Isovists, Occlusions and the Exosomatic Visual Architecture

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Abstract. Recently, simulation agents (or animats) using an exosomatic visual architecture (EVA) have been shown to correlate well with observed pedestrian movement in both building and urban environments. An EVA uses a grid overlaid on a two-dimensional plan of a system to record the locations visible from the current grid square. The agents are allowed to roam freely in the environment, and lookup visual information from the EVA in order to guide them through the plan. This allows many agents to navigate concurrently using visibility relationships. However, while good correlation between observed physical and virtual systems has been shown, experiments to date have been based on agents which move stochastically to visible locations. This leads to them congregating in large open vistas, where there are more visible locations. In contrast, when people are observed, they tend to follow the edges of spaces to move or take direct routes across open spaces to the far side. Here we hypothesize that rather than using open space to guide them, people instead use the visual clue of an occluding edge to indicate where further movement potential may lie. We supplement the information in the EVA with details of the isovist at each location, to supply the locations of occluding edges from each grid square. We show that these new agents follow paths much more similar to observed pedestrians using an open space. We speculate that the invariance of the occlusion points within a plan may thus lead to an economic skeletal mapping of the environment, and possible basis for a cognitive map.

1 Introduction

An isovist is the visible polygon from a location in a plan of an urban or building environment, as shown in figure 1. Benedikt introduced the concept to architecture in order to try to quantify the perceptual experience of a place [1]. In particular, he recognised that the way people moved around a space might be influenced by the shape of the isovist, not simply by the objects within it. He supposed that people would be guided by isovist properties, following Gibson's suggestion that people may be guided by direct (or active) perception, that is, simply respond directly to the affordances offered by the environment rather than any higher cognitive function [2].

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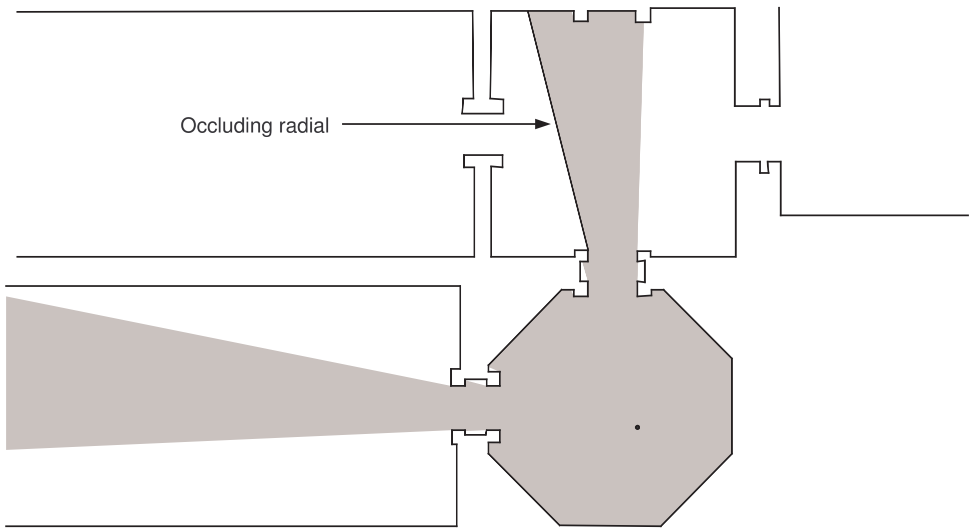
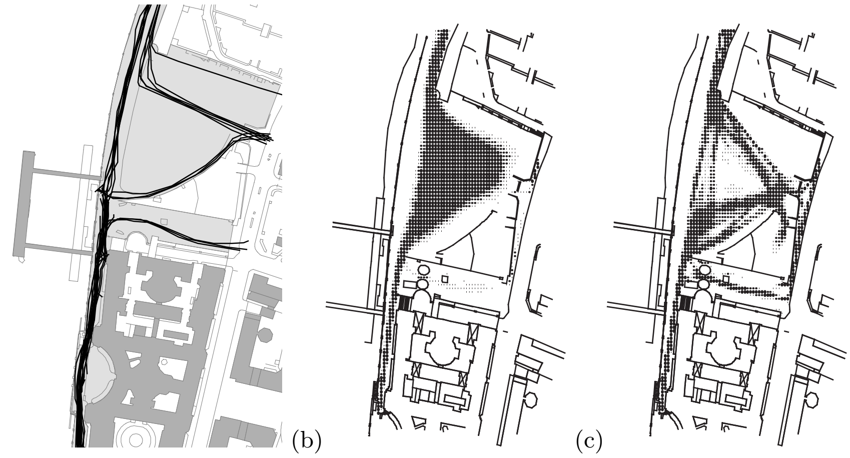


Fig. 1. An isovist from a location, with occluding radial marked.

