Measurability, Representation and Interpretation of Spatial Usage in Knowledge-Sharing Environments – A Descriptive Model Based on WiFi Technologies

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Abstract. The paper explores the potential of using available WiFi networks as an input for a space-use analysis model capable of describing - observing, recording and quantifying - and visualizing spatial usage and users' spatial behaviours in knowledge-sharing scenarios and correlating this information to spatial structure. Knowledge-sharing scenarios are defined as physical locations where people go for acquiring, transmitting and producing knowledge carrying mobile devices functioning as location probes. The proposed model is based on a crossover of Space Syntax and Spatial Information Visualization. Emerging spatial patterns of knowledge-sharing are identified by combining spatial description with spatial information visualization. The paper considers the representation of inputs acquired by WiFi network of Instituto Superior Técnico campus using FLUX* visualization platform; the comparison between patterns of spatial configuration and user mobility and the discussion of the proposed space-use analysis model potential.

Keywords: wireless sensors, WiFi, FLUX*, information visualization, space-use analysis model, knowledge-sharing patterns.

1 Introduction

In the paper we developed a space-use analysis model capable of describing – observing, recording and quantifying – spatial usage and users' spatial behaviours in knowledge-sharing scenarios and correlating this information to spatial structure. Knowledge-sharing scenarios are defined as physical locations where people go for acquiring, transmitting and producing knowledge carrying mobile devices functioning as location probes.

Space-use analysis is about techniques that objectively describe environments and relate this description to specific problems of use. It is about mapping environments

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and users' spatial behaviours and exploring their relationship. In recent decades various much research effort has gone into defining spatial descriptive models, which explore patterns of co-visibility and co-accessibility and can be quantified and correlated with functional/behavioural data. These included Isovists [1] and Space Syntax [2], further complemented by space partitioning schemes [3] and visibility graph analysis [4].

Space Syntax provides a valuable framework for space-use analysis. It has been applied to different types of knowledge-sharing environments such as university campuses [5], research labs [6,7], design studios [8], working spaces [9,10] or exhibition settings [11,12,13]. These studies above all focus on configurational properties and suggest that social and informational interaction are influenced by how a space is defined as well as by how that space relates to and is integrated with other spaces. However, users' spatial behaviours are established and assessed through direct observations or questionnaires. These procedures, besides being intrusive, also depend on the human factor. Hence they do not allow for the collection of unbiased data, regardless of observer accuracy.

As far as knowledge-sharing scenarios are concerned, we are currently witnessing a great increase in the use of mobile technologies within the university community, including laptops, PDA's and other WiFi devices. Due to the existing infrastructure and its increasing widespread use, the use of wireless antennas behaving like ad-hoc sensor networks as an input for space-use analysis seems to be a plausible one since it allows for recognition of user location. The research question refers to such technology's potential to identify spatial patterns of knowledge-sharing and to further explore how knowledge-sharing scenarios may become "interactive learning devices" [14].

In a recent research project carried out at the MIT, log files from MIT wireless network (2300 Access Points) were used [15]. The aim was to monitor and collect extensive data on on-campus WiFi usage, in order to understand the emerging daily working patterns of the academic community in real time and re-evaluate the qualities of physical space supporting them. This study provides new insight into space-use analysis at the urban level. It works as a real-time mapping exercise, permitting a dynamic view capable of acquiring different layers of real-time information through simple cartographic evidence.

The paper investigates the capacity of WiFi networks to give space-use inputs at the building level. Large-scale applications are more compatible with the identification of Access Points` ranges. At the building level that correlation is not so obvious since built elements introduce great irregularities in wireless coverage of the signal distribution. Subsequently, it was necessary to develop a methodology to determine that coverage and correlate the extension of Access Points` signals with the physical space.

The proposed space-use analysis model explores relationships between the virtual web space (user communication in a more or less ubiquitous field) and the physical space (users movements in a more or less permeable system) in order to identify patterns of knowledge-sharing. It is based on a crossover of Space Syntax and Spatial Information Visualization.

Spatial Information Visualization is suitable for producing emerging social and mobility patterns and correlating this information to spatial properties. Geographic

Information Systems have been extensively used to input, store, query, transform and visualize spatial data. Recent approaches to Spatial Information Visualization have reduced the data operations available to users by separating visualization from data transformation and storage. Examples of this are Google Earth and Microsoft Virtual Earth, the former being closer to the definition of a spatial Virtual Environment [16] due to the 3D nature of the background information. Such environments have an advantage over traditional cartographic maps in exploration and analysis tasks because they do not require thorough understanding of symbols, conventions and formalisms. By relying on an open specification and being relatively user-friendly, Google Earth is now becoming de facto a geographic visualization platform.

The Civil Engineering and Architecture department building on the Instituto Superior Técnico (IST) campus in Lisbon was selected as a case study to test the space-use analysis model. The WiFi network allowing Internet access covers the whole IST campus. All department buildings including learning and social spaces are now fully covered. Information Technology (IT) is used extensively for information, communication, collaboration and socializing by the IST community. In preliminary analysis it was identified that the Civil Engineering and Architecture department building presents a considerable activity in terms of WiFi network use. Moreover it receives many students from others departments demanding spaces for individual and collective work and socializing. The resident population that uses WiFi is, essentially, students. Staff use, predominantly but not exclusively, the fixed network installed in their own work spaces despite the increasing use of the wireless network. For the purpose of this paper, the reference population is the student population, since it represents a larger group with greater impact in the use of wireless network.

The IST campus has 158 Access Points, with the Architecture department building having 18. The visualization platform FLUX* [17,18] allows one to register device traces in Access Points. Traces can be used to obtain two kinds of information: locations (how many devices are in a specific antenna, in a specific moment) and flows (when a device is subsequently detected by two, or more, antennas in a given period).

