Looking ahead: a vision-based software for predicting pedestrian movement*

Ver no es mirar: el desarrollo de un programa computacional basado en la visión, para predecir el movimiento de los peatones

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ABSTRACT

This paper presents ongoing research on the use of agents equipped with "exomatic visual architecture" (Turner et al., 2001). The main objective was to test whether some rarely explored isovist measures, like drift and longest line of sight, are associated with aggregated movement patterns of downtown Santiago, Chile. To test this idea, a series of algorithms were created and compared with observed data recorded at approximately 200 points during an entire workday.

The main results show that drift-based algorithms were better suited to predict aggregated patterns than random behavior, although the extent of such relation is still weak (r2 = 0.27). From a theoretical point of view, these results seem to be in accordance with current cognitive theories (Clark, 2009; Thompson, 2007) stressing the dynamic nature of human behavior.

Keywords: pedestrian movement, drift-based movement, agents, vision.

RESUMEN

Este artículo presenta una investigación en curso sobre el uso de agentes provistos de visión exomática (Turner et al 2001). El objetivo principal es evaluar si algunas medidas, raramente examinadas, como las isovistas: líneas de visión más extendida, están asociadas a flujos de movimiento existentes en el centro de Santiago de Chile. Para ello, se crearon una serie de algoritmos que guían a los agentes y se compararon con los flujos detectados en cerca de 200 puntos, durante un día hábil completo.

Los resultados principales, mostraron que los algoritmos basados en el Drift fueron más efectivos en reproducir los flujos de movimientos, comparados con los algoritmos basados en un movimiento aleatorio de los agentes, aunque esta correlación es aún débil (r2 = 0,27). Desde un punto de vista teórico, estos resultados parecen estar en línea con las teorías de cognición contemporáneas (Clark, 2009; Thompson, 2007) que tienden a enfatizar la naturaleza dinámica del comportamiento humano.

Palabras clave: movimiento peatonal, movimiento basado en Drift, agentes, visión.

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1. Introduction

Pedestrian movement is a fundamental part of cities. It shapes and contributes to the development of land uses (Jacobs, 1961; Hillier, 1996), especially uses (like retail) that are dependent on the flow of people, it also helps people perceive their environment as secure. Pedestrian movement is also vital for making cities more livable (Whyte, 1980) and for improving the sense of community among citizens. For these reasons, enhancing pedestrian movement has become a central part of urban policies in various parts of the world since the seventies, especially those aiming at regenerating cities (Imrie et al., 2009),.

In spite of this, the dynamics of pedestrian movement have been poorly understood (Batty, 2001; Papadimitriou, 2009). Batty (2001) has argued that pedestrian movement has been historically neglected mainly due to the fact that transport models have been imported (without much thought) as a means to understand how people move, despite the fact that the latter behavior is more discretionary than the former.

In the last ten years, a series of studies have attempted to overcome this limitation. Conroy-Dalton (2003), for example, has shown that people "follow their noses" while navigating; that is, they tend to deviate as little as possible from straight trajectories. In attempting to explain these phenomena, she proposed that people would prefer the longest route choice as long as this option would not deviate from the final destination more than any other route. Golledge (1995) has argued that pedestrian movement, when examined on a micro scale, posed an interesting problem,

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for people do not necessarily choose the same path when going to a place than when returning from it.

It has been argued that a promising line of inquiry to better comprehend people's movements is the employment of agent-based models (Batty, 2012). Until recently, these models were difficult to build due to processing constraints, but recent developments in hardware has made it possible to test them with real-world data. Furthermore, it has also been argued that models of pedestrian "micro simulation have become simpler, rather than complex, due to recent improvement in computational processing" (Kerridge et al., 2001).

Most of these models, however, assume certain preexisting "social" knowledge on the part of agents, meaning that their rules of behavior have been encoded by the researcher based on humans' attitudes observed in real-world scenarios. The underlying assumption is that to be able to reproduce human movement one has to understand people's tendency to cooperate, follow or avoid others. However, human movement is not only the result of one's position in a cultural and social environment, but also the outcome of some capabilities resulting from our corporeal, real nature. We are equipped with eyes that permit most of us to see the world ahead and with a body that can move, rotate and bend in order to reach what is perceived by our eyes.

Since the eighties, scholars have studied the role of visual factors for human navigation with the hope that this might help them to better understand how human movement occurs in the real world. This is the aim of this research; it aims to test the role of visually-guided agents in reproducing real-world movement.

2. Context

The main precedents of this study can be traced back to the work of Gibson and his idea of optic flows. According to him "we must perceive in order to move, but we also move in order to perceive" (1979, p. 223), thus placing locomotion not as the result of an internal cognitive process, but making it a cause of mental processes taking place in our minds.