Recently Turner and Penn introduced simulation agents guided by the simple isovist property of visible area in the direction of movement [3]. They constructed a dense grid visibility graph [4] of a floorplan and allowed agents to choose their next destination from a selection of grid points in the agents' field of view. They discovered that if the agents are given a field of view of 170° and allowed to progress three steps before reselecting a destination, then aggregate movement of agents in a gallery space correlates well with observed movement of people. However, application to larger scale spaces has proved less successful, perhaps due to a less controlled environment where entrance and exit are unconstrained, but also perhaps because the agents appear to congregate in larger spaces, as direct perception leads them towards open areas. This can lead to a stark contrast between agents and observation where there is park space. For example, in the area of the South Bank in London by the London Eye, paths recorded for people followed through the space differ strongly from the patterns of agent movement (compare figure 2(a) with figure 2(b)).

However, when Benedikt introduced isovists, he also proposed a measure of *occlusivity*. This measure indicates where isovists have long lengths of occluding radials, that is, a radial that marks a boundary between visible and occluded objects (see figure 1). For navigational purposes these occluding radials might also be important, as they mark areas of unexplored space that may be entered by continuing in the direction of the occluding radial. Therefore, in this paper we examine the effect of agents guided by occluding radials.



(a) (b) (c)

Fig. 2. (a) Pedestrian movement through the South Bank, London. Observations and image by Christian Beros. (b) Standard direct-perception agents (c) Agents driven by occluding radials.

2 Methodology and Analysis

We construct a set of isovists covering a dense grid[1], placed every 0.75m throughout the environment, as this gives an approximation to human step size. We break each isovist down into a series of 32 angular bins, and record the occluding radials in each bin. This provides a database of the visual connections within the system which is an external to any simulation agents in the system, i.e., exosomatic (outside the body). Thus, this visual system is called an exosomatic visual architecture [5]. We run agents system which use this architecture as a lookup table for their vision. Following [3], each agent has a field of view of 15 out of the 32 bins (about 170°, which approximates the human field of view). However, rather than selecting a point from the isovist to move towards, as in [3], our agents herein choose an occluding radial at random from those available in its field of view. We weight the choice of radial by the distance to the occluding point, on the grounds that near occlusions may simply be a distraction to the onward movement of the agents: our preliminary experiments showed that without this weighting, the agents were simply attracted to high densities of occluding edges, such as columns or trees. We also needed to account for the detail of our plans, where slight deviations in the border created short occluding radials. Hence, if the occluding radials were less than 1.5m, they were ignored. The resulting model is still far from ideal: clusters of radials attract the agents, and so the agents were told simply to pick the furthest occluding point from each

[1] The experiments in this paper were conducted using the Depthmap program written by the author. Depthmap is freely available for academic use, see http://www.vr.ucl.ac.uk/depthmap/ for details.

bin. For each model, a quantitative assessment was made against two test cases for which we have pedestrian data: a small model of an urban area (Barnsbury in North London) and the Tate Britain Gallery in Millbank. In both cases, little improvement was made over the original direct perception agents. However, in a qualitative analysis of the South Bank in London, the improvement of the new agents was demonstrable. Figure 2 shows observations made by Christian Beros, and the two sorts of agents. As we noted, the direct perception agents tend to aggregate in the open space, with little movement along the major axes. However, the occlusion driven agents, whilst not perfect, pick out much better the sorts of paths the pedestrians follow.

3 Conclusion

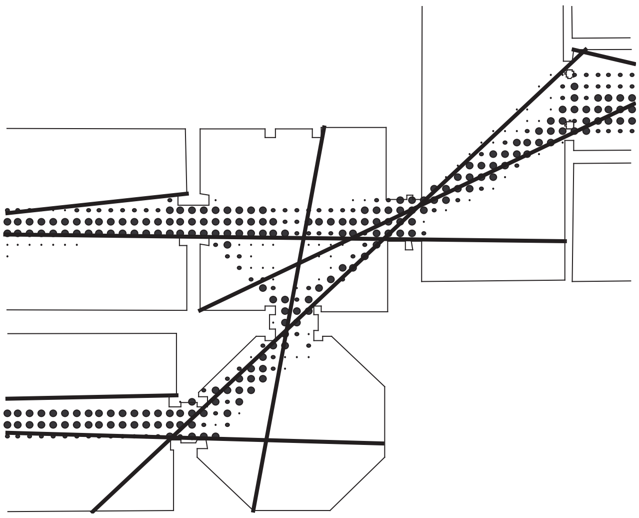


Fig. 3. Cummulative paths for occlusion-driven agents (dots) overlaid on an axial map (bold lines) in part of the Tate Britain Gallery.

This paper has sketched out how agents may be programmed to use occluding radials to guide their movement. We have shown that, in open areas, the paths generated by these agents correspond more closely to observed pedestrian movement than agents driven by direct perception.

One further observation is that the occluding points at the start of occluding radials are invariant as the agents move from location to location. These convex vertices in the plan might be considered as the basis for a line map, joining the edges traversed by the agents. Such a map is much like an axial map from the domain of space syntax [6]. Indeed, it is interesting to compare an automatically generated axial map [7], based on similar vertex joining rules, with the trails left by our agents. Figure 3 shows the comparison. It is worth noting that in the construction of the axial map, certain lines from the skeletal network have been removed. Some lines on the axial map do not quite match the underlying movement pattern, and vice versa, but the similarity implies that a map linking topological skeleton and movement patterns may well be possible. These lines of reinforced movement would seem to be an ideal basis for a skeletal cognitive map, such as proposed by Kuipers [8].

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