FLUX* started registering traces in January 2006 but not in a continuous way. This work considers a period of intensive student usage (classes and evaluation period). During this period, FLUX* registered a total of 553,759 traces in the Architecture department building and a total of 2,370,283 traces in the whole IST campus. The total number of devices registered in the building was 2,683, while in the campus it was 5,879. The time span granularity between each registration in an Access Point is 5 minutes.

The Architecture department building population is about five thousand. This means that the number of devices registered by FLUX* inside the building is a sample superior to 50%. In relation to the entire campus (about eight thousand) the sample decreases to 32%.

The paper considers four parts. The first one describes the methodological procedures applied to develop the model. The second refers the main tasks carried out. In the third part, inputs acquired by the IST campus WiFi network (user locations) are represented using the FLUX* visualization platform. The mobility patterns, emerging from the ubiquitous network access, are analysed. Patterns of spatial configuration and patterns of user mobility are compared. Correlations between space and mobility are established. Reflections about the potential of FLUX* visualizations in what concerns to the representation of spatial behavior are made. Finally the potential of the proposed space-use analysis model is discussed.

2 Methodological Procedures

Space-use analysis model development considers several stages. Spatial Information Visualization and Space Syntax procedures are carried out separately (Fig. 1). Spatial Information Visualization entails six stages: 1) definition of an Access Points taxonomy; 2) production of an exploratory trace; 3) identification of the spaces covered by each Access Point; 4) identification of overlapping positions between each Access Point spatial range; 5) production of an ad-hoc mobility matrix; 6) definition of queries. Queries are filters applicable to FLUX* database. Through these filters, it was possible to extract useful information concerning space-use analysis model goals. The information is mapped using different visualization models: force-directed graphs [19], treemaps [20] and 3D representations based on Google Earth application.

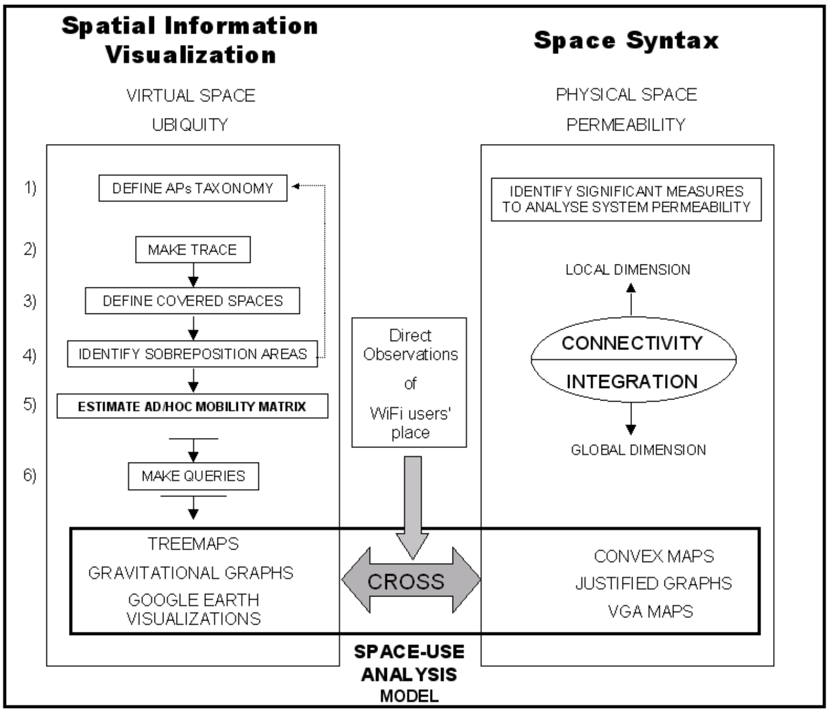

Fig. 1. Methodology diagram

In the proposed space-use analysis context, force-directed graphs will help to identify, syntactically, central nodes in the space. Treemaps will be used to visualize variables like people's occupation of space and to compare patterns between different types of knowledge-sharing of the same place. The Google Earth geographic visualization platform will be used to produce 3D visualizations of mobility flows in Architecture department building and IST campus.

Procedures 2), 3), 4) are sequential. The goal is to develop the ad-hoc mobility matrix, an important tool for FLUX* detection of flows between Access Points. Procedure 4) allows readjusting the Access Point taxonomy. Procedures 1) and 5) are the basic ones for making queries - the interfaces between FLUX* database and FLUX* visualizations.

Space Syntax procedures are based on the identification of the basic configuration properties allowing the analysis of spatial system permeability. In the virtual space of the Internet, ubiquity is the corresponding property of permeability. Encounters in space and wireless communications through net interact to make possible the production of knowledge. Hence, the main task is to analyse spatial system connectivity (permeability at a local level) and integration (permeability at a global level).

Space Syntax methodology and analytical tools were applied to investigate the configurational properties of architectural space for correlation with socio-functional implications and the emergent communication patterns (Spatial Information Visualization). As such, visibility graph analysis (VGA) was used, through "Depth Map"[3], convex maps and justified graphs. The measures applied consider the visual integration and connectivity. Depth Map enables analysis of the spatial structure of the learning setting and correlation to spatial usage and user movements by exploring patterns of co-visibility and co-accessibility. It was also attempted to interpret the identifiable relations established with the Access Points` locations and their influence over the system space. Convex maps and justified graphs [2] were adopted to understand, at a local level, the direct permeability of the structuring of the spatial layout and its implications.

Space-use analysis model crosses Architecture department building space patterns with WiFi network wireless communication patterns. Through that intersection, it evaluates relationships between social dynamics and the built space and identifies spatial patterns of knowledge-sharing.

Parallel to this, direct observations were made to WiFi users inside the Architecture department building. The aim was to map their distribution in space and time. This procedure has allowed to validate FLUX* results.

