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TOWARDS A MIXED APPROACH COMBINING VISIBILITY AND MOBILITY STUDIES TO ANALYZE THE ELEFThERIA SQUARE, NICOSIA (CY)

Thomas Leduc(1) and Odysseas Kontovourkis(2)

(1) LUNAM Université, CNRS, CERMA UMR 1563, école nationale supérieure d'architecture de Nantes, Nantes, France – thomas.leduc@cerma.archi.fr

(2) Department of Architecture, Faculty of Engineering, University of Cyprus, Cyprus – kontovourkis.odysseas@ucy.ac.cy

ABSTRACT

In the present joint research, authors are trying to correlate surroundings assessments with pedestrian movement behavior through visibility and mobility studies respectively. In order to achieve this objective, several isovists field simulations have been applied on the one hand, and a virtual forces based model has been introduced on the other hand. A specific aspect of the present study is that it proceeds in a systematic evaluation of the whole region of interest and does not only focus on several given trajectories. The field oriented analysis of the open spaces through a drift based shape index exhibits several morphological saliencies. The virtual forces model gives an indication of pedestrian movements through generated trajectories. As a result, both approaches have been merged in a common geographical information system which allows achieving reliable spatial comparisons. For instance, movement accelerators have been spatially correlated to areas of lowest drift magnitudes.

1. INTRODUCTION

Visibility is predominant in the human perception of the urban fabric. As illustrations, (Morello & Ratti, 2009) notices that there were “many attempts to translate visual-perception research into architectural and urban design” and, in a famous contribution, (Lynch, 1960) deals with the visual appearance of cities. They assert that city mental maps contain many elements that can describe our experience and the image of the environment. These maps can explain our tools for orientation and memorization, and also represent an evaluation of the ‘legibility’ of a built context. Based on this concept of legibility, (Lynch, 1960) introduces the derived notion of “imageability” which is a kind of indicator of the evocation power of an environment.

The present research is aimed at developing a procedure to combine the urban (visualscape) openness with the mobility study. It intends to take advantage of improvements in measurement techniques, and developments in Geographic Information Science and Technology. It is one more attempt to link behavioral, qualitative and configurational issues of the built environment. The objective is to investigate whether or not there is any correlation between pattern of space use and openness patterns of the surroundings.

Authors are, nevertheless, conscious of the limits of such an attempt. In urban way finding and navigation processes, several other parameters need to be taken into account. Among them all, one could mention efficiency constraints, aesthetic preference, subjective sense of safety or danger, overcrowding and other environmental conditions, landmarks salience, etc. Thus, in her hierarchy of walking needs, (Alfonzo, 2005) organizes the decision process of walking into five levels: feasibility, accessibility, safety, comfort, and pleasurability. Nevertheless, as noticed by (Foltête & Piombini, 2010), it appears important to stress anew the role of urban landscape. Once, safety conditions and facilities designed for pedestrians are satisfied, landscape quality, the type of atmosphere, and all the other aspects composing comfort and pleasurability have to be considered as significant criteria for urban planning.

1.1 Surroundings delineation: openness assessment

As noticed by (Weitkamp, 2010), one way to link perceptual factors with spatial information is provided by the concept of isovist, which has had a long history in architecture and geography, as well as mathematics. As summed up by (Davies & Mora, 2006), the keyword isovist has its roots in the seminal work of Gibson (Gibson, 1979), who argued that “one can perceive surfaces that are temporarily out of sight”. That is, by virtue of motion or deduction people can infer the existence of spaces beyond an isovist's occluding barriers.

An isovist is the set of all points in an environment of opaque surfaces that are visible from a given point (the limit of the isovist is an artificial one functioning something like a horizon in the absence of any other intervening surfaces). Essentially, isovists describe local geometrical properties of spaces with respect to individual observation points and weight all the possible view directions equally. An isovist is a 2D horizontal slice of pedestrian's surrounding space. The appeal of the concept is that isovists are an intuitively attractive way of thinking about a spatial environment, because they provide a description of the space 'from inside', from the point of view of individuals, as they perceive it, interact with it, and move through it (Turner, Doxa, O'Sullivan, & Penn, 2001). It is a useful tool to define the open space concept.

