

© 2006 by Evan Acharya. All rights reserved.

MYMAP

BY

EVAN ACHARYA

B.A., Macalester College, 2004

THESIS

Submitted in partial fulfillment of the requirements  
for the degree of Master of Science in Computer Science  
in the Graduate College of the  
University of Illinois at Urbana-Champaign, 2006

Urbana, Illinois

# Abstract

myMap is a dynamically changing map that displays different landmarks that are related to a user's current context. Since such a map is more likely to be related to a user's cognitive map than are traditional maps, it is hoped that myMap will reduce the cognitive load on a user. Furthermore, myMap is designed as a personalized map that is unique in the sense that it displays landmarks that reflect a user's spatial identity. myMap brings together brings context, commonsense and maps together in an attempt to develop a framework that is able to display dynamic user centered maps.

# Acknowledgements

I want to take this opportunity to thank Prof. Karrie Karahalios for her able guidance and intellectual support throughout this project. If it wasn't for her patience and inspiration, this project would not have been possible.

I also want to thank my fellow friends in the Social Computing group who, through humor and sometimes derision, made sure I stayed the course and finished myMap. Feedback received from them are highly appreciated.

Finally, I would like to thank members of my family for supporting my decision of doing research through difficult times in their own lives. The last two years of research experience wouldn't have been possible without their moral support.

# Table of Contents

<b>List of Tables</b> . . . . .	<b>vii</b>
<b>List of Figures</b> . . . . .	<b>viii</b>
<b>Chapter 1 Introduction</b> . . . . .	<b>1</b>
1.1 Project motivation . . . . .	1
1.2 Layout of thesis . . . . .	2
1.3 Related Work . . . . .	2
<b>Chapter 2 Cognitive basis</b> . . . . .	<b>6</b>
2.1 Animal navigation and cognition . . . . .	6
2.1.1 Landmarks . . . . .	7
2.1.2 Cognitive maps . . . . .	7
2.1.3 What aspects of maps are important? . . . . .	8
2.2 Overview of maps . . . . .	9
2.2.1 Maps before the age of technology . . . . .	9
2.2.2 Maps in the age of technology . . . . .	10
2.2.3 Sketch maps . . . . .	15
2.3 Commonsense . . . . .	17
2.3.1 Overview of commonsense . . . . .	17
2.3.2 Commonsense knowledge for maps . . . . .	19
2.3.3 Inherent inaccuracy . . . . .	20
2.3.4 Speculations on personalized commonsense . . . . .	21
2.4 Context . . . . .	21
2.4.1 Maps as tools . . . . .	21
2.4.2 User Context . . . . .	23
2.4.3 Context awareness in literature . . . . .	24
2.4.4 Context awareness in maps . . . . .	25
<b>Chapter 3 Map Components</b> . . . . .	<b>26</b>
3.1 Landmarks . . . . .	26
3.1.1 What is a landmark? . . . . .	26
3.1.2 Personalized landmarks . . . . .	27
3.1.3 Universal landmarks . . . . .	28
3.1.4 Landmarks in maps . . . . .	28
3.1.5 Mining data about landmarks from the web . . . . .	29
3.2 Nearness - concepts and calculations . . . . .	30
3.2.1 Spatial nearness . . . . .	30
3.2.2 Conceptual nearness . . . . .	31
3.2.3 Temporal nearness . . . . .	34
3.2.4 Social nearness . . . . .	35
3.2.5 Putting it all together . . . . .	36

