Representing urban cognitive structure through spatial differentiation

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Abstract

A spatial differentiation measure conceived as a reference system between the physical environment and the corresponding cognitive structuring that takes place in human minds is formulated as a virtual spatial interaction. The proposed measure aims to represent the widely shared features of the cognitive structure given to the environment. The theoretical framework includes concepts from self-organisation (synergetics) and cognitive information processing. This approach permits that the mental processes behind the structuring of environmental information be “projected” onto the urban space, becoming an intrinsic part of it. Hence, the structure given to the environment is defined as an imposition of a possible hierarchical order, determined by features internal and external to the observer. The fundamentals of environmental cognition were defined as the identification of information patterns by different criteria and the aggregation or segregation of information based on similarities (or equivalence) and differences in the detected information. Attributes are used in different combinations for the determination of variables that represent distinct aspects of environmental information structuring, and the interaction rules use these variables in processes of competition and co-operation between the environmental elements to determine which tend to create isolated patterns of information and which will be agglutinated in more generalised patterns. An experimental module was applied and the obtained results were contrasted with results from traditional survey methods of public image.

1. Introduction

The way urban agents structure spatial information plays an essential role in their interactions with the environment. It is in accordance with this detected structure, rather than the objective reality, that they drive their decisions and act in/on urban spaces (Proshansky et al., 1978; Smith et al., 1982). The way the city is experienced affects how it is transformed, and this, in turn, affects how it is experienced (Ittelson, 1978). Action and reaction are cyclical and inseparable. Thus, the cognitive structure given to urban environments affects the overall dynamics of urban processes.

In this context, a spatial differentiation measure capable of creating a referential system between the physical environment and the correspondent cognitive structure elaborated by human minds may become an important instrument in the representation and understanding of the different urban processes. The present paper reports the theoretical and methodological base used in the creation of a spatial differentiation measure that aims to describe the urban environment as cognitively structured information. We also report early results reached with the application of an experimental module, carried out to test the applicability of the proposed methodology.

2. General conception and theoretical framework

Cognitive structure given to environmental information is the result of an arrangement imposed by the environment's physical characteristics and the perceptual and cognitive processes involved in environmental cognition. The resulting product of this ordering, that each person stores in the mind, is called a mental representation.[1]

Even though each person perceives the environment in a relatively unique and particular way, and thus creates unique mental representations, it is possible to detect similarity patterns amongst different representations given to the same environment. These similarities are said to be due to the proper structure of the physical environment – that induces or stimulates certain apprehensions, and also to physiological similarities amongst individuals (Gibson, 1979; Cosmides et al., 1994), and to the social and cultural bases of environmental knowledge (Vygostsky, 1984; Donald, 1991). In urban studies the concept of "public image" (Lynch, 1960) is used to make reference to these similarities originated from the widely shared features of individual mental representations of the environment. Similarity patterns present in the public image are responsible for the environmental cognitive structure that is important for urban processes. It is this structure that we intend to detect in the urban environment through a spatial differentiation measure.

The description of the cognitive structure of urban environment is made by a virtual spatial interaction process. The proposed spatial differentiation modelling process is centred on the physical characteristics of the environment (attributes) and on the way that they are accessed and processed by humans (environmental cognition). Therefore, the urban environment is not measured directly by its physical characteristics, but by these defined and organised as a function of the mental processes and also by the simulation of relations and interactions amongst the stimuli.

2.1 Urban environmental cognition as a systemic process

Environmental cognition has long been recognised as a systemic process (Barker, 1963; Lynch, 1960; Rapoport, 1977 among many others). Apparently, conceptions from complex systems and self-organisation can be related to the data structures present in mental representations:

- General structure is dependent on the interactions or relations between the diverse elements. Neither the person nor the environment alone determines what is perceived; codification of information depends on the interplay between both (Gibson, 1979). Thus, data structures depend on internal and external factors. The latter include interpersonal, social and cultural information that are available in the environment (Barker, 1963; Ittelson, 1978; Portugali, 1996; Krafta et al., 1998). The environmental elements lose strength as isolated units defined only by their proper attributes, and the physical context in which they occur as well as the mental processes responsible for apprehension are reinforced. Consequently the urban system is better represented by both its external components (environmental elements and socially shared information) and its internal components (mental processes).