To quantify space in a more systematic way, (Benedikt, 1979) suggests that the way in which we experience a space, and how we use it, is related to the interplay of isovists. Therefore, isovists field records a single isovist property for all locations in a given area. The underlying aim is to assess the way corresponding features vary through space. To achieve such an objective, he defines six different shape indicators strongly related to openness such as: the visible area and the visible perimeter, the occlusivity of the isovist (the accumulated lengths of edges of the isovist boundary that are not solid wall stopping the isovist), the variance and skewness of the function of radial distances, and, at last the circularity of the isovist (a compactness measure).

To enrich this set of shape indices, (Conroy, 2001) proposes some other indicators such as the longest line of sight, the distance to the closest opaque object, the drift ("an exceedingly interesting measure") of the isovist polygon, etc. The drift is the distance in meters between the location from which the isovist is generated and the "centre of gravity" of the isovist. In her PhD thesis conclusion, she asserts: the patterns formed by areas of minimum drift tended towards the centers of spaces and roads were incredibly suggestive of patterns of pedestrian movement. She also notices: it would be particularly interesting to investigate whether drift could be connected to sufficient paths and axial analysis.

1.2 Behavior modeling through virtual forces

The 'virtual force' pedestrian modeling approach (Kontovourkis, 2012) describes the interaction and movement behavior of pedestrians influenced by various forces. This idea can be categorized in a broader area dealing with particle behavior modeling, a general term used to describe interaction between individual components (flock of birds, pedestrians, etc) that are simulated in real time and in parallel based on simple rules resulting self-organized and emergent behavioral outcomes (Goldstein, 1999). Similar approaches can be used, for instance, for the computer simulation of animal behavior (Reynolds, 1987; Terzopoulos, 1999). In each case, different types of particles and rules are applied according to the problem under investigation but following the same principles. In case of human behavior modeling related concepts can be found that describe interaction and movement of pedestrians (Helbing, Buzna, Johansson, & Werner, 2005; Turner & Penn, 2002).

Specifically, in pedestrian modeling the idea of 'virtual forces' can be placed within the broader area of microscopic modeling and can be distinguished from other types of pedestrian modeling categorized by (Turner & Penn, 2002) as macro- and mesoscopic-simulations. In microscopic level of modeling a number of approaches can be also categorized according to (Teknomo, Takeyama, & Inamura, 2000). (Helbing, 1994; Helbing & Molnar, 1995) introduced the idea of 'social force' modeling, a pioneer work that can be categorized in microscopic level, which achieves to accelerate interaction and movement of pedestrians by calculating changes of pedestrian's position in space in each time step and under the influence of various forces. This work has been influenced by Kurt Zadek Lewin (1890-1947), a German psychologist, who introduced the 'field theory', a social science approach that aims to analyze human behavior based on 'force field' (Lewin, 1952). Similar principles can be found in 'magnetic force' model, in this case, using magnetic forces (Okazaki & Matsushita, 1993). Such approaches focus on the interaction behavior of pedestrians with each other and the built environment used to analyze various phenomena like pedestrian intersection flow and emergency evacuation.

Analytically, the 'virtual force' model assumes that pedestrian's velocity and acceleration change due to various forces. It can be said that forces motivate pedestrian's movement but also social behavior. The overall behavior can be seen as the resultant force that includes forces accelerating actual movement of pedestrians but also virtual forces motivating pedestrian's behavior influenced by various needs and desires. A pedestrian modeling approach cannot be completed if it is not accompanied by techniques that simulate more complex movement behavior than simply interaction between individual components. Hence, 'virtual force' technique develops in parallel concepts

based on 'route choice' behavior that is the choice of pedestrians to select particular destinations with specific goals of movement actions. Similar techniques as well as modeling that takes into account human perception and cognition of space have been also examined including 'route choice', 'spatial cognition' and 'space syntax' models (Hoogendoorn, Bovy, & Daamen, 2002; Turner & Penn, 2002).