3.2.6	Accuracy in calculations . . . . .	37
3.3	Learning components . . . . .	37
<b>Chapter 4</b>	<b>Implementation . . . . .</b>	<b>39</b>
4.1	Implementation details . . . . .	40
4.2	Graphic component . . . . .	43
4.3	Improvements . . . . .	43
<b>Chapter 5</b>	<b>User comments and Conclusion . . . . .</b>	<b>48</b>
5.1	User Comments . . . . .	48
5.2	Conclusion . . . . .	49
<b>Chapter 6</b>	<b>Appendix . . . . .</b>	<b>50</b>
6.1	Input Data . . . . .	50
6.1.1	User location . . . . .	50
6.1.2	Landmark text from web . . . . .	50
6.1.3	Location of landmarks . . . . .	51
6.2	Calculations . . . . .	51
6.2.1	Code Structure . . . . .	51
6.2.2	Eight sets from raw data . . . . .	51
<b>References</b>	<b>. . . . .</b>	<b>56</b>

# List of Tables

6.1	<i>The relative location of all landmarks used in the project.</i>	52
6.2	<i>General code structure. Only the important classes/objects are shown.</i>	53
6.3	<i>The first four of the eight lists created from the raw data of <code>bombayGrill</code>.</i>	54
6.4	<i>The last four of the eight lists created from the raw data of <code>bombayGrill</code>.</i>	54
6.5	<i>Normalized conceptual nearness values for a few landmarks.</i>	55

# List of Figures

1.1	<i>Two different versions of the map of Cyberguide by Abowd et. al, [1]. . . . .</i>	3
1.2	<i>GloBuddy, a translation tool that uses commonsense by Lieberman et. al, [25]. . . . .</i>	4
2.1	<i>Titled: Rock art - map. Redrawing of the oldest known plan of an inhabited site, Bedolina, Val Camonica, Italy, circa 1200 BC Source: [3]. . . . .</i>	9
2.2	<i>Titled: Diwali celebrations at the royal palace at Kotah, Rajasthan. This map and many others like it were commissioned by kings for decorative, commemorative and utilitarian purposes, circa 1600 Source: [3]. . . . .</i>	10
2.3	<i>Titled: Africa. The Africa shown in this map forms a part of an eclectic world map from India, circa 1700. Source: [3]. . . . .</i>	11
2.4	<i>Titled: Panoramic Map of Buddhistic India. This is a map drawn by Hashimoto Sadahide in 1860 depicting his conception of India Source: [39]. . . . .</i>	11
2.5	<i>Titled: A description of East India. This is a map drawn by William Baffin and Thomas Roe of the Mughal empire in India, circa 1600 Source: [3]. . . . .</i>	12
2.6	<i>Titled: Hindoostan. This is a map of India drawn by James Rennell for East India Company, 1778. Source: [3]. . . . .</i>	12
2.7	<i>Titled: Map of India. This is a modern political map of India. Disputed regions have been shown as parts of India. Source: [21]. . . . .</i>	13
2.8	<i>Titled: Google map. This map shows the location around the author's university campus shown in figure 3.1. Source: [17]. . . . .</i>	13
2.9	<i>Titled: Satellite map. This map shows satellite image of the same location as seen in figure 2.8. Source: [17]. . . . .</i>	14
2.10	<i>Titled: Hybrid map. This map shows information of both figure 2.8 and figure 2.9. Source: [17]. . . . .</i>	15
2.11	<i>Titled: Ch'onhodo: 'All Under Heaven'. This map from the year 1800 maintains China at the center of the known universe and shows both real and mythical places. Source: [3]. . . . .</i>	16
2.12	<i>Sketch map of a portion of the university campus of the author. . . . .</i>	16
2.13	<i>An excerpt from ConceptNets semantic network of commonsense knowledge. Compound (as opposed to simple) concepts are represented in semi-structured English by composing a verb (e.g. drink) with a noun phrase (coffee) or a prepositional phrase (in morning). . . . .</i>	19
3.1	<i>A small portion of the campus map of the author's campus. . . . .</i>	27
4.1	<i>Function <math>f(y) = \frac{1}{2+y}</math>. . . . .</i>	40
4.2	<i>Temporal nearness of four landmarks at different times. . . . .</i>	41
4.3	<i>Conceptual nearness value of bombayGrill for different values of maximum number of hyponyms and maximum number of lemmas. . . . .</i>	42
4.4	<i>Conceptual nearness value of beckmanInstitute for different values of maximum number of hyponyms and maximum number of lemmas. . . . .</i>	42
4.5	<i>Old version of the program. . . . .</i>	44
4.6	<i>The map as displayed at time 9:30. . . . .</i>	45
4.7	<i>The map as displayed at time 9:40 am. . . . .</i>	46