- Hierarchical structures. Environmental information may be coded simultaneously in different observation scales (Cohen, 2000). Information can be stored in memory as a small detail like when we refer to "the building entrance", to the whole building, or even to a street or large areas as when we refer to "the city core". The level used depends on which level will be cognitively more efficient (maximum information with minimum cognitive effort) for the given situation (Rosch, 1978; Tversky et al., 1983; Lakoff, 1987). The lower levels of the system are responsible for what happens in higher levels and these in turn regulate what happens in lower levels. Components are related to each other through a small number of interaction rules that are capable of generating the observed behaviour patterns. Even though each level is distinct in nature, the basic functional rules are similar for all levels. In the synergetic approach to environmental cognition (Haken, 1997; Portugali, 1996), the behaviour patterns observed in higher levels are due to order parameters that impose themselves on the environment and on the observers' cognitive processes.

- Self-organisation and emergent properties. Self-organisation processes are acknowledged in all the extensions of environmental cognition.[2] Gestalt psychology recognises them in visual perception when it asserts that the different parts of the stimulus interact with each other, and what is perceived is a single whole, different from the sum of the component parts. Cognition as well as perception presents global qualities or emergent proprieties that are not inherent tin the isolated components. Many authors have observed that environmental elements present in mental representations are clearly distinct in nature from their component parts, and that alterations in one urban element may affect the apprehension of all the others.

2.2 Perceptual and cognitive processes and environmental information structuring

Statements in perceptual and cognitive processes can elucidate a lot about how environmental information is processed and what kind of data structures are used during interactions with the environment and in storage of environmental information in memory. They can also help to define what mechanisms are used in the construction of mental representations. Apparently, an analysis of statements in perception and cognition indicates that the elaboration of environmental mental representations includes processes of:

53.4 - Selective information pickup. Selectivity renders manageable the quantity of information used and keeps data storage restricted to relevant information (Ittelson, 1978). The inclusion of environmental elements in mental representations has in common the high level of information and utility for environmental interaction.

- Clustering processes in the organisation of information. Clustering occurs in all stages of information processing and has the result of facilitating information processing and storage (Kintsch, 1970). Clusters can be formed by similarities of physical characteristics or by equivalence of meaning or symbolism.

- Simplification of available information. Environmental information is simplified by clustering and the elimination of irregularities (Lynch, 1960; Passini, 1992). Simplification helps memorisation and structuring information.

- Categorisation processes. Information, when possible, is classified into categories that, in most cases, are culturally shared knowledge (Rosch, 1978). Categorisation implies associations between environmental information and pre-existing mental concepts of known categories. Elements may be more or less typical for a certain category, and this level of typicality (or degrees of membership) influences the ease of "reading" the environment and recognising objects and places.

- Incorporation of related information. Subjective and previous knowledge, as well as socially acquired information, are incorporated into the objective information from the environment. Normally this incorporation depends on the proper physical characteristics of the environment.

- Meaningful information. Environmental elements included in mental representations generally refer to meaningful information. Socially created and shared meanings are part of the perceptual qualities of the environment (Gibson, 1986; Neisser, 1994). These meanings result from learning. Their apprehension depends on the specific properties of buildings or urban spaces as well as the interpretation made with the use of socially created and culturally shared codes. Therefore, buildings and urban spaces incorporate subjective qualities of collective character.

These processes serve as the more general framework for the elaboration of the interaction rules and environmental variables to be used in the spatial differentiation measure.

2.3 Environmental elements and attributes present in mental representations of the environment

Lynch identified five environmental elements present in mental representations: paths, edges, districts, nodes and landmarks. All five elements can be understood as the manifestation of the system's emergent properties: they are information patterns emerging from the system as the result of interaction rules which order parameters that impose themselves both on the environment and on the individuals' cognitive processes. Using principles of information structuring during perceptual and cognitive processes and Passin's (1992) work as a basis, we assume that the selection and formation of the five environmental elements depends basically on two differentiated criteria:

- Information aggregation. This process detects continuities in the environment, defining useful groupings of information and, in this way, facilitates general orientation in the environment and comprehension of its overall structure. It is used for situations, objects and places that are similar or equivalent, creating environmental elements such as districts and paths;

- Information distinction or segregation. Distinguishes significantly different or strategically located information, in order to create environmental elements for orientation and reference such as nodes and landmarks. This process detects discontinuities that can serve the purpose of anchoring environmental information and reference points, defining local identities and facilitating more precise localisation in the environment.

The environmental element that Lynch defines as edges can arise both from the first process – as a consequence of boundaries between districts, and from the second process – when they define physical barriers or limits that serve as reference points or orientation elements.

Aggregation or segregation of information in the environment depends both on the proper characteristics of buildings and urban spaces, as well as on the context were they occur. Together, these criteria serve the basic purposes of cognitive economy and organisation of information to satisfy the individual's functional needs in his/her interaction with the environment.