The 'virtual force' pedestrian modeling focuses its investigation in two or three-dimensional built environment (Kontovourkis, 2009, 2010, 2011). As it has been explained, the modeling is achieved by the application of forces that motivate movement and interaction between individual objects like pedestrians, obstacles, etc. but also 'signs' (sort of landmarks or movement behavior attractors) and 'destinations'. Interaction that might motivate behavior is achieved by applying rules and attributes in different two and three-dimensional objects investigating their behavior, for instance, between pedestrians and 'signs' that lead to specific movement outcomes.

1.3 Spatial cognition: joint approaches

The present joint approach is motivated by (Turner et al., 2001) assertion: "The measurement of local and global characteristics of the graph, for each vertex or for the system as a whole, is of interest from an architectural perspective, allowing us to describe a configuration with reference to accessibility and visibility, to compare from location to location within a system, and to compare systems with different geometries. Finally we show that visibility graph properties may be closely related to manifestations of spatial perception, such as way-finding, movement, and space use".

2. METHODOLOGY

The investigation on visibility mobility is based on a systematic analysis of the isovists field of the given region of interest as suggested by (Benedikt, 1979). The implementation we propose is an adaptation of the method presented in (Woloszyn & Leduc, 2011) to the drift specific shape indicator.

The investigation on pedestrian mobility is based on 'virtual force' model. For analytical description regarding this methodology see (Kontovourkis, 2012). The approach for pedestrian modeling follows a number of steps including; pedestrian flow and geometrical configuration of the built environment; pedestrian movement and interaction behavior; and simulation outcomes. The current research investigation follows the procedure used in macro-scale level (for more details see (Kontovourkis, 2012)) that is the simulation of pedestrian flow in order to produce circulation systems and hence trajectories indicating basic pedestrian movement behavior in the built environment under investigation.

2.1 Isovists field as a way to assess surroundings in a systematic way

An isovist corresponds to a horizontal slice through the field of view taken at eye height and parallel to the ground plane. Redefined into space syntax theory, it is "the sum of the infinite number of lines of sight (or axial lines) that pass through a single point in space (usually at eye height) and occupy the same plane (usually parallel to the ground plane)" (Dalton & Bafna, 2003). Translated into computer graphics theory, it can also be understood as the area not in the shadow cast from a punctual source of light (located at the vantage point itself).

In the same "ray casting" vein, one can assimilate the Euclidean vector linking the vantage point with each point of the isovist¹, to a sort of "visual stress" from the generating location (the view point) towards the remote location. Assuming that space is uniformly weighted from the visual point of view (we mean that each point of the isovist produces an equivalent visual stress towards the vantage point), the sum of all Euclidean vectors starting from vantage point towards all isovist's points corresponds to the local resulting visual stress (see Figure 1). This spatial continuous Euclidean summation (integration) corresponds, by definition, to the Euclidean vector which starts from vantage point towards the center of gravity of the corresponding isovist. It also corresponds, by definition, to the drift mentioned previously. One may conclude that the isovist drift is a sort of accumulated visual stress all over the isovist shape. Therefore, the drift is not only a measure of the distance of

¹ Indeed, as a shar-shaped polygon, each isovist is a polygonal area in the plane which is a star domain (it exist a point, the so called vantage point V, such that for each point P of the isovist, the segment VP lies entirely within the isovist.

the vantage point from the gravity centre of the corresponding isovist, but also a measure of the effort required to align the visual center of a given open space (assuming isovist is an open space delineating solution) with its own center of gravity.

