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WAYFINDING MEASUREMENT THROUGH PATH CHOICE OPPORTUNITY

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Abstract

The term wayfinding is understood as being the experience of urban systems` users on orienting themselves, as well as navigate through urban space. Other interpretation to the term may be addressed, where it convey the existence of a series of direction choices made upon points inside the urban network where such choice would fit. Aiming to measure the user`s navigation capability within urban networks, an indicator that takes advantage of movement choices is suggested. Such indicator is based on morphological characteristics of space, and does not take into account any external characteristics. The study is realized, primarily on synthetic urban grids, where the phenomena was observed and measured. The collected data from the proposed indicators are submitted to morphological consistency verification, through its comparison with data from "junction integration" (classical syntactic measurements, from the space syntax theory). It is expected that this work contributes to the understanding of urban morphology as an element of influence on path choices, and is also a starting point to the creation of the bases for a more sophisticated index related to urban navigability. Limitations to the proposed method are also pointed out.

1. FRAMEWORK

The term “wayfinding”, which is used in this research, is understood as being the experience of urban transportation system`s users in orienting themselves, as well as “navigating” through space; or still the action of finding paths when departing from a certain origin to a predetermined destination, in this very urban space (Lopes, 2007). As described by Allen (1999) and Golledge (1999), this would be a directed and motivated movement, with a starting and ending point, whereas such destination is not visible or tangible by the “navigator”. In a more generic way Lynch (1960) points out various examples of orientation methods, using focal points, and references through space, time and culture; being these methods direct references to how “wayfinding” has being evolving, and also highlighting strong relation between legibility, a term created by the same author and that will be issued later; memory and cognition with this study in progress.

Another way to understand “wayfinding” is described as being a series of direction choices, taking place at decision points within the urban grid (Klippel at al. 2004), or still as the ability of finding paths to a particular destination, in a convenient way and being able to recognize the destination once it is reached (Peponis at al. 1990). While these choices are referenced by external factors, besides the navigator`s personal subjectivity; reference characteristics, especially in urban setups, are responsible for the creation of “legibility” and are taken as part of the “wayfinding” concept. It is understood that this would be the cognitive element of navigation; as exposed by Darken et al. (2001), which says: “*It is the cognitive element of navigation…the tactical and strategic parts that guide movement. It is not merely a planning stage that precedes motion. “Wayfinding” and motion are intimately tied together…”*. This last statement points to the importance of seeking where, in space, decisions concerning movements happen, and what are its consequences.

It is possible to point out various reasons to support the importance of navigability study as a research theme. As said by Moughtin (1999), the freedom with what people may walk may as well be understood as a measure of how civilized a society might be. Universal urban Access may be either a great gain to a population`s segment which presents impaired movement ability (Eg. Elderly, people with special needs, children, etc…); or may also be nothing more than the most basic rights to be legally granted. Within this line of thinking, a good definition to what “navigability” might be is presented here and will be dealt with through other terms and literature related to the matter.

The first of these terms would be “Permeability”; meaning “…*the extent to which an environment allows a choice of routes both through and within it. It is also a measure of the opportunity for movement*.” (Carmona, 2003). Evolving from this idea, not only the grid`s physical characteristics should be taken into account to understand the system from the permeability point of view; but also its “*topoceptive*” and geometric characteristics. Besides the path or route choices, the size of blocks and number of connections between the various movement system`s layers, which are pointed out by specialized literature as important factors to understand urban permeability (Moughtin, 1999); there are other aspects to be accounted for, such as the existence of urban attractors and specific individual characteristics of users.

Another important concept to understand the idea of “navigability” is that of urban “legibility”. As well explained by Lynch (1960), the study of “legibility” aims to “…*indicate the easiness with which the city parts can be recognized and organized in coherent models*.”, and also argues that the ability with which urban space navigators (users) may as well dislocate or move through the built environment is intimately connected to the ease of organizing “mental images” of environments organized in coherent patterns. It should be emphasized here that such concept draws attention to the importance of users’ cognitive processes during navigation; being this neither an attempt in rationalize the process of mental images creation , nor a script to how utilize it.

To better understand navigability the concept of information should also be worked. According to the dictionaries "The American Heritage" (2000) and "Collings English Dictionary" (2003), information is a collection of facts from which conclusions may be drawn; or still, the knowledge acquired through study, experience or instruction. One should perceive the intimate link between what defines "legibility" and "information" as defined here. The capacity of producing coherent mental patterns about the space may only occur by the conclusions taken from the experience one may have had with the space in question.

For all these reasons the definition of navigability should be one that encompasses all the variables presented, as well as addressing other two aspects related to transportation; which would be accessibility and orientation. Urban navigability is a quality attributed to a well defined urban zone, measureable by the ease with which users may or may not navigate (to dislocate oneself and be oriented simultaneously) through or within such urban space. According to Weisman (1981), the variables that influence the "*wayfinding*" process, and therefore, intimately linked to navigability, in urban setups may be categorized in four (04) groups, starting with (a) *Visual access*, or as several other researchers may call it, visual permeability, (b) *architectural differentiation*, being a fundamental brick for the creation (acceptance) of landmarks, as stated by Lynch (Lynch, 1960) (c) *signs* and numbered destinations, and (d) *paths configuration*, related to the topological accessibility among its elements, being such matter explored by excellence by the space syntax theory. For the sake of this study, all experiments and results referred to in this paper are related to this last variable, the paths configuration, leaving the other three topics to subsequent developments.