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[3] "Depth Map" was developed at University College London. It consists on a class of tools for spatial description – analysis, interpretation and evaluation – of the spatial configuration of built environments, incorporating Benedict's pioneering work on Isovists (1979) and other models of the description of built space developed by researchers on space syntax. The visibility graphs comprises the breaking up of space into a grid of points which is then analysed on the basis of how many points can see how many other points providing spatial measures capable of explore patterns of co-visibility and co-accessibility.

3 Development

3.1 Labeling the Access Points

In FLUX*, to extract information from the recorded database, one needs to define categories for the Access Points. Categories are tags that can be applied to wireless antennas. Each antenna can have multiple tags.

In this case, seven tags were defined. One tag considered antennas identification through its Internet Protocol number: IP. Three tags concerned building space: “floor” (vertical position of Access Point); “location” (space where Access Point is installed); and “covered spaces” (spaces where the Access Point signal is detected). The three other tags concerned building use: “occupation” (department that occupies a space); “sectors” (departmental group that occupies a space) and “knowledge-sharing types” (Fig. 2). This last category is based on the typology defined by Scott-Webber [21] for knowledge-sharing: a) delivering knowledge; b) applying knowledge; c) creating knowledge; d) communicating knowledge; e) using knowledge for decision making.

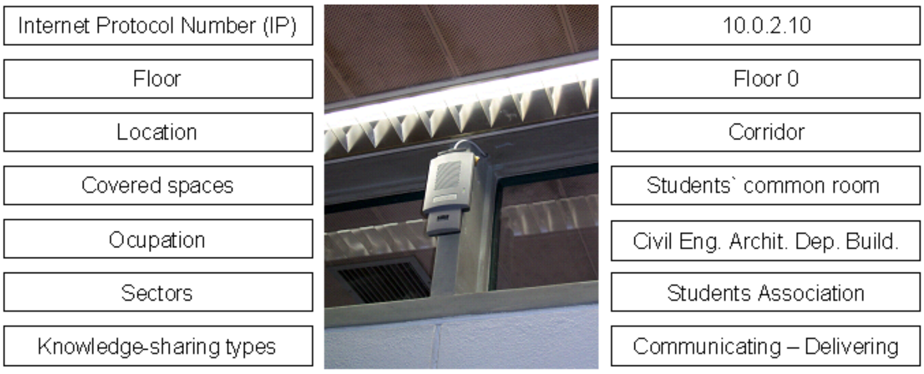

Fig. 2. Access Point 1 in ground floor – tags

These scenarios where adapted to the Architecture department building in order to understand the kind of knowledge flows supported by the physical space. Each typology describes an environment where knowledge is sharing in a specific way. Those knowledge environments implicate particular behavioural premises, layouts and protocol attributes.

Synthetically, we may describe each one in the following way: “delivering” describes places where information is transmitted in a formal method so that others can learn (classrooms, auditoriums); “applying” describes places where organizations puts knowledge into practice (labs); “creating” describes places where organizations produce and implement new ideas (researchers` and teachers` rooms); “communicating” addresses places where people go to exchanging information in an informal way, verbally and non verbally (atriums and others circulations spaces, cafeteria, students` rooms); places where knowledge is used for “decision making” refers to environments where information is distilled and judgments are made and acted upon (teachers` and administration rooms). The correspondence between some current spaces uses and archetypal layouts is indicated in Fig. 3. Some spaces, like teachers' working rooms belong to hybrid categories (Decision making/Creating).

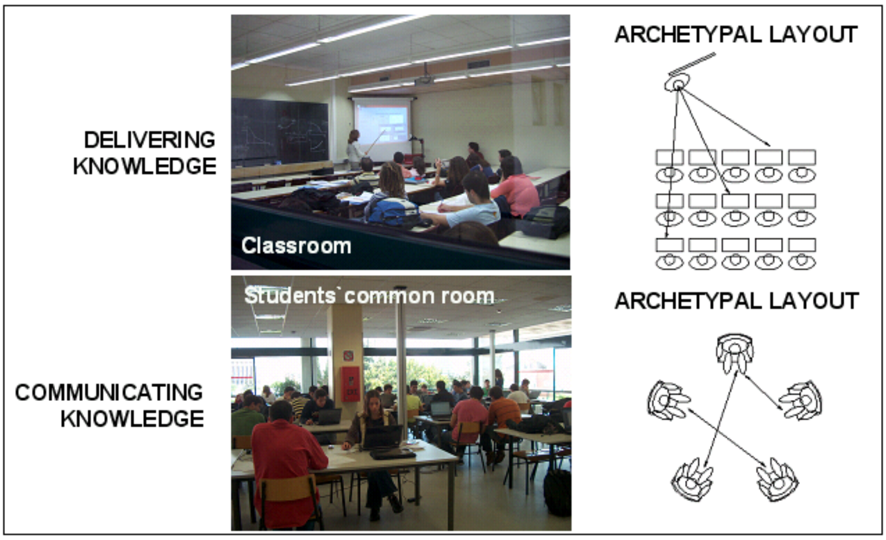

Fig. 3. Correspondence between some current spaces uses and knowledge-sharing types` layouts

The vertical distribution of the knowledge-sharing types is the following one: at ground floor level, the main type is "Communicating" which take place in atriums, cafeteria, students` common room and several classrooms open twenty-four hours for students learning. At floors 1 and 01, locate "Delivering" knowledge-sharing type. Associated spaces with this category are classrooms and auditoriums. "Decision making", "Applying" and "Creating" knowledge-sharing types are located in deeper levels. "Decision making" is related with teachers` rooms and administration rooms (floors 2 and 3). "Applying" is related with Labs (floor 02). Spaces identified with this "Creating" are: researchers and teachers rooms (upper floors) and experimental labs (lower floors).

3.2 Tracing the signal

The signal propagation model looks like a donut one hundred meters in diameter in open space. This concept, in real situations, is distorted by the built barriers in buildings (walls, ceilings, floors) and by equipment in rooms. Hence, to establish relationships between the spatial system and the wireless communication system it was necessary to determine the range of each Access Point in space.