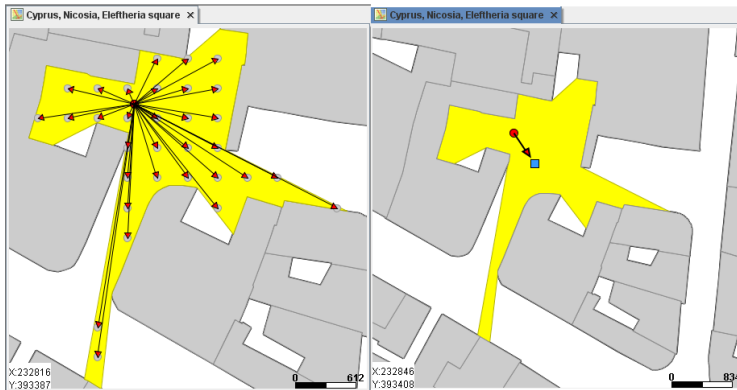


Figure 1: Left hand side: an isovist (yellow colored polygon) delineating the visible portion of space generated from a given vantage point (black focal point). The rays represent a sample of 32 Euclidean vectors (“visual stress”) starting from this vantage point towards each isovist point. Right hand side: in the same isovist delineating the visible portion of space generated from the same given vantage point (red bullet), the drift is the Euclidean sum of all “visual stresses”. It is represented by an arrow linking the view point with the gravity center of the isovist (blue rectangle).

One of the objectives of the present paper is to analyze the visibility potential of a given area. Therefore, the method we need has to evaluate and characterize visibility in a systematic way all over the area. The geo-process we adopt has been presented in (Leduc & Woloszyn, 2011; Woloszyn & Leduc, 2011). It consists first in a regular sampling of the given region of interest into a set of points. Each of these points is the node of a regular orthogonal grid that covers the whole of the input area. The numerous these points are (the finer the mesh is), the more accurate the final result will be. In a second task, an isovists field computation is performed, based on the one hand on this set of equidistant punctual positions and, on the other hand, on the buildings layer. At last, in each vantage point (for each isovist), a drift is computed and a Euclidean vector is produced. Objective is to provide each vantage point with a local accumulated “visual stress”. The global result is a Euclidean vectors field that will be compared with the results of the mobility study.

2.2 Attractors and pedestrian mobility in the built environment

The mobility study is based on virtual forces (movement forces, social forces, etc) acting upon each pedestrian motivating his/her movement behavior in the built environment. Obviously, virtual force approach is directly related with the configuration of the built environment influencing the way pedestrians move and behave in given urban fabrics. This investigation can be achieved, first in local and second in global level. In local level, the movement of each pedestrian is motivated by the ‘sign’ that is closest to his/her position in space in each time step. This is based on the assumption that in each moment pedestrian’s movement is triggered by various needs and desires virtually coded into attractor objects. These attractor objects can be either actual signs that direct his/her movement or any other form of attractor that describes pedestrians desires.

In global level, the number, direction, and combination between various attractors according to the configuration of the environment are represented by ‘signs’ motivating overall pedestrian’s movement behavior. This can be achieved by organizing ‘signs’ (attractors) and ‘final destinations’ (that is the end of pedestrian movement) in ‘route choice strings’. Such ‘strings’ describe for each pedestrian or group of pedestrians a movement scenario or a sequence a movement steps necessary to be taken in order to fulfill his/her movement action in the given space.

2.3 Initial assumptions

The method we need has to evaluate and characterize visibility in a systematic way all over the shape. Nevertheless, one must admit that the implemented isovist based method, is far from real human visual experience insofar as it does not take into account the vertical dimension. More precisely, the method we use has much more to do with a systematic surroundings evaluation in every punctual position.

In order to let this method remain easily and widely repeatable, we want it to be based on “classical” data of vector type. That is why, in the following use case, we present a simulation that is only based on a polygonal buildings layer.

By definition, isovist shape depends on a clear definition of opaque edges. These edges or boundaries are the barriers that impede vision beyond themselves. An obvious reality principle (related to data availability) leads us to limit the set of opaque objects to the buildings structures. An enhancement would be to consider bus shelters and others (opaque) street furniture as visual mask.