Central to the Gibsonian perspective is the idea of affordance. To Gibson, certain spatial characteristics afford exploration on the part of the user, whereas others, such as a hiding place, afford concealment. Drawing on these ideas, some authors have tested the role of isovist characteristics for navigation and spatial perception. Benedikt (1985) showed that isovists were perceived as larger than less complex ones. In accordance with this line of inquiry, Wiener and Franz (2004) demonstrated that, all other things being equal, spiky fields of view are perceived as more interesting by people than more convex ones, whereas Meilinger and others (2012) found correlations between people's mental representations of space and isovist features. More recently, Koch (2012) suggested that visual properties of space shape the way doctors and nurses use a medical layout for work-related and social practices.

In 2001, Turner proposed a vision-based software aimed to reproduce "natural" human movement, or movement guided by spatial affordances. The application, part of a software called Depthmap (now in its 10th version), provided agents with a two-dimensional exosomatic vision architecture of 170° (an isovist), allowing them chose a location from it at random. Upon arriving to the initial location, agents move toward a random point of their new isovist until completing a certain number of steps (usually set at 10,000). Since buildings and cities have spaces of different sizes and shapes, agents' isovists vary greatly as they move. This, in turn, creates emergent effects, for large spaces and well-connected spaces were likely to attract more movement than small and secluded spaces. Turner tested his ideas against movement patterns recorded in the Tate Gallery, in London. His results showed that highly visible places were likely to be explored by the agents, in a manner that reproduced people's trajectories to a significant degree ($R2 = 0.72$).

In order to expand Turner's interesting line of inquiry, this research addresses some aspects that, as also acknowledged by the author (Turner, 2007), remained unsolved. Two issues are of special importance here; first, Turner's software did not always perform satisfactorily in open urban spaces, in which agents tend to congregate to the core of spaces due to these spaces' higher degree of inter-visibility, although more often than not people themselves occupy the margins of these spaces (Turner, 2003). Second, Turner's agents' movements were very simple, for they were caused only by virtue of an isovist's size. Recent research has shown that isovists' properties could also provide information regarding people's navigational strategies. Conroy-Dalton has shown that an isovist's centroid, represented by its drift ("indicates the distance between the isovist viewpoint and its center of gravity"), seemed to be related to places where people stopped to gauge their environment in order to amend their routes (Conroy-Dalton, 2003). Taniguchi et al. (2012) have suggested that an isovist's accessibility and visibility properties can be analyzed independently in order to produce a new measure, which they called view and viewed analysis, that hopes to provide an account of the easiness of observing a space and being observed from an accessible space.

With the aim to expand these ideas, a vision-based agent tool was used, one whose engine is not only the visible available space (as in Turner's), but also some other isovist properties like drift and the longest line of sight. Specifically, this study investigated vision-based agents moving randomly or toward their drift or their longest line of sight locations, and compared their trajectories with data of Santiago's downtown.

$$A = \frac{1}{2}\sum_{i=0}^{n-1}(x_i y_{i+1} - x_{i+1} y_i)$$
$$C_x = \frac{1}{6A}\sum_{i=0}^{n-1}(x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_1)$$
$$C_y = \frac{1}{6A}\sum_{1=0}^{n-1}(y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i)$$

Figure 1: formula employed to calculate drift

3. The software

For the initial phase of this research, a software program was designed. This used an open source platform Processing[4] and considered pixels as destination places for the navigating agents. As in Turner's Depthmap, all public space was considered as navigable, providing the fact that any person could circulate on it.

Agents could perform 1000 moves before disappearing. Their field of view was set at 170° (as in Turner's) and chose their destinations according to three main scenarios. The first, let the agents move randomly. The second, was a combination of random and drift-based movements. This means that agents had to select any pixel from their point of view, go to this location and then

[4] *Processing* es una biblioteca de código Java creada por Benjamin Fry y Casey Reas, consta de una IDE mínima le permite funcionar cómo lenguaje autónomo. http://processing.org.

move to the centroid of their field of view at this location. After that, they again selected a random location to move. The last scenario combined random movement with movement to the most distant pixel in sight in a manner similar to the second scenario.

4. Application

To test our ideas, a vast area of downtown Santiago was observed (see Figure 2). This sector comprises many governmental offices of the country, as well as many shops, cinemas, banks, department stores and restaurants. The existence of three large and well-equipped boulevards (Ahumada, Huérfanos and Estado) and a series of internal alleys on many blocks make the area interesting to study.[5] The observation took place on an entire weekday in the month of August, 2010. A total of 203 gates were defined and counted for five minutes per hour during six consecutive hours (11:30 to 12:30, 12:30 to 13:30, 13:30 to 14:30, 15:00 to 16:00, 16:00 to 17:00 and 17:00 to 18:00). As a result, we obtained a mean and an absolute number of people passing through each gate, which was compared with the number of agents counted at these places. Figure 3 shows the 203 gates tested in this study, whereas Figure 4 graphically depicts volumes of people passing through each gate; as can be seen, larger flows were found in pedestrian passages and along Alameda, Santiago's main avenue.