2. GENERAL PROBLEMATIZATION

It may be found in scientific literature terms related to "navigability" in other senses other than the one concerning this study. Such found studies concentrate the understanding and development of tools to assist the navigation, such as interactive GPS systems (Global Positioning System), or yet ITS systems (Intelligent Transportation Systems). Several of these terms presented here are of great importance to the development of navigability studies within other disciplines, such as robotics and artificial intelligence (Remolina and Kuipers, 1998; and Arena et al. 2009). In studies about the interaction of complex networks, Rosvall (2005) presents a model of behavioral approximation within such networks, and still presents applications of the model in urban spaces and built environment, referring to navigation as dependent of information and legibility.

With the development of new location and positioning technologies, such as the GPS and similar tools (to cite some similar GPS tools; the Rusian Glonass and the European Galileo), GIS technology (Geographic Information System), etc… it was verified an increase in the quantity of information related to urban assisted mobility. Although, Lynch (1984) and Alexander (2004) indicate that certain terms, as well as some important areas of study, such as navigation, intersection or landmarks related studies, are all referent to human movements inside built environments; they are not easily modeled by the traditional computational methods. Maybe this is the reason for the scarce scientific production in these fields, which relate the form of the city and the human behavior.

In the specialized literature related to transportation, one may observe the use of navigability almost exclusively related to the types of transportation by water, maritime, fluvial or lacustrine. The term navigability is used by Constantinou (2007) as referring to the meaning this study seeks, albeit it does not discuss the merits.

In the studies of "wayfinding" similar to the pretended in this article, it may be highlighted the work of Dalton (2001), where the understanding of pedestrians decision making process is modeled inside a controlled environment (a virtual grid). Daltons` work intends not only the measurement of choices and paths which are offered by the grid; but it aims at the perception of user behavior relative to the importance of angularity of paths and routes to be chosen while "navigating" from a starting point to a determined destination. Angular analysis and segment analysis are understood to be rather important for future researches concerning navigability, but they are not dealt with, at this time.

Relative to the configuration studies of urban environments which are pertinent to the concepts presented here, it is indicated those of space syntax analysis. The research field of space syntax was originally introduced by Hillier and Hanson (1984). Since its creation to present days much was added in what concerns the modeling of urban space and indoor environment. Afterward, adjusted methodologies and new variables were introduced (Turner, 2005 and 2007; Medeiros, 2004 and Dalton, 2001), referring to integrating several constituent elements of space in relation to the whole; such as the measurements of what was designated as "deepness", "control" or "connectivity", etc…

3. ESPECIFIC PROBLEM

The creation of models that represent satisfactorily the reality under study is a basic necessity for any research methodology, especially for characterizing a given phenomenon. It is understood that the better the phenomenon representation by a proposed model the more efficiently such model might be applied and better the expected results.

The phenomenon of path choice within urban setups is dependent on the user or navigator previous knowledge about that specific urban space, translated into streets, squares, plot occupations, architecture; as well as cultural aspects related to the spatial dominium of pedestrians. Traditionally, it is detected the incapacity of current models, which refer to the transportation system and are based on demand measurements of mobility and accessibility, of presenting concrete results about the influence of spatial configuration (e.g. The pattern of streets and paths; or/and existence or not of urban landmarks, etc…) in such phenomenon of path choices. Being that so, the present paper`s contribution lays in bringing to light the first steps into the construction of a navigability index for urban spaces. Is there any correlation what so ever, between the city space configuration and the behavior of pedestrian`s path choices? It is expected to be confirmed that existing models, which represent the spatial supply instead of demand, might be a better option to answer the questions more adequately. Important to note that previous researches already pointed for the possibility of measuring "*wayfinding*" through morphologic characteristics (Penn & Croxford, 1997; Peponis et al, 1990); following its lead the presented methodology was conceived.

4. PRESENTING THE VARIABLES

This paper seeks to better define a method of measuring the **possibility** supply of users/navigators movements inside urban environments. For this matter, the most important object for this study is the space where such movement occurs. So that it becomes more understandable, it is necessary to start with the presentation of such elements that take part in this phenomenon modeling attempt. Initially, it is prime to be cleared that the current effort seeks the modeling of urban space and its spatial configuration`s effects on movements possibilities; therefore an urban grid representation should be the starting point. The constituent elements of such grid, which are relevant for the goals defined here, are derived from the interpretation of theories earlier presented, for instance, the knowledge about *wayfinding*, and conceptions of the social logic of space (Hillier et al. 1984).

This last one, which presents the space syntax method, models the space as a system of axis, attributing importance to the way these *axis* articulate amongst themselves. Simultaneously, the grids` streets crossings, which are mostly concomitant with the axis` crossings from the space syntax model, will be understood as where movement direction is mostly inclined to suffer a change; or, in other words, as the decision making points, regarding dislocation. Therefore, the three fundamental elements are; the **axis**, the **crossings** and de **decision** of changing direction during a dislocation. It is important to be clear that in no given moment of this paper, working with movement itself was considered; but with the possibilities urban space grants to such movements to happen. In future works the measurements of real movement might become a valuable method`s validation.

4.1 Micro Access Index (*IAm*)

An index was defined, which is called "Micro Access Index" or "*IAm*", and is formed by the measurement of path choice probability, relative to the number of options a given user or navigator might have at each decision making points within the urban grid. The measurement takes into account only the direction options within the system, not accounting for any external interference, but only for the grid configuration (Fig. 01).