To this end, exploratory traces were generated by walking around the building with a WiFi device. On this walkthrough, the device registered the Basic Service Set Identifier (BSSID) of each Access Point mapping the extension of each Access Point coverage area, frontiers between Access Points, variation of signal quality and "dead zones". The BSSID is a unique identifier that acts like a name for a particular network adapter. This unique number allowed us to identify, in every moment, which antenna was captured by the exploratory device.

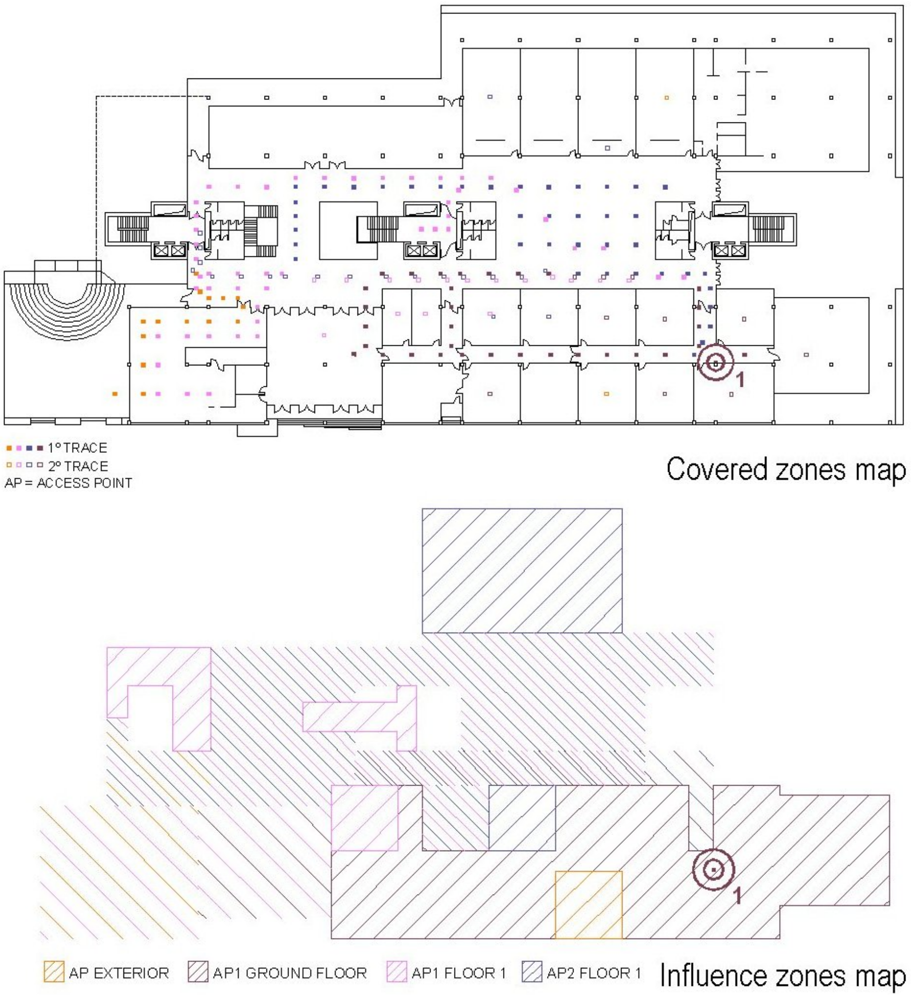

Fig. 4. Civil Engineering and Architecture Building (ground floor): Access Points` maps

After these exploratory traces, the zones covered by each Access Point were identified. In open spaces (e.g. central atrium on the ground floor) several Access

Points were detected, making it difficult to establish clearly defined frontiers between Access Points. In many cases, as expected, their coverage areas go beyond the built barriers and don't match with space geometry.

The maps of spaces covered by each Access Point resulted in diagrams showing their coverage area extensions (Fig. 4). Sometimes the coverage areas have overlapped zones (zones simultaneously covered by more then one Access Point) in the same floor and between floors.

Analysis of the diagrams revealed great irregularity concerning the spatial distribution of the Access Points` coverage areas. This was particularly evident in floors 0 and 2 because of the interference of Access Points 1 and 2 (floor 1) through main atrium. This irregularity was accentuated by the action of external Access Points. Indeed, rooms near the west, east and south façades (especially on floors 1 and 2) are covered by such Access Points.

3.3 Defining mobility

In terms of FLUX*, mobility refers to users' movements between Access Points` coverage zones during their daily activities. Hence, mobility is given when people take their WiFi devices and carry them to another space/Access Point in reasonable time intervals. When a device is registered in an Access Point on a certain day, and is registered, in another Access Point, in the next day or the following week, this is not considered mobility. For defining mobility patterns two factors must be considered: movement in space and the time span.

The ad-hoc mobility matrix was an important tool for generating mobility visualizations between Access Points (Fig. 5). The matrix sets, in an ad-hoc way, the mobility probability between Access Points. If a device is captured inside an overlapped zone it means that mobility between Access Points might not have taken place. Zones with overlapping Access Points` ranges introduce a degree of uncertainty as to mobility that must be estimated.

The probability of mobility among Access Points was estimated by considering the coverage area of each Access Point. The dimensions of these areas are always different. This means that overlapped areas don't have unique mobility values. Also, the certainty that mobility took place depends on the movement direction: mobility from Access Point 1 to Access Point 2 is different from Access Point 2 to Access Point 1.

The asymmetry of the matrix is a property resulting from the irregular distribution on space of Access Points` coverage areas. The lower probability (<1) is concentrated along the table diagonal (on each floor). That is particularly evident on floor 1 (all Access Points fields cross with each other). Values <1 expand from floor 1 (Access Points 1 and 2) in all table directions. It seems to be related to configuration of main atrium as a nine meters height open space.