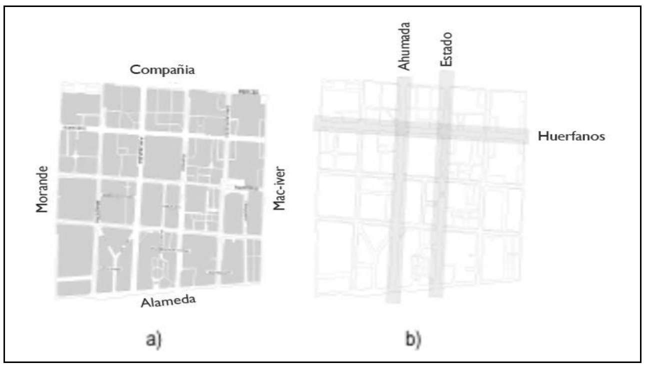

Figure 2a (left) the area of study; 2b (right) pedestrian streets in the area.

Figure 3 (top): the 203 gates were people were counted.

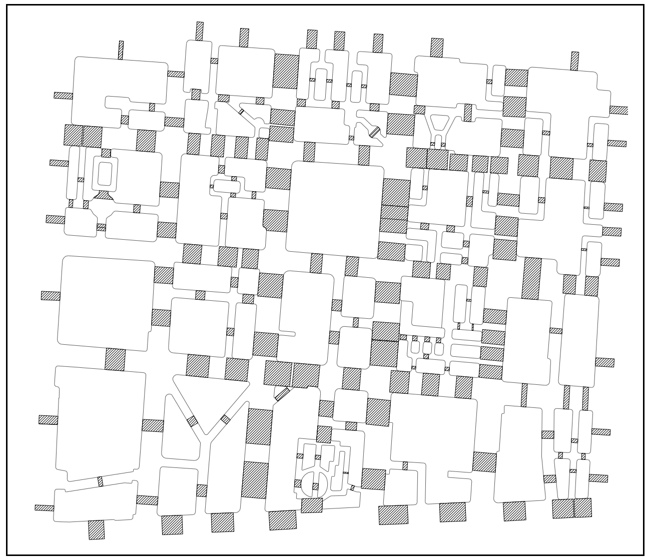

Figure 4 (bottom): flows of people in the area. The length of hatched rectangle corresponds to the number of people passing by.

For the agents to move, the first step was to decide where. Could they walk all over the area, regardless of the fact that on certain streets there were many vehicles passing or could it be the case that only sidewalks and formal crossings were apt for movement? The reality showed that the large number of people moving in the city center, paired with the severe restrictions on the movement of cars (few cars move around the center), made the area a relatively free zone for pedestrians, who crossed streets at almost any point according to their necessities. Moreover, since the various existing galleries were not necessarily aligned between themselves, users tended to move through street segments and alleys in search of their destinations. Agents were liberated in a homogeneous way across the entire available open space, facing any direction.

5. Results

Table 1 shows the results of this simulation in the three scenarios considered in this research: random movement, furthest location on sight movement, and drift-based movement. Two conditions were considered for the origin of agents. Condition one assumed that agents started throughout the open space in a homogeneous manner, whereas in condition two, agents started their navigation at each of the incoming streets in a proportional manner. In order not to distort any correlation between passing people and counted agents, these gates were not included in the correlation.

Table 1 Results of the simulation.

	Homogenous distribution	Proportional distribution
Random movement	0.178	0.142
Farthest location of sight – based movement	0.122	0.142
Drift-based	0.198	0.271

As can be seen, the relationship between real movement and agents counted reached r2=0.178 in the random scenario, r2=1.22 in the furthest location on sight based scenario, and r2=0.198 in the drift-based scenario, when agents started their journeys homogeneously distributed across the open space. These values

[5] It is interesting to note that there were no updated records of pedestrian movement in this area of Santiago.

reached r2=0.142 (random), r2=0.142 (furthest) and r2=0.271 (drift-based) when agents started their journeys at each entrance in proportion to the number of people counted at these places.

6. Discussion

Although not extraordinary, the results obtained are of interest for those dealing with agent-based software. The fact that a drift-based algorithm could better predict existing movement patterns than a random movement of agents, suggests that isovist characteristics can be used, to some extent, to simulate how people move in real environments. This finding is in accordance with recent research that suggests isovist properties, other than its area and perimeter, might play a role in determining how space is perceived by users.

To some extent, these results expand findings from other studies over the past thirty-five years. They are similar to Benedikt's seminal ideas (1979) in the sense that the ultimate nature of vision consists not only of seeing information (of any kind), but also of perceiving the shape of what is being seen. More recently, Wiener and Franz (2004), showed that jaggedness, a measure resulting from the relation between an isovist's area and its perimeter, is related to people's perception of interestingness. Finally, Peebles, et al. (2007) showed that isovist characteristics, in particular drift, were related to people's assessment of their sense of orientation in maps.

The role of drift as a metric capable of predicting, on some levels, human navigation might be significant to scholars dealing with how distance is cognitively encoded. Since the eighties, various authors have suggested that navigation in real world scenarios tend to change according to the direction of travel (Golledge, 1995; Bailenson et al., 2000; Mora, 2010), and due to how people internalize distance (Raveau et al., 2011). Until now, few attempts have been made in trying to link these processes to specific isovist properties. Further research is needed to expand these theories.

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