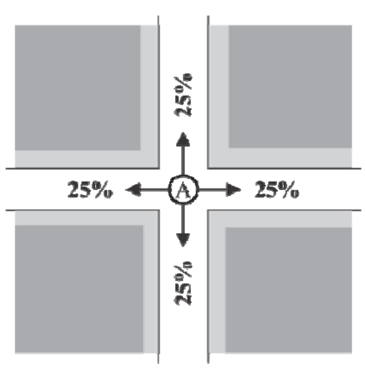

Figure 1.a - Four-way crossing

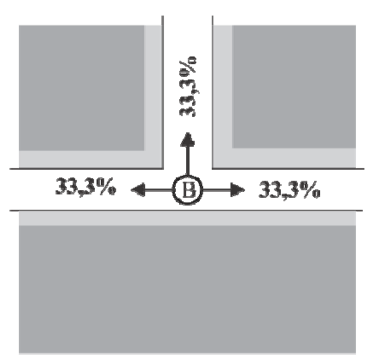

Figure 1.b - Three-way crossing

Figura 1
Two examples of how to measure the raw direction probability, based on a choice system.

The given example (Fig.01) shows two examples, similar to regular and common urban grid configurations, a four-way crossing (Fig. 1.a) that offers a 25% possibility of choice for each direction; and a three-way crossing (Fig. 1.b) which renders identical 33,3% choice possibility for each of the 3 ways. It is observable that the measurement of choice possibility is given, in practical matters, through the division of all choice possibilities (or 100%) by the number of possible directions; which means that if we have a crossing with 10 possible paths it would render us a distribution of 10% of choice possibility for each direction; since ten times 10% is equal to 100%. According to specialized literature (Klippel et al. 2004) the crossings are defined as the points where such decision is most inclined to take place, a decisive factor for the practice of "*wayfinding*".

The calculation suggested by the "*IAm*" (Equation 1) is formed by the summation of probability values (P_n) which **give access to** any given decision making point or, as understood by the space syntax, the junctions located at the axis crossings. It is a numerical index related to each crossing individually. It must be clear that the summed probabilities for the constitution of the proposed "*IAm*" index are those **coming from** the choice probability measurements (as seen in Fig. 01) from the directly connected crossings, adjacent to the crossing which "*IAm*" is pretended to be measured (Fig. 02). This index intends to quantify how the spatial configuration of decision making points favors or not the access to a given crossing inside the grid.

$$\mathbf{IAm\ (A) = P1 + P2 + P3 + ... + Pn} \qquad \mathbf{(1)}$$

where: *IAm* (A):Micro Access Index of point "A";
Pn: Probability of Accessing point "A", coming from points "n", directly adjacent to point "A".

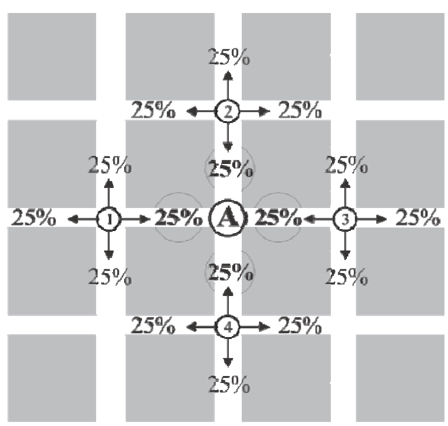

Figure 2
"IAm" (Micro Access Index) according to the equation (1). The "IAm" for crossing "A" would be 1.0 =P1 + P2 + P3 + P4, or 0.25 + 0.25 + 0.25 + 0.25; the circled figures.

The example given on figure 02 illustrates the construction of "*IAm*" for a given point "A" inside an urban grid. The "*IAm*" for point "A" if formed by the summation of choice probabilities coming from the directly adjacent crossings (in this case they are 4 crossings), which were called points 1, 2, 3, and crossing number 4. From the example it may be seen that the probability of each one of the 4 adjacent crossings is determined by its very spatial configuration; more specifically, by its number of path or direction choices, from which one may chose. Again, the external factors from the spatial configuration, such as traffic rules, users desired destinations, etc… are not taken into account.

This index, by itself, may not reflect satisfactorily the accessibility conditions of urban grids since other spatial configuration factors may play important roles. The most evident elements at work here are the crossings` relative positioning inside the spatial cutout grid, considering all other points. This position relativity, through the spatial configuration influence of the given urban grid, turns out to limit the access possibilities of certain areas and, therefore, lessening the chance of movement from each point of decision making that suffers such influence. One may notice that not only the directly adjacent crossings to the decision making point under study influence the outcomes, as it was suggested by the "*IAm*" method.

4.2 About control

It may become very clear to some that the proposed index, the IAm, is indeed a direct variation of "control", which was presented still in the "Social Logic of Space". While it is true that, in terms of mathematical measurements, both variables present a similar way of materializing (both depend on measurements from the adjacent elements of the grid); it is very important for the differences to be stressed out. The measurement of Control, as presented in the literature, encompasses the power, or control (as expresses by its name) of a convex space over other adjacent convex spaces; but its measurement is purposefully local. In terms of axial lines, in the words of Asami et al. (2003) "Control can be thought of as a measure of relative strength of the axial line in "pulling" the potential from its immediate neighbors". The concept behind the measurement of control stands on the intention of recognizing direct relations of certain convex space, as well as its local participation in a hierarchical influence system. The concept behind the creation on IAm stands on the relation of movement and the spatial configuration of an urban grid cutout. Recognizing the origin of measurements as being different makes I possible to advance into more generalized and spatially engaging indexes, as the IAg, which is proposed subsequently. The most important difference from Control and IAm is the phenomenon being modeled, which is enough for anyone to say they are completely different.