Time threshold was defined, too. The maximum value considered was 24 hours. Beyond a day, mobility is not considered. The minor is the time interval, the greater is the probability that mobility happened. So, the smallest interval considered was 5 minutes.

FLOOR		f3			f2		f1				f0	f01				f02			
	AP	1	2	3	1	2	1	2	3	4	1	1	2	3	4	1	2	3	4
f3	1		1	0,95	1	1	1	0,99	1	1	1	1	1	1	1	1	1	1	1
	2	1		0,87	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	0,93	0,86		1	1	0,98	1	1	1	1	1	1	1	1	1	1	1	1
f2	1	1	1	1		1	1	0,89	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1		1	0,97	1	1	1	1	1	1	1	1	1	1	1
f1	1	1	1	0,99	1	1		0,59	0,97	0,97	0,9	1	1	1	1	1	1	1	1
	2	0,99	1	1	0,95	0,98	0,43		0,93	0,97	0,92	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	0,92	0,92		0,92	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	0,9	0,93	0,89		1	1	1	1	1	1	1	1	1
f0	1	1	1	1	1	1	0,73	0,85	1	1		1	1	1	1	1	1	1	1
f01	1	1	1	1	1	1	1	1	1	1	1		0,78	0,86	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	0,8		0,95	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	0,95	0,98		0,92	1	1	0,96	0,99
	4	1	1	1	1	1	1	1	1	1	1	1	1	0,9		1	1	1	1
f02	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		0	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0		1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	0,94	1	1	1		1
	4	1	1	1	1	1	1	1	1	1	1	1	1	0,97	1	1	1	1	

AP = Access Point

Ad-hoc mobility matrix.

Mobility traces scatter map.

Each square represents a flow of a device moving from one AP to another. Upper left flows have a greater probability of representing mobility in the same user context (small time span).

The majority of flows have a high probability of mobility because the coefficient is close or equal to 1. Visualizations used flows from the upper left corner.

Fig. 5. Ad-hoc mobility matrix and Mobility traces scatter map

3.4 Inquiring FLUX*

Queries are means of extracting meaningful information from the FLUX* database. The answers provide input for FLUX* visualization tools. Two main groups of queries were made: location queries (traces) and mobility queries (flows). Location queries were divided into three subgroups: general queries, category queries and time queries. Mobility queries consider the number of devices moving between inbound and outbound, between each knowledge-sharing type and between each department sector. Queries supply quantitative information complementary to the visualizations models used (GE representations, force-directed graphs and treemaps).

3.5 Detecting relationships between permeability and (conditioned) ubiquity

Wireless antennas are mainly located in circulation spaces: atriums and corridors with few exceptions on floor 02, Access Points 1 and 2 (auditorium) and Access Point 4

(Geotechnics Lab). Those distribution zones are, naturally, closely connected to the others spaces in the system.

Analysing relationships between Access Points` location and configurational properties, it is possible to conclude that on floors 0, 1 and 01, Access Points are positioned in more narrow spaces with a high number of direct adjacencies (Fig. 6). On other levels, particularly floor 2, Access Points are located in deeper zones seeking to cover specific sub-areas of the spatial system.

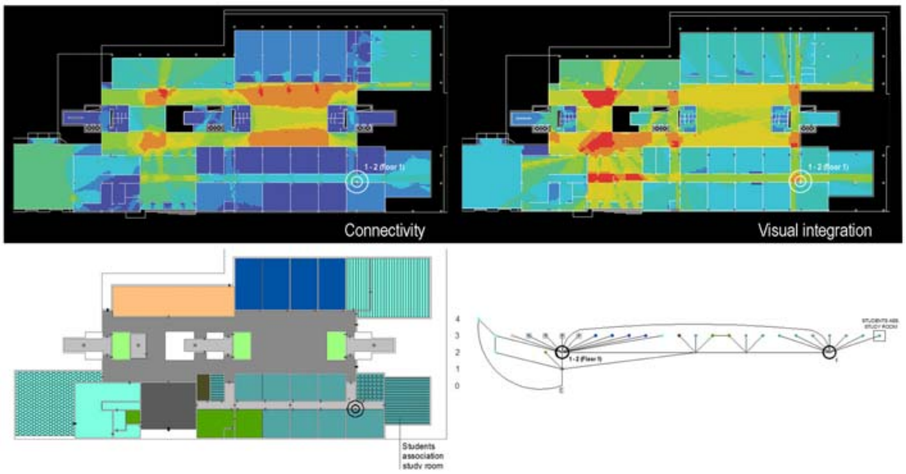

Fig. 6. Civil Engineering and Architecture Building (ground floor): syntactic models

Another strategic Access Points` localization detected was in nodes that belong to cycles or nodes that gather cycles. Access Point 1, on the ground floor, belongs to a cycle that also includes main atrium. This node is within the range of Access Points 1 and 2 (floor 1). This cycle is linked to another one where the entrance node is located. Analysis of VGA maps confirms, generally, Access Points` location in more connected/integrated spaces in spatial system: atriums and corridors. In fact, overlapping zones are given, particularly, in those spaces.

Main atrium - the great circulation space - stands out for its high spatial connectivity/integration. A comparison with the Access Points` coverage zones shows that this space supports the most mixed and extensive of all overlapped zones. A comparison of Figs. 4 and 6 illustrates this.

A direct relationship was detected between spatial permeability and the concern with maximizing the wireless signal propagation. Where ubiquity is highly conditioned by the built barriers, the logic for Access Points` installation was to seek spaces that were highly connected or integrated in the spatial system. Coverage flaws detected in some rooms (floors 1, 2 and 3) are due to scarcity of Access Points, and not mistakes in locating the existing ones.