3. PRELIMINARY RESULTS AND DISCUSSION

3.1 Case study: Eleftheria square in the old city of Nicosia, Cyprus

The used case study for this joint research investigation examines visibility and mobility of pedestrians in Eleftheria square in the Old City of Nicosia, Cyprus. The old city is the main historical center of the capital of Cyprus, including the well preserved medieval Venetian walls that traced back to 16th century, as well as various buildings and monuments with great historical value. The capital of Cyprus and specifically the old city is divided into the north and south part due to the Turkish invasion in 1974. Currently in the Greek south part where research is held, ones can observe high potential for living, working as well as for shopping activities. Important aspects strengthening such activities are the well known shopping streets, mainly Ledras and Onasagorou, which attract a number of visitors (native and international) all day long as well as the well known old neighborhood with buildings and monuments and accommodated activities for tourism. Figure 2 shows part of the old city including Eleftheria square and main shopping streets.



Figure 2: Map of Eleftheria Square and surroundings

At the end of Ledras Street, in the south part of the old city and just after the surrounding Venetian wall, is the Eleftheria Square, probably the most well known square in Cyprus that is currently under renovation. The renovation follows the modern design proposal of an international design competition won by the famous architect Zaha Hadid. Due to the current situation that do not allow us an investigation into the whole area of Eleftheria Square, the study apply its methodology in the remaining part of the square that includes the northern smaller square area connected to the main shopping streets of the old city. Following Figure 3 shows images from the remaining Eleftheria Square. The city square is basically a transition place that connects the new and the old city. It is a place that links the main shopping streets and functions as a meeting point due to its central position. In this area ones can observe a number of movements towards and from the shopping streets and for this reason the square can be characterized as a place where intersecting pedestrian flows and other movement activities are occurred.

