The Nature of Landmarks for Real and Electronic Spaces

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Abstract. Landmarks are significant in one's formation of a cognitive map of both physical environments and electronic information spaces. Landmarks are defined in physical space as having key characteristics that make them recognizable and memorable in the environment. The challenge of defining measurable features of landmarks that can be used in designing and recognizing landmarks in information spaces is explored. By drawing on diverse areas such as urban planning, architecture, cognitive science and hypertext, a coherent definition of a landmark is proposed, which is relevant to both physical and electronic spaces. It is argued that landmarks can be classified in terms of visual, cognitive and structural dimensions, which has implications for how environments can be designed or built in such a way that landmarks will emerge appropriately for unique situations.

Keywords. Landmarks, navigation, physical space, electronic space, hypertext.

1 Introduction

Wayfinding is a fundamental process of all large-scale spaces [18]. It is through exploration, route planning and other forms of navigation that we are able to manage and use spatial information to its fullest extent. Our ability to function depends on forming an understanding or representation of the environment and to plan routes to areas that are not in view. Inherent in navigation is the use of landmarks. Landmarks are prominent, identifying features in an environment, which provide an observer or user of a space with a means for locating oneself and establishing goals. The use of landmarks transcends human navigation of physical spaces to include navigation by non-human species [14] and human navigation of virtual spaces, such as hypertext and virtual environments [12].

In this article, we examine the nature of landmarks from a number of different disciplinary perspectives, including urban planning, architecture, cognitive science and information systems design. By examining landmarks from a variety of diverse perspectives, we develop a comprehensive framework of landmarks, which is relevant to both physical and electronic spaces. We begin by examining the foundational

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issues of representation of spatial attributes and navigational goals. In the fourth section, we review the use of landmarks and develop a taxonomy of critical characteristics of landmarks. In the fifth section of the paper, a tripartite typology is introduced based on visual, cognitive and structural dimensions. Finally, we conclude with some observations concerning the implications of a comprehensive theory of landmarks.

2 Representations of Space

A key factor in the ability to navigate through a physical environment is the facility to represent the spatial characteristics of that environment. While initially identified as a cognitive map [42], more recent literature has used the term cognitive collage [43] or cognitive atlas [22] to emphasize the integration of partial bits of multimedia knowledge (collage) and the multiple frames of reference (atlas) that are inherent in spatial knowledge representation. Other recent theories have focused on the notion of image schemata as organizing principles [35] or the framework of geocognostics, which organizes space-time events as views and trajectories [13].

In addition to such global terminology, various partitions of spatial knowledge representations have been delineated over the years. For example, Siegel and White [40] distinguished between place, route, and survey knowledge. Spatial acquisition often begins with place knowledge, particularly for landmarks. These landmarks are then used in constructing routes, and later are used for orienting one's self in open (survey) space. Here we see one of the many intertwined notions of landmark and space, where it is hard to discuss one without the other.

3 Navigational Goals

Navigation in physical space (or active navigation) has been defined as consisting of a cognitive component, often referred to as wayfinding, and a motor component, which is physical locomotion [11]. The motor component of navigation refers to the actual locomotion involved. Locomotion is behavior or movement from one point to another that is guided by one of the senses, most typically vision. This article focuses on the cognitive components of navigation to examine what are the commonalities between physical and virtual navigation.

Navigation does not take place without purpose. Thus, it is useful to consider the reason for interacting with the environment. Allen [3] used a three-category scheme for classifying wayfinding in a physical environment: travel to a familiar destination, travel to a novel destination, and exploratory travel returning to a known starting point. To accomplish these three tasks, a number of means may be introduced, including oriented search, following a marked trail, habit, referring to a cognitive map, and piloting between landmarks based on route knowledge, path integration or dead reckoning. In electronic environments, one finds similar goals and strategies, some of which map directly to the physical environment, while others are unique to the domain [24]. Studies by Canter et al. [8] and McAleese [27] have shown that in electronic environments navigational strategies include searching for information in either a known or unknown location, browsing for new information, and exploring a space to determine the quantity and coverage of information without regard to the details. To accomplish these tasks, one may use a directory, use a keyword-based search engine, follow likely links, or use a known sequence. One detailed model of route following based on synergetics has been proposed by Haken and Portugali [20] who demonstrated how environmental cues can act as feedback to the navigator of the route, while at the same time providing the input for the next decision stage. This is similar to the 'view-action pairs' of Remolina and Kuipers [36]. Such a model is domain independent and could be applied to both physical and cyber worlds.