4 Results

Visualizations (V) allowed to understand users' spatial behaviours and to identify spatial patterns of knowledge-sharing. Some data filters (indicated in figures) were applied for obtaining emerging visual patterns.

Analysis of the global wireless relationships inside IST campus shows that the Architecture department building has the most wireless activity of all campus buildings (Fig. 7 – V1). The greater number of mobility flows (inbound+outbound) occur between the Architecture department building, the main building and Mechanics and Computer Science department buildings (Fig. 7 – V2). Inside the Architecture department building, most flows are linked to Computer Science Lab, students` common room and main atrium (Fig. 7 – V3). Students from other departments intensively use these spaces to work, study and socialize. These spaces correspond to articulation nuclei (external/internal) in terms of "Communicating" knowledge type. They are located in the shallowest places and relate to each other through highly integrated spaces.

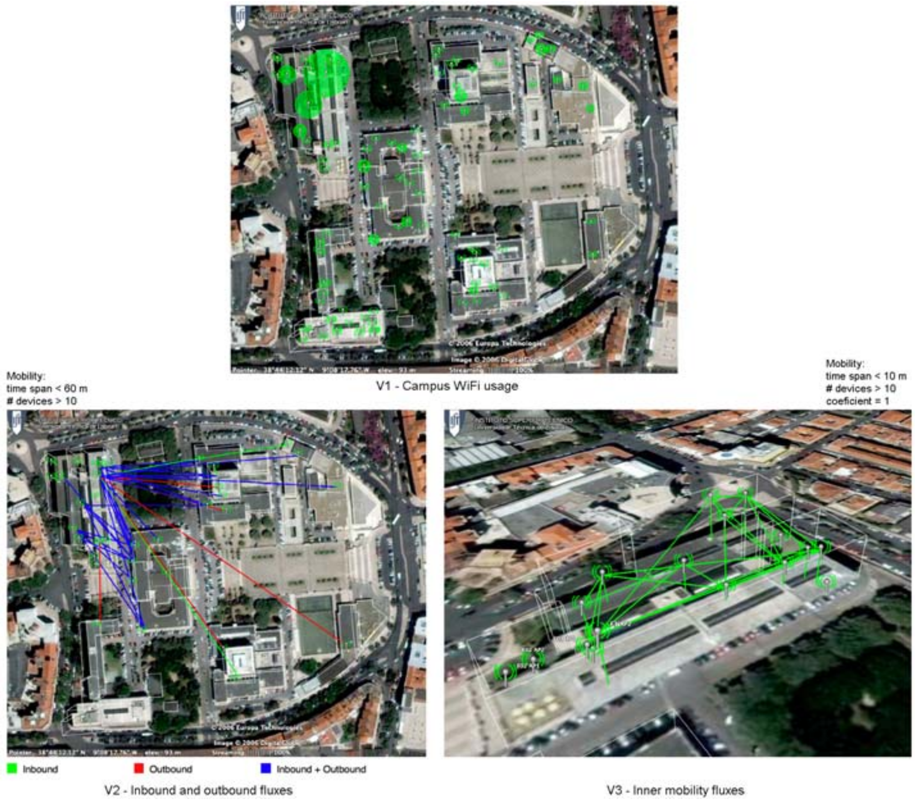

Fig. 7. FLUX* mobility visualizations (V1; V2; V3)

A look at the campus syntactic model shows that the Architecture department building is close to the integrated nucleus, where most of the movement and campus life can be observed (Fig. 8). It belongs to a cycle linked to one of the entrances and an axis that passes through the main entrance campus. Moreover, the most globally segregated lines show a high degree of local integration. Therefore, no area is left without a natural flow of people. This spatial condition allows for generation of movement through the Architecture department building and supports wireless mobility flows. Within the campus, the most frequent paths surround the Architecture department building, making the building recognizable to users. Nevertheless, as the Architecture department building is not on the main axial line, it maintains a certain degree of reserve with respect to campus.