# Chapter 1

## Introduction

### 1.1 Project motivation

In its true essence, ubiquitous computing is invisible, everywhere computing that does not live on a personal device of any sort, but is in the woodwork everywhere [45]. The initial incarnation of ubiquitous computing was in the form of “tabs”, “pads”, and “boards” built at Xerox PARC. This served as an inspiration for mobile computing and helped us shape our research question - what kind of maps would be suitable to display in a mobile device?

As the project evolved, we became convinced that a static map in a digital medium would offer little beyond existing traditional solutions. Furthermore, the display in mobile devices are typically small and traditional maps - digital or otherwise have been designed with no display area constraints in mind. To add oil to the fire, although many services in a mobile setting were taking advantage of sensor information that indicated a user’s context, there seemed no way to incorporate that information in maps.

Our innocent research question started becoming a complex web of interrelated questions and inadequately explored concepts. After a few months of literature survey and blind exploration of ideas, we decided to abandon our initial quest for maps on mobile devices and instead focus on the meat of the problem itself - **what is, if any, the theoretical foundation that decides what a map should look like?** This project is an attempt to answer that question.

In our investigations, we found out that a dynamic map that shows only those landmarks that are of concern to the user at any given time is perhaps the *right* kind of map to display. As will be explained in later sections and chapters, this requires careful thinking about what physical space means to animals and how one’s changing social and physical context alters one’s perception of what is important in a map.

The software that came out of the project wasn’t meant to be a full fledged end product so our efforts were focused on developing the framework for myMap rather than the visual interface. A better interface design and a future user study would definitely have been the next step were the project to continue longer.

## 1.2 Layout of thesis

myMap consists of three main components - context, commonsense and maps - which have traditionally been thought of as independent areas of research. This thesis paper is written to highlight the key research questions of each of these components and highlight links where they exist between these components.

This chapter describes the motivation for the project and provides pointers to related research serving as an introduction to the project. The next chapter, chapter 2, explores each of the components as independent entities and also explores their relationship with one another. With the addition of a section on cognitive maps, the chapter tries to outline a cognitive basis for the project.

Chapter 3 describes the theoretical contribution of this project. Novel reformulation of the concept of landmark is provided and a new concept, called nearness, is introduced in sections 3.1 and 3.2 respectively. Although not implemented in the project, a future research direction that incorporates reinforcement learning is discussed in section 3.3.

Chapter 4 describes the implementation of the ideas presented in the preceding chapter. The input data, the mechanisms for manipulating the input to generate the map and the final product of the project are described in this chapter. Screen shots of the running program and tables related to the implementation can be found in both chapter c4 and the appendix, chapter 6.

Finally, chapter 5 serves as a conclusion of the thesis outlining what we have achieved through this project. In lack of a user study, we also provide anecdotal user comments in section 5.1.

## 1.3 Related Work

As outlined in the previous sections, myMap consists of three main components - context, commonsense and map. As of this writing the author is not aware of any other project that attempts to integrate all three components. In this section, we will discuss a few projects that incorporate some parts of one or more of these components.

Context, which is the subject of a more detailed analysis in section 2.4.2, is pervasively present in most modern day computing applications in one form or another. Applications like self-locking cars have enjoyed certain commercial success but majority of context aware applications remain mostly in the laboratories.