Orientation has an obvious importance to wayfinding in the physical world, but also reveals itself in electronic spaces in a comparable manner. A hypertext system creates an intricate network of links defined between nodes, which creates a tremendous flexibility in how users browse and use the system. This flexibility puts a burden on the user to understand clearly not only the task or goal, but also to have or develop an understanding of the electronic space in order to locate the desired nodes and information [9]. In addition, a user may often come across multiple interesting paths and must then keep track of those link locations to return to and follow later. At that later time, the user must recall a sufficient amount about the node and its location to be successful. This need to maintain one's orientation in a hypertext system has been widely discussed in terms of the problem of disorientation [9, 15, 44]. Disorientation is described as including a number of different aspects. It refers to the problem of the user not knowing where he/she is within the space, confusion about where to go next, or not knowing how to locate something that is believed to exist in the space [9, 44]. Definitions also include the sense of not knowing the "boundaries of the information space" [44, p. 61]. Kim and Hirtle [24] and Smith and Wilson [41] provide extensive summaries of the literature on navigation problems and the cognitive constraints hypertext navigation places on the user.

4 Landmarks

We begin the discussion of landmarks, not with a definition, but rather with a look at the use and characteristics of landmarks, as described in the research literature on cognitive mapping and on electronic navigation. We then propose a definition of landmarks that incorporates the characteristic of landmarks in both physical and virtual spaces.

4.1 Role of Landmarks

In the literature, 'landmark' is a concept that has been used in fundamentally different ways. Some authors have used the term landmark in a very general way to refer to any decision point in the space. Siegel and White's [40] trichotomous theory of landmarks, route and survey knowledge supports this flavor of landmark. Presson and Montello [34] argued that this minimal definition, where all points are landmarks, is of little interest and that an alternative meaning, akin to what Sadalla et al. [38]

defined as reference points is a critical concept to consider in theories of spatial cognition. This discrepancy can be resolved by considering a continuum of landmark values. For example, the anchor point theory of Couclelis et al. [10], assumes that there is a subset of anchors, called primary anchors, which are the most salient and most familiar anchors in the space [19]. In a similar vein, Sadalla et al. [38] referred to the degree of referentiality in describing reference points.

Landmarks serve multiple purposes in wayfinding. As Golledge [19] has argued, landmarks can serve as either an organizing concept for space or as a navigational aid. While there is overlap among these uses, it is useful to consider each use separately and how it might alter the definition of landmarks.

Landmarks as an organizing concept. In organizing space, landmarks can represent a cluster of objects at a higher level of abstraction or scale and present an anchor for understanding local spatial relations [19]. Presson and Montello [34] offered two examples of organizing concepts. Symbolic landmarks, such as the Eiffel Tower in Paris, can come to represent the entire city. Spatial reference points form another kind of organizing landmark in that objects are often recalled as being near a reference point and not vice versa. Such reference points have been shown to be defined by a combination of features, including greater familiarity, visual dominating nearby locations, visible from a distance, and of greater cultural importance [38].