Inclusion of environmental elements in mental representations of the environment depends, according to Lynch, on their legibility and imageability. Legibility is an environmental quality concerning the facility of the visually perceived cues (stimuli) being understood as a coherent information pattern. Imageability is related to those qualities of the physical setting that give it a high (or low) probability of evoking a strong mental representation in any given observer. Even though in Lynch's definition these concepts are said to be environmental qualities, they can only be explained taking as reference the mental processes of information structuring.

The concepts of legibility and imageability may both be related to general principles of self-organisation. Both are dependent on the configuration of the whole system and are due to the self-organising processes of formation of information patterns. Legibility refers to information patterns that emerge spontaneously as proprieties or characteristics of the system, and that are readily recognised by people. High imageability is related to these information patterns becoming order parameters, imposing themselves on the environment and cognitive processes by their easy incorporation in the mental representations of the environment.

Analysis in urban environmental cognition reports indicate that the variables responsible for the level of imageability of buildings and urban spaces are:

- Visual identity or physical appearance – where the intensity of the physical characteristics and the level of distinctiveness or similarity of the building or urban space with their surroundings are both important;

- Visibility and localisation in the environment – determined by the higher or lower frequency of visual interaction with the building or urban space and also higher or lower probability of the information having utility in locational terms;

- Having a meaning – meanings may be due to the recognition of meaningful categories, that is, general categories of buildings or urban spaces defined in terms of functional, social, economic or aesthetic criteria. They may also refer to social-symbolic meanings that are specific to a given building or space, and many times are independent of physical characteristics. These specific meanings are socially shared and normally have a name or label designated to them;

- Evaluative associations – where positive or negative evaluations influence the probability of inclusion in mental representations. This factor has less strength in larger spatial units;

- Individual associations – factors not socially shared that are originated by the individual interacting with the environment.

All variables except the last are expected to be related to the environmental elements present in the public image, and thus are expected to be significant in the determination of the cognitive structure of the environment. For Rapoport (1977) congruence in more that one factor may generate particularly strong mental representations, but Passini (1992) observes that meaning and physical appearance are not mutually exclusive, and buildings or urban spaces may have high imageability based on only one factor. It will be upon these variables that the spatial differentiation measure will be determined.

3. General description of virtual simulation of the cognitive structure of urban environment

The proposed virtual simulation process aims to capture directly some of the environmental elements present in Lynch's work: architectural landmarks, place nodes, paths and districts. These represent the most common and frequently used elements in public image. Other kinds of landmarks and intersection nodes are not actually contemplated in simulation, and edges can only be indirectly defined (some paths maybe acting as edges, and the boundaries between districts are identifiable).

The adopted theoretical framework points to the:

- interdependency between internal and external factors of environmental cognition. In principle, it is possible to think about "projecting" the mental processes behind information structuring onto the environment, making them an intrinsic part of the environmental characteristics. Hence, the component parts of the system may be restricted to spatial units of the environment with physical and mental attributes, facilitating virtual simulation, and determining "information units" which represent both the internal and external factors involved in environmental cognition.

- existence of hierarchical structures that induce a multiple-level representation of the environment. Self-organisation principles indicate that these levels are correlated in bottom-up and top-down processing. The first indicates that the interactions between the information units in the lower levels generate the patterns or environmental elements in the higher levels. The second indicates that the higher-level environmental elements constrain the lower level information units in their interactions. Hence, it is expected that buildings and urban spaces (lower level information units) will be responsible for the formation of environmental elements of higher level such as paths and districts and these, in turn, constrain the landmarks selected inside them.

- adoption of an information structuring strategy resulting from the interaction between the diverse information units of the environment. These interactions represent the perceptual and cognitive processes of environmental cognition. Thus, perceptual and cognitive principles, as well as empirical findings, are used as guides for the formulation of the processing rules used in simulation.

3.1 Representation of urban environment

In the representation of the urban environment, the spatial *continuum* needs to be divided into discreet units. These must be congruent not only with environmental characteristics but also with the apprehension of environmental information. This makes the spatial units reflect what we called information units: discrete spatial units with attributes and associated behaviour (in the system). The urban environment is represented in the virtual spatial interaction process by a:

- Set of cells – representing the information units. The urban environment is divided in two types of cells: β cells that represent information units given by urban lots and buildings; and α cells that refer to information units given by fragments of open urban spaces through which individuals circulate and experience the city (Figure 1a). These fragments are defined as segments of the axial lines between intersections, that is, the topological changes where the potential observer will face the choice of either moving along the same route or selecting an alternative route (a_1), and public squares (a_2). The associated attributes comprise physical characteristics (concrete and measurable features), relational properties (due to the relative position in the environment), and social and culturally shared information (meaningful categories and specific meanings). Apart from these attributes, α cells also carry properties due to events (like movement and activities) that occur inside them and information about all connected β cells.