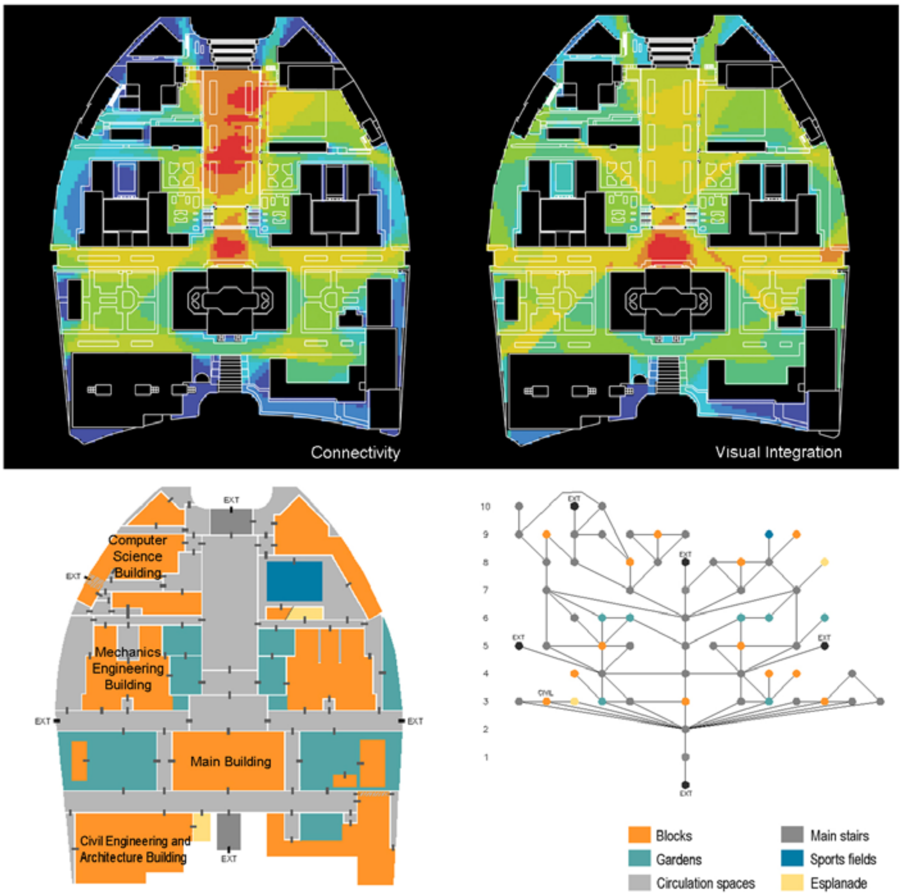

Fig. 8. Instituto Superior Técnico campus: syntactic models

This condition stimulates, simultaneously, movement through and permanence in the Architecture department building. Some flows (inbound+outbound) link main atrium, classrooms (architecture classrooms, specifically), library and students` common room to the cafeteria (Access Points located on Central Building terrace), revealing intense daily exterior-interior wireless mobility.

Main atrium, the most integrated space in the system, provides everyday access to the Architecture department building. The generalised and relatively homogenous high levels of connectivity and visual integration of main atrium play a determinant role in influencing the generation of movement and co-presence. Observations suggest that there is no deterministic circulation pattern in that movement and the potential level of co-presence and encounters are generated by randomness in this space.

Syntactic models show that exterior-interior flows are induced in the Architecture department building through two cycles that link main atrium to the exterior through the outdoor café, on the one hand, and more segregated corridors, on the other. Main atrium is the kneecap of this double-cycle subsystem that promotes movement and random encounter in the Architecture department building.

Main atrium is linked (horizontally and vertically) to a sub-system of corridor-spaces that also responds to special needs for management of visibility and permeability relations. The visual articulation of main atrium, with these corridor-spaces (open galleries), allows an immediate local correspondence between permeability (where you can go) and visibility (what you can see) defining a natural compensation between visual integration and axiality. Open galleries, and corridor-spaces, in general, allow visibility to a series of near and distant convex spaces like Computer Science Lab and students` common room.

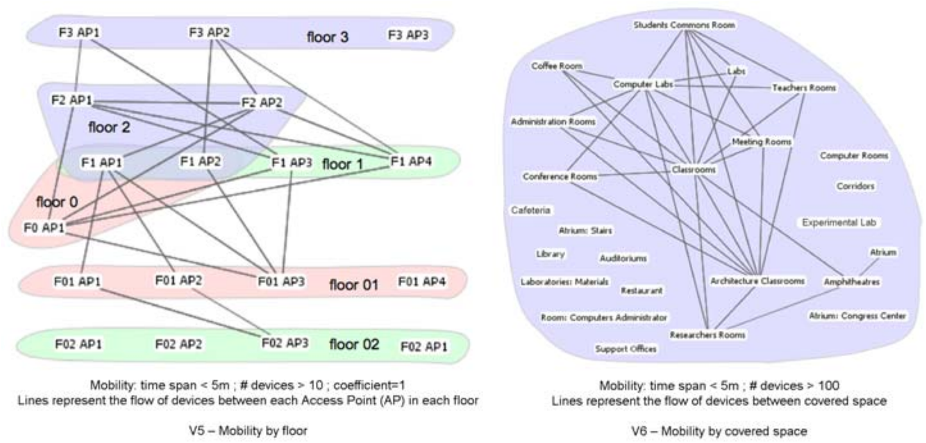

Fig. 9. FLUX* mobility visualizations (V5; V6)

Floors 0, 1 and 2, have the highest wireless activity (more traces/devices) (Fig. 9 – V5). Some Access Points are central to the mobility flows: Floor 0 – Access Point 1 (students` common room) presents the largest number of flows; Floor 1-Access Point 1 (classrooms) and Floor 1-Access Point 2 (main atrium) presents the more extensive flows, directly linked to the lower floors (3-01). Main atrium, during evaluation time, was equipped with tables and chairs. Students spontaneously appropriated it for individual and group activities. In the force-directed graph, Floor 1-Access Point 1 and Floor 1-Access Point 2 polarize other floors because of their suspension over the main atrium open space, which is, visually, highly integrated in the spatial system.

Mobility by covered space shows central spaces in mobility flows: classrooms, architecture classrooms and students` common room present the largest flow figures (and the highest number of traces/devices) (Fig. 9 – V6). Those spaces, located in the more confined zones of the spatial system, with high accessibility, support many WiFi connections with other spaces. Particularly, flows with classrooms as source, or target, always present the highest number of devices moving between covered spaces.

Mobility by knowledge-sharing types shows great mobility between all types of knowledge-sharing scenarios (Fig. 10 – V8). Particularly, “Communicating” and “Delivering” are the knowledge-sharing scenarios most linked to others. Creating is the more isolated one and its WiFi connections are, essentially, with “Communicating/Delivering” types. “More isolated” means that this knowledge-sharing type registered less number of dislocations then the others. It seems a more “static” knowledge-sharing type. This result is coherent with the current space usage because of some reasons: teachers and researchers group represent a minor group comparatively with the student population. So, it is reasonable that their wireless connections are much lesser then those made by students` population (in spite of staff use mostly the fixed network). Their activity is much more located in space then students activities. During a day of classes, students have to move between several rooms and floors. The results of the query about “How much time is spent by knowledge?” shows that “Creating” has the higher time average (58 minutes) of all knowledge-sharing types. “Communicating” and “Delivering” have the lower time average (30 minutes). These results are compatible amongst themselves and with the “static” nature of “Creating”.