In electronic worlds, landmarks provide a similar purpose. Shum [39], in work on spatial cognition in real and electronic spaces, noted the importance of the human desire and need to impose structure on an environment. Ark et al. [5] emphasized that people must impose structure to help simplify the vast amounts of information received from the world. This physical structure that is imposed should reflect the conceptual structure in order to best assist in navigation [39]. Landmarks help to organize space because they are reference points in the environment [5]. Maglio and Barrett [26] analyzed data from experienced web users seeking answers to specific questions on the World Wide Web. They found that key nodes were remembered during the subjects' recall of the searches, and that these key nodes (landmarks) were helping the users structure memory.

Landmarks as a navigational tool. Landmarks in navigation serve a different purpose by identifying choice points where navigational decisions are made, identifying the origin and destination points, providing verification of route progress and influencing expectations, providing orientation cues for homing vectors and suggesting regional differentiating features [19]. The essential nature of landmarks for navigation was discussed in the field of architecture by Passini [32], who pointed to the lack of distinctive units in labyrinths as the central reason people do not understand the spatial layout of labyrinth environments. Although many people enjoy solving paper maze puzzles, there is a certain level of discomfort at being placed in a physical maze and attempting to navigate out. One can seek to envision the layout of turns during navigation through a maze, but the uniform appearance of the labyrinth's walls or tunnels make each intersection look like a variation of the last. This shows the importance of differentiation in composing a cognitive understanding of an environment. People's sense of disorientation in mazes is essentially caused by the lack of landmarks [32]. The problem of navigating in an environment that does not contain distinguishing landmarks is also illustrated in observations of the King Saud University in Saudi Arabia. Abu-Ghazzeh [1] described the unusual appearance of the University, which contains a set of buildings with nearly identical external architecture and internal floor plans. His research showed that the uniform visual nature of the space made the environment extremely difficult and frustrating to learn and navigate [1]. Passini [32] described how people depend on landmarks, and will impose organization in a complex environment, even if it doesn't fit well.

Heth et al. [21] described two ways that landmarks are used in navigation. Landmarks are the memorable cues that are selected along a path, particularly in learning and recalling turning points along the path [2, 6]. Landmarks also enable one to encode spatial relations between objects and paths, enhancing the development of a cognitive map of a region. This distinction can also be described as two types of relationships: landmark-goal relationships, where landmarks are cues along a path to a goal, and landmark-landmark relationships, which provide a global understanding of the environment [33]. Landmark-goal knowledge may be particularly used in active navigation, and landmark-landmark knowledge may be most essential in orientation activities. In all types of environments, whether open terrain or networked space, landmarks provide key information about the relationships of locations, objects and paths, and are used in active navigation and in orientation tasks. The use of landmarks to build survey knowledge of the environment enables one to orient oneself in space, to develop new routes, and to discriminate features of a region.

4.2 Characteristics of Landmarks

Landmarks clearly are significant in both physical and electronic spaces. They are key to the ability to orient oneself and navigate in an environment. The basic concept that a landmark is something of importance that aids the user in navigating and understanding the space pervades both the real and electronic worlds. It is useful to understand landmarks in a way that supersedes knowledge of the environment.

In this section, characteristics of landmarks defined in research on either physical world navigation or electronic world navigation are discussed as relevant to each domain. The discussion of all of these characteristics in both domains leads up to our definition of three types of landmarks that are found in these environments. Developing a framework that defines landmarks in all environments provides a structure by which to judge landmarks or environments in which landmarks could exist. A unified definition will help provide a way to evaluate landmarks and environments, and the theoretical basis implied by the framework that is developed will strengthen design decisions.

A landmark may be any element in an environment that is external to the observer and that serves to define the location of other objects or locations. A landmark may have particular visual characteristics, may have a unique purpose or meaning, or may be in a central or prominent location that makes it effective as a landmark [4, 38]. A number of characteristics will be examined in turn, to describe their various aspects and examine their appearance in both physical and electronic spaces. We begin with three characteristics described by Lynch [25] and discuss how they might be relevant for electronic environments.

