However, it is certain that, providing a digital platform or a digital representation of the city does not adequately justify the description of an urban system as innovative. In the following sections, the main framework of the research presented in this paper elaborates on the above questions and proposes a new method for a *smarter* city.

1.1 Research Framework

Digital applications, sensors, and software often interact towards the creation of the *city of the future*. However, the real challenge in contemporary reality is to develop a "smart city", which starts from the city of today and enables the combination of smart practices. The current research attempts to define the concept of the smart city based on the structure of an existing city. Due to this, Landscape is introduced as a parameter, which in the proposed method acts as a key reformer of the urban fabric.

This paper is organized in two main parts. The first part addresses methodological issues: the importance of landscape ecology and its application to metropolitan planning; and the range of model approaches available in order to create a smarter city. The second part of the paper addresses a new methodological approach to design with emphasis on the landscaping component; the implementation of CA in this strategy; followed by an extended discussion; and ending with some conclusions.

2 THE STATE OF THE ART

Landscape Urbanism is a neologism, introduced in 1996 by Charles Waldheim that attempts to describe the landscape as an urban phenomenon, on an effort to reduce the conflicts between the man-made and natural environment of the cities. Landscape Urbanism is today a thriving interdisciplinary practice that emerges as a renewed perception for recording, dealing with, and strategically examining, or designing, towards contemporary problems of the structure of the urban landscape.

Waldheim, through a presentation of two projects from the 1930's and 40's, presents the early emergence of an "organic urbanism" which can be viewed as early versions of landscape urbanism principles. His account in these projects becomes the basis for a brief look into the rise of this organic way of thinking – that is the rise of landscape urbanism.

2.1 Defining the Idea of a *Smarter* City based on the Landscape

As mentioned earlier, the natural landscape, on the one hand, is the lens through which we can describe and visualize the smarter city, while on the other hand, the appreciation of the natural landscape is linked to a search for the landscapes dynamic capabilities as a design standard. Therefore, the landscape comes into the public scene as an indicator of the sustainable growth of the urban fabric, and as an indicator of sustainability to the extent that it can control the delicate dynamic balance between the natural space and the urban fabric. This renders landscape an attractive intervention environment worthy of a smarter city. In this paper, we will try to outline methods and strategies that can manage the dynamic conditions of the natural landscape. Specifically, the aim of the presented research is to propose a method for managing the landscape in the form of a diagram, and an approach, which will be linked with the concept of a smarter city, that is based and builds on the city of today.

3 THE MEASURING AND MINING URBAN DATA

The need to incorporate the ecological component in regional planning and landscape ecology ideas is broadly acknowledged as the fitting reason for environmental planning in urbanizing , however there is as yet a gap between the hypothetical originations of scene biology, the advancement of demonstrating approaches and the genuine usage of coordinated metropolitan planning. Such a comprehensive methodology requires a complex framework approach, so as to more readily comprehend the procedures included and to guarantee that future urban structures are practical and ecologically benign. Then, and most likely because of the absence of incorporated investigation and planning, there is an absence of instruments accessible to lead dynamic recreations of metropolitan land use change that coordinate landscape ecological concepts and principles.

3.1 Scope of Model Methodologies Accessible

A few studies have been done utilizing geological information systems (GIS). Nevertheless, few have endeavored to incorporate scene methodologies concentrated on scene availability, or having ecological segments collaborating progressively with urban pressure(s), or time development.

To analyze pattern and process all through a metropolitan landscape requires models that are delicate and receptive to heterogeneous nearby conditions and changeability. Shape Grammar and Cell automata (CA) are useful in doing this since they are cell-situated in their examination and results, sensitive and versatile to nearby conditions.

4 LANDSCAPE ECOLOGY AND A NEW APPLICATION TO METROPOLITAN PLANNING

In this section we attempt to define the research methodology. The notion of the smarter city as a hybrid field between the natural and the urban fabric permits the exploration of processes that will lead to the effective management of the properties of both systems (natural and urban). According to Herbert Simon (Simon, 1996), the dominant directions in landscape management are: a) prevision and b) the homeostatic and feedback adjustment. Prevision presupposes understanding the initial conditions, the selection of appropriate variables, and decoding of the relations between them. On the other hand, homeostasis refers to the flexibility of a system to absorb environmental changes remaining unchanged, while feedback presupposes a kind of dynamic adjustment of the system. Thus, we will try to outline a strategy for the hybrid development of smarter cities based on these two basic directions.

