

MAPPING URBAN PERCEPTION: HOW DO WE KNOW WHERE WE ARE?

BY

SHAN HE

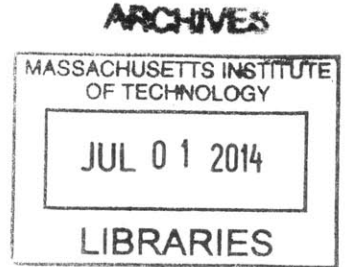
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# Mapping Urban Perception: How Do We Know Where We Are?

by  
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## ABSTRACT

How do we remember urban space? How can we measure what is remembered? This thesis presents a new approach to study urban spatial perception in an efficient, automated, and scalable way. It explores the use of novel tools developed for online surveys and data visualization.

Previous studies in human spatial perception have used methods such as face-to-face interviews, questionnaires, recognition tasks and surveys that ask subjects to draw sketch maps. Those conventional methods produced significant urban studies such as the one by Kevin Lynch (1960), but they are laborious, sensitive to the individuality of subjects, prone to examiners' biases and conducted with a limited number of subjects. Their results are also difficult to quantify. In contrast, the method developed here uses geo-tagged street views and a web-based visual survey.

An online experiment conducted in this thesis collected 394 participants in 20 days who were asked to guess the locations of street views from a familiar neighborhood. Results are presented in the form of interactive visualizations. Analysis revealed that memory for exact location of place improves with degree of interaction and proximity to center, rather than number of encounters; memory for one location may vary dramatically between different viewpoints. The results also suggest that the irregularity of urban structure doesn't prevent the forming of strong mental images.

While this new method cannot completely replace face-to-face interviews, it demonstrates the possibility of using available technology to scale visual surveys to hundreds or even thousands of people and rapidly visualize the resulting data. It thus opens up new possibilities for large-scale, fine-grained studies in urban perception.

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## Chapter 1

### INTRODUCTION

An urban neighborhood is determined not only by geographical and economic factors, but also by the images that its inhabitants and those of other neighborhoods have of it.

—*Chombart de Lauwe, Paris, essais de sociologie*

In the five decades since Kevin Lynch's seminal work, *The Image Of The City*, scientists from a variety of fields have conducted studies investigating the relationship between the urban environment and the images its inhabitants have of it. The researchers focused on the nature of mental maps, the process of acquiring spatial knowledge to form such maps, and their roles in everyday spatial activities, such as navigation choice, way-finding behavior and route learning (Golledge, 1997). A major challenge that remains is the externalization of spatial knowledge: how to elicit cognitive data from people and what medium to use to represent it. A wide range of techniques has been used to collect and analyze cognitive data. Commonly used methods include verbal interviews, sketch maps, protocols, toy play, matching tasks, proximity judgments, recognition tasks etc. (Golledge, 1997). Each of these methods requires hours of interaction with subjects and a considerable amount of work to compile and translate cognitive responses into quantitative data. The results are also sensitive to idiosyncracies of subjects and their ability to master the testing media.

Beyond studying an individual's cognitive maps, city designers and planners are primarily interested in the mental images that are shared by large numbers of city dwellers (Lynch, 1964). By studying the collective mental maps and investigating areas of agreement, designers and planners are able to examine which parts of the city are more likely to evoke strong mental images. Such knowledge can provide guidance to design vivid urban environments that facilitate rapid learning and easy orientation (Kitchin & Freundschuh, 2000). Cities are inhabited by millions of people and composed of billions of unique images. To investigate how a variety of places in a large-scale urban environment are remembered by their inhabitants, conventional methods with time-consuming interviews among a limited number of subjects are evidently not sufficient. There is a need for methods that can be used with a large number of subjects, and allow fine-grained observations in an efficient, automated and scalable way.

Fortunately, today's dominant web technology enables crowd-sourced data collection. Google's geo-tagged streetviews provide a large number of urban images. This thesis uses a web-based visual survey in the form of a geo-guessing game to efficiently solicit people's responses to how well they remember different urban images. In this study, participants were asked to guess the locations of random streetviews from a familiar neighborhood by placing a pin on a map. This method evaluates how well each urban image is remembered on the basis of two spatial familiarity indicators: location identification and visual recognition. The data collected were used to create interactive cartographic representations, and answer the following questions: how are different types of spatial entities remembered by their inhabitants; how is spatial memory acquired throughout time; and how do an individual's daily activity patterns affect his comprehension of the urban environment.

The analysis concludes that the memory about the exact location of a place improves with the degree of interaction and proximity to the center, rather than the number of encounters. It reveals that memory for one location may vary dramatically when viewed from different angles. The findings also suggest that the irregularity of urban structure doesn't prevent forming of strong mental images, which challenges Lynch's statement that a regular city structure is more likely to evoke strong mental images.

This thesis concludes that the method presented here is able to rapidly elicit spatial knowledge among a large number of city dwellers, and allow us to conduct quantitative data analysis. Moreover, this thesis proposes that the method can be used beyond the familiarity evaluation of urban images. It can be adopted in future investigations including spatial knowledge acquisition in an unfamiliar neighborhood, cognitive representation of spatial relationships, and results of perceptual knowledge on human mobility behavior.

This thesis is organized as follows. Chapter 2 and Chapter 3 describe the precedent study of mental images of the city and the methodology used. Chapter 4 presents the experiment. Chapter 5 discusses the results. Chapter 6 presents data visualizations that were generated during this thesis. Chapter 7 presents conclusions and offers suggestions for future research.

## *Chapter 2*

### **FROM SPATIAL PERCEPTION TO THE COLLECTIVE IMAGES OF THE CITY**

If we are aware of people's preferences for, perceptions of, and attitudes toward different environments, then better matches between planning and policy making and the felt needs of the populations, for whom plans are being made, can be achieved.

—Gärling, T., & Golledge, R. G. (1989)

In the scope of urban and city studies, the term “imageability” evaluates how well the city spaces are understood and remembered by their inhabitants. The concept of “imageability” was first established by Kevin Lynch (1964), an American urban planner, in his influential book *The Image Of The City*. Lynch's study focused on how people perceive space and navigate through the urban environment. He states that people navigate in a familiar urban environment by means of mental maps—a memory representation of spatial information in our minds, also referred to as cognitive maps (Lynch, 1964; Golledge, 1997). According to Lynch (1964), a highly imageable urban environment has a high probability of evoking a strong image among various observers. This chapter discusses the nature of human urban perception, how we use mental maps to comprehend the complex urban environment and how spatial information is obtained, stored and organized to form mental maps.

### **Urban Perception**

Millions of people travel through the city everyday. What they choose to see and not to see, what they like and do not like, what they remember and do not remember is of profound interest to city planners and architects. The urban environment is a complex, formless and fragmented system. Empirical studies suggest what people are more likely to store in their memory—buildings with dominant shape and bright color, historical sites, intruding signage—yet little has been done to systematically survey different aspects of the city and investigate the probability of each to evoke strong mental images among a large number of residents.

We choose to perceive urban environment for different purposes, such as looking for places to stop and paying attention to the traffic lights. Appleyard (1973) in his influential



essay *Notes on urban perception and knowledge* proposes that people perceive the urban environment in a categorical fashion. He categorized urban perception into three types: operational, responsive and inferential. Operational perception is performed as a person uses the city. People are more likely to remember the details of traffic circles and subway stations. Responsive perception is passive perception. Buildings with bright color and distinctive shapes are more likely to catch people's eyes. This type of perception is extensively discussed in Lynch's imageability theory. The third type of perception is inferential, which emphasizes actions of synthesis and generalization when new experiences are matched with old experiences (Appleyard, 1973). People are more likely to remember the Bank of America branch when moving to a new neighborhood, if they have seen a similar looking branch previously.

Clearly, the categorization proposed by Appleyard is more theoretical than practical, because it is almost impossible to isolate each type to examine its role in obtaining a specific type of spatial knowledge. Appleyard himself also stated that our spatial knowledge is a complex collection of varyingly perceived items, qualities, and events. It is a multi-modal representation of the city (Appleyard, 1973). His theory was the first attempt to connect urban spatial perception with human perceptual and cognitive processes and provides a theoretical framework for studying the inhabitants' images of the city.

### **Mental Maps**

Have you ever lost your way in your own neighborhood? Have you ever found yourself losing orientation immediately after coming out of a different exit of the subway stop you take every day? A bear can find its way to honey using smell and its instinct alone; a dog abandoned by its owner thousands of miles from home eventually finds its way back after three months. Some animals even possess specialized senses and faculties to navigate through familiar or unfamiliar environments, such as magnetic field sensitivity or the ability to navigate using the sun as a reference point (Ellard 2010). Humans, on the other hand, while superior in our cognitive abilities, always seem to perform badly when it comes to figuring out where we are. It's easy to see how bad we are at dealing with our relationship with space simply by counting the number of apps we have on our smartphones to help us find our way.

While other animals possess prodigious talents for memorizing their paths or the subtle hints in the natural environment, human beings comprehend the urban environment by following a somewhat different course (Ellard 2010). Cities are man-made large-scale environments, filled with salient and familiar views, and composed of spatial objects with distinctive forms (e.g., buildings, roads, squares, bridges etc.). Humans, survivors of this complex environment, have to sense, store, record, and organize bits of spatial information into exclusive knowledge sets with the task of living (R. G. Golledge, 1997). The product of this living knowledge process is an abstract organization of spaces in our minds. Psychologists often refer to this organization of space as mental maps or cognitive maps. To perform everyday navigation tasks such as going to work, picking up dry cleaning or describing how to get to one's home, people rely on their mental maps of the city.

The mental maps we construct in our minds are highly schematized, and often bear little resemblance to the real environment. This is because our mind tends to simplify visual patterns. We straighten curves, simplify geometry, and reduce complex spaces to a simple collection of basic shapes (cited in Ellard, 2010). Barbara Tversky, a cognitive psychologist at Stanford University, conducted groundbreaking studies on cognitive mapping, especially the differences between mental maps and the physical spaces they represent. One important finding of Tversky's study is that our minds tend to blur distance and direction but treat topological relations with great clarity (Ellard, 2010). When asked to imagine how to travel from point A to point D, we tend to first think about how to get to B, then C, and finally D. Although we have a good understanding of how places are connected, we don't seem to be able to accurately recall either the distance between places or their directional relationship (imagine how many times we find ourselves saying: "I know how to get to A, but I am not sure if it's the shortest route").

### **Units and Configurations of Mental Maps**

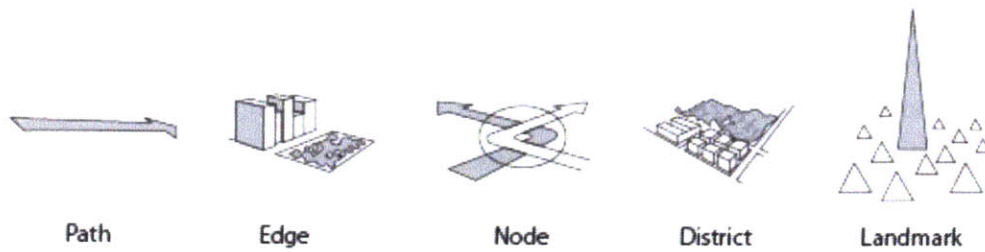
Mental maps are formed through a way-finding process, just as a mouse's spatial memory is formed through its searching for cheese in a maze. The study of mental maps is concerned with how we comprehend physical space by storing, organizing and positioning spatial information internally. Despite the different terminology that is used, it is commonly agreed that mental maps primarily represent spatial relationships and contain some map-like qualities (Evans, 1980). They consist of the topological relationships of spaces, rather than

their absolute coordinates and distances. This section discusses the basic units perceived from the environment and the schemata that are applied in the process of forming mental maps.

From the environment, we obtain spatial knowledge such as where the supermarket is, how far the next intersection is, which road passes by our home etc., by living in it and traveling through it. The basic elements of mental maps are environmental units that are most familiar to us (R. Golledge, 1992). However, different hypotheses exist in cognitive psychology about how these environmental units are recorded, stored and represented internally. Neuroscientists believe that there is a certain brain mechanism that connects specific neurons to encode the perceived spatial information; most psychologists believe that spatial information stored in our mind exists in some type of psychological space whose metric system is unknown (Ellard 2010). In their perspective, the elements in such space maintain rough, isomorphic correspondence to the physical world often by their functional property, rather than physical forms (Evans, 1980).