One feature that can make something a landmark is *singularity, or* sharp contrast with its surroundings [25]. This feature makes a landmark visually conspicuous in its environment. Examples of singularity in physical environments include distinction of a building from its immediate surroundings due to difference in size, shape, position, age, or cleanliness [25]. As an example, consider the Cathedral of Learning at the University of Pittsburgh, shown in Figure 1. This 42-story building contrasts with the surrounding smaller buildings and is visible from almost anywhere on campus. The building serves as a clear and common landmark among students and visitors alike. In hypertext, a landmark node might contain a unique graphical design or layout that is not used in other parts of the system [31]. In physical space, Lynch [25] claimed that this characteristic was the most important in determining a landmark. In contrast, landmarks in hypertext appear to be based more on connectivity [17].

Fig. 1. The Cathedral of Learning on the University of Pittsburgh campus, which represents a common landmark for orientation based on the property of singularity.

Prominence of spatial location is a second characteristic that contributes to the definition of a landmark [25]. In physical space, this might be a building that is visible from many locations, or that stands significantly at a junction of roads. The Capitol dome in Washington DC appears to have this property for residents and visitors alike, as it is both visible from most of the district and defines the radial axis system of city streets. In a hypertext environment, this feature may correspond to the level of connectivity of a node, or the location of that node in a [partial] hierarchy. Two key measures of connectivity are the number of places you can get to from that node, and the number of ways you can get to the node. Some pages may be landmarks because they have many links to be followed, allowing the user to start there for many different actions. In the WWW, the home page for a site is typically accessible from any page in the site, through the implementation of an icon or text link on each page. Another measure of prominence in the WWW is the depth of the node at the site. One measure of this is the length of the URL. For example, the site http://www.pitt.edu may be a landmark based on this characteristic.

Lynch [25] also distinguishes *distant landmarks* that are used by the general population to identify a skyline, but rarely used in navigation. Mount Ranier near Seattle, Telegraph Hill in San Francisco, and the John Hancock building in Boston are all visible from many parts of the city, but not used in giving local directions. By contrast, *local landmarks* are used in idiosyncratic ways by long-term residents to assist in navigation and organize space. In some cases, these might be as specific as 'turn at the blue mailbox'. The usefulness of local landmarks often outlives the landmark itself, lending to the classic direction of 'turn left where the red barn used to be'.

In hypertext, there is a difference between locating information on a page and locating a page in the information space [7], but both can be examined as navigation tasks and landmarks can be used for both types of tasks. Landmarks within a smaller location such as a page, may correlate to Lynch's definition of local landmarks. In hypertext, a navigation bar may be a landmark within a page, just as in real space, a blue mailbox may be a local landmark.

Research in electronic space suggests *accessibility* as another characteristic of landmarks [31]. In hypertext, a page such as a home page may be designed to be accessible from other pages in the system by placing an icon or text link on each page. Local landmarks may also be designed for subsections of a hypertext and made available in the same way. Landmarks in hypertext can also be made accessible through the use of various types of overview diagrams (e.g. fisheye views [16], or focus+context views [29]). Accessibility is also a characteristic of landmarks in the physical world. For example, a building or object located at an intersection of multiple roads (e.g. near a rotary or roundabout), or even the intersection itself may be a landmark because it is easily accessible from multiple paths.

An element in the environment may also be a landmark based on its *content*, meaning, use, or cultural significance [4]. A building or site may be a landmark because of its historical significance. In electronic spaces, a landmark based on meaning might be an FAQ page which provides an expert's answers to "frequently asked questions" and gives the expert's recommendation on links to follow for more information or assistance on a given topic. Another example of a landmark that is based on meaning, not visual characteristics, is an official company site, such as the official Volkswagen site, www.vw.com, as opposed to the many other sites that also offer information on VWs.