Capturing and maintaining context is the main research agenda of most context aware computing projects. Most systems capture current context partly from sensors, partly from existing information (dairies, to-do lists, weather forecasts etc.), partly perhaps from user models and task models, partly from the state of the user's computing equipment and the user's interaction with the equipment, and partly from explicit

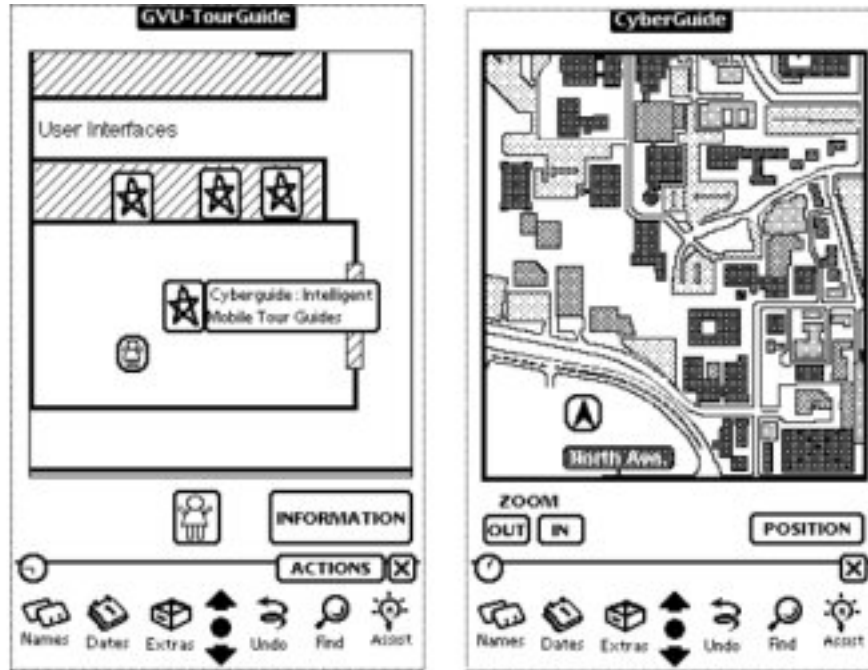


Figure 1.1: *Two different versions of the map of Cyberguide by Abowd et. al, [1].*

settings by the user [6]. Once context is thus captured, it is exploited to create applications that are responsive to their environments. One of the early context aware application involved PARCTab, a mobile device that used infrared-based cellular network for communications [40]. This early application spurred a lot of interest in context aware systems for mobile computers.

Dey et al. describe CybreMinder, a prototype context-aware tool that support users in sending and receiving reminders that can be associated to richly described situations involving time, places and more sophisticated pieces of context [11]. Seiwiorek et al. describe SenSay, a context-aware mobile phone that adapts to dynamically changing environmental and physiological states [42]. Ho et al. describe a context aware mobile computing device that automatically detects postural and ambulatory activity transitions in real time using wireless accelerometers [20]. These and other approaches to context aware mobile computing make heavy reliance in sensors. For example, SenSay employs accelerometers, light sensors and microphone to capture context and uses that to manipulate ringer volume, make call suggestions when user is idle or provide the caller feedback on the current status of the SenSay user.

Burrell et. al implemented a location-sensitive college campus tour guide called Campus Aware that allows users to annotate physical spaces with text notes [7]. Similarly, Abowd et. al describe Cyberguide, a mobile context-aware tool guide that uses the user’s current location, history of past location to provide services that “we (have) come to expect from a real tour guide” [1]. Both of these systems use location/time



Figure 1.2: *GloBuddy*, a translation tool that uses commonsense by Lieberman et. al, [25].

context to overlay relevant information in a digital map. A more general survey of context-aware mobile computing is done by Abowd et al. [2] and Chen et al. [8].

In addition to end-user context aware systems, a lot of research has been done to make frameworks that support context aware computing. Harter et al. describe a sensor-driven platform for context-aware computing that enables applications to follow mobile users as they move around a building [19]. *a CAPpella* is a programming by demonstration context aware prototyping environment intended for end users [10]. ContextPhone is a prototyping platform for context aware mobile application that aims to provide context as a resource to existing applications [36]. Chen et al. describe an ontology for context aware pervasive computing environments [9]. The ontology is called CoBrA (context broker architecture) and it models the basic concepts of people, agents, places and presentation events in an intelligent meeting room environment.