Specifically, depending on the issue raised each time, the dynamic planning tool is organized in three levels, namely tanks (provision), conduit (homeostatic), affordance (feedback adjustment). Along this policy lines, the first level regards the data configuration. Specifically, all data - parameters derived from the reading of the landscape are identified, recorded and assessed, as well as feed the system and affect its evolutionary path. The data collected, are classified into three categories, which will be constituted as “tanks”. The information entered in these tanks include the investigation of parts (for example number and sort of spatial components and species), the investigation of examples (for example natural connections that assistance set up and support species) and the investigation of procedures (for example natural capacities after some time).

4.1 Measuring and Mining Urban Data: Configuration

This paper proposes that a reasonable comprehension of ecological planning approaches and a clear understanding of spatial configuration of the landscape systems components is central Understanding spatial structure is one of the key activities in picking up a comprehension of patterns and process and in accurately getting ready for their working. In terms of full operational models of the spatial configuration, only two approaches have been widespread in use, due to their flexible implementation. In this way the above mentioned data are identified through Shape Grammar and CA.

4.1.1 Shape Grammar and Measuring Urban Data

Shape grammars were introduced by Stiny (Stiny, 1980) in A shape grammar consists of a set of rules regarding the embedding and analysis of a shape and its replacement by another. The rules are formed in the following manner:
Transformation Rule

C' = [[C - t(g(x))] + t(g(y)) in which C= initial shape, t= transformation, x=Rule condition, y= Rule conclusion

Table 1: Shape rule syntax.

C' = [C - t(g(x))] + t(g(y))		
	New Shape	(visual)
C	Initial Shape	
t	transformation	
x	Rule condition	
y	Rule Conclusion	

Why shape grammars in cities?
Cities have been shaped through the century not only by landscape or climate but by culture, social

composition and daily life as well. All that create a unique character that defines each city expressing all the things that make it familiar to its citizens and express their way of life.

Shape grammars can be helpful at the visual representation of an existing condition that affects the spatial interrelations of a city's components, such as the Built Environment - Natural Environment. After the research parameters are set, the grammar can be be applied analytically to a defined region in order to discover the spatial rules that have been formed up to that moment in the region. The problem can then be decomposed to its basic requirements such as physical elements, physical landscape, geodynamics, buildings and urban expansion. Shape rules can be derived from the interaction of the above and can be used to study the elements' behavior.

Table 2: Shape rule for Natural – Urban transformation.

$C' = [C - t(g(x))] + t(g(y))$		
	Modern State	
C	Initial Condition/ Natural State	
t	transformation	
x	Natural element	
y	Urban Element	

4.1.2 The SLEUTH Cellular Automaton Model and Measuring Urban Data

SLEUTH is a CA model created to figure urban development and land use change. SLEUTH is an acronym for Slope, Land Use, Excluded Areas, Urbanization, Transportation, and Hill shade, the information layers that make the model run.

SLEUTH requires five inputs maps: urbanization, transportation, areas excluded from urbanization, slopes, and a hill shaded map (prepared using GIS and then converted to 8 bit GIF images). For all these layers, 0 is a null value, while all the values in-between 1 and 255 are a measured value. The model also requires that the input layers have the same number of rows and columns and are correctly dereferenced, as the model is sensitive to layer misregistration. Urbanization is the most important layer in the model, and for statistical calibration of the model at least four urban time periods or spatial extent 'snapshots' must be used.

The model works in the following way: after reading the input layers, initializing random numbers and controlling parameters, a predefined number of interactions takes place that corresponds to the same number of years. An outer loop executes each growth history and retains statistical data, while an inner loop executes the growth rules for a single year. After each model run, sets of descriptive statistics are computed and saved to a file for the purpose of calibration. There are thirteen scores, and include: r2 population (least squares regression score for the number of urban pixels compared to actual urbanization for the control years), edge r2 (least squares regression score for the length of the urban-rural edge compared to actual urbanization for the control years), r2 clusters (least squares regression score for modelled average urban cluster size compared to known mean urban cluster size for the control years).

Table 3: Sleuth required input files.