Landmarks may also be selected because of *prototypicality;* that is, how typically they represent a category. Rosch et al. [37] found that people name particular items, or prototypes, most often as examples for a category. These prototypes are easier for people to learn, recognize and categorize. Glenn and Chignell [17] recognized that these characteristics are effective attributes for landmarks as well. For example, it is common for small towns in New England to have a white wooden church with a tall steeple near the town center. Such a building is an effective landmark for people familiar with the region, and might be referred to just as the "town church", needing no other description, although there is no longer any affiliation between the town and the church. For example: "As you come though the town center, turn left up the hill so that the town church is on your left." Just as a prototype can be used to represent a category, prototypical landmarks, such as the town church in New England or the Eiffel Tower in Paris, can come to represent the local environment on a larger spatial scale. In a hypertext environment such as the WWW, a scientific researcher might have separate pages for a curriculum vitae, research interests, and publications, which are presented in a standard format and therefore may be effective landmarks for a user.

4.3 Computational Approaches to Landmark Definition

Several researchers have measured aspects of both document content and hypertext structure as a way to determine what nodes are landmark nodes in a hypertext. Glenn and Chignell [17] developed an algorithm that involved measuring the co-occurrence of index terms within the documents of the hypertext, and calculating the second-order connectivity for each term as a measure of landmark quality. First-order connectivity for a term was defined as the number of terms that were directly related to it. Second-order connectivity for a term was defined as the number of terms that could be reached by following two relational links, for example the nodes marked "2' in the network around node A of figure 2. They used this process to construct a landmark view for any node, allowing the user to indicate the desired distance from the selected node.

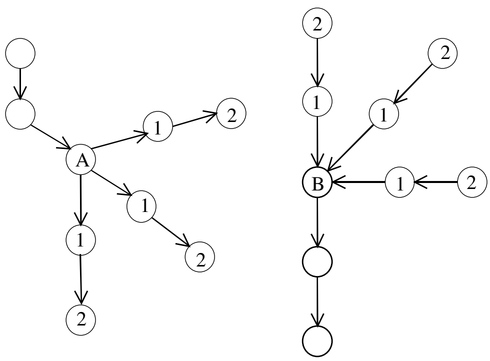

Fig. 2. First-order (outdegree) and second-order connectivity to node A and back first-order (indegree) and back second-order connectivity to node B. (based on a diagram by Glenn and Chignell [17] and description in Mukherjea and Hara [29])

In the context of the World Wide Web, Mukherjea and Hara [29] define a landmark as a node that is important to the user because it helps to provide an understanding of both the organization and the content of that part of the information space. They identify three features which contribute to the importance of a node are (1) its connectivity (how many nodes contain links to it, and how many links out it contains), (2) how frequently the node/site/page is accessed, and (3) depth (based on URL).

Mukherjea and Foley [28] defined one method of showing the user certain contextual information about the location of the current node in relationship to important or landmark nodes. The algorithm they developed to identify landmarks relies on structural analysis of the web network based on four factors: the node's outdegree, the node's indegree, its second-order connectedness, and its back second-order connectedness. See figure 2 for a graphical illustration of these measures. While Glenn and Chignell [17] referred generally to the number of terms directly related as first-order connectivity, Mukherjea and Foley distinguished between the indegree and the outdegree of a node. The outdegree of a node is the number of nodes that can be reached from the node by following only one link. The indegree of the node is the number of nodes that can reach that node by following only one link. The second-order connectedness is essentially the same as described in Glenn and Chignell's work above, the number of nodes that can be reached by a node when following at most two links. And the back second-order connectedness is the number of nodes that can reach the specified node by following two links. The close landmark nodes are identified for a given node (e.g. the current location of the user), and then the procedure is called recursively to identify more distant landmarks related to those found in the first round. Mukherjea and Foley [28] concluded that contextual analysis such as the use of access counts is also needed to determine the importance of a node.

It is interesting note that, while computational approaches are common in the analysis of hypertext and other electronic systems, they are relatively uncommon in the cognitive mapping literature. Of course, with the exception of some indoor environments, in real space one rarely has a straightforward topology with a limited number of in and out nodes. However, expanding the notion of landmarks to include both physical and electronic environments suggests the importance of structural characteristics in physical environments and visual characteristics in electronic environments. In the next section, these ideas are incorporated to provide a basis for a theory of landmarks.