“Delivering” and “Communicating” are the knowledge-sharing types with more traces/devices (Fig. 10 – V9). Flows related with them, as source or target, support the higher numbers of devices moving between knowledge-sharing types. Spatially, those categories are located on floors 0, 1 and 01, corresponding to highly permeable spaces (visually and physically), vertically linked by the main atrium. “Decision Making” and “Creating” types are located in lower areas where students only go occasionally. Labs are essentially located in floors 01 and 02. Those are spaces of more punctual use than current classrooms. The more intense wireless activity is concentrated on narrow levels.

From these results (confirmed by WiFi users` observations) a spatial pattern of knowledge-sharing use emerged revealing a more dynamic and permanent wireless activity located at more permeable levels and confined spaces (floors 0 and 1), specially related with knowledge-sharing types of “Communicating” and “Delivering”. The main atrium spatial structure – the central distribution space of the Architecture department building – promotes random users encounters and co-presence. The greatest proportion of interaction was found in the open space of main atrium and common spaces (Computer Science Lab and students` common room), where people meet to talk as well as study. The integrating nucleus of main atrium links the more relaxed and informal area used by students on the ground floor (Computer Science Lab, students` common room and studying classrooms) to the more segregated spaces on the upper and lower floors (teachers' rooms, researchers' rooms, labs, amphitheatres and auditorium). More restricted wireless uses, related with knowledge-sharing types of "Creating" and "Decision making", were located in deeper and segregated spaces (floors 2, 3 and 02) assuring the necessary privacy to those activities.

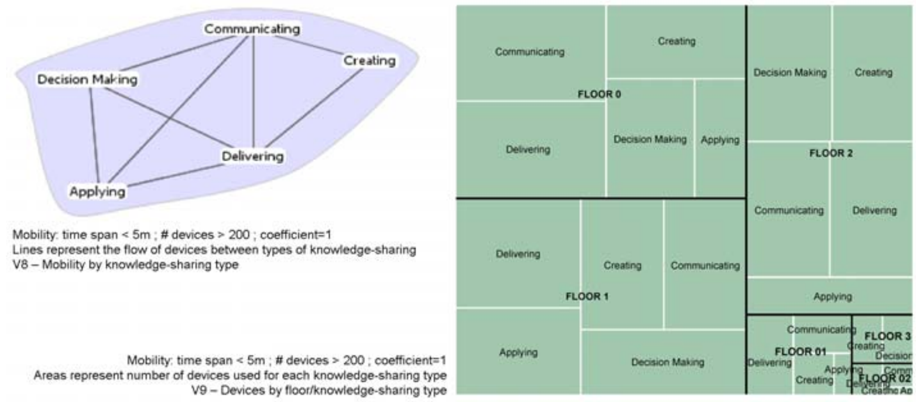

Fig. 10. FLUX* mobility visualizations (V8; V9)

These results also suggest that FLUX* visualizations may became a vehicle for the interpretation of spatial behavior observed. The interpretation of people spatial behavior implies to known how people and space interact with each other. Space is an active agent in the activities processing, influence people mobility. The syntactic models allowed us to know the configurational space properties. Spatial Information Visualization was applied to the representation of users` spatial behaviors. The two representation types are associated. This association is essential to study interactions between space and users.

It is important to notice some intrinsic qualities of FLUX* representations. Besides the direct information that these representations express, some of them support other levels of non-direct information. Direct information is information that the representation is supposed to transmit in the first place. Non-direct information is information that is not included on the FLUX* numeric data tables and only emerge from the representations. Corresponds to an increment of information besides the principal data that is supposed the representation communicate. Google maps allow other levels of non-direct information like wireless flows extension – cases of "Inbound+Outbound Flows" and "Inner mobility fluxes". These one, shows flows extensions in vertical dimension too. All Google maps allow the direct representation of the use spatialization. The consideration of space representation makes the interpretation of the relationships space-users easier.

"Devices by floor" is a more abstract representation. The spatial dimension is not so obvious but, nevertheless, the essential information - vertical organization of space - is expressed. It is possible to identify the more intense wireless communication concentrated in specific floors, the antennas that polarize those communications, and the more extension flows established between floors. Another non explicit information that arises exclusively from the representation itself.

The more abstract representations are related with knowledge-sharing types. Abstraction is a consequence of the absence of space representation. In spite spatial connotations are underlying to the concept of each knowledge-sharing type, the location of those spatial behaviors are not directly established through representations. On those cases, the interpretation process only can deal with direct information. Those are narrow representations: they don't allow adding the interpretation process any other information. The absence of other levels of information (non-direct ones), don't contribute with more profound insights about the knowledge of the interaction space-use like happens with the more deep representations like Google maps.

5 Conclusions and Future Work

This paper explores the capacity of WiFi networks as a space-use analysis input tool applied to describing emerging spatial patterns of knowledge-sharing. It is based on a crossover of Space Syntax and Spatial Information Visualization analysis applied to the building scale. For this purpose, a department building within a university campus was used as a case study.

One can conclude that the WiFi network shows capacity to function as an ad-hoc WiFi user trace system since it enables detection of user locations as well as movement flows in space and time. This data is non arbitrary and free of human factor.

Through the application of queries to the database, the FLUX* visualization platform allows one to extract relevant information for understanding the spatial knowledge-sharing patterns. The taxonomic definition of the wireless antennas is fundamental in this process. The models of visualization of the spatial use dynamics, and their quantification, have become adequate complements to the Space Syntax methodologies. The space-use analysis model revealed analytical capacities for spatial contexts for the sharing of knowledge.

However, the application of the space-use analysis model to an architectural context revealed the need for refinement in the methodological processes used. The main difficulty identified had to do with matching the wireless antennas' coverage area with the physical space.

The results seem to suggest that this analysis could have many further developments: the use of autonomous probes to track the space and registering Access Points` signal quality; the development of specific software for mapping probe information and automatically drawing, on the building plans, the course of the probes and the antenna coverage zones and calculation of overlapping areas. The definition of the Coverage Matrixes for the FLUX* programme would allow one to establish more direct space/signal correlations.

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