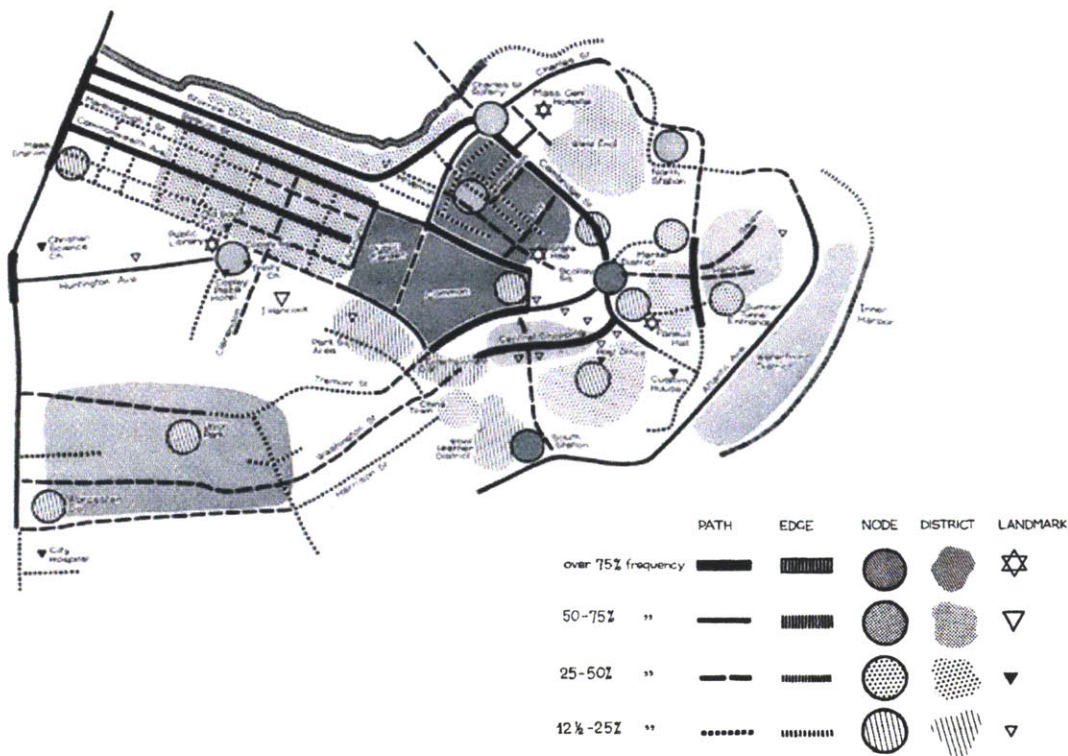
In urban perception and cognition studies, the most accepted view is that the environment is stored in the format of symbolic representations using “Euclidean metric”, attached with abstract labels (Golledge 1999, Evans, 1980). In fact, much of human spatial knowledge is traditionally represented as a Euclidean metric with basic elements including points, lines, areas and surfaces (R. G. Golledge, 1999). Some researchers believe that the maps we sketch are the best representation of the properties of space that inhabit our minds (Ellard 2010). One example is the sketch maps that Lynch asked the local people to draw in order to illustrate their memories of the city. Lynch stated that mental maps reflect basic elements of the physical city form (as cited in Evans, 1980). He suggested five basic elements as primitive elements of mental maps: paths, edges, districts, nodes and landmarks (Lynch, 1964).

Paths are routes people travel along, such as streets, roads and sidewalks. Edges are usually boundaries, such as buildings and riverside. Districts are large areas of the urban space that are usually referred to be the same identity, such as downtown, SOHO and the upper east side of Manhattan. Nodes are locations that are usually referred as strategic focus points, a busy intersection or a public square are such examples. Landmarks by definition are spatial elements that are frequently identified as reference points.



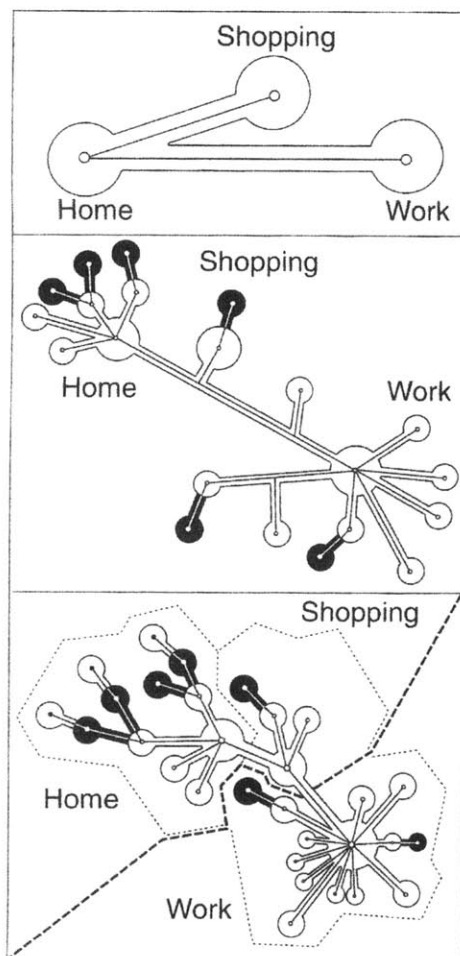
**Figure 1.1 Lynch's five basic elements of the mental maps**  
 Source: Lynch, 1964

Lynch asked local people from Boston to draw sketch maps of downtown Boston as they remembered it. Based on all the drawings, Lynch constructed a map of downtown Boston representing the structure of its spatial elements reflected in people's memories, and how well they were remembered. He used simple geometry to represent spatial elements: lines represent paths and edges (boundaries); circles represent nodes (intersections); areas represent districts; and triangles represent landmarks. The thickness of the lines, darkness of the circles and areas represent the strength of mental images evoked by that element.



**Figure 1.2 The view of Boston constructed in Lynch's study**  
 Source: Lynch, 1964

Lynch's five elements were derived primarily from the shapes that repeatedly used in people's hand sketches and coded with respect to the physical forms of the actual elements. He proposed that paths were the structural feature that connected all the others elements. He also stated that paths are what people primarily use to navigate through the urban environment (Lynch, 1964). Golledge, on the other hand, suggested that landmarks were the organizing features in a way-finding context. He stated that landmarks acted as anchor points for organizing other spatial information into a layout (R. G. Golledge, 1999). The "anchor point" theory proposed by Golledge and Spector (1978) suggested that the complex urban forms stored in our memory in the form of a linked-node configuration. Nodes are spatial reference points and links are paths we take to travel between the nodes. The process of acquiring spatial knowledge involves continuously adding new nodes to the existing node-link framework (King & Golledge, 1978).



**Figure 1.3** Golledge's anchor point theory of spatial knowledge acquisition.  
Source: Golledge, 1976

Despite the opposed views, the objective of this thesis is not to take a stand on whether nodes or links should be the basic feature that organized other spatial elements into a mental layout. Instead this thesis acknowledges that both of them are undeniably the prime elements that constitute the basic framework of our mental representation of the space. Thus the primary focus of this thesis is to examine how both of these two basic elements are remembered by a large number of city dwellers.

### **The Collective Images of the City**

Each resident has his/her own experience with some parts of the city, so it seems that each individual possesses his/her own mental map of the city. The information we perceived from the environment may be different depending on individual preferences, but what we remember is deeply associated with the mechanism in our brain

that is in charge of understanding spatial structure, which is similar among people. Thus, there seems to be substantial agreement among residents of the same urban neighborhood with regard to the environment they share experience with (Lynch 1964). It is this group consensus, represented by a collective mental map of the city, that greatly interests city planners who wish to understand how different environmental elements facilitate or hinder the formation of clear mental maps, and eventually design a better urban environment that supports the uniqueness of human spatial perception.

Previous studies also investigated whether different social and economic variables might result in disparities in the mental images between different groups of people. In one study, Golledge (R. G. Golledge & Spector, 1978) concluded that access to an auto and amount of time spent in the city are obvious indirect contributors to ability to accurately locate sample places. Other studies also investigated the correlations between length of residency, where people work or live, social classes, income and degree of familiarity (Evans, 1980).

### **Practical Applications**

Lynch's imageability study has profoundly influenced the later practice of regional planning and city design. The most recognizable contribution of studying the mental maps of the city is to design a way-finding-friendly, vivid urban environment that can evoke strong mental images. Cities with homogeneous views are monochromatic, less exciting and sometimes frustrating. A legible city is most likely to be remembered and appreciated by its dwellers. For example, people can easily identify a path by linking one node with another, recall a landmark by locating it alongside a path or define a district using an edge as its boundary. Downtown Boston, for instance, has a clear mental map. People in Boston usually refer to Commonwealth Avenue as the path that links the Harvard Bridge and the Boston Common, and both of them are frequently identified as major landmarks. They refer to Beacon Hill as the district that is located next to Boston Common, and that stops at the Charles River.

Lynch (1964) also concluded that a highly imageable city would be one whose "districts" or "landmarks" or "pathways" are easily identifiable and are easily grouped into an overall coherent pattern. However, studies following Lynch overemphasized the importance of a regular city structure to an extent that they proposed cities and districts with regular shapes

formed by parallel streets and perpendicular intersections. We all know that one effective strategy to compose highly imageable views is to use distinctive elements in terms of size, color and form. Regular cities might be easy to navigate in, but their repeating grid structure might eventually evoke tiresome.

Each individual's perception of the urban environment is determined by the information he/she obtained in terms of location, proximity, distance and area, which furthermore influences his/her everyday behavior (Golledge 1999). People make mobility-related decisions such as which route to take, which coffee shop to go to, and whether to drive or walk based on their memories of the spatial relationships acquired through their everyday activities. They tend to pay more visits to places that seem easier to get to than others. If a place seems further away than it really is, they may tend to take the car instead of walking there. They decide whether to make a stop at the post office based on whether they think it is on their way to the grocery store.

As a result, another practical application of investigating mental maps of the city is to design cities that can influence people's behavior by prudently organizing spaces, tinkering with their size and shape to support and extend our mental penchant to comprehend physical space (Ellard, 2010). For example, when designing a pedestrian-friendly neighborhood, one strategy is to make it feel smaller than it really is by inserting highly recognizable destinations within walking distance of each other. People are more likely to think the post office is close to their home if they think of it as only a few steps from the bookstore, which is a few steps from the supermarket, which is only a few steps from home.

The fundamental belief here is that people make living decisions based on the perceived urban environment. And if by studying the mental images the citizens have of their own city, knowing their preferences for, perception of, and anticipation towards various urban images, city planners can design improved environments that induce better decision making (Gärling & Golledge 1989).

## Chapter 3

### METHODOLOGY

Those were lengthy interviews, normally lasting about one and a half hours, but almost always attended with great interest by the subjects.

—Kevin Lynch (1964)

One major challenge that researchers face when investigating people's mental images of the city is how to externalize an individual's spatial knowledge of a familiar environment. This chapter discusses the conventional methods that were used in urban perception studies and the problems and concerns they raised. Alternative methods are proposed, in particular, the use of online visual surveys with geo-tagged images to collect quantitative data of perceived urban environment.

#### **Spatial Familiarity Evaluation**

The commonly accepted theory on constructing mental maps is that their basic units are places that are "most familiar" to the great proportion of residents (Gale 1990). The concept of spatial familiarity is, by definition, the ability to be able to identify places that one has physically visited or encountered by other means, such as looking at a photo, trying to recall its name or seeing it on the television (Gale 1990). However, it is difficult to measure spatial familiarity, because it is an internal measurement of our knowledge of the space. That people sometimes have a hard time recalling the name of a place they visit frequently doesn't necessarily suggest that they are not familiar with that place.

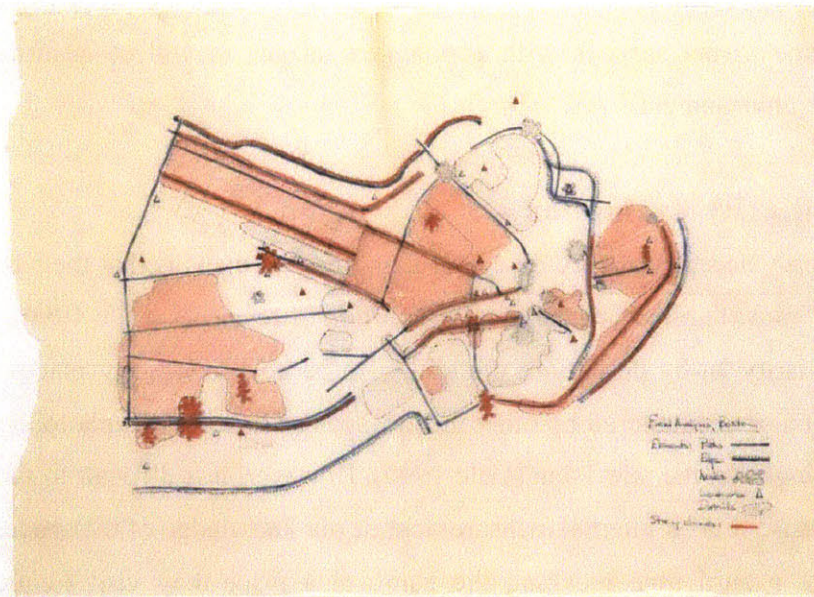
Gale (1990) states that familiarity can be assessed or inferred; his study attempts to decompose spatial familiarity as an operational variable in the models of spatial knowledge and behavior. He designs experiments to test different indicators of spatial familiarity: location knowledge, visual recognition, name identification and interaction frequency. According to Gale, the most direct indicators of spatial familiarity is the "sense of locational knowledge," that is, being able to clearly point out where this place is verbally or by pointing to a map (Gale, Golledge, Halperin, & Couclelis, 1990). The second spatial familiarity indicator is visual recognition, which is the ability to remember "having seen it before" when presenting a visual representation of the place. The other familiarity indicators are title recognition and interaction frequency. Gale (R. G. Golledge, 1999) was able to conclude that



the degree of a person's familiarity with a place is highly collinear with visual recognition and locational accuracy.

### Sketch Maps

To measure and analyze spatial knowledge, despite the different understandings of its internal representation, the most common practice to externalize the stored spatial information is to have subjects produce hand-drawn sketch maps. Subjects are asked to draw a map of a specific urban area based on their memories. Some researchers believe that the maps we draw are the best evidence of the spatial relations in our minds.