4.3 Global Access Index (IAg)

For this reason a necessity of adjusting the proposed values of "*IAm*" arose. This adjustment is done by incorporating, through summation to the value of "*IAm*", the values of other existing points within the spatial cutout of urban grid under study. These other points are those belonging to the approximation axis that shape the crossing under study itself, as can be seen in figure 03. Once the researcher takes into account the influence of those other points to the construction of this new index, in reality he/she is dissipating the participation of one`s urban grid spatial configuration, that will be represented by a larger number of points (or crossing, or nodes), in the formation of its accessibility, what was called Global Access Index (*IAg*). This way "*IAg*" may be obtained from the application of equation 2, and illustrated in figure 3.

$$IA_g = \sum_{i=1}^{n} IAm_i \qquad (2)$$

where: IAg: Global Access Index; i: the first crossing to be account for;
IAm: Micro Access Index; n: the last crossing to be accounted for.

From figure 03 one may understand the proposed index construction and specialization. The "*IAg*" for the central point in Fig.03, highlighted with the larger circle, is constituted by the summation of "*IAm*" of each one of the points that take part in the approximation axis that compose the refered crossing. It is important to notice the limitation imposed by the very spatial cutout of the urban grid, which define the whole area under study, and therefore the area influence limits. In our example the spatial cutout is represented in the image but it does not mean that it is the totality of the real urban grid. Different cutouts will produce relative different outcomes. The final result is an index that intends to represent how much access opportunity the spatial configuration of a grid is offering to each one of its decision making points. It is therefore characterized, through a measurable index, the influence of spatial configuration to the opportunity of movement within urban grids.

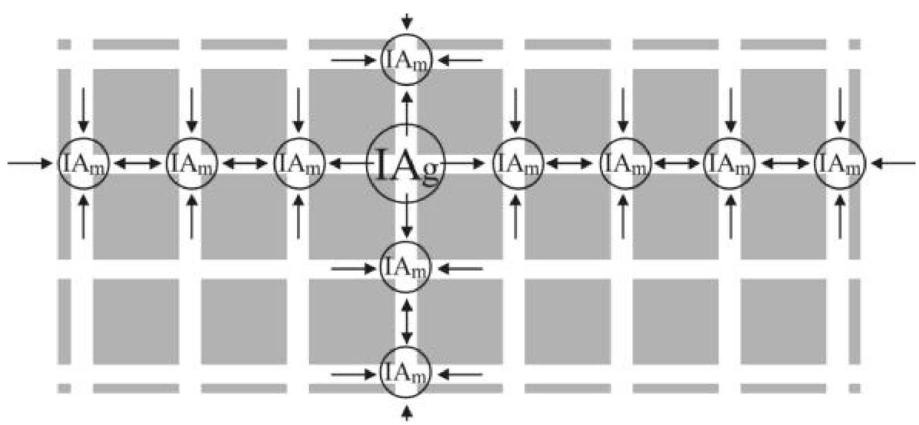

Figure 3
Global Access Index (IAg), formed by the sum of all IAm values, from the various crossings pertaining to the conforming axis that form the crossing under study, limited by the defined spatial cutout.

5. DATA

5.1. Micro Access Index (*IAm*)

Data was collected to what is referred to a real urban grid with the intention of constructing a measurement of movement choice opportunity, understood as a way of approaching *wayfinding* measurement; according to the proposed variable. The chosen spatial cutout was a part of *Makuhari* Bay Town, in the surroundings of Tokyo, Japan. The choice was derived from the previous development of research related to *wayfinding* (Lopes, 2007), where similar variables were used through the experimentation of virtual navigability in urban setups. The map may be seen in fig. 04.

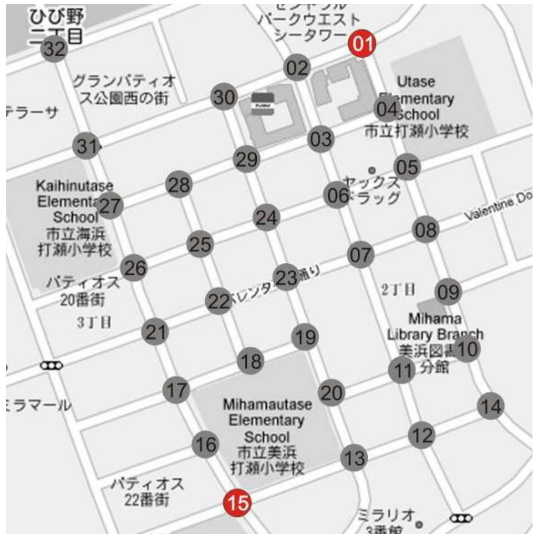

Figure 4
This map represents the area under study, the urban streets network of Makuhari city, in the surroundings of Tokyo, Japan. Makuhari is a designed urban setting.

The model application, as explained in item 5, will give us the *IAg* values for each numbered crossing from the image above. As an example, for measuring the *IAm* of crossing 23 (see Fig. 04), one must use the values of decimal probability (ex.: 10% = 0,1 r 5% = 0,05) of access to the cited crossing, measured from the directly adjacent crossings, namely crossings 24, 22, 19 and 07, as can be seen in fig. 04. Making this same procedure to all the points we have the values of *IAm* for all crossings, presented in table 01.