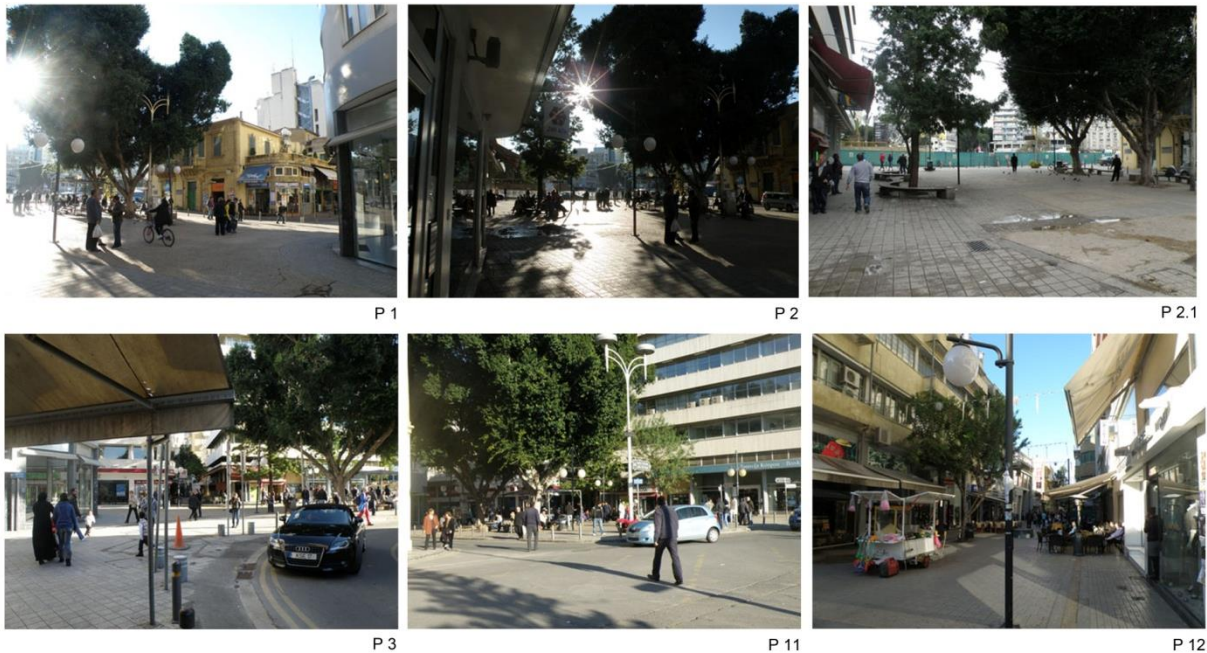


Figure 3: Images from Eleftheria Square

3.2 Isovists field measures

As written before, an isovists field consists in a collection of isovists polygons at every vantage points of the given region of interest. More precisely, focusing on the drift property of the isovists, the isovists field represents the corresponding “potential” in each analyzed vantage point (that is the accumulated Euclidean vector that corresponds to the drift is calculated and assigned to each point of interest). As noticed in (Morello & Ratti, 2009), isovists field sum all single visual perceptions and offer an objective and unique characterization of an environment. Indeed, the description of open spaces through maps visualizing isovists field allows the character of the space to emerge clearly

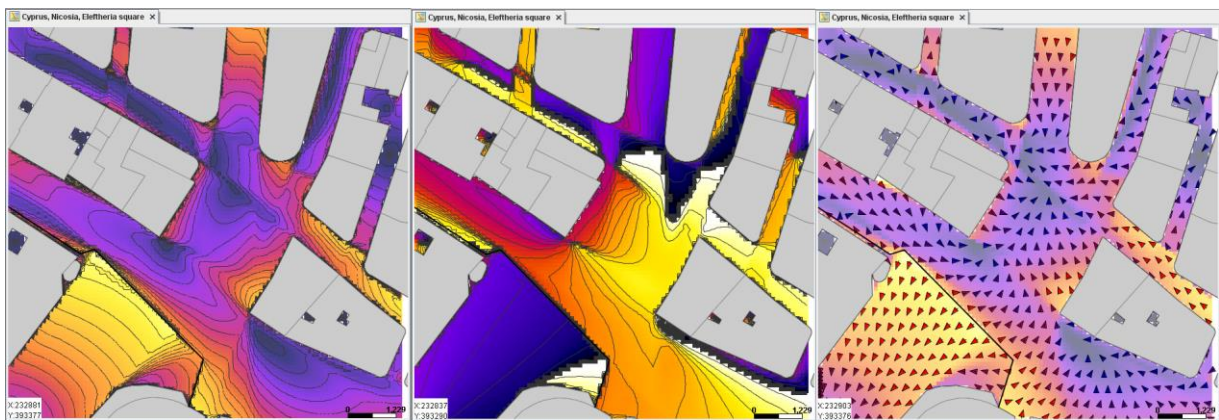


Figure 4: Three isovists fields for different properties computed on the open spaces around Eleftheria Square (Nicosia, Cyprus). Left hand side: isovists field of drift magnitude – Center: isovists field of drift azimuth - Right hand side: isovists field of drift Euclidean vector

In the Figure 4, three different representations of the drift all over the isovists field are drawn. First one corresponds to the drift magnitude, second one to the drift azimuth, and third one to a combined representation (through rescaled Euclidean vector) of the drift magnitude and azimuth. The side effects (in term of visibilities) of the square renovation process are obvious near the fence which is located in the south-west part of the square. This temporary fence plays indeed an efficient repellent effect for the drift indicators. This repellent effect is translated into a sort of vortex or edge effect at a distance of about 15 meters in its north side.

3.3 Behavior measures

Pedestrian flow and geometrical configuration of the built environment: the investigation starts by defining various movement scenarios within the given area based on actual pedestrian movement behavior. For this purpose a number of observations are made in regards to the actual pedestrian movement. All movement scenarios have an initial starting point and a final destination represented by 'route choice strings'. Observations in the area lead to the conclusion that actual pedestrian movement behavior is motivated by shopping activities. As it has been explained in the previous paragraphs, the two main shopping streets trigger such behavior and for this reason the 'route choices' are formulated according to these activities.