**Figure 2.1 Lynch, K. (1964). Composite map of Boston.**  
Retrieved from <http://bostonography.com>

The statement is to some extent accurate and has received certain theoretical validation. In order to retrieve spatial knowledge, people first need to image and reconstruct spaces in their minds. The reconstructed internal representation has some map-like qualities and is primarily embedded with the topological relationships of the physical spaces. Sketch maps can reveal some general spatial cognition measurement such as the relative location of places, shapes of elements, or even cognitive distance between places. However, the results of sketch maps are very hard to quantify and compare. This is mainly because individuals' drawing abilities vary dramatically. A person drawing a public square much larger than it really is doesn't necessarily indicate that the person bears a stronger image of the square. Some

researchers treat sketch maps with great scrutiny, using measurements retrieved from the sketch map to indicate level of perceived information. Golledge has argued that sketch map data should be treated either descriptively or analyzed within an ordinal scale (Evans, 1980).

## Surveys and Interviews

Other commonly used methods to solicit response from subjects to analyze how they comprehend space are verbal interviews, questionnaires and cognition tasks. In Lynch's study, he conducted five years of interviews and surveys among residents of three different cities. Examples of the questions he asked are: what symbolizes the word "Boston"? Please give me complete and explicit directions for the trip that you normally take going from home to where you work. What elements of central Boston do you think are most distinctive? (Lynch, 1964). Approximately 100 people from each city participated in the interview, which lasted normally one hour and half and was entirely recorded.

Golledge and Spector's (1978) study interviewed a sample of 151 local people to elicit information concerning the spatial structure of the mental maps of Columbus, OH. People were asked to compare a sample of distance relationship between forty-nine well-known places (Figure 2.2a). The experiment attempted to predict knowledge of interpoint distance relationships between those places as a function of where and how extensively individuals travel about the city and (by inference) their need to store and organize spatial information (R. G. Golledge & Spector, 1978). The result was constructed as a contour map representing the imaged relative location of places in Columbus (Figure 2.2b).



Figure 2.2a Location of cues in Golledge's Columbus study

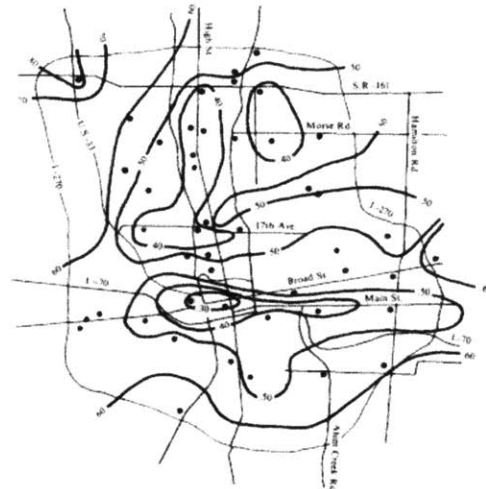


Figure 2.2b Contours of Location Errors in Golledge's Columbus study

## **Problems and Concerns**

The top concern when studying images of a city processed by its citizens is the lack of an efficient method to collect urban perception data. Sketch maps are inaccurate during quantitative analysis and carry significant amount of noise due to individuals' drawing abilities. Interviews require a considerable amount of time to interact with participants. Previous studies frequently attempted to generalize findings about the mental images of a large urban environment based on observations of a small fraction of its inhabitants.

Another concern is the degree of schematization that applied to the overall environment. The collective urban perception and knowledge are complex structures that derived from the formless fragmented urban cities. Yet when generating the cognitive representation of large cities, researchers frequently adopt methods discussed above that simplify, structure, and stabilize the flux of environmental experience (Appleyard, 1973). It is reasonable that, according to Appleyard (1973), people have to schematize drastically if they wish to understand the overall comprehension of urban structure, primarily due to the difficulty of collecting a vast amount of fragmented urban experience and the lack of adequate techniques to quantify cognitive data

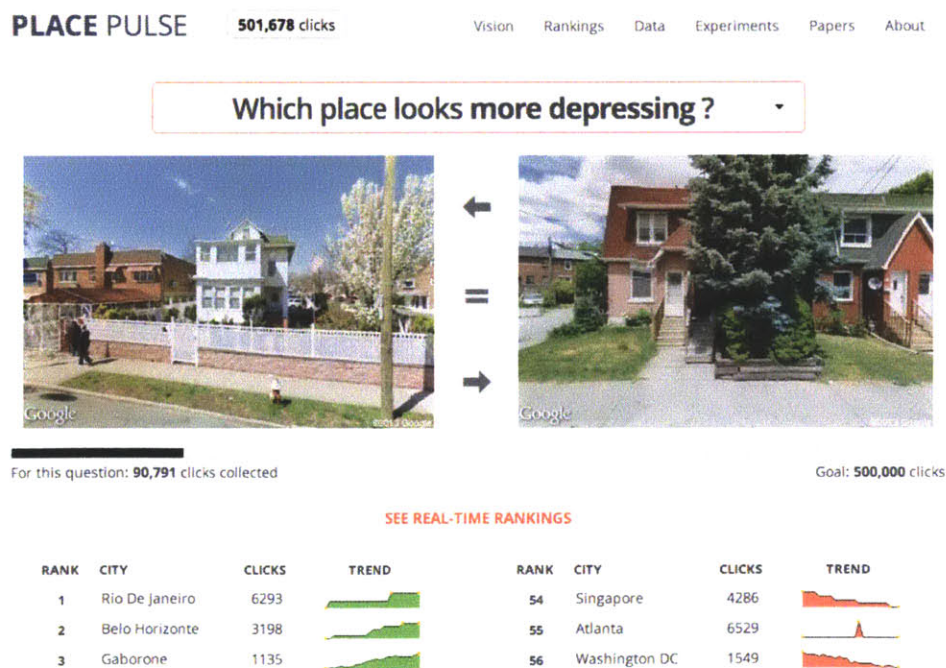
The urban cities are inhabited by millions of people; however the number subjects involved in previous studies are extremely limited. To revolutionize the investigation of collective mental images of a city, there is a strong need for an efficient, automated and scalable method to collect and analyze urban perception data, bridging urban perception with other quantitative measurement in urban studies with respect to social, demographic, economic and cultural context of cities.

## **Visual Surveys with Geo-tagged Images**

In 2010, a pioneering study named "Place Pulse" conducted by the Micro Connection group at the MIT Media Lab used crowd-sourced visual surveys to solicit responses towards streetview images from different cities (Salesses, Schechtner, & Hidalgo, 2013). The group built a website to ask people to vote on how they feel about a variety of urban images derived from Google's streetview engine. Visitors of the website were presented with two streetviews from two different cities. They were then asked to vote based on the questions such as "in

which city do you feel safer,” “which place looks more beautiful,” “which place looks wealthier,” “which place looks more depressing” etc. The “Place Pulse” has successfully collected more than 500,000 votes, based on which they conducted analysis on urban perception and characterized the inequalities among cities from all over the world (e.g., New York City, Boston, Salzburg, London, Tokyo, Bangkok etc.). This study concluded that online images could be used to create reproducible quantitative measures of urban perception among cities images (Salesses, Schechtner, & Hidalgo, 2013).

By using online visual surveys, the availability of participants has exponentially increased. It also enables us to capture great details about every corner of the urban environment. Researchers don’t have to conduct hour-long interviews with selected subjects, who have to make time and arrange visits to the institute. By carefully designing the user interface of the survey website, implementing interactive features, providing instructions that are easy to follow, the researchers enable participants to perform required actions without face-to-face guidance.



**Figure 2.3 Place Pulse**  
Retrieved from <http://pulse.media.mit.edu/>



## Chapter 4

### THE EXPERIMENT

We created UrbanExplorer because we want to make a game about [your own city]. We want this game to help you know your city better.

—*UrbanExplorer*

The objective of this experiment is to evaluate the familiarity of different places in a small urban area using an online visual survey and geo-tagged streetview images. Participants were shown random streetviews from their familiar neighborhood and asked to guess where this place was by pointing to a map. Thus, the person's familiarity with a specific image is assessed by two joint indicators: whether it can be recalled by its visual image and whether it can be located accurately on a map.

#### **Tool Design**

The experimental idea was inspired by the popular online game GeoGuessr (<http://geoguessr.com/>), a geography game that takes people to random places around the world and tests their ability to recognize the surroundings. The website designed for this study is named Urbanexplorer (<http://uexplorer.meteor.com/>) and designed as a game to help people explore their familiar urban neighborhood (Figure 3.1).

Urbanexplorer takes advantage of thousands of geo-tagged streetview images retrieved from the Google streetview API. Urbanexplorer encourages participants to play the game by asking the challenging question: how well do you know Cambridge? Guesses are scored based on the time taken to place the guess and the distance between the guessed location and the real location of the image. This way, people are encouraged to place their guesses as accurately as possible without hesitating for too long. On average, participants took 2-3 guesses to gain proficiency at the required actions, such as clicking in the map, looking for the precise locations and moving on to the next guess. Thus, in the analysis, the first two guesses placed by each participant are ignored. Each individual's familiarity with a given place is a function of reaction time and guessed distance to answer. The overall familiarity of the place can be inferred from the collective actions and responses of all players. Streetview images are shown to participants in random order. Once participants have placed a guess, the

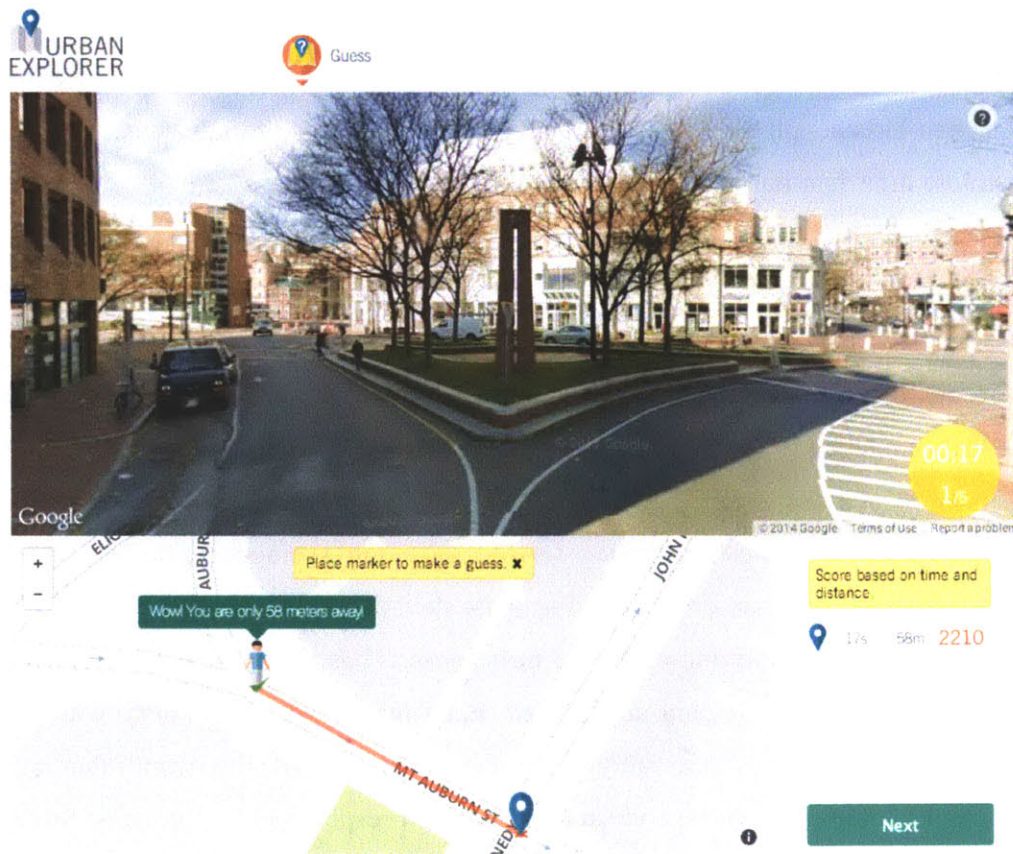
real location of the streetview is revealed. All the guesses are stored in the database with a set of attributes (Table 3.1).

---

Place id:	Each streetview is given an unique id for easy retrieving
Time spent to guess:	Time is calculated from the moment a streetview is shown to the moment the person clicks the guess button
Location of streetview:	Longitude and Latitude of the streetview
Location of guess:	Longitude and Latitude of the guessed location
Distance to answer:	Distance are calculated between the two locations above
User information:	Information of the user matched with his/her survey
Time of creation:	Time when the guess is made
Score:	Score is a function of distance and time spent based on a scale of 1 to 2500

---

**Table 3.1 Attributes associated with each guess**



**Figure 3.1 The User Interface of UrbanExplorer  
Retrieved from <http://uexplorer.mit.edu>**

**Survey**

In order to collect data on the demographics of the participants, as well as exclude answers of participants who have never been to Cambridge or the studied area, the website asks them to answer a three-question survey after they have placed three guesses looking at images of Harvard Square. The survey questions are:

1. How do you know Cambridge? I ... Cambridge (multi-selection).
  - A. live/lived in
  - B. work/worked in
  - C. live/lived and work/worked in
  - D. visited
  - E. have never been to
2. How old are you?
  - A. less than 25
  - B. 25-34
  - C. 35-44
  - D. 45-54
  - E. older than 55
3. How many times have you visited Harvard Square?
  - A. less than 3 times
  - B. 3-10 times
  - C. more than 10 times

**Site**

The urban area that was chosen for this study is Harvard Square in Cambridge, MA. Located in the center of Cambridge, adjacent to Harvard University, Harvard Square is an area frequently visited by tourists and local residents. It consists of a variety of local attractions, such as restaurants, salons, clothing shops, bookstores, coffee shops, florists and hotels. The MBTA stop “Harvard Square” is a major transportation hub that links subway, bus and taxi stops, transporting thousands of people to and from this area every day. Most of the people who live in Cambridge or adjacent neighborhoods have visited Harvard Square in the past.