- <u>Connection network</u> – that makes explicit the physical and spatial structure of the environment by the representation of the relational structure or the connections of all possible interactions between the information units of the system (Figure 1b);

- <u>Neighbourhood areas</u> – that are the located regions in the connection network that represent the spheres of influence of each cell within the system, and it is within these pre-defined areas that interactions among information units occur. Neighbourhood areas are specific for each type of cell and hierarchical level of the system (Figure 1c).

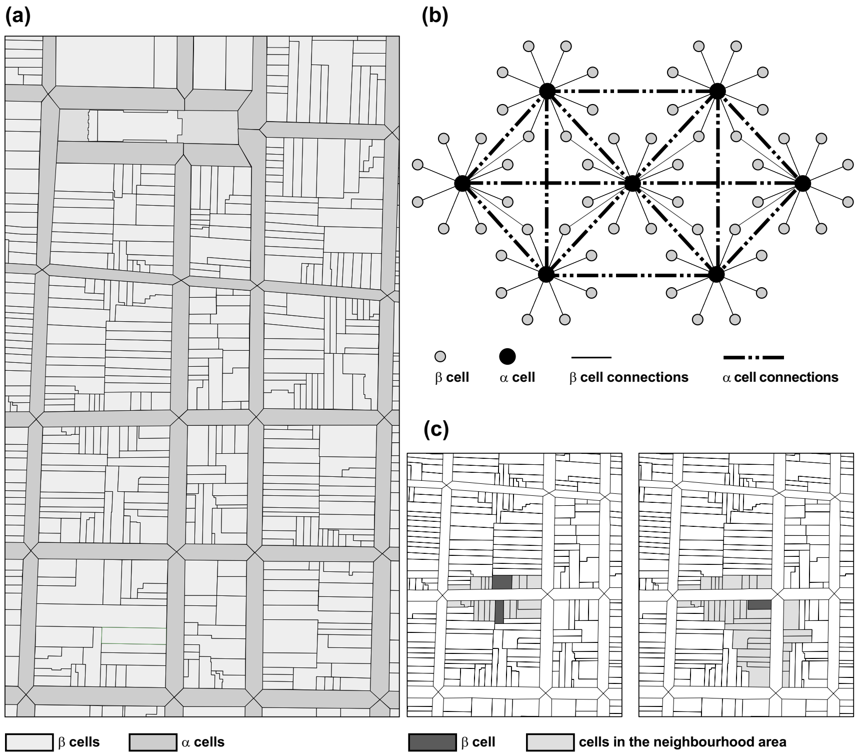


Figure 1: Graphic representation of: (a) urban environment as a set α and β cells; (b) the connection network; and (c) neighbourhood area of β cells

3.2 Hierarchical levels and interaction rules

The hierarchical structure of the model is composed of three levels corresponding to lots and buildings, small-scale spaces, and large environmental wholes. These levels represent specific perceptual and cognitive interactions between people and the environment (direct apprehension and apprehension constructed along time), and are also representative of different aggregation levels of environmental information.

The virtual simulation aims to capture the emergence of the diverse environmental elements present in the cognitive structure based on the individual behaviour of information units and their interactions. In each level, cells are processed by a set of interaction rules that generate the self-organising production of higher-level environmental elements. The interaction rules represent information structuring and perform the same functional proceedings in each level, but have specific qualities that depend on the initial state of each cell and are due to particularities of environmental cognition in the different scales of the environment.

Interaction rules are algorithms that codify the behaviour expected to be responsible for information structuring, and define the cells state value at the different hierarchical levels of the model. According to the previously presented ideas, the main principles behind information processing are distinction or aggregation of environmental information based on differences and similarities or equivalence. Inclusion in mental representations depends on the value that the considered information unit, and all the other units in its neighbourhood have for the variables that interfere in the imageability level.

The proposed interaction rules consist of three consecutive processing modules that are applied in parallel to the α and β cells:

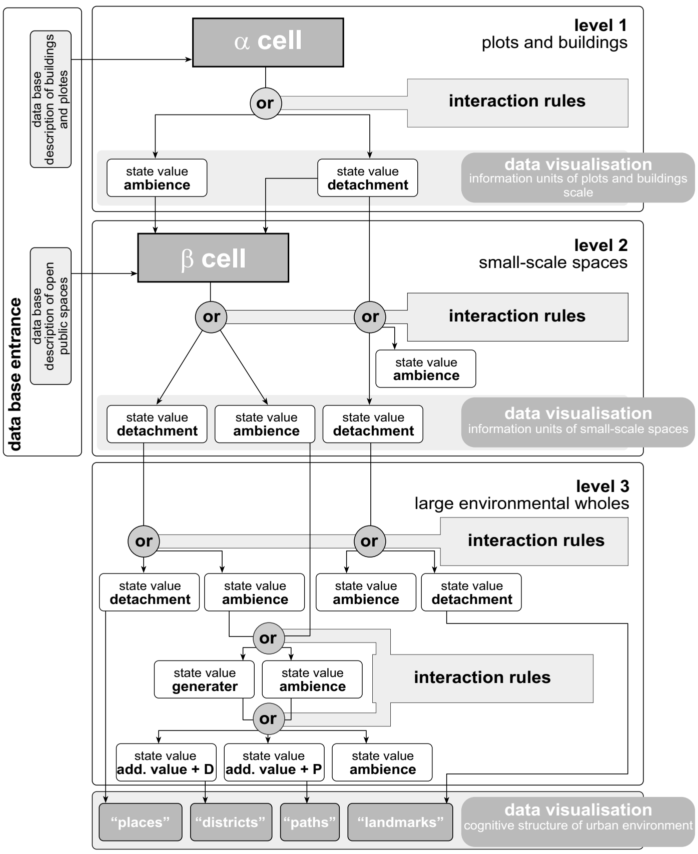
- <u>Module 1: preparatory procedures</u>: using IF – THEN – ELSE type of sentences the cells' attributes are processed in different combinations in the calculus of the values for each cell variables. Variables reflect the physical characteristics and their apprehension conditions. The calculated variables are distinct for each cell type and represent the several overlaid information patterns of the environment that are simultaneously read;

- <u>Module 2 – competition processes</u>: determines the general distinctiveness (GD) of the cell (how distinct the cell is in its neighbourhood) based on the variables' set of values and on a comparative process among the cells. It simulates the competition between the different information units in order to be recognised as segregated units of information, and identifying the winning cells. These cells get state value "detachment", the others are defined as "ambience". Only the cells with state value defined as "detachment" remain as autonomous information units in the next level of the system. For these, module 2 will be applied again in the next level while "ambience" cells are processed directly with module 3;

- Module 3 – co-operation processes: Detects both the aggregation tendencies and the higher-level environmental elements formed by cell aggregations. This last module is only applied to the cells that have state value defined as "ambience" assigned by the previous module. Using the variables' set of values and a comparative process, the similarity level (SL) of each cell is determined in its neighbourhood area. Criteria for comparison between cells changes along hierarchical levels, with perceptual processes having primacy in lower levels, and cognitive processes becoming more important in the higher levels. The higher-level environmental elements have their properties defined by the simplification and generalisation of the original set of attributes coming from the aggregated cells. Cells with high SL have an additional value added to the state value that makes explicit the kind of variable(s) responsible for detected similarities. Cells with low SL values will remain with state value "ambience" and are discarded in the next level. Only cells with the additional state value will be used in the next level of the system, being processed again by module 3.

Interaction rules are applied in successive iterations for the different levels of the system, always in parallel for α and β cells, and with gradually enlarged neighbourhood areas. Initially all cells have state value nill and are all processed separately by cell type. After the fist interaction, however, the same type of cells with state value "detachment" and "ambience" have distinct processing (Figure 2).

Figure 2: General diagram of environment information units' formation in the virtual simulation process



Cells that "survive" as segregated information units along the three hierarchical levels have a high probability of being included in this information level in mental representations, and thus represent environmental elements of the cognitive structure. So the b cells with state value "detachment" after interactions in the last hierarchical level indicate potential landmarks, and the a cells with state value "detachment" represent probable nodes corresponding to small urban spaces with strong identity.

Cells that stand in the last hierarchical level with state value "ambience" and additional value have high probability of representing environmental elements of higher level (composed of more than one information unit). The β cells with state value "ambience" and additional value refer to building sets that form unique architectural environmental element (like when you refer to “the ninety century houses of the central square”). The a cells with state value “ambience” and additional value represent paths when located continuously along a same axial line, and represent districts when aggregated in several different directions.

Hence, as in a public image of the environment, after having carried out this process for the three levels of virtual simulation there will be environmental elements from all levels of the system, and gaps in the urban environment corresponding to unclear or irrelevant environmental information.

4. Application of the experimental module and initial results

An initial experimental module of the proposed measure was created with the methodology responsible for the detection of information patterns originated by the β cells. The aim was to test the power of the model in detecting buildings with high probability of becoming landmarks. For this purpose, the experimental module was restricted to the proceedings specific for variable calculus and competition processes (interaction rules modules 1 and 2) with β cells.