5 Towards a Theory of Landmarks

There are multiple characteristics that can make something a landmark in its environment. It is important to have descriptions of different characteristics of landmarks, to provide us with words with which to discuss and judge them theoretically. However, it is helpful to develop a typology that defines different types of landmarks. Characterization is needed in order to evaluate in which situation a landmark is effective and what purpose it is fulfilling. Research by Glenn and Chignell [17] has suggested that landmarks may be particularly visual or cognitive, and that these functions are intricately tied as parts of a symbol system.

We propose three categories of landmarks: visual, cognitive, and structural. As will be described, we see that each of these types of landmarks plays a different role in affecting a user's or observer's navigation in a space.

A *visual landmark* is an object that is a landmark primarily because of its visual characteristics. As described above, these may include the features of contrast with surroundings, prominence of spatial location, and visual characteristics that make the landmark particularly memorable. An example of a visual landmark in physical space is the Cathedral of Learning at the University of Pittsburgh described above and shown in Figure 1. An example in electronic space would be a typical university home page, where photographs and layout are unique when compared to all the subordinate pages. Visual landmarks have remained prominent in the study of physical landmarks, including architectural studies, but have not received much attention in electronic worlds with the exception of virtual reality environments.

A *cognitive landmark* is one in which the meaning stands out. A feature or object may be a cognitive landmark because it has typical meaning, or because it is atypical, in the environment. Cognitive landmarks are most likely to have characteristics of unusual or important content or prototypicality. If the content of the landmark is in contrast to the surrounding locations, there is a greater likelihood of a cognitive landmark forming. It might be culturally or historically important. For example, a resident advisor's room in a dormitory, although structurally and visually identical to the other rooms, may form a landmark for the dormitory residents based on its unique status. Cognitive landmarks tend to be more personal and can be missed by those not familiar with the environment, unless they have some distinguishing markings or signage, such as you might find outside a post office or police station. The ability to bookmark an electronic cognitive landmark is a tool that is not easy to replicate in physical space.

A *structural* landmark is one whose importance comes from its role or location in the structure of the space. This class of landmarks may be highly accessible, and may have a prominent location in the environment. One example of a structural landmark in hypertext is an index page. The designer of a hypertext document or space makes certain decisions about the links between documents and at what points visitors are expected to enter the site or its sub-sections; these decisions can result in structural landmarks. In physical space designers often create certain spaces, intersections or aspects in the environment that can be considered structural landmarks, for example Dupont Circle in Washington, D.C., Trafalgar Square in London, or a typical downtown plaza.

These three categories, visual, cognitive, and structural landmarks, encompass the reality of differences within the realm of landmarks in both real spaces and electronic information spaces. However, these categories are not discrete. The strongest landmarks in an environment will be landmarks in terms of all three elements: visual, cognitive and structural.

As environments change or perceptions of environments change, there can be shifts in landmarks, which reflect the dynamic environments. For example, Raubal et al. [35] have argued for the structuring of space through image schemata, which are recurring, imaginative patterns used to comprehend and structure space [23]. If the concept of structural landmark is taken to be image schemata of attraction, then initial landmarks may vary from later landmarks as one learns about an environment. Consider the situation of meeting a new client in a large office building. On the first visit, the landmark of attraction is the front desk where one inquires about access to the office. On the next visit, one might head directly to elevator, but consult the directory to identify the correct floor. On each subsequent visit, the decision point (landmark of attraction) would move further inside the building. A similar sequence can occur in electronic navigation. For example, one might begin by accessing the New York Times at the main address, http://www.nytimes.com. On subsequent visits, one might quickly proceed to (or bookmark) the news index and later perhaps an even more detailed index, such as the index of technology articles, http://www.nytimes.com/yr/mo/day/tech/index7day.html. As the user becomes more familiar with the environment, the point of attraction moves to deeper point in the space. Thus, for both physical and electronic environments, dynamical systems can keep constant the image schemata of an attraction point, while altering the physical location that represents that schema. Thus, dynamic systems that keep consistent landmark classes will be easier to navigate then environments in which the landmark classes change.