The area that was chosen to study covers the center of Harvard Square, extends north to Cambridge Common and south to the river. The land-use types of the studied area are mainly commercial, transportation and educational. The road system of this area is extremely complex and irregular. Most of the roads don't follow the square block system, and most of the major intersections are not perpendicular. The highly visited public places, various land uses and irregular structure render it an ideal location for our study.

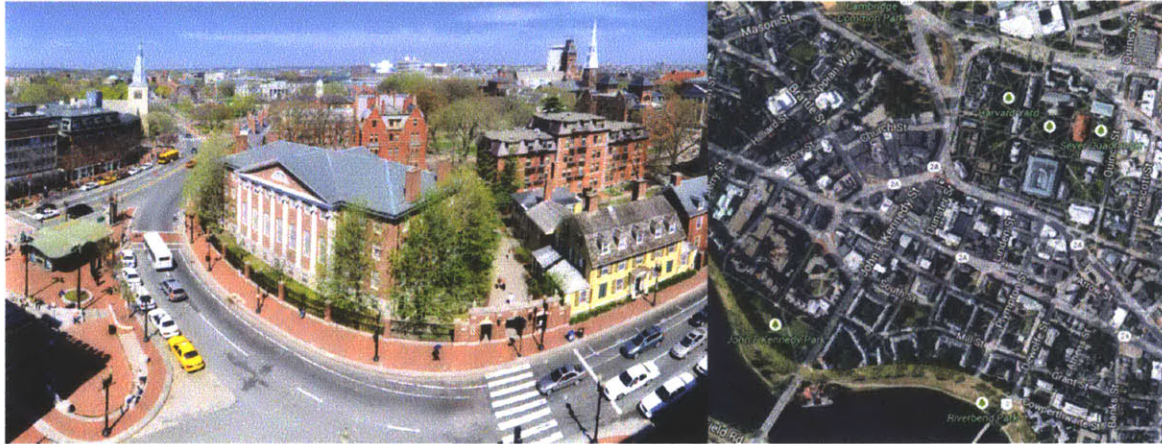


Figure 3.2 Aerial Photo of Harvard Square  
Retrieved from <http://maps.google.com>

### Geo-tagged Streetview Images

For this study 190 geo-tagged streetviews around Harvard Square were manually selected, along with 50 streetviews of other popular places in Cambridge. Each streetview has a predefined point of view, so that a participant cannot look around. The purpose of including images from outside the Harvard Square is to prevent participants from only placing guesses in that area. The images around Harvard Square were categorized into two groups representing nodes and links. The nodes are images of intersections, public squares and single buildings that, according to Lynch's five elements and Golledge's anchor point theory, are usually referred to as spatial reference points. The links are images of the street section between the nodes. For each node, 3 to 4 images are selected looking at different points of view. For each link, 2 images are selected looking at different directions.

All 240 images are randomly picked and shown to people by the program. Each image will only be shown once to the same participant. On average, each participant placed 10 guesses before quitting the game.



**Figure 3.3** Location of all street views selected around Harvard Square



**Figure 3.4** Samples images of the link



**Figure 3.5** Sample images of the node

## Participants

The survey was sent primarily to people who were associated with universities. Most of them were students or faculty members. In all, 394 people participated in this study. Most of the participants were people who currently live and/or work in Cambridge. Among these, 68.0% of the participants stated they currently live or work in Cambridge, or have done so in the past; 79.4% of the subjects claimed to have visited the studied area more than 10 times in the past, and another 15.5% claimed to have visited the studied area 3-10 times; and 84.0% of the subjects are under 35 years old.

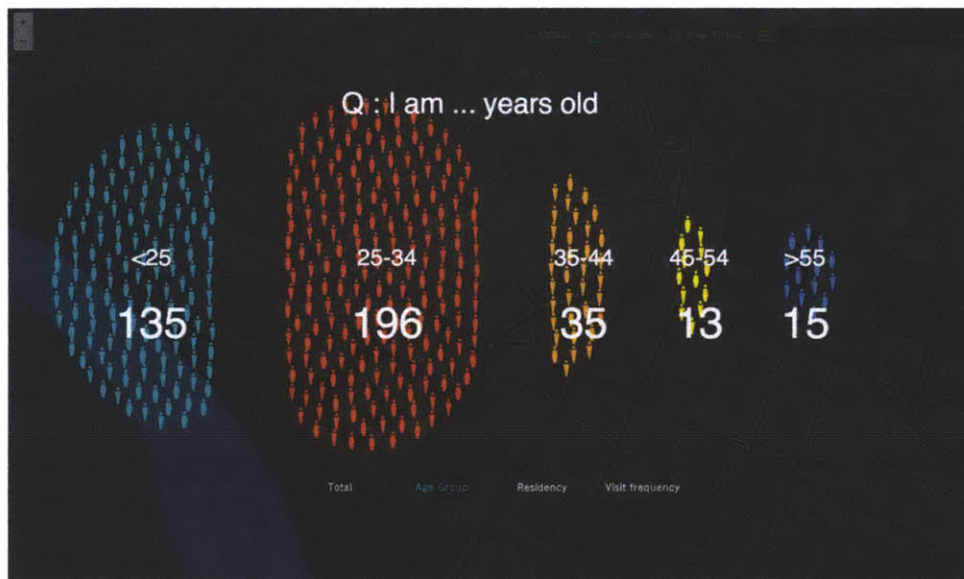


Figure 3.8 Ages of all participants

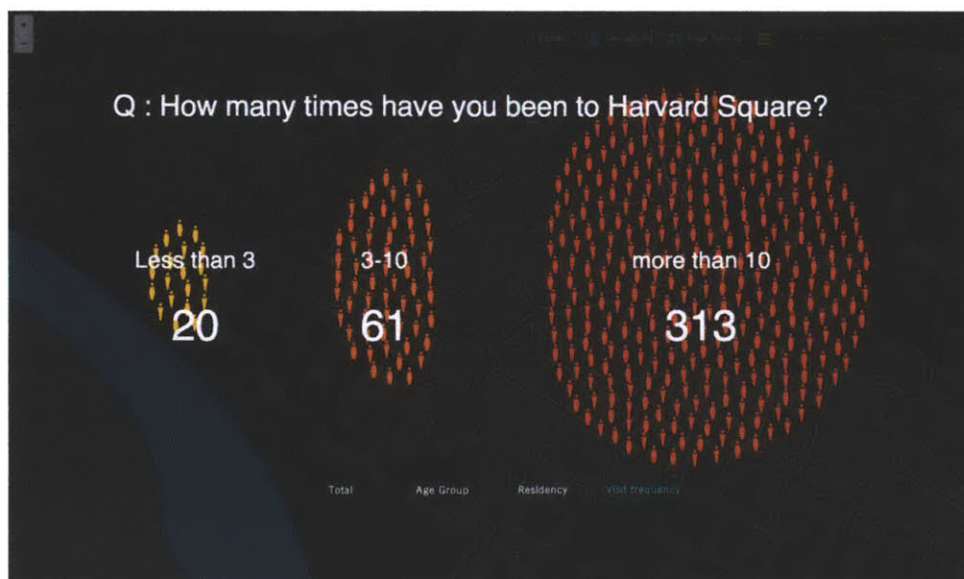


Figure 3.6 Visit frequencies of all participants



Figure 3.7 Modes of interactions of all participants

### Algorithm

For each image, a score indicating how familiar people are with it was calculated based on all guesses. The score is the sum of the percentage of guesses that were made within 50 meters, the percentage of guesses made between 50 to 100 meters multiplied by 0.75 and the percentage of guesses made between 100 to 150 meters multiplied by 0.5. The range of the score is 0 to 1, 1 indicating high familiarity. An image will receive a score 1 if all the guesses of it were made within 50 meters. The calculation is shown below.

- $Q_1$  - Number of guesses made within 50 meters of the answer
- $Q_2$  - Number of guesses made between 50 to 100 meters to the answer
- $Q_3$  - Number of guesses made between 100 to 150 meters to the answer
- $Q$  - Total number of valid guesses

$$S = (Q_1 \times 1 + Q_2 \times 0.75 + Q_3 \times 0.5) / Q$$



## Chapter 5

### RESULTS AND DISCUSSIONS

The creation of the environmental image is a two-way process between observer and observed. What he sees is based on exterior form, but how he interprets and organizes this, and how he directs his attention, in its turn affects what he sees. The human organism is highly adaptable and flexible, and different groups may have widely different images of the same outer reality.

—Kevin Lynch, *The Image Of The City*

In total, 4216 guesses were made, of which 3617 were made by people who filled out the survey, and 2851 guesses were made to guess the 190 streetviews in Harvard Square. On average each image received 15 guesses.

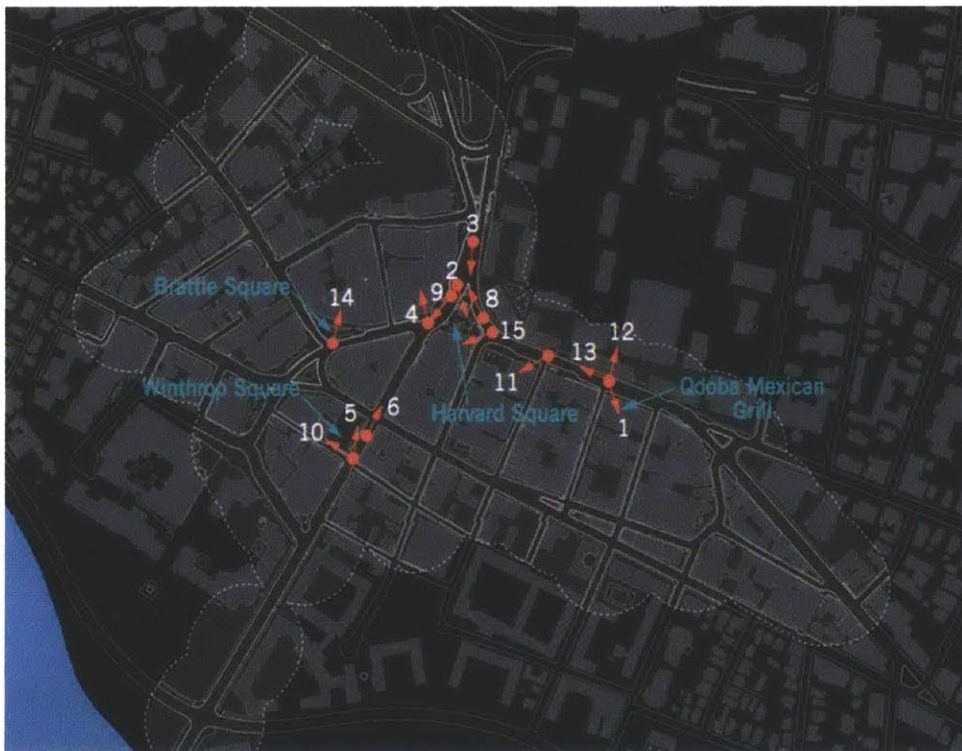


Figure 5.1a Locations of the 15 most recognized streetviews

### Most Familiar and Least Familiar

Not surprisingly, the places with the highest scores are primarily public spaces at the center of the studied area, such as Harvard Square, Brattle Square and Winthrop Square. Certain stores at the center of Harvard Square (e.g., Harvard Coop) and along Massachusetts Avenue (e.g., Qdoba Mexican Grill) also received high scores. In fact, the place that is most recognized is the Qdoba Mexican Grill along Massachusetts Avenue, with a score of 0.847. The links with the highest score are streets within one block to the center (e.g., JFK Street and Massachusetts Avenue). This finding indicates that the degree of interaction and the proximity to center is highly correlated with the probability of being recognized by most people.