MODEL	SLEUTH
REQUIRED INPUT FILES	1.urbanization, 2.transportation, 3.areas excluded from urbanization, 4.slopes, (besides the slope, a constraint or exclusion map represents water bodies, or natural and agricultural reserves)

4.2 Conduit

4.2.1 How Shape Grammar Can Derive Sleuth Rules for Spatial Configuration

As mentioned in (4.1.1) shape grammars can be used analytically to visually express spatial properties of a given problem and form shape rules that express them, for example how does built environment develop itself around existing rivers in a specific city? The formation of such rules can help establish a certain vocabulary of the case study region.

p.e

```
If ( C = initial condition){
  If (river_not_covered){
    riverbank();
    builtEnvi();
```

```
If (r_bank && b_Envi) {

    If ((r_bank ∩b_Envi) ≠0){
        Shape Rule  Y1 = (Overlap_Shape);
        Shape w1 = (r_bank – b_Envi);
        Shape b1= (b_Envi-r_bank);
        }
    Else if  ((r_bank ∩b_Envi) =0){
            inBetween();
            Shape Rule  Y2 = (Inbetween_Shape);
            }
    Else () {
            neighboring= true
            }
        }
Else() {
    urbanEnvironment();
        .
        .
        .
  }
}
```

Table 4: Shape rules syntax for intervention strategy.

	C' = [C - t(g(x))] + t(g(y))	
	Desired condition	
C	Current Condition	
t	transformation rule based on Shape Grammars	
x	Element to be replaced	
y	New element	

Y1 and Y2 are shape rules while {w1,b1} are subsets. More steps can be used in order to acquire more properties such as riverBank (); which can be used to define shape transformation of the river bank, the kind of material that exists on the bank. In order to complete the analysis and create a “language” one needs syntax. Cellular automata come in to logically define the neighboring properties of the shape’s interrelations. More specifically, SLEUTH CA, can help create a list of neighboring Logic Rules based on the data of the SLEUTH method. The data are used as parameters for the shape grammars. The purpose of this cross referenced method is to create one, final, list of rules, a language. This way the set of rules is multilayered and holds properties spatial interrelations, neighboring, materials, physical elements or even social properties.

Once the analysis is completed and the problem has been defined one can study the best strategy of intervention and composition by using the language of the existing region, creating a landscape that is familiar to the city and works with it.

4.2.2 How a CA Model Can Direct Sleuth Urban Rules

This Understanding spatial structure is one of the key activities in picking up a comprehension of patterns and process and in effectively anticipating their working. CVCA builds on SLEUTH and builds up a lot of countervailing methodologies to the urban development dispensed by SLEUTH. This dynamic association is valuable, since it permits urban development produced by SLEUTH to be headed to different territories where the techniques are not connected. CVCA starts by surveying the underlying condition of the scene, creating a few scene measurements dependent on the underlying state, and utilizing these measurements to choose and execute the proper scene procedures. CVCA then interfaces yearly with SLEUTH so as to have the scene techniques upheld, along these lines managing SLEUTH forward to 'great to-develop' regions, and buffering essential environmental regions distinguished by CVCA from anticipated urban improvement. (Silva, Ahern, Wileden , 2008)

This is the principle motivation behind why the CVCA show is named 'countervailing cellular automaton'. It utilizes a lot of scene biological methodologies to balance urban development to great to-develop territories.

The CVCA demonstrate requires a similar info layers as SLEUTH (Slope, Hill shade, Transportation, Urban, Excluted). The excludes layer must be changed altogether, in any case, so as to recognize an alternate class that represents to every one of the territories outside the boundary of the metropolitan zones. These zones are avoided from urbanization, yet for CVCA purposes they can't be viewed as a similar kind of prohibition, since they don't figure in the use of the natural techniques. The measurements utilized were picked by the spatial indicators that have been referenced in various landscape ecological studies .

SLEUTH will work, in this way, as the background of urban elements, where a lot of natural elements needs to countervail. Through time, this round of cooperation of urban– landscape will create an alternate picture of the metropolitan territory, where the requirements of urban development are fulfilled, however where environmental necessities are likewise kept up, expanded or enhanced.

4.3 Affordance

The movement of the conduit is double at the level of the switching, depending on the sign of the vector objects located therein. Since the vector objects with negative sign (-) are considered those whose size deviation from the permissible limits (indicators) is the highest, as indicated by the indices. In the second selection step from said selected vector objects, we chose to consider first those which the chart has indicated from the outset that require special attention against the particular way in which they are studies.

The CVCA yields four classes that coordinate five diverse scene arranging methodologies (protective, defensive, offensive, opportunistic, let it grow). As examined in the presentation, it is imperative to build up this sort of model, where urban and ecological elements can be coordinated, taking into consideration reenactments where both urban and natural needs are considered and designated in a feasible future.