TABLE 01: "*Iam*" values for all crossings witin spatial cutout of Makuhari bay town.

Crossing	*IAm*	Crossing	*IAm*	Crossing	*IAm*
1	0,583333	12	0,833333	23	1,083333
2	1,250000	13	0,833333	24	1,000000
3	1,083333	14	0,583333	25	1,083333
4	0,833333	15	0,583333	26	0,833333
5	0,833333	16	0,500000	27	0,833333
6	1,000000	17	0,916666	28	0,916666
7	1,000000	18	0,833333	29	1,166666
8	0,833333	19	0,916666	30	0,750000
9	0,583333	20	0,916666	31	0,916666
10	0,916667	21	0,750000	32	0,583333
11	1,166667	22	1,083333	33	0,500000
Variance	**0,040**	**Std. Deviation**	**0,201**	**Arith. Mean**	**0,864**

5.2 Global Access Index (*IAg*)

Once more as an example, for the measuring of *IAg* of Crossing 23 one should take into consideration the *IAm* values of each crossing which pertain to the approximation axis that form the crossing under measurement, whereas, in our example those crossings would be: 13, 20, 19, 24, 29, and 30, for the vertical axis; and 21, 22, 07, and 08, for the horizontal axis (Figure 05). The values of *IAg* for crossing 23 are described in table 02.

Table 02. Example of how to acquire a crossing's *IAg* value. Summation of *Iam* values.

The crossings and its respective *IAm* values; from table 01.									
13	20	19	24	29	30	21	22	07	08
0.833 + 0.916 + 0.916 + 1.000 + 1.166 + 0.750 + 0.750 + 1.083 + 1.000 + 0.833 = 9.25									

Repeating the process exampled in table 02 to all other crossings within the spatial cutout one may acquire the *IAg* values for all decision making points, presented in table 3.

Tabela 03. *IAg* values for all 33 crossings inside the spatial cutout environment under study.

Crossing	*IAg*	Crossing	*IAg*	Crosing	*IAg*	Crossing	*IAg*
01	7,5000	**09**	4,5833	**17**	6,7500	**25**	6,5000
02	7,8333	**10**	6,3333	**18**	4,9167	**26**	9,0000
03	9,5000	**11**	7,5000	**19**	7,5000	**27**	9,0833
04	8,3333	**12**	8,0000	**20**	7,8333	**28**	6,8333
05	8,2500	**13**	7,8333	**21**	9,1667	**29**	9,1667
06	9,5833	**14**	6,8333	**22**	6,5000	**30**	8,6667
07	9,5833	**15**	7,5833	**23**	9,2500	**31**	7,5833
08	8,2500	**16**	5,4167	**24**	9,4167	**32**	5,8333
Variance	1,867	Std. Deviation	1,366	Arith. Mean	7,692	**33**	6,9167

Figure 5
Construction of IAg and IAm of junction 23, represented by the dark arrows and the cross shaped box.

These values represent measures, which are only comparable amongst themselves restricted to measurement of each spatial cutout, of decision making point`s macro accessibility level. This index is an non-dimensional measure, although being formed by summation of percentage values, once it does not represent values relative to a fixed total; it instead is a gross measurement of how a decision may be interrelated to several totals, expressed as different crossings and its relative position within the grid. A simplified exploratory statistical analysis for the given data may show its behavior as an approximation of a normal distribution, represented in Figure 06 by the bar graph and its similarity with the bell curve[1].

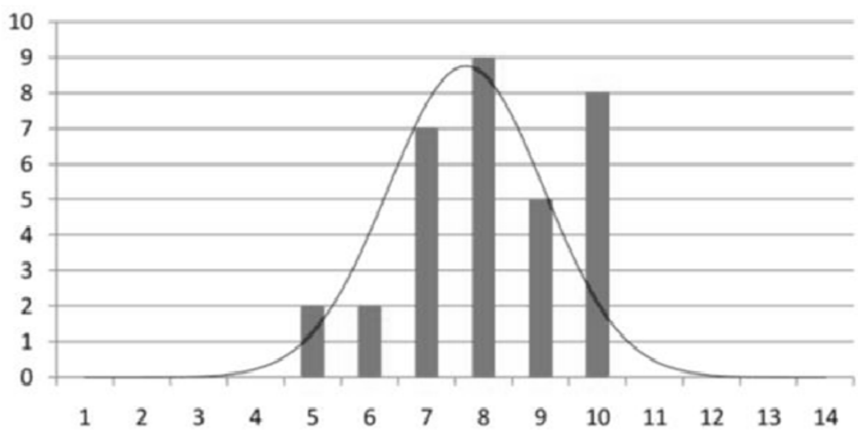

Figure 6

Frequency diagram for IAg values. The horizontal coordinate represents the intervals between classes of values, being the indicated number its highest value.

6. TESTING THE MODEL RESULTS

For the evaluation of any existing relation between variables of any given model, which includes the proposed *wayfinding* model, a statistical method was used; the correlation measurement between sets of random variables. This measurement intends to identify if there is or there is not any dependence relation between the observed variable "*IAg*", obtained by the proposed method, and another group of observed variables which refer to the same studied phenomenon, the urban setup configuration, especially its physical barriers, translated by the Integration variable proposed by the space syntax (SE) theory. The SE, created by Hillier and Hanson (1984) is applied in this study by the usage of AJAX-light[2] software, which may be obtained freely on the internet from the *CASA* research group (Centre for Advanced Spatial Analysis) at the *University College of London* (UCL).