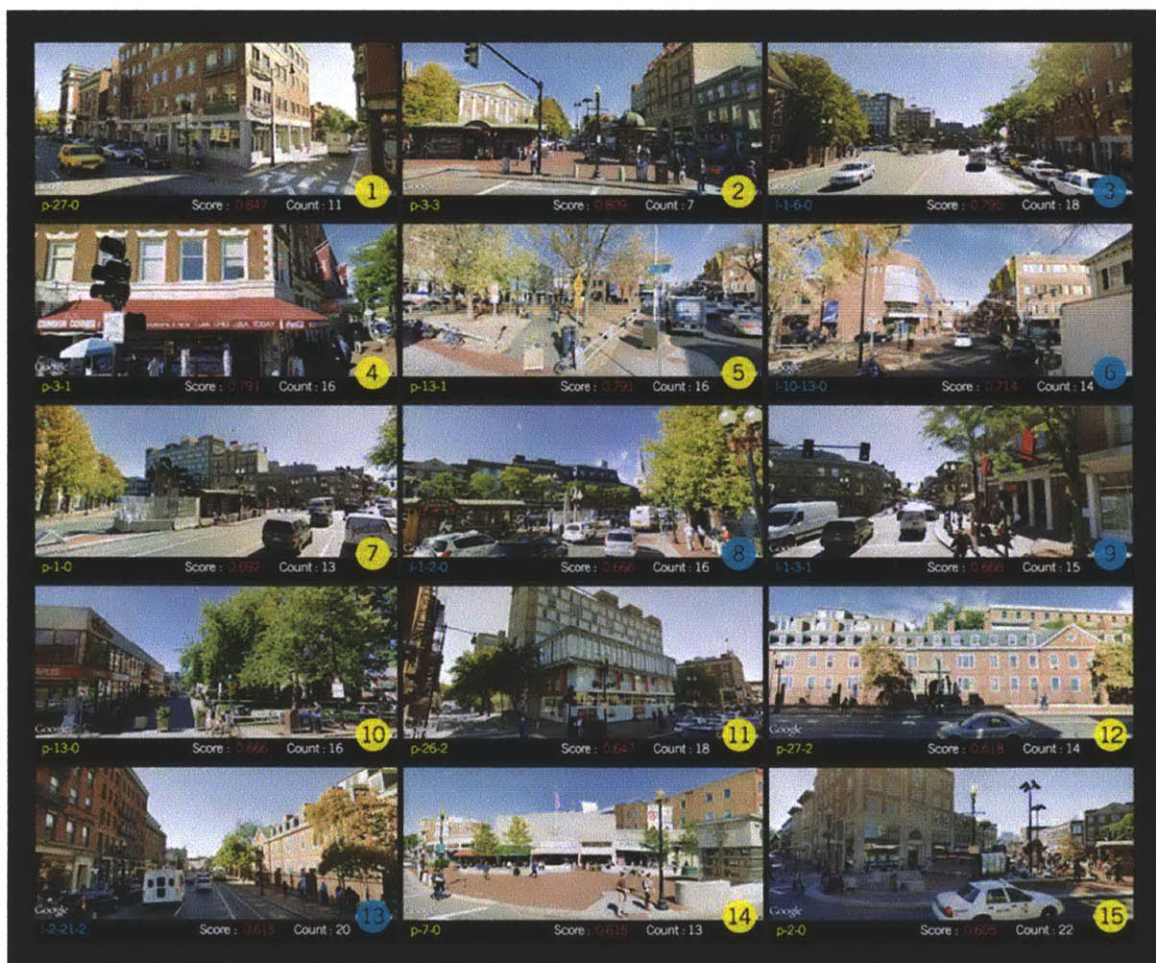


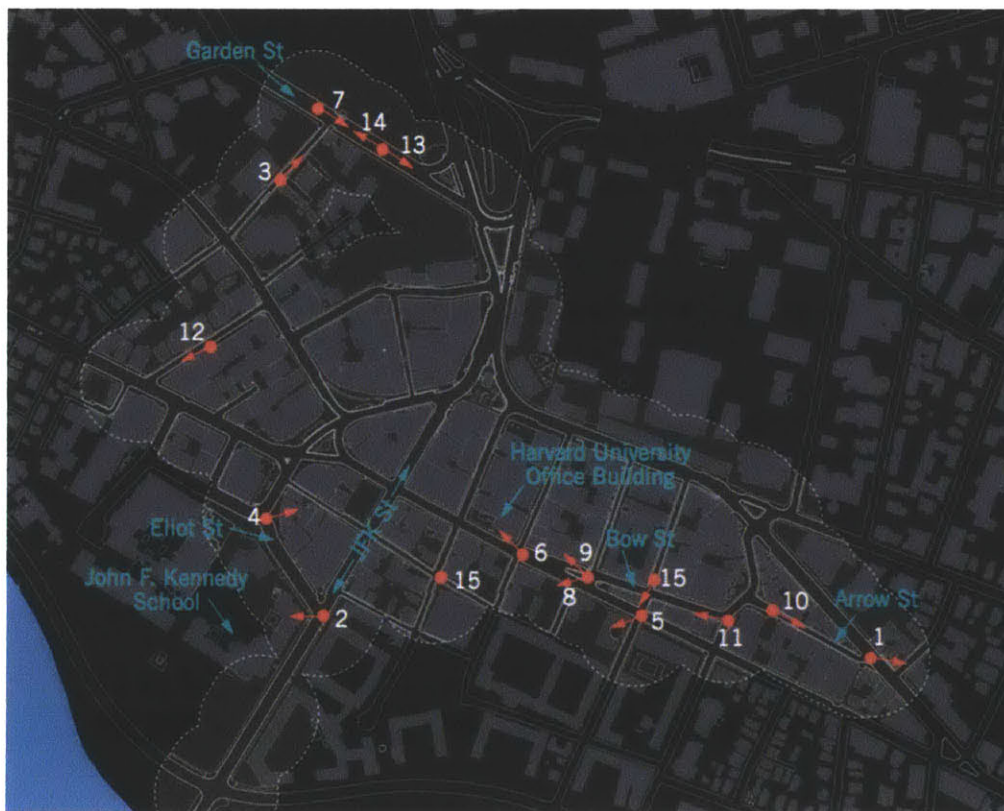
Figure 5.ab The 15 most recognized streetviews

The observation also suggests that the irregularity of urban structure doesn't prevent forming of strong mental images. Most of the highly recognized places are in the center of

the studied area, where road system is extremely complex. The shapes of the highly recognized squares are triangular, and the roads are circled. This finding challenges Lynch's statement that a regular city structure is more likely to evoke strong mental images.

The places with the lowest scores are primarily school or residential buildings with no eye-catching signs or distinct features, as well as streets that don't have much activity (e.g., Garden Street, Bow Street and Arrow Street). It is very obvious that the least recognized places are all located away from the center of the studied area. Some findings that are worth mention include:

1. The second least recognized streetview with a score of 0.022 is the building of the John F. Kennedy School, located at the intersection of JFK Street and Eliot Street. JFK Street is the busiest street in Harvard Square with heavy traffic and frequent congestion. The fact that the building at one busy intersection is very unfamiliar to people indicates that frequently passing by a place does not necessarily evoke strong images.



**Figure 5.2a** Locations of the 15 least recognized streetviews



2. The sixth least recognized streetview with a score of 0.074 looks at the back of the Harvard University Office Building, which takes up the entire block. However, the eleventh most recognized streetviews looks at the front of the same building, where large red windows decorate the three-story podium in the center of the view. This observation suggests that large-size buildings do not necessarily evoke strong mental images, because pedestrians are more likely to look at features visible at eye level.

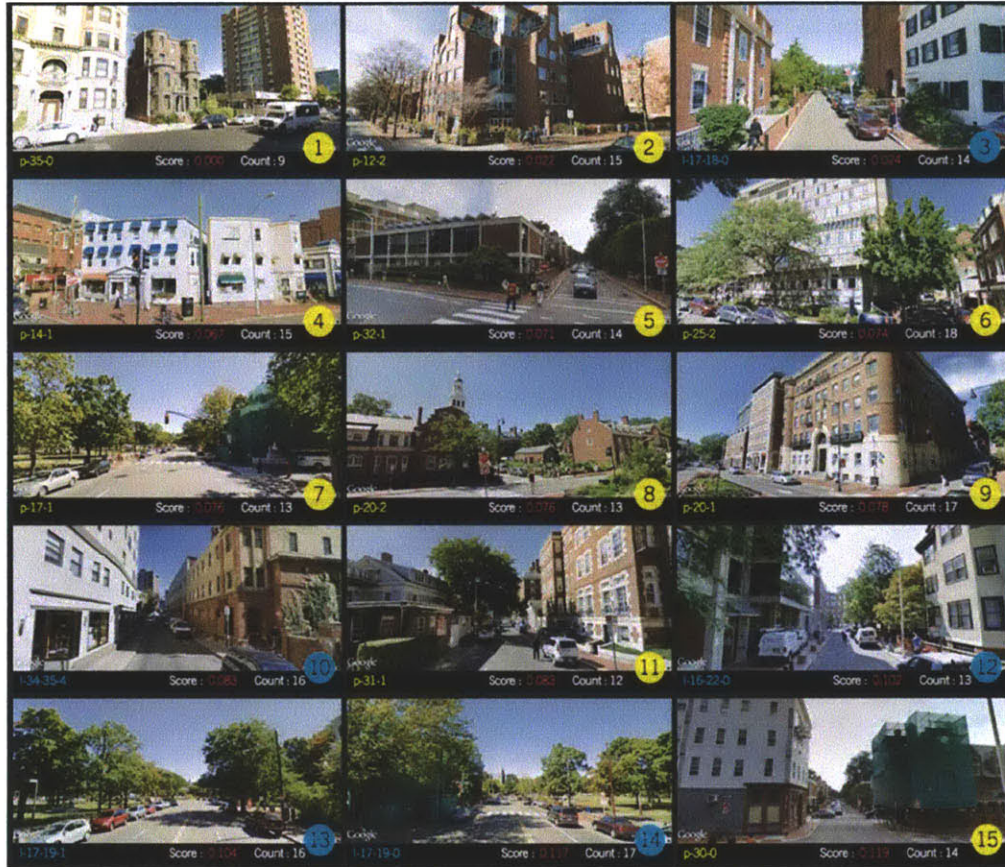


Figure 5.2 b The 15 least recognized streetviews

## Links and Nodes

Of all the answers placed within 100 meters of the correct location, 30% of the answers of the nodes were concentrated within 20 meters of the true location, whereas only 15% of the answers of the links were within 20 meters. This indicates that if people recognize the image, they tend to place the marker more accurately (within 20 meters to the real location) when the image they are guessing is a node. On the other hand, guesses for links tend to be less accurate.

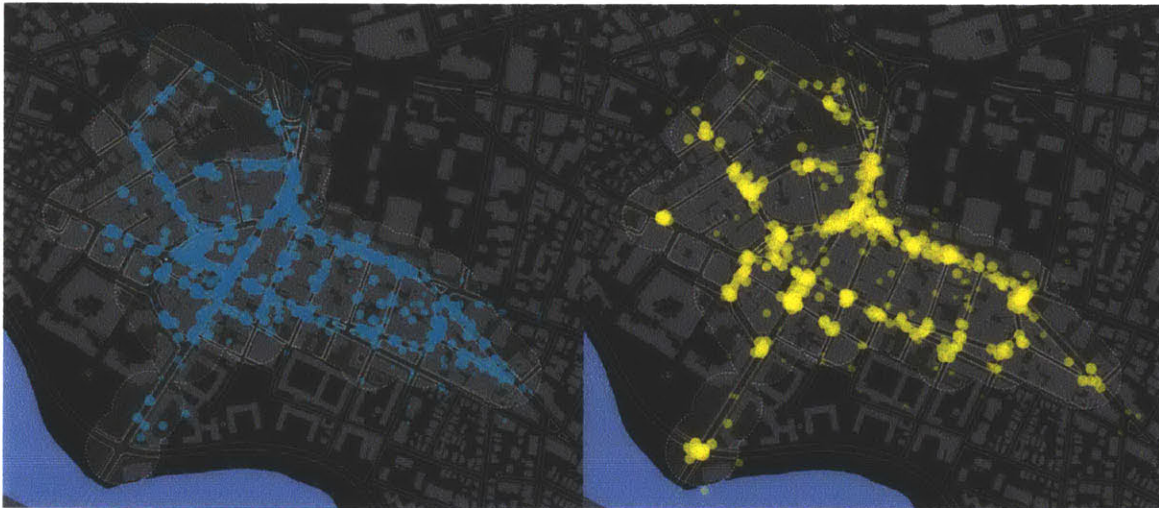


Figure 5.3 Left: All guesses for links. Right: All guesses for nodes

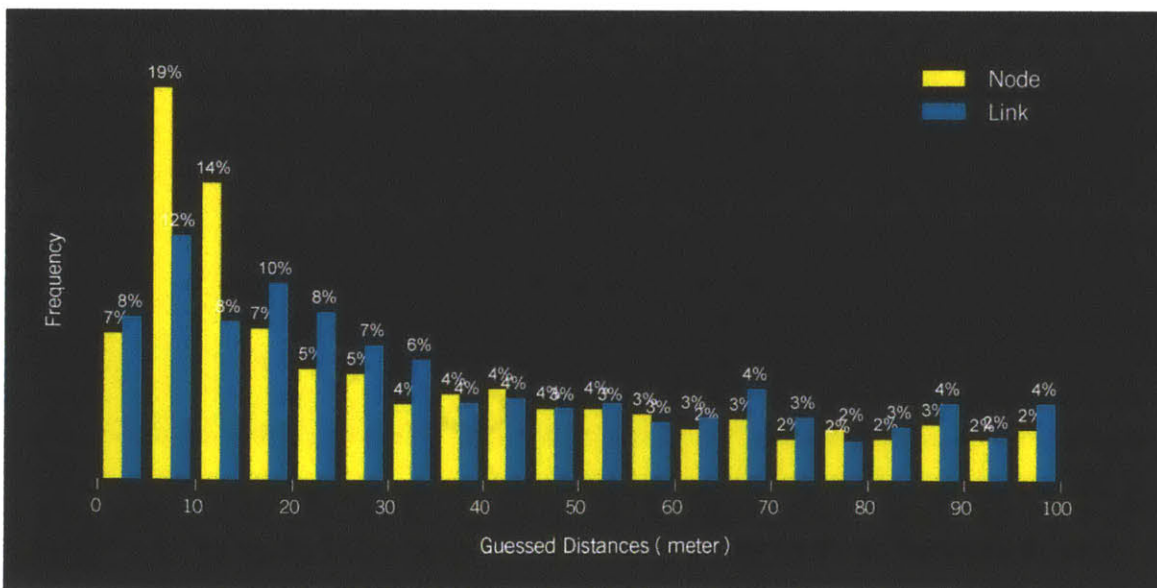


Figure 5.4 Histogram of guessed distances

Figure 5.5a shows the scores of all nodes. The size of the ellipses indicates the score. The nodes more familiar to people are located along Massachusetts Avenue and JFK Street, which are the two busiest streets. Most of the nodes along these two streets point to stores or shops along the street. Along Massachusetts Avenue, the more familiar views are mostly towards the south side of the street. On the other hand, among the nodes along Mt. Auburn Street, the more familiar views are all towards the south. A magnetic field seems to exit between these two parallel streets that draws more attention. This is the area that has many restaurants and cafes.