Each point on 'route choice strings' represent a position that might influence pedestrian movement behavior, either to change the direction of movement towards and from shopping streets or to influence shopping behavior acting as passing point. Each of these points is organized in a sequence of movement steps always including one entry and one destination points. In parallel, the outline of urban fabric is defined influencing the position of each point in the 'route choice strings'. Groups of pedestrians are given a starting point and according to given movement scenarios. Specifically, A, B, C, D, and E group of pedestrians follow different movement scenarios. Figure 5 shows possible movement scenarios represented by 'route choice strings' and according to the initial observations.



Figure 5: Pedestrian's shopping behavior is represented by 'route choice strings' for A, B, C, D and E group of pedestrians. The red lines corresponds to group A, the green lines to group B, the blue lines to group C, the purple lines to group D and finally the gray lines to group E.

As it can be observed from the 'route choice string' analysis different groups of pedestrians might use common entry, passing, crossing or destination points. This can also be found in real situations where pedestrians, even if their overall goals of movement actions are different, parts of their movement behavior in the 'route choice string' share common points. This can probably produce phenomena of intersecting flows, blockage of movement, and so on.

Pedestrian movement and interaction behavior: pedestrian's movement is motivated by 'signs' positioned according to specific 'route choice strings' and a final compulsory destination. Analytical explanations in regards to pedestrian's movement behavior based on Experiment type 1 can be found in (Kontovourkis, 2012). Each 'sign' directs pedestrian's movement towards the next 'sign' and hence to the selected destination corresponding to specific 'route choice string'. In order to avoid collision between pedestrians due to the intersection points each pedestrian is given a virtual social repulsive force. The resultant force motivates pedestrian shopping behavior as the results of sign and destination movement forces as well as repulsion avoidance forces.

Pedestrian movement simulation: simulation shows possible pedestrians movement trajectories in the urban fabric. This is the results of movement scenarios based on specific shopping behavior (see Figure 6).

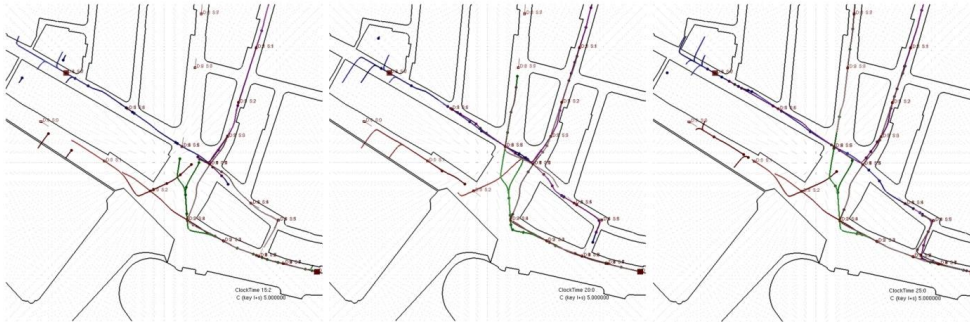


Figure 6: Results of simulation and pedestrian movement trajectories in the Eleftheria square. Each color corresponds to different group of pedestrians; group A (red), group B (green), group C (blue), group D (purple), and group E (gray) (three basic time steps)

3.4 Isovists field and behavior measures

Both simulations have been produced in the same coordinate reference system. This is the reason why we decided to present them as a set of overlaying layers in a geographical information system. Figures below combine trajectories with surroundings assessment through drift in the same order as they have been presented in Figure 7.