Figure 3: Studied area represented in β and α cells and examples of built environment (photographs by the author)

The experimental module was applied in the urban core of a middle size city (Pelotas, Brazil). The study area has 2 public squares and 82 blocks divided in 1899 lots. The selected area has a relatively regular grid and a flat topography, ensuring minimum influence of urban design on the β cells. The study area also has many internal sub-areas with distinct character and great diversity of building types and functional uses (Figure 3). These qualities are important because they guarantee variability of spatial contexts, making possible a better verification of the proposed methodology.

The attributes selected for the β cells were based on reports of urban environmental cognition and on the specific characteristics of the building set. The attributes are: building height, volumes shape, doors, windows, disposition of openings, colour, texture, surface treatment, special elements, presence of signs and lettering, maintenance quality, setbacks, formal categorisation, functional categorisation, socially shared name, localisation in the block, and α cell(s) of access.

4.1 Module 1 and the variables calculus

The variables used in virtual simulation are composite measures that depend both on the physical characteristics of the environment and on the characteristics of perceptual and cognitive processes. Variables calculated for β cells are:

- Prominence value (PV): defines the distinction level of physical appearance of the cell in its neighbourhood by the comparison of its physical attributes with attributes of the other cells. For each attribute that singles the cell out it is assigned a score value. PV figure results from adding the attributes' weighted scores. Increase in the number of non-shared attributes causes the exponential growth of PV values:

$$PV = 10^{\sum_{k=1}^{n} \Pr_k \cdot a_k}$$

Where: a_k = attributes score

Pr_k = weight value

- Visibility and localisation (VL): defines the potential utility of the cell as a reference point in the environment. This potentiality is determined by how visible the building is and by localisation in strategic points of the urban environment. The cell receives a score for localisation in distinct or large open spaces, access by more than one a cell, significant height, and for big front setback. VL is calculated by adding the first three attributes' weighted scores, and the subtraction of the last attribute's weighted score:

$$VL = 10^{\sum_{x=1}^{3} \Pr_k \cdot a_k - P_4 \cdot a_4}$$

Where: a_k = positively related attributes score

a_4 = negatively related attributes score

Pr_k = weight value for the positively related attributes

P_4 = weight value for the negatively related attributes

- Categorisation and level of typicality (LT): the belonging or not to each category is defined as the cell's attribute. LT is defined by the higher or lower similarity of the cell attributes with the attributes of a typical member of the category. The cell scores for each attribute equal to the attributes of the typical member. Calculus of LT is given by the summation of the score received from each attribute multiplied by its weight.

$$LT = 10^{\sum_{x=1}^{n} \Pr_k \cdot a_k}$$

Where: a_k = attributes score

Pr_k = weight value

- Unique membership of the category (UM): cells that belong to formal or functional categories that are not present in other cells of the neighbourhood receive a score. UM results from the summation of both scores' multiplied by the weight values:

$$UM = 10^{\sum_{x=1}^{n} \mathrm{Pr}_k \cdot a_k}$$

Where: a_k = score for each category
Pr_k = weight value

- Specific meanings (SM): this type of meaning normally has an associated name or label, and some also have related physical attributes. For each kind of specific meaning the cell receives a score for the related attributes and socially shared labels. Calculus of SM is made by the summation of total scores in each specific meaning multiplied by its weight.

$$SM = 10^{\sum_{x=1}^{n} \mathrm{Pr}_k \cdot s_k}$$

Where: s_k = score for each specific meaning
Pr_k = weight value

- Evaluation (EV): refers to the potential positive or negative valuation of the cell. EV is calculated by the summation of the set of attributes considered negative, multiplied by their weights, subtracted from the summation of attributes considered positive, multiplied by their weights:

$$EV = \mathrm{sgn}\left(P_1 a_1 + P_2 a_2 - P_3 a_3 - P_4 a_4\right) \cdot 10^{\left|\frac{P_1 a_1 + P_2 a_2}{P_1 + P_2} - \frac{P_3 a_3 + P_4 a_4}{P_3 + P_4}\right|}$$

Where: P_1, P_2 = weight value of positive attributes
a_1, a_2 = positive attributes
P_3, P_4 = weight value of negative attributes
a_3, a_4 = negative attributes

$$\mathrm{sgn}\, x = \begin{cases} 1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases}$$

4.2 Module 2 and the competition between b cells

Processing with module 2 of the interaction rules will define the state value of each cell. State value makes explicit the tendency of each cell standing as an individual information unit in the next level of the model, or being incorporated in the more general information of the environment. This tendency is measured by the general distinctiveness (GD) of the cell in its neighbourhood. GD is defined for each β cell as:

$$GD = P_{av} \cdot EV + \prod_{x=1}^{n} P_k \cdot V_k$$

Where: P_{av} = weight value for EV

EV = evaluation value

P_k = weight value for the variables

V_k = variables (PV, VL, LT, UM, SM)