5 LARISSA AREA

Larissa, Greece is the territory of examination of the exploration (Fig. 1). So as to more readily comprehend the subsequent measurements inside the alignment results and in this manner in the situations. The case study was a landfill outside the city that was meant to be an Agricultural Center and a Park. Since the landfill was not occupied the stage of analysis gave way to analytical approach of composition through the use of Cellular Automata.

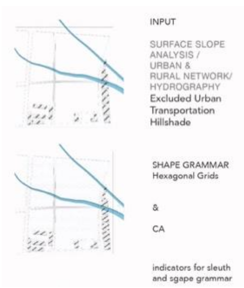

Figure 1: Sleuth and Shape Grammar required input files and indicators.

Figure 2: Offensive strategy. Set up an external support to the fix and a passage to its neighbor.

Figure 3: Defensive strategy. 50% (all cells are low probability of change).

Figure 4: Opportunistic strategy. Establish corridor between the fix and its neighbor.

Figure 5: Protective strategy. Establish corridor and create outer buffer.

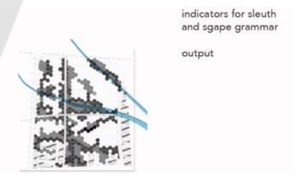

Figure 6: Output files.

The application of CA formed cells of 8 different qualities, *built areas*, *hard ground*, *soft ground*, *urban water*, *non urban water*, *urban green*, *free space and sports* which are set with specific neighboring properties. The next step was to use Shape Grammars to bring these qualities into shape and turn them into human scale spaces.

The main part of that study was the imprint of the underwater veins on the surface and how that could be a living space. Each Shape Rule is connected to a neighboring condition of the CA.

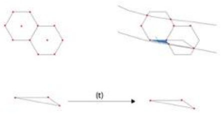

Figure 7: Shape rules for water points, the initial condition is represented on the left. The initial condition is the hexagon cell defined by its nodes. The first step is the intersection of the cells with the water vein imprint which gives us new nodes. The second rule is the application of the triangle shape through transformation to the shape result from the intersection.

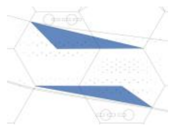

Figure 8: Shape result.

Following the urban water cells, came the formation of the 'banks' the neighboring cells according to the CA results. The shape rules that were applied were aimed at the formation of a landscape supporting the strategy.

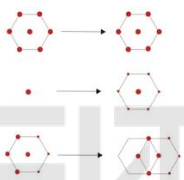

Figure 9: Shape rules for the landscape formation, initial condition is on the left and shape result is on the right. After the shape has been finalized there is one more step, that of node interpolation. The shape results must not include more than 3 neighbouring cells and must not intersect with more than 3 of their segments.

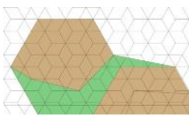

Figure 10: Shape result example.

6 CONCLUSION

To sum up, if today the cultural consideration changes looking for a smarter city, then design strategies should move to manufacturing techniques that manage change through ecological evolving and developing platforms. On an effort to form a smarter city, natural landscape should not be a backdrop on which the urban articulation will be placed, but a dynamic field of study, management and recovery of the urban fabric. On this basis the research presented in this paper a first conceptual approach to a mechanism that may monitor the transformation of natural space, fed with data obtained from its analysis, in order to compose them and redefine the urban space. It could be said that this mechanism acts as a filter which not only receives information but also checks if this information can be changed and also produces connections and forms supported by computer generated programs. Unlike traditional urban fabric design methods, or the digitized form of smart cities, this mechanism aims to produce a smarter city through a renewed perception of convergence of the aspect between man-made environment and natural space.

This paper sets up the need to incorporate the natural part in region planning, and featured landscape ecology concepts as the proper reason for environmental planning in urbanizing districts. The gap between the hypothetical originations and the practise of landscape is apparent; the advancement of displaying approaches and the real usage of coordinated metropolitan planning will in general be ignored. While we can point to a few explanations behind this gap, it is imperative to feature one of its plausible main drivers: an holistic methodology requires a complex system approach, so as to all the more likely comprehend the procedures included and to ensure that future urban structures are practical and naturally generous; and the truth of the matter is that we are utilized to deal with the issues and solutions.

By proposing an urban model (SLEUTH) that can cooperate with landscape ecology model (CVCA) and with a social-economic tool (Shape Grammar) so as to propose plenty of arranging techniques that can guide urban development, this paper is contributing to the progress of research in and practise with regards to landscape planning.

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