Finally, the type of landmark used will vary with the type of navigational task, as proposed by Allen [3] and discussed in section 3. Navigation to reach a specific known new goal would tend to use cognitive and structural landmarks. For example, having planned a route given a map, a driver depends on structural landmarks such as signs, to follow the correct roads to the novel destination. In hypertext, navigation to a specific known new goal requires following links based on the structure of the site, without particular attention to visual information, for example using the navigation bar provided by the designer. That is, to find publications by Professor X, known to be at the University of Pittsburgh, one might start at the University or Department home page, follow links to that faculty member and then to the publications.

Navigation to a familiar goal implements the use of visual and cognitive landmarks. The path that is followed is likely to be lined by landmarks memorable due to their visual features or to their meaning, such as the example of returning to a client's office that was described above. Navigating in an unfamiliar environment would use visual and structural landmarks to help maintain orientation and build a cognitive map of the space. When the environment is more familiar, cognitive landmarks also play a role in orientation.

6 Summary and Conclusions

An understanding of how each of these types of landmarks addresses different challenges in our use of an environment provides a structure for applying this typology during the design of spaces in both physical and electronic worlds.

These three categories, visual, cognitive, and structural landmarks, seem to appropriately encompass the reality of differences within the realm of landmarks in both real spaces and electronic information spaces. Understanding each of these types of landmarks will contribute to understanding how landmarks can be designed, where they exist naturally, and also how we can specifically design spaces that allow landmarks to emerge more effectively. The question of how this research can be applied to the design of spaces or environments in order to facilitate the emergence of landmarks is an interesting relevant research question.

For over 30 years, the term 'landmark' has formed the basis of theories of spatial cognition and wayfinding. By revisiting the term and how it has been used in such diverse areas as environmental psychology, urban planning, architecture, cognitive science and information systems, it has been argued that landmarks can be classified in terms of visual, cognitive, and structural dimensions. Furthermore, the analysis suggests that the discussion of landmarks in physical space has minimized the contribution of the structural dimension, whereas the discussion of landmarks in electronic spaces has minimized the contribution of the visual dimension.

By including the importance of the visual dimension in landmarks for electronic spaces, several design issues emerge. First, designers tend to overload the structural elements of major entry points at the expense of visual clarity. For example, Yahoo now has 140 links from its top-level page. On the positive side, Yahoo has maintained a core directory of only 14 levels and furthermore has kept the directory prominently displayed in the center of its home page. However, the limit of being able to successfully browse a directory is being reached as the World Wide Web continues to grow at a phenomenal rate [30]. By keeping strong visual legibility on web pages, along with supplementary navigational and search tools, one can improve the navigability of electronic environments.

In physical space, it is important to revisit the structural dimension and to develop appropriate computational methods of calculating the strength of a landmark. For example, the analysis suggests a benefit in exploring the separation of out- and in-degree of nodes for possible landmark locations. Upon reflection, this notion can be related to what Lynch [25] referred to as distant and local landmarks. A distant landmark, such a Telegraph Hill in San Francisco has a high in-degree, as it is visible from numerous other landmarks in the city. However, it has a small out-degree, since after arriving at the landmark, one has few options as to how to head off of the hill and back into the city. Such a landmark serves a very different function from an Italian piazza, which has both a high in- and out-degree and is used heavily for local navigation and wayfinding.

The approach taken in this paper is exploratory and additional research is needed. Through both additional empirical work and theoretical analysis the ideas presented can be refined and verified. The results have strong implications for the understanding of spatial cognition and the application to the design of spaces or environments in order to facilitate the emergence of meaningful and useful landmarks.

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