Differences in the hierarchical levels are represented by alterations in neighbourhood areas. In the first level neighbourhoods consist of all β cells connected to the same α cell of access, in the second level neighbourhood comprises all β cells with state value "detachment" in the limit distance of one step from the α cell of access, and in the third level neighbourhood is extended to all β cells in the system with state value "detachment". Differences also appear in the weighted values used with the variables in GD. In the first level, weight is stressed on PV and UM, representing greater dependencies on perceptual issues. For the second and third level the weights on SM and VL are reinforced, representing the importance of cognitive features and information utility in these levels.

With the GD values, cells compete with each other in their neighbourhood areas, and those that have the highest GD values, values until 20% smaller that the highest, or even values bigger that the minimum level (corresponding to two variables with maximum value) are understood as being more easily coded individually and receive state value "detachment". The cells that do not satisfy these conditions receive state value "ambience". Only the cells with state value "detachment" remain in the next level of the model as valid cells for processing with module 2 of the interaction rules. All b cells that still have state value "detachment" after the application of interaction rules in the third level of the model represent the potential environmental elements defined as landmarks.

4.3 Obtained results and model validation

A recent survey in the same urban environment as our study area detected 30 buildings as landmarks using traditional survey methods for public image (mental maps and interviews) with 60 respondents (Azevedo, 2000). These buildings were used for comparison with the obtained results and model validation.

In the simulation process all variables received weight 1 (one), except the stressed variables in each hierarchical level that received weight 1.5. However, initial analysis indicated the need for adjustments in the calibration of the relative weight that each variable plays in environmental cognition. Apparently SM, UM, VL and PV are the most important (in this order). The variable LT was found negatively correlated to landmarks, but it seems important in the aggregation processes (module 3) and the definition of the α cell's character.

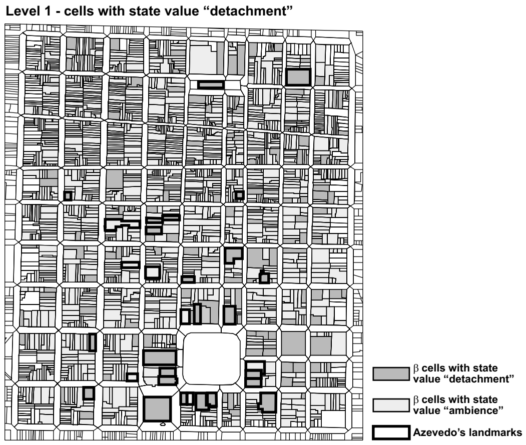


Figure 4: Visualisation of cells with state value “detachment” in first level of the model

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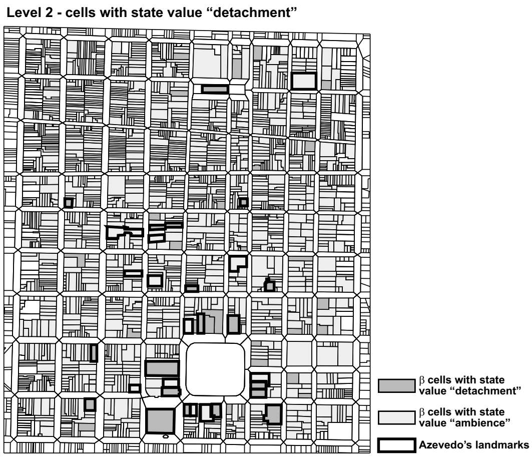

Figure 5: Visualisation of cells with state value “detachment” in second level of the model

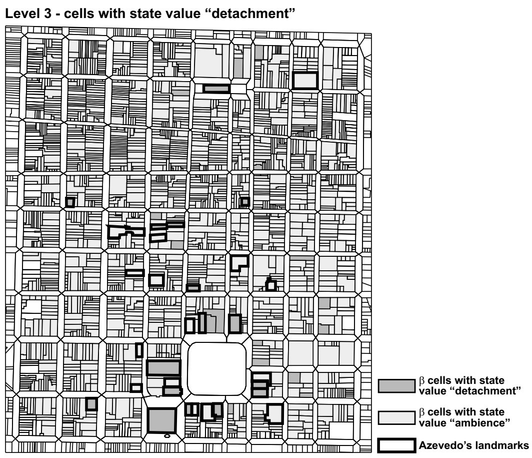

Figure 6: Visualisation of cells with state value “detachment” in third level of the model

Analysis of GD values indicated a high correlation of the proposed measure with the buildings of Azevedo: 24 of the 30 buildings were in the 10% higher values of GD, and in 20% all were included. Even so, after the last interaction in simulation, only 15 of the 30 buildings were correctly detected (Figures 4, 5 and 6). Initial analysis indicated the need to consider the feedback processes from the environmental elements of the higher levels of the system (paths and districts).