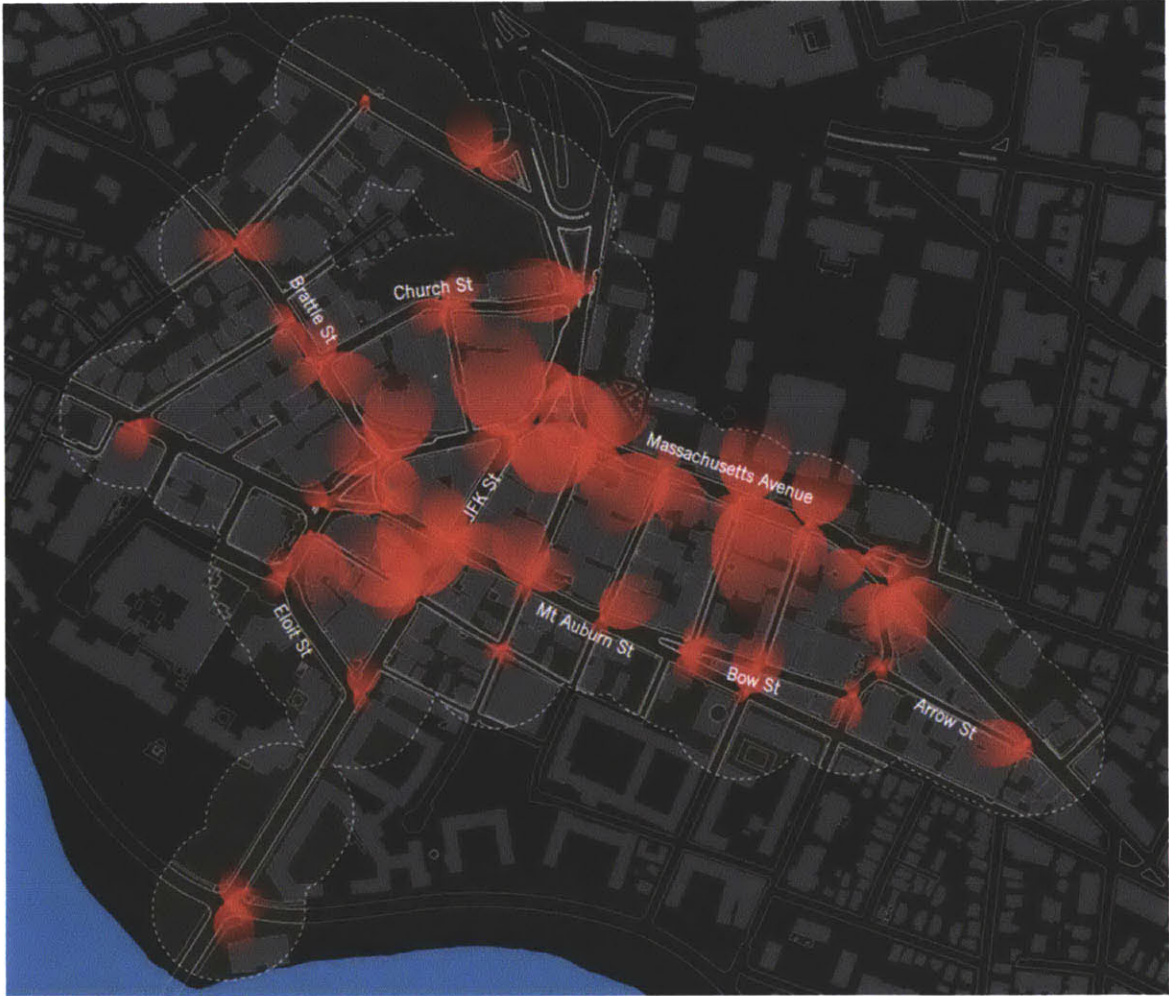
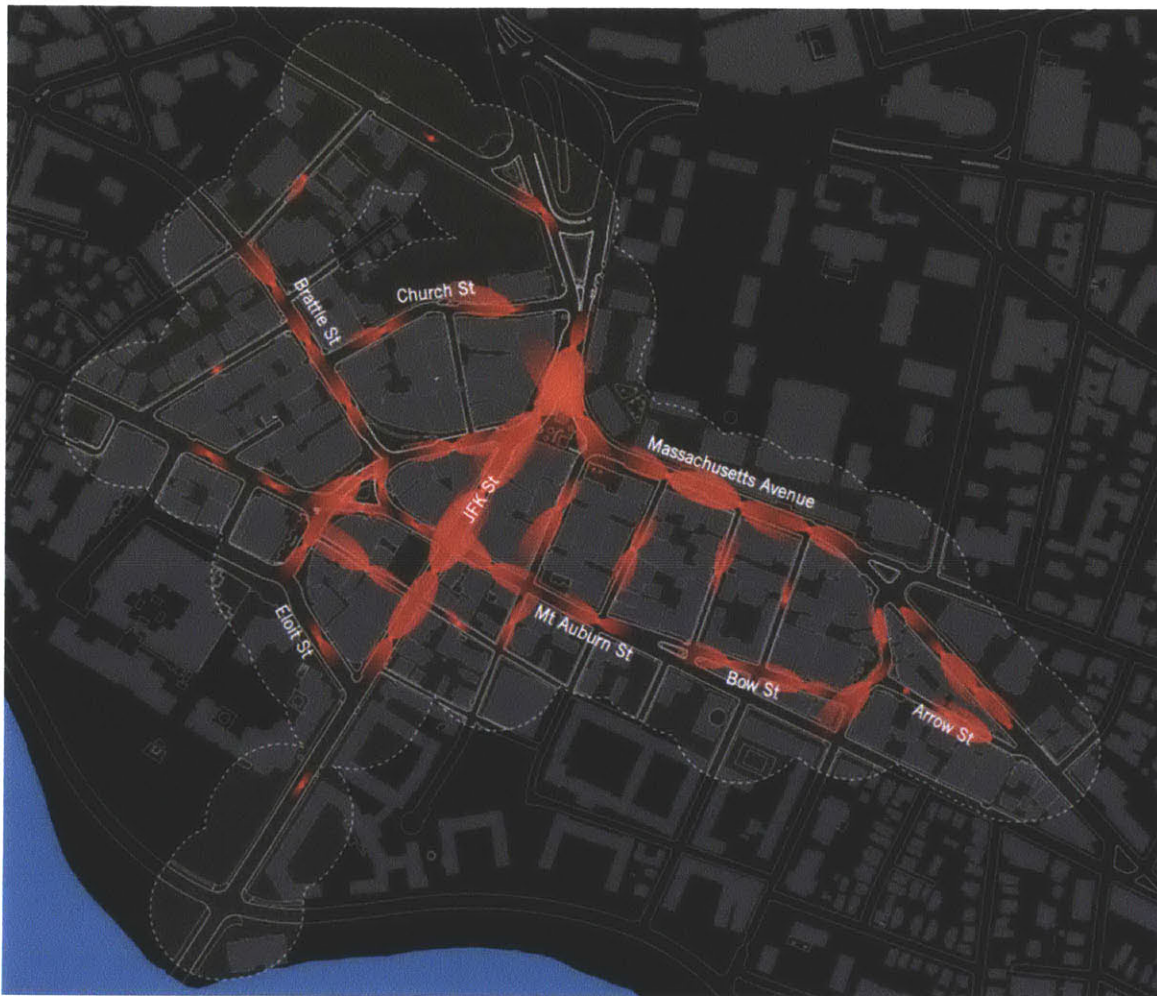


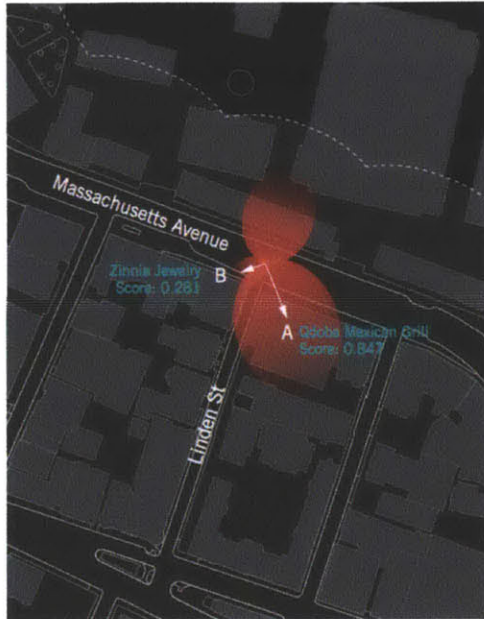
Figure 5.5a Score of nodes

Figure 5.6b shows the score of all links. The more familiar streets are Massachusetts Avenue and JFK Street. A pattern can be observed among the streets between Massachusetts Avenue and Mt. Auburn Street. The closer the street is to the center, the more familiar it is to most people. This again verified the earlier observation that proximity to center has strong correlation with the degree of familiarity.



**Figure 5.6b Score of links**

An interesting finding was observed when conducting high-resolution analysis of every angle of this urban area. This experiment asked participants to guess streetviews without rotating the view, which allows us to compare the familiarities of different viewpoints at the same geographic location. At most locations, the familiarities of different viewpoints vary to some extent. In fact, at certain locations, the familiarities between different viewpoints are dramatically different. For example, the shop next to the Qdoba Mexican Grill—the most

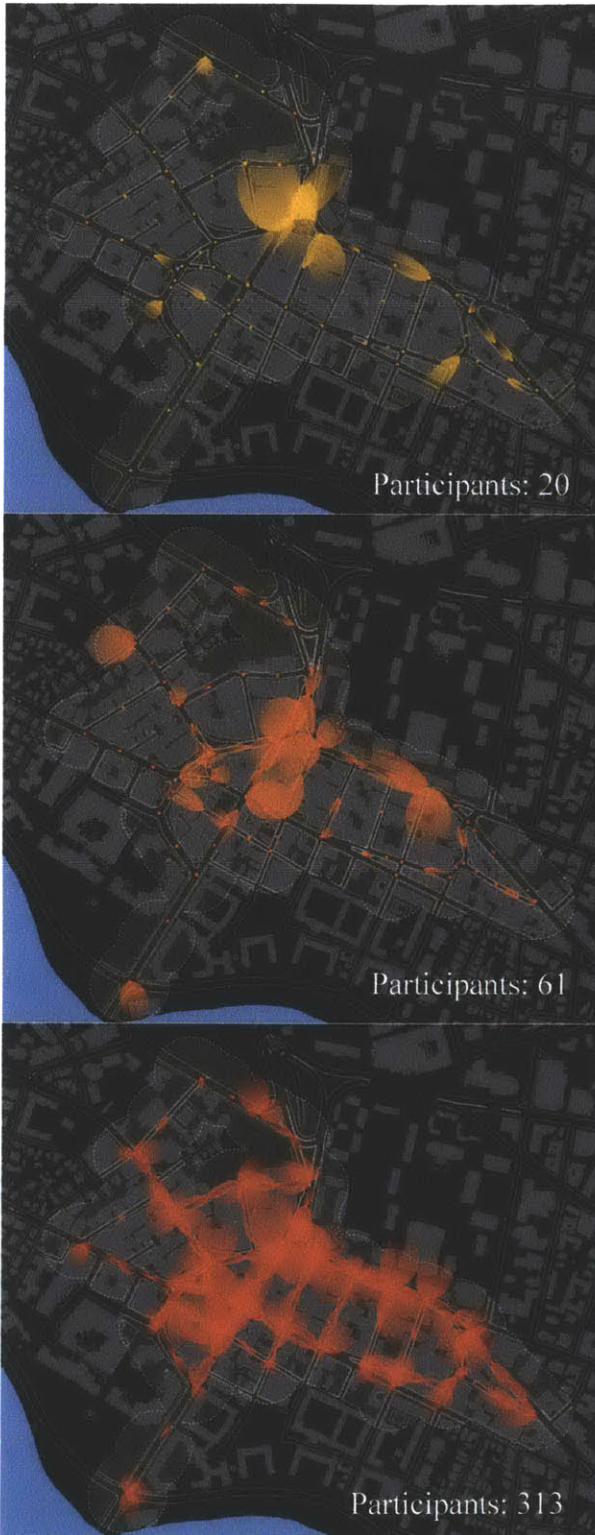


**Figure 5.7** Two different viewpoints at the intersection of Massachusetts Avenue and Linden Street

recognized place—is very poorly recognized, although these two places are only 10 meters apart. At viewpoint A, the Qdoba Mexican Grill, 8 out of 12 people made a guess within 20 meters. In contrast, at viewpoint B, Zinnia Jewelry, only 2 out of 14 people made a guess within 20 meters, and 10 people didn't even guess within 800 meters, which suggested that they couldn't recognize this place at all. There are many possible explanations. Qdoba is a fast food restaurant, which people frequently visit, whereas Zinnia is a small jewelry shop that does not attract many people. Another possible explanation is that the church tower at the very far end of image A provides a hint to the location of this streetview.