[1] According to the *Central Limit Theorem*, developed by the French mathematician Abraham de Moivre, "every sum of random independent variables with finite mean and limited variance is approximately normally distributed; assuming the number of summation terms is sufficiently large". This means that any sufficiently large sample might represent the approximate population global behavior within the system under study.

[2] AJAX-Light may be found on: http://www.casa.ucl.ac.uk/ajax/

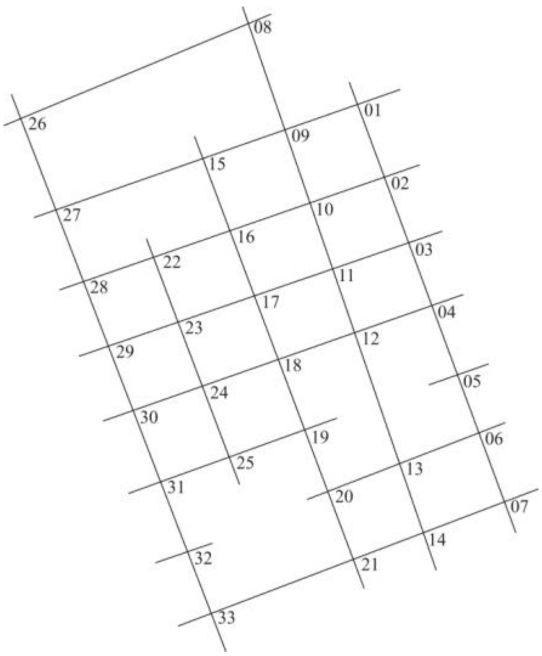

Figure 7.a – Source axial map

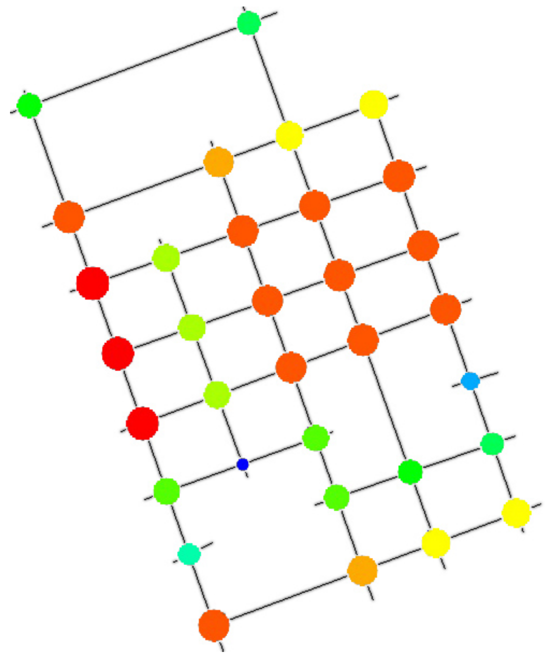

Figure 7.b – Junction Axial map processed

Figure 7

(Left) Axial map with all the numbered axis' crossings, and (right) the processed junction map. These maps are a product of space syntax based study, produced with AJAX-light software.

The obtained results from the software are related to the same decision making points inside the spatial cutout (Makuhari Bay Town, in Japan) used for the previous variable. Following the numbered crossings presented earlier it is possible to see both, the axial construct from the software implementation for the selected area (Fig. 7.a), and the software processed Junction Integration graph (Fig. 7.b). The list of values in table 03 present the results acquired from the AJAX-light software and are related to each and every numbered crossing within the spatial cutout.

Table 03. "Junction integration" values, from AJAX-light software (numbered crossings from fig. 07)

Crossing	Integration	Crossing	Integration	Crossing	Integration
1	**0,74362**	12	**0,91138**	23	**0,66416**
2	**0,91138**	13	**0,51332**	24	**0,66416**
3	**0,91138**	14	**0,74362**	25	**0,00000**
4	**0,91138**	15	**0,82597**	26	**0,51331**
5	**0,17745**	16	**0,91138**	27	**0,91138**
6	**0,44167**	17	**0,91138**	28	**1,00000**
7	**0,74362**	18	**0,91138**	29	**1,00000**
8	**0,44168**	19	**0,58743**	30	**1,00000**
9	**0,74362**	20	**0,58743**	31	**0,58743**
10	**0,91138**	21	**0,82597**	32	**0,37236**
11	**0,91138**	22	**0,66416**	33	**0,91137**
Variance	0.0424	Std. Deviation	0.2059	Arithc. Mean	0.7187

For linear correlation test it is necessary to assume some premises, required by the statistical method. First, the samples must be formed by a set of paired data (both *IAg* and integration, in this case, present values for each and every numbered crossing) as well as random; second, the paired variables must follow a bivariate normal distribution. Due to the difficulty to prove the second supposition, it is largely acceptable to assume a simplification of such verification, which requires simply that the values of each variable must follow a normal distribution. The frequency distribution for integration values may be seen in Figure 08. As well as in the *IAg* frequency distribution diagram, there is a tendency to higher values, what may be a reflex of the spatial cutout selection. It is expected in larger spatial cutouts the distortion to be less pronounced.