Although the number of context aware projects seems to be rapidly increasing, questions remain about their usefulness. Oulasvirta posits that there are only few successful applications of context-adapted HCI, arguably because use scenarios have not been based on holistic understanding of the society, users and use situations [35]. Barkhuus et al. show that users feel less in control when using either passive or active context-aware applications than when personalizing their own applications [4]. Both authors discuss possible scenarios where this perceived burden of context aware computing could be overcome.

There are a lot of projects in the field of artificial intelligence that incorporate commonsense knowledge

in some way. As will be detailed in section 2.3, myMap uses ConceptNet as its commonsense resource. A typical usage of ConceptNet is demonstrated by Lieberman et. al in the implementation of GloBuddy [25]. GloBuddy is a translation tool in a mobile device that allows “them to understand the semantic context of situations and statements, and then act on this information”. Liu et. al use the OMCS (Open Mind Commonsense) database to automatically generate a model of a person’s attitudes from an automated analysis of a corpus of personal texts written by the person being modeled [26]. They discuss the theoretical and pragmatic implications of such research to intelligent user interface design. Singh et. al describe LifeNet, a common sense knowledge base that captures a first-person model of human experience in terms of a prepositional representation [44].

Of the projects described above, Campus Aware and Cyberguide make use of maps in mobile settings. There are many other specialized tools that use map in one form or other. Some new tools that use maps as a substrate are popularly known as “map-mashups” and are detailed in section 2.4.

# Chapter 2

## Cognitive basis

### 2.1 Animal navigation and cognition

Humans, like other mobile animals, must learn something about the layout of their environments in order to reliably locate food sites and other important resources, return home, or migrate between known locations. Navigation strategies may be classified in terms of the demands they place on memory storage and cognitive processing, independent of their implementation in a particular agent [15]. In the literature on psychology and neuroscience, following navigation strategies have been identified:

1. Guidance. Guidance is the most basic navigation strategy in which the agent successfully travels in relation to a perceptible beacon.
2. Landmark navigation. This navigation strategy requires the ability to remember particular objects in the environment or vistas of a scene. The agent navigates by orienting itself to such objects or scenes.
3. Path integration. Path integration is also called dead reckoning and requires the agent to remember a “homing vector” so that by continually moving in the direction of the vector, the agent can move towards its target. (The target is often home, hence the term homing vector.)
4. Route based navigation. This navigation strategy involves remembering specific sequences of *positions*, which may be defined as sequences of landmarks, junctions, vistas, homing vectors, turns and so on. The agent follows the exact sequence of positions to arrive at its target. If a landmark or other information is removed from such a sequence, the agent is lost.
5. Map based navigation. This navigation strategy involves remembering some form of survey knowledge of the environmental layout. The agent uses the underlying geometry of a map to navigate in a complex environment.

The above list should not be treated as mutually exclusive or exhaustive. Most animals use a combination of strategies for navigation. Animals such as desert ants, honeybees, geese etc. often rely both on path

integration and route based approaches. Humans have at least two distinct navigational strategies available to them - landmark based and map based strategies - and can switch adaptively between them [15]. Humans generally rely on accurate landmark-based navigation, but can fall back on *survey knowledge* if landmarks are absent or are perceived as unreliable. The TOUR model by Kuipers is intended to capture the multiple representations that make up the cognitive map, the problem-solving strategies it uses and the mechanisms for assimilating new information (in the map) [23].

### 2.1.1 Landmarks

Each animal needs a consistent way of identifying and organizing sensory cues from the environment - identifying places and objects that possess threat to its existence or remembering locations that has food in it. For humans, the environment is usually a complex urban setting. In the process of way-finding each individual holds a mental picture of the exterior physical world, a mental image [28], that helps her navigate through complex urban environments. Landmarks can be thought of as the components of such a mental image - places that have meaning to the individual in the map. More generally, landmarks consist of those features of the physical environment that have some potential value to an agent.