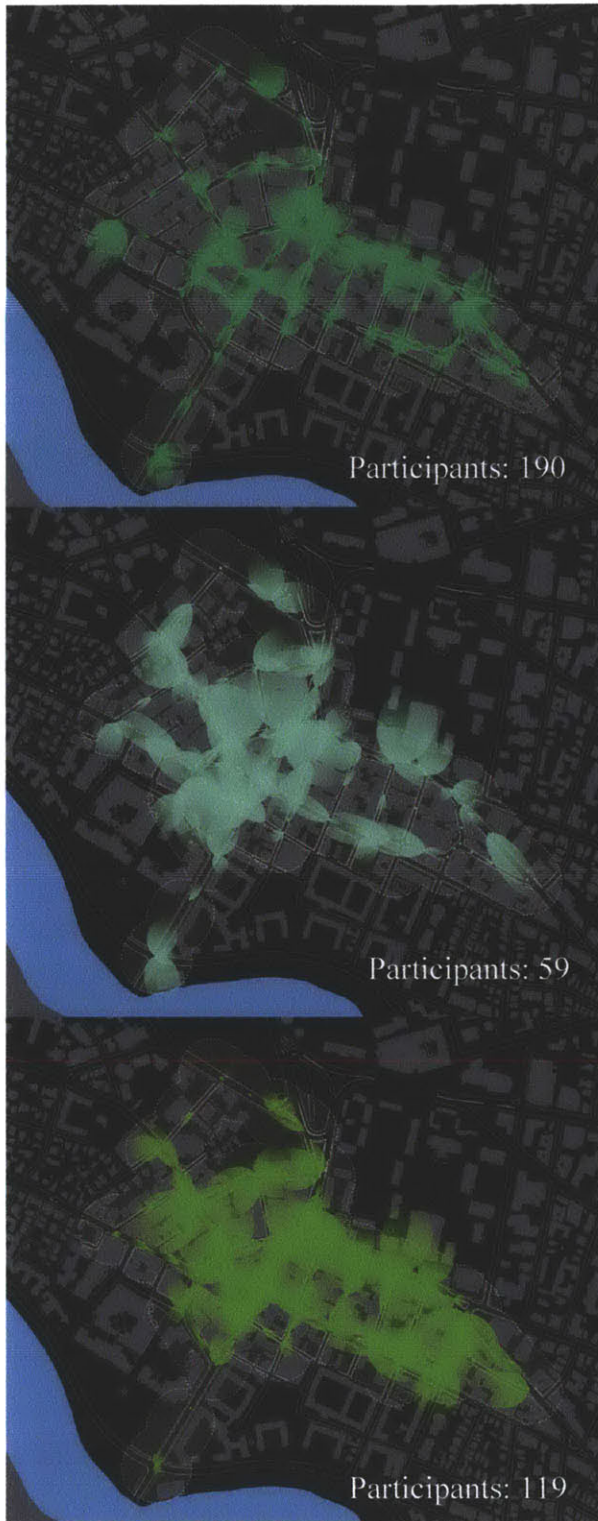
**Figure 5.7** Left: Poorly recognized viewpoint. Right: Highly recognized viewpoint.



**Figure 5.8** Above: Score of people visited less than 3 times. Middle: Score of people visited 3-10 times. Below: Score of people visited than 10 times.

### Knowledge Acquisition

Figure 5.8 shows how spatial knowledge is acquired when more visits are paid. From top to bottom, images show the familiarity of places among people who have visited this area less than three times, between three and ten times and more than ten times. When people visit once or twice, spatial knowledge of the activity center is first obtained. When more visits are paid, people start to gain knowledge of the spaces that are spatially close to the center, including the part of the streets that connect to the center of this area, and intersections that are one or two blocks away from the center. Finally, when people have visited the place more than ten times, the structure of their spatial knowledge starts to appear. This observation seems to favor the anchor-point theory, which proposes that the spaces in our mind are formed as a linked-node structure. However, the anchor-point theory is mainly concerned with each individual's spatial knowledge. It might not apply to the collective mental maps of the city. What can be observed here is the spatial knowledge system seems have some kind of hierarchy embedded, that it can only grows from the center.



### Modes of Interaction

Figure 5.8 shows how modes of interactions affect spatial familiarity. From top to bottom, images show the familiarity of places among people who only live in Cambridge, only work in Cambridge, and live and work in Cambridge at the same time. In comparison, the familiarities among people who only live in Cambridge extend more towards the surrounding area, where mostly residential districts, rather than concentrated in the center activity area. The familiarities among people who only work in Cambridge concentrate along the busy streets and center activity area, not so much on the parallel streets in between Massachusetts Avenue and Mt Auburn Street. The familiarities among people who work and live in Cambridge at the same time are confined to the middle portion of the studied area framed by Massachusetts Avenue and Mt Auburn Street, including the parallel streets in between. All the places in the middle area are very well recognized by people who live and work in Cambridge. The observation suggests that the modes of interactions can affect the distribution of familiar places. In general, people know places better if they work and live in the area at the same time.

**Figure 5.**Error! No text of specified style in document..9  
**Above: Score of people live in Cambridge. Middle:**  
**Score of people work in Cambridge.**  
**Below: Score of people live and work in Cambridge**

## Discussion

Many of the results that are discussed above are simply observations from the data this study collected, and the results confirmed statements in some previous studies, such as that familiarity is correlated to the proximity to center, the degree of interaction determines the level of familiarity and modes of interaction affect distribution of familiar places. There is also interesting findings that were only observable when conducting research using this fine-grained approach. Findings, such as that different viewpoints of the same location might induce extremely high and low familiarity, two viewpoints toward different directions at the same street might be highly and poorly recognized, can only be observed when we are able to ask a large number of people to guess every corner of the streets in the studied area.

We were also able to observe differences among various groups of people in respect to level and distribution of familiarity. Comparison was made among people with different numbers of visits, modes of interaction and ages. More studies can be done to further analyze different cultural, economic and class factors that affect familiarity, by adding questions to the survey such as “what is your occupation,” “what are your primary activities when visiting this area,” and “what modes of transportation do you usually choose when coming to this area.”

Further investigation can be conducted to analyze the semantics between familiar and unfamiliar places, such as whether a high familiarity place will induce higher familiarities among views that contain such a place; whether the familiarity of different directions of one link is determined by the nodes that it connects; and whether some type of magnetic field can be calculated at certain areas. We believe that views are connected, and the familiarities of places in the same area are also connected, the relationship between which can be calculated through network analysis.

Urban perception is related to human mobility behavior. Future studies in this field can use the method demonstrated in this thesis to verify mobility data, to determine the causal relationships between these two factors. Some of the observations in the study can also be verified when more data related to how people move around in the studied area are collected.





## Chapter 6

### VISUALIZATIONS

What would happen if, when saying that some image is human-made, you were increasing instead of decreasing its claim to truth?

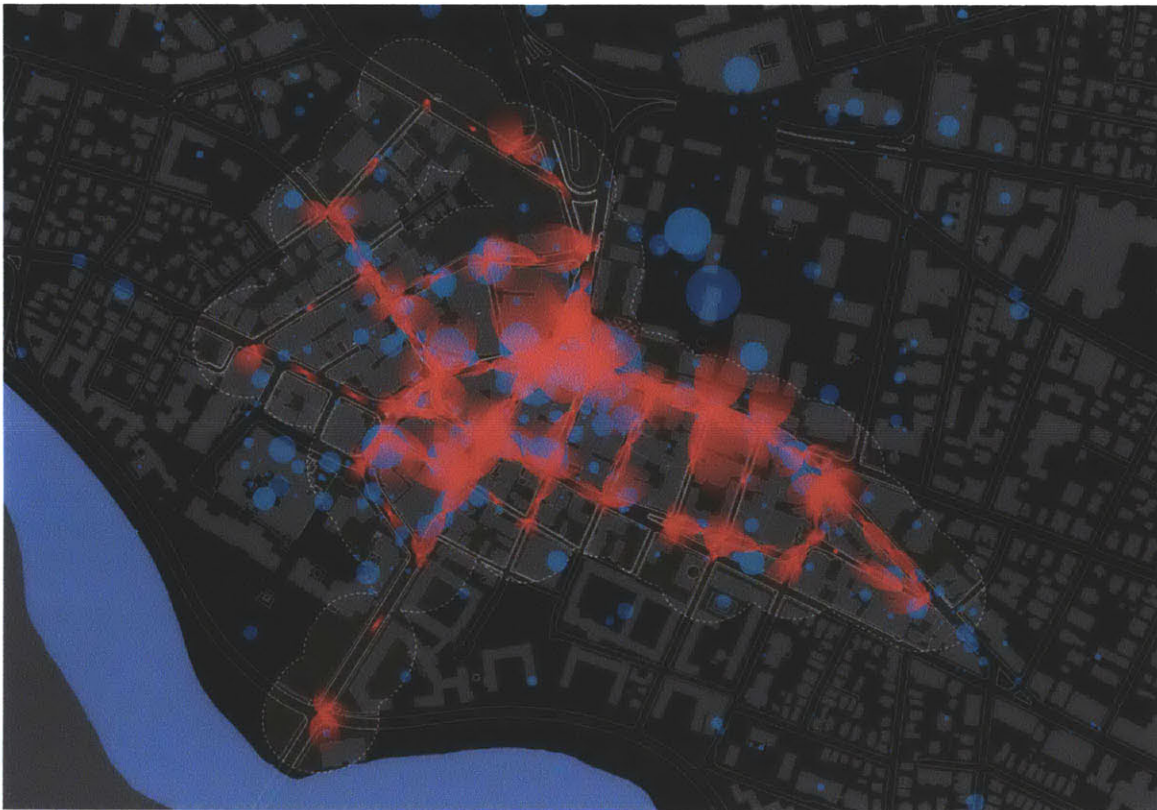
—Bruno Latour, *Iconoclash*

With 394 participants placing on average 10 guesses, we were able to build interactive visualizations to represent how well places are remembered on a map. The visualization below presents the collective memory of Harvard Square by the study participants. The size of the ellipse represents the degree of familiarity. Instead of a schematized approach, this study demonstrates the use of computer algorithm and mapping techniques to process and calculate data collected from a large number of people, and represents the results using interactive data visualizations. The familiarities of each view are automatically calculated by querying all the guesses stored in the database. This visualization is also immediately updated when new guesses are made.



**Figure 6.1** Interactive data visualization showing the score of all streetviews

Comparison can be easily made between different data sources. Foursquare is a location-based social networking website for mobile devices. Users "check-in" at venues using a mobile device by selecting from a list of venues the application locates nearby (Wikipedia). Foursquare data is a direct indicator of the how alive an area is. Below is a map generated by overlapping Foursquare check-ins with the score of all streetviews. The size of the blue circle represents the number of check-ins at that location. Trends can be observed that high check-in locations are always correlated with highly recognized streetviews, especially at the center of studied area (e.g., Harvard Square, Massachusetts Avenue, JFK Street etc.)



**Figure 6.2 Map overlapping Foursquare check-ins with the score of streetviews**

An interactive data visualization platform was built to study and visualize the collected data. A user is able to browse between different aggregations of data, for example, differentiating nodes and links, making comparison between people among different numbers of visits, modes of interactions and ages. It also enables researchers to look at each streetview at high resolution, by showing the location, ranking, distances and user profile of all the guesses.