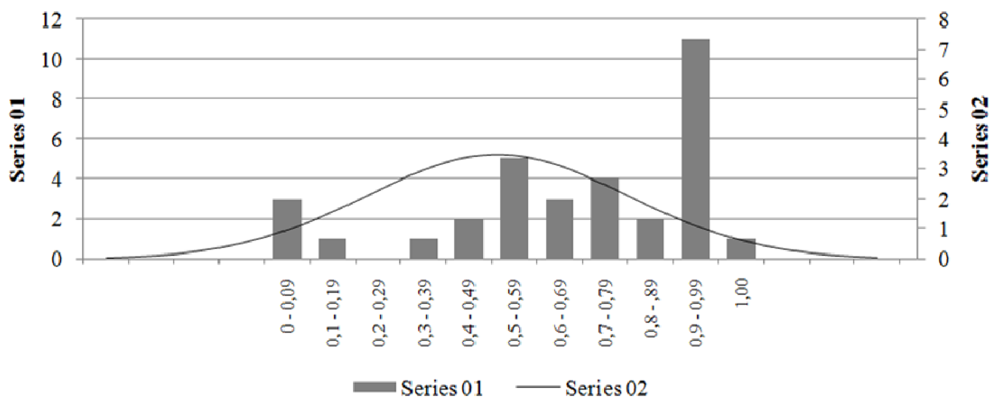

Figure 8

The frequency distribution of Integration values follows a normal, bell shaped curve. A deviation at the right end indicates how it may be affected by selected spatial cutouts.

The linear correlation coefficient, commonly denominated "r" will indicate how much related are the paired variables. To reach such result the following mathematical expression (equation 03), denominated Pearson`s Correlation Coefficient was applied.

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum y^2)}\sqrt{n(\sum y^2) - (\sum y)^2}} \tag{3}$$

Em que: r: correlation coefficient; x: first variable of the pair;
n: number of paired values; y: second variable of the pair.
$(\sum x)^2$: ·sum of all values of "x", squared;
$\sum x^2$: sumo of squares values of "x".

The values of "r" are always between the -1 and 1 limits, inclusive. Acquired values close to zero indicate lesser correlation, or independence of variables. Using the "r" evaluation criteria presented by Triola (1999), assuming a 99%, or 0,99 degree of confidence; or still a significance level (α) of 01%, or 0,01. The significance level, or the result`s statistical significance is the characteristic of how unlikely it is to have happened by mere chance. This means that the lower the critical value, which defines the significance level, the lesser the tolerance for mere chance.

Since each map created from the applied methods generated a different set of numbers to represent the same crossings inside the spatial cutout, and since they form paired values related to each crossing individually; an explanation becomes necessary on the equivalence of the numbers presented for each crossing in the different maps. It is represented (table 5) the different numbers from both maps (fig. 5 and 7) that indicate same crossings. From this point forth, the numbers indicating the crossings to be used will the ones represented on Fig. 07.

Table 05. Equivalence of numbered crossing, from *IAg* map and *Junction Integration* map.

Crossing on:		**Crossing on:**		**Crossing on:**	
Figure 05	Figure 07	Figure 05	Figure 07	Figure 05	Figure 07
1	1	7	12	25	23
4	2	11	13	22	24
5	3	12	14	18	25
8	4	30	15	32	26
9	5	29	16	31	27
10	6	24	17	27	28
14	7	23	18	26	29
33	8	19	19	21	30
2	9	20	20	17	31
3	10	13	21	16	32
6	11	28	22	15	33

7. RESULTS

Applying the equation 3 to the paired set of data, from table 06, the obtained value or “r”, the correlation coefficient, is 0.8784. From the criteria defined by Triola (1999) we have that, for at least 30 data pairs (in this experiment we have 33 pairs, one for each crossing), without any linear correlation between the pair of variables x and y, it is understood that there is a probability of 1% that the values of “r” may exceed 0,463. Comparing the obtained “r” value and the expected value for the significance level (α) of 0,01; it is easy to assume that a high degree of correlation was reached, and consequently dependence, between the two variables. Figure 09 visually presents the *scaterplot* for the two variables, and the R^2 values (which is the result of a different method, called the *linear least square method*; easily obtainable from electronic spreadsheets software), confirming the linear relation between both variables.

Table 06. Paired values of *IAg* (from table 03) and *Junction Integration* (from, table 04).

Crossing	IAg	Integration	Crossing	IAg	Integration	Crossing	IAg	Integration
1	7,500	0,74362	**12**	9,583	0,91138	**23**	6,500	0,66416
2	8,333	0,91138	**13**	7,500	0,51332	**24**	6,500	0,66416
3	8,250	0,91138	**14**	8,000	0,74362	**25**	4,916	0,00000
4	8,250	0,91138	**15**	8,666	0,82597	**26**	5,833	0,51331
5	4,583	0,17745	**16**	9,166	0,91138	**27**	7,583	0,91138
6	6,333	0,44167	**17**	9,416	0,91138	**28**	9,083	1,00000
7	6,833	0,74362	**18**	9,250	0,91138	**29**	9,000	1,00000
8	6,917	0,44168	**19**	7,500	0,58743	**30**	9,166	1,00000
9	7,833	0,74362	**20**	7,833	0,58743	**31**	6,750	0,58743
10	9,500	0,91138	**21**	7,833	0,82597	**32**	5,416	0,37236
11	9,583	0,91138	**22**	6,833	0,66416	**33**	7,583	0,91137