It is important to emphasise that all buildings with more significant levels of citation in Azevedo’s study were correctly detected. Considering the small cohort of respondents and the low number of citations of the non detected buildings, and also that no calibration was made for attributes and variables, the results obtained with the experimental module may be considered quite encouraging.

Initial tests with the feedback processes from the higher level environmental elements (paths and districts) are now underway and have improved results in terms of total number of detected buildings and also in correlation between GD and number of citations. Feedback processes were responsible for higher weights in variables related or congruent with the higher-level environmental elements in which the b cells were nested. Thus, weights were defined distinctively for different localisations in the environment. The diagram below shows the improvements in the correlation (Figure 7).

5. Final remarks

Representing environmental cognitive structure by a spatial differentiation measure seems to be possible in theoretical and practical terms. The created instrument, even though in a preliminary and partial version, indicates the possibility of

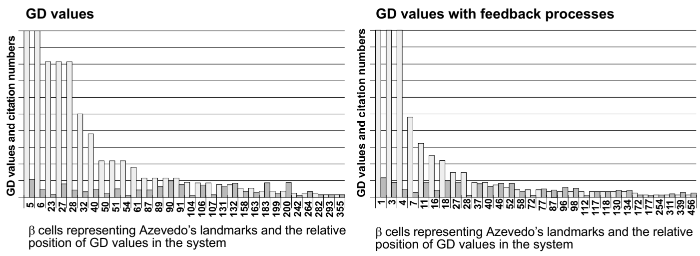

Figure 7: Diagram comparing GD values with citation numbers in Azevedo for measures with and without feedback processes

simulating the cognitive structure of urban environment. The proposed methodology points to the possibility of not only capturing, but also measuring and quantifying the cognitive structure. The initial simulations apparently indicate differences in the importance of each variable in imageability and cognitive processes. They also show that the environmental elements of higher-level in the system probably influence the importance of each variable for buildings situated inside them.

Simulations with the experimental module also indicated several problems to be solved. The order of cellular processing at each level is responsible for small alterations in the simulation's final results, which requires adjustments in the simulation process to rectify this problem. There is also the possibility that competition processes have a maximum distance of influence and, therefore, further investigations are necessary at this point. Most importantly, the data base is far too extentive, making the model, in its actual formulation, intractable for practical use. However, preliminary analysis of correlations between attributes and variables and between these and final results seems to indicate the possibility of reducing the number of attributes. Conclusions on the identified problems and the identification of the real potentialities and limitations of the proposed methodology depend on the complete development of simulation process and a significant number of tests in different urban areas. The complete development of the proposed spatial differentiation measure opens new possibilities in the modes that fundamental morphological elements can be represented in urban simulations.

One final comment, reporting the exposed matter to the space syntax domain, seems necessary, as the approach and methods used here look quite afar from the syntax orthodoxy. It could be said, firstly, that we deal with urban form in a structural way, just like space syntax does, and this would put us all in the same (broad) field, but it would be too easy and obvious. It could also be said that this work is about representing spatial relationships among urban components in a meaningful way, and, by doing that with its own means, it enlarges both the knowledge on urban configuration and the configurational toolkit itself. This is not trivial anymore, but maybe is still not enough to catch one's imagination. Thirdly, the work elaborates some hypothesis on how space prompts people's perceptions, and therefore, how spatial intelligibility is actually built up. Its findings are not necessarily in opposition to syntactic definition of intelligibility - although they can be in the future - but present an alternative development to the topic, apart from suggesting that intelligibility could be anchored as firmly in the built form as it is in the public open space. Finally, the work deals with one of syntax's foundation stones – the psycho logic linear reading of space by moving individuals. The least that its findings suggest is that urban spatial cognition works as a sort of relay system based on both channels of movement and built form references. By doing that, it shows that it is possible to conceive "*shortest path*" in a rather different way, more in accordance to the expression "*preferred path*", increasingly used in substitution to shortest path to encompass an array of motives people uses to decide upon routes and movement. Built form is said to punctuate space, so that the resulting cognitive maps could easily differ from schematic axial diagrams.

Notes

1 - Other names that appear in the literature are: schemata, cognitive map, mental map, image and spatial representation.

2 - However, this term is rarely used.

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