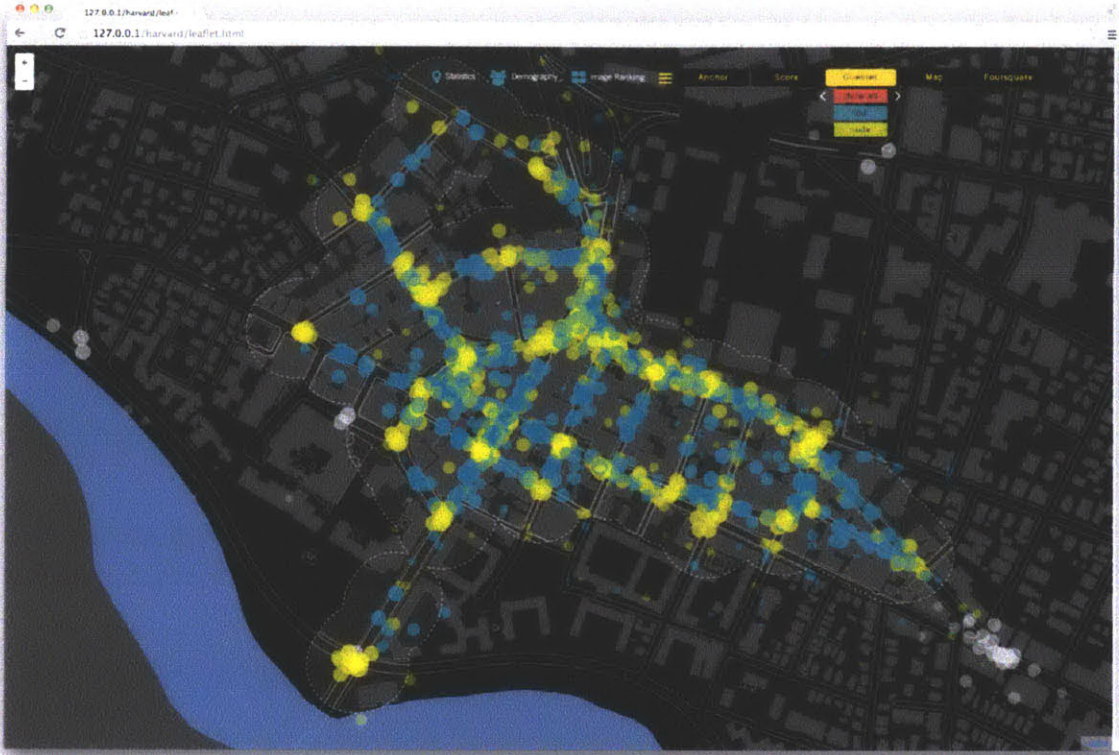


Figure 6.3a Interactive data visualization platform visualizing nodes vs. links

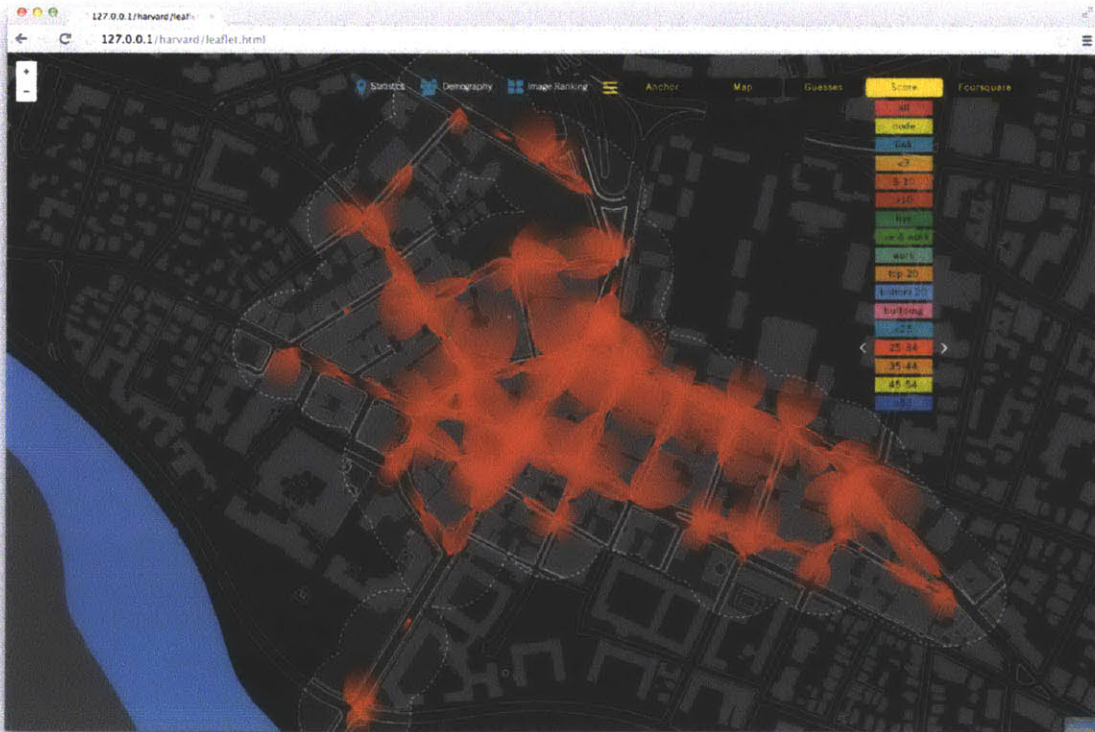


Figure 6.3b Interactive data visualization visualizing score of people between 25-34 years old

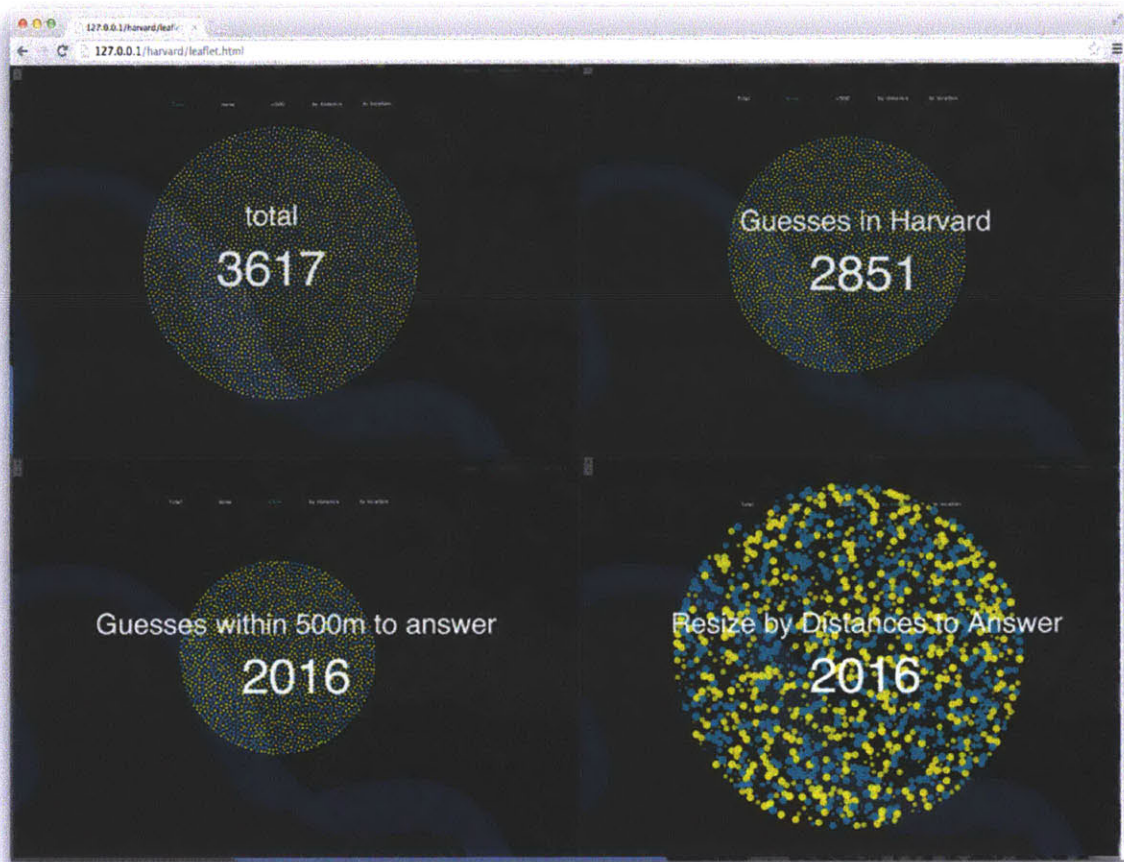


Figure 6.3c Interactive data visualization visualizing all guesses

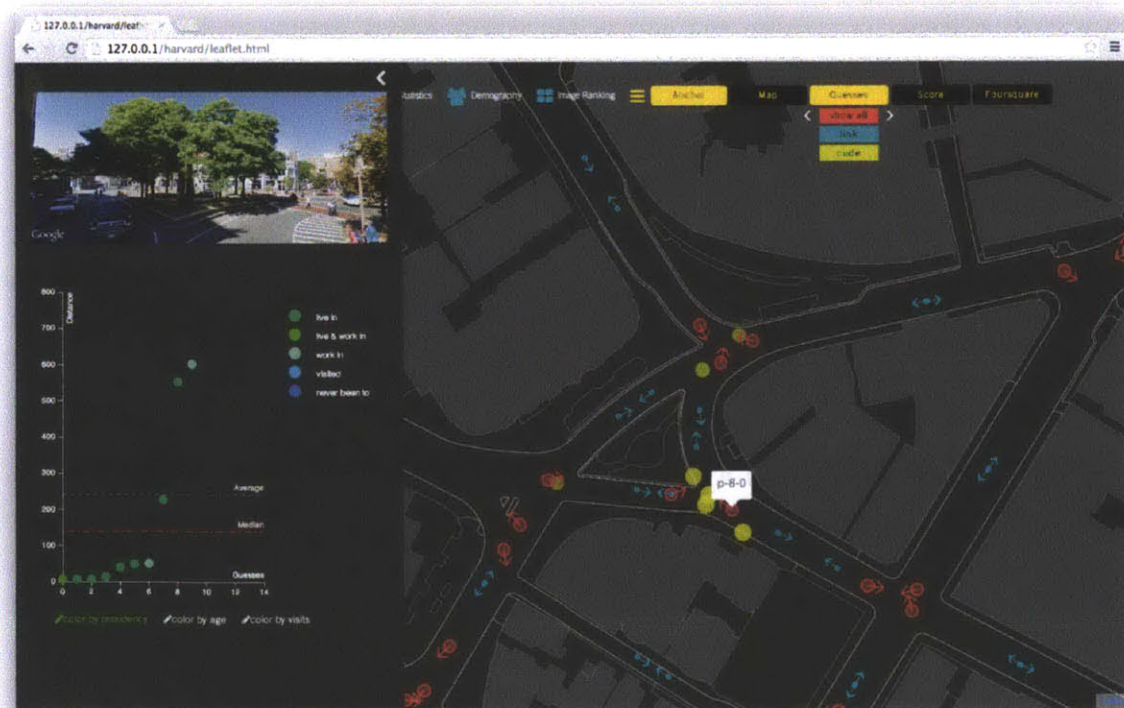


Figure 6.4d Interactive data visualization visualizing guesses of each streetview

This thesis collected the spatial knowledge around Harvard Square of 394 people. It painted the collective memory of the city using people's memory, highlighting the most remembered and least remembered sections of the cityscape. This is a first attempt made to paint a drawing of the collective memory of the city using literally people's memory. We wish to collect all memories of the city and create a similar painting of cities of all the continents.



**Figure 6.5** The collective memory of the city



## Chapter 7

### CONCLUSIONS

There is a strong need to create quantitative bridges that can help us link urban perception with other social, political, economic and cultural aspects of cities.

— *Salesses, Schechtner, & Hidalgo, The Collective image of the City*

The mental map of an urban environment is crucial for the daily activities of thousands of city-dwellers. Yet until now, the availability of data about urban perception has been limited, and so has our ability to collect a large amount of fine-grained data representing how people comprehend their familiar urban environment. In this thesis, we presented a method to automatically collect people's responses to measure spatial familiarity of two basic elements: link and node. Using a website to conduct a visual survey, we invited 394 participants to guess the location of 240 geo-tagged street views captured from a familiar urban environment. We then used quantitative calculation and data visualization techniques to measure how well different places are remembered by people.

This analysis confirms some of the earlier statements that were made. It concludes that the familiarity is a function of proximity to center and degree of interaction. Places closer to the center of activity are more likely to be remembered. However, proximity alone does not result in high familiarity. Places along a busy street can be poorly recognized if most of the people had limited or no interaction with such a place. The distinctive features of the building can evoke high imageability if the feature is constantly visible from a pedestrian's viewpoint.

The unique findings of this thesis based on the fine-grained data are related to how familiarity can be dramatically different at the same geo-location. Google's geo-tagged images that this thesis collected enabled us to survey every corner and every angle of the studied area. We were able to observe that two viewpoints of the same location have dramatically different familiarities. One is extremely highly remembered (8 out of 12 people guessed within 20 meters), and the other is very poorly remembered (2 out of 13 people guessed within 20 meters). Views of the same building from different angles also result in



diverse familiarity: the back view of an office building along a busy street is the 6<sup>th</sup> least remembered view among 190 streetviews in that area, whereas the front view of the building is the 11<sup>th</sup> most remembered view. These findings suggest that when general distribution of familiarities in a small area can be observed as highest at the center of activity and declining towards the edge, differences in viewpoint can still be dramatic. People's spatial knowledge is complex and fragmented. The findings also suggest that the irregularity of urban structure doesn't prevent forming of strong mental images, which challenges Lynch's statement that a regular city structure is more likely to evoke strong mental images.

This thesis also observed that spatial knowledge was acquired throughout time. With limited visits, people are only able to remember some spots that they have limited interaction with. The more visits paid, the more spots will be added to their memory starting from the vicinity of the center. This to some extent is in alignment with Golledge's (R. G. Golledge & Spector, 1978) anchor-point theory. This thesis also observed that modes of interactions can affect distribution and level of familiarity.

This thesis also explores how cartographic techniques can be used to map the virtual memory of the city that its inhabitants and those of other neighborhoods have of it. By analyzing data collected using an interactive data visualization platform, we are able to conduct fine-grained statistical analysis at each streetview and among different groups of participants. We are also able to efficiently conduct comparison by aggregating data differently or overlapping with other sources of urban data in demographic, economic, cultural, social media context.

This thesis presents an innovative approach using web-based visual surveys to conduct studies of urban spatial perception in an efficient, automatic and scalable way. Using online surveys and geo-tagged images, we are able to collect a large amount of fine-grained data from a large number of participants. Compared to conventional methods such as interviews and face-to-face surveys, online surveys eliminated the time required to interact with each participant, exponentially enlarging the number of participants that can be involved.

Clearly, there are limitations. One concern is the lack of control over the demographics of the participants. People who are willing to take the survey are more likely to be medium or

higher income groups, who have access to the Internet and are willing to voluntarily participate in academic research. Another problem is that there is no means to filter irrelevant data. People might carelessly click around without paying attention to the instructions. Future improvements can be made using machine learning to control and balance demographics of the users, and designing better user interface to eliminate user errors.

This thesis concludes that the method presented here is able to rapidly elicit spatial knowledge among a large number of city dwellers, and allow researchers to conduct quantitative data analysis. Moreover, this thesis proposes that the method can be used beyond the familiarity evaluation of urban images. It can be adopted in future investigations including spatial knowledge acquisition in an unfamiliar neighborhood, the semantic relationships between spatial knowledge, and results of perceptual knowledge on human mobility behavior.



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