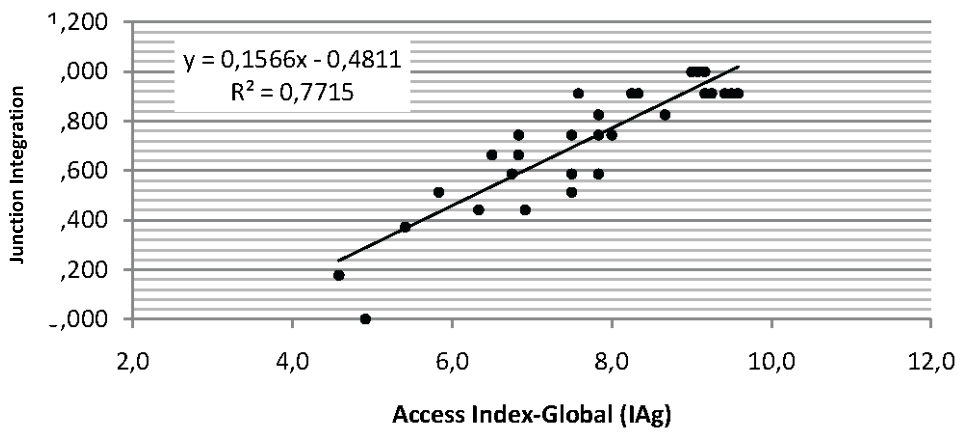

Figure 9
Scaterplot and Least square method (R^2) of Junction Integration and IAg variables.

8. CONCLUSION

From the development and verification of *IAg* variable, based on its dependence relation with a spatial configuration variable, the integration level of urban setups within selected spatial cutouts; it is notable, from the indication of high linear correlation between both proposed and pre-existing models, that the spatial characteristics that grant the accessibility conditions. In short, **the capacity to offer access opportunity to certain decision making points within the urban grid is determined primarily by the urban grid spatial configuration**, or any other navigable grid. The presented variables that show greater degree of influence on the *IAg* index behavior and validity are the very measure of access possibility for each decision making points, represented by the sum of crossing composing junctions` *IAm* values. Another important characteristic, according to what could be learned from the experiment, is the relative position of studied crossings within the selected spatial cutout, which was expected from the beginning.

Relative to approximation axis, a certain difficulty to define and identify these entities is experienced. In every circumstances and situations that an urban grid may take form, how can one identify such forming axis that might affect the junctions` navigational or *wayfinding* capabilities? This understanding is essential for the construction of the *IAg*, as described by the method. Not by chance, the given examples in this essay are those that represent the simplest urban setups, formed by orthogonal crossings, with small variety. Therefore, intended future endeavors should seek, firstly to better define what are and how to identify the junction composing approximation axis; should also attempt to adjust the method of obtaining *IAg*, pondering the importance of *IAm* values that would compose the Global Access index, according to its distance to the measured junction; weather this distance should be metric or topological is another question; and also start taking into account the angularity of grids in the possibility of paths choices opportunity.

The greatest contribution of such model is the intended approximation between *wayfinding* as a phenomenon that materializes as movement, occurring in specific points within urban environments, and being influenced by choices made on such points; with the possibility of measuring the characteristics of space configuration. The presented model does not need the construction of classic axial maps for the values of choice opportunity to be acquired, as it consists mainly of points of decision making and the possibilities of movement from and for each point. This brings us to other conclusions regarding the limitations of such method, as it is possible to understand the disconnection between the junctions in real urban environments and the points of decision making elected by real users.

About limitations, one must understand that the presented method assumes several simplifications that incurs in several limitations. The fact that the presented index is not parametric for any situation, functioning as a comparison factor only for junctions measured within the same spatial cutout is a limitation that may still be dealt with for a better and more universal *IAg* usage. Another apparent shortcoming is regarding the uncertainty of how some of the values should be worked in more complex urban grids, or even *organic* grids. Concerning the final outcome, as being the development of a navigability index; it may not be developed without considering exogenous aspects, those external to the urban spatial configuration itself. Future studies should evolve into accounting for the influence of urban landmarks, architectural typing, and visual permeability; in short, the "*topoceptive*" dimention, as presented by Holanda (2002) to the path choice phenomenon.

9. NEXT STEPS

Developing a navigability index requires several more steps to be taken. This attempt to address the matter was very limited to the morphological aspect of urban environments; which still needs to be further developed. It may be coherent to continue the pursue of a close *wayfinding* measurement concerned to the space configuration; but to fully model the behavior of human path choices within these environments, a bridge from the space itself and the human perception of such spaces is irrevocably needed.

It may be possible to point out the four (04) items presented by Weisman (1981), which were treated earlier as a good starting point. While the *configuration (d)* portion is still under development, future works demand a better understanding of the visual relations with the environment; encompassing the *visual permeability* (a) as well as the architectural differentiation (b) (landmarks). The other element which was dealt with in a previous work (Lopes, 2007) is *signs* and *external information* (c). Once this bridge between *space form* and *space perception* is theoretically sketched real movements may, then be measured and empirically analyzed in correlation to the physical characteristics of built environments.

More specifically, intended themes to be addressed in near future researches may be:

- Add information to the models about grid angularity, which was not dealt with this time;
- Measure the importance of topologic and metric distance to the morphological model;
- Make the *IAg* values a parametric index, so that different setups may be compared directly;
- Understand the path choice decisions, as a continuous phenomenon through space;
- The importance of visual permeability to the choice of route; (the adaptation of VGA [Visual Graphic Analysis] usage on urban scale may be a good starting point.

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