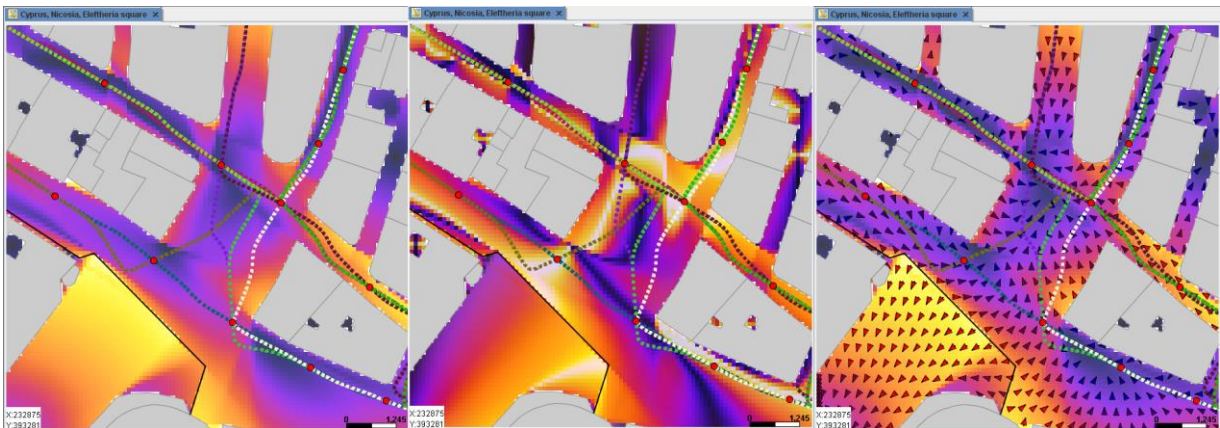


Figure 7: Three images combining isovists fields with pedestrian trajectories on the Eleftheria Square (Nicosia, Cyprus). Left hand side: trajectories are superposed to isovists field of drift magnitude – Center: trajectories are superposed to isovists field of drift azimuth - Right hand side: trajectories are superposed to isovists field of drift Euclidean vector

Our first observation is concentrated on the relationships between markers location (red bullets) and areas of lowest drift magnitude potential. These areas correspond to places where vantage point is close to the gravity center of the isovist. It also corresponds to place where there is some sort of coherence between physical and visual impressions. In the movement behavior simulations, these markers or attractors have been positioned in a semi-arbitrary manner (taking real observations but also empiric and experienced considerations into account). The fact that almost all these markers are located at open spaces “centers” (places of lowest drift magnitude values) exhibits some correlation.

Our second observation is concentrated on the probable relationships between the already mentioned markers and the yellow (and white) colored areas (one could say “corridors”) in the drift azimuth potential figure. All these areas share same south to north drift orientation. This sort of global orientation reflects the attractiveness of the north part of the square due to the two shopping streets. It is also clearly exhibited in the vector representation map of the drift potentials.

At last one may noticed the drift azimuth asymmetry in the figure. It corresponds to a property of the actual (and probably functional) configuration of the square.

4. CONCLUSIONS

In this paper, following (Franz & Wiener, 2008) who demonstrates that human spatial behavior and experience cannot be investigated independently from the shape and configuration of environments, we have tried to correlate surroundings delineations (through visibility studies) and motion behavior (through agent based simulation). This correlation was made possible thanks to geographical information tool and agent based approach that facilitates easiness in replication and increases independency against other subjective and uncontrolled parameters. To conclude, one may notice some similarity between the two models. Indeed, they both process data at a local scale (the one of a pedestrian in his own surroundings) and with an anthropocentric objective.

Concerning the results, a spatial correlation appears between markers or attractors that have been positioned in a semi-arbitrary manner (taking real observations but also empiric and experienced considerations into account) and areas of lowest drift magnitude potential.

To achieve a motion behavior closer to the natural one, we suggest enriching agent based models by adding visibility assessments at each time-tick and in each punctual position. Concretely speaking, this enrichment should provide sort of *in-situ* movement behavior (unconsciously decided) using the field oriented analysis of the urban fabric. At last, to validate this joint approach, it would be of great interest to track real motion behaviors and compare corresponding trajectories to our own results.

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