Using the terminology in *The society of Mind* by Minsky, each landmark can be thought of as being stored in a frame. A collection of such frames is called a frame array. “We represent directions and places by attaching them to a special set of pronome-like agents called direction nemes [33].” When we move in space, these direction nemes are activated such that they update the internal frame arrays that describe the external landmarks.

The word landmark is used slightly differently in this project and is explained in more detail in section 3.1.

### 2.1.2 Cognitive maps

The map based navigation strategy requires acquiring some sort of *survey knowledge* of the environmental layout. From our perspective, two questions are relevant:

1. How is this *survey knowledge* built?
2. What is the nature of this *survey knowledge*? More specifically what is the representation that is used for the storage and cognitive processing of such knowledge?

In humans the *survey knowledge* is build from (i) visual information (such as optic flow) about topographical knowledge and (ii) path integration. Topographical knowledge is thought to comprise information about

both landmarks and spatial relations between landmarks [30] and the processing involved in understanding it is too complex to go into detail here. Path integration involves the estimation of one's position within an external frame of reference by integrating information about one's linear and angular velocity or one's linear and angular acceleration (inertial navigation) to determine the distances and angles traversed, or by measuring them directly (dead reckoning) [15].

It is not entirely clear how the *survey knowledge* is encoded for cognitive processing and storage in humans but there are indications that survey knowledge might be stored in Minsky's frame-like structures. Frames represent what we call landmarks and our query on how *survey knowledge* is built and stored leads us to ask two more related questions:

1. How many and what type of landmarks should the agent remember?
2. How should the geometric properties of the landmarks and the spaces between them be remembered?

No conclusive answers have yet been found to these questions although progress is being made both in psychology and neuroimaging. The brain areas that support navigation in humans (and animals) have been linked to allocentric (world-centered) representation of locations in the physical world. These allocentric representation of locations, also called cognitive maps, are related to spatially tuned neurons in the hippocampal regions of the brain [29].

The term *cognitive map* was first coined by Tolman, who defined it as a representation of the environment which indicated the routes, paths and environmental relationships that an animal uses in making decisions about where to move. Although the anecdotal reports - of rats escaping from mazes and running directly to the goal - that convinced Tolman that rats had cognitive maps were later discredited, other researchers have maintained that some animals possess cognitive maps. A very good summary of differing views on cognitive maps can be found in Bennett's paper on cognitive maps [5].

### **2.1.3 What aspects of maps are important?**

The importance of landmarks and navigation strategy in the cognitive abilities of animals provides valuable insights on how maps should be designed:

1. A map should be landmark based meaning it should display those locations and objects that are useful to a user.
2. The map should match, as closely as possible, the cognitive map of the user. The better the match, the less cognitive stress it puts on the user in interpreting it.





Figure 2.1: Titled: Rock art - map. *Redrawing of the oldest known plan of an inhabited site, Bedolina, Val Camonica, Italy, circa 1200 BC* Source: [3].

3. Certain aspects of the physical world, for example the direction between different landmark, should be preserved in a map since navigation strategies as path integration rely on accurate homing vectors.

## 2.2 Overview of maps

According to the definition formulated in 1987 by the late Brian Harley and David Woodward, “maps are graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes, or events in the human world” [3]. In this section, we will visually explore a few maps and draw some lessons on what should be included in myMap.

### 2.2.1 Maps before the age of technology

As soon as humans learnt to scribble things in stones, they started drawing their surroundings in some detail as shown in figure 2.1. These “rock art” have been interpreted variously and some even doubt that the fields, springs and interconnecting paths represented an actual landscape [3].

If we assume that these maps were drawn as representation of the physical, cultural or social landscape of a place, then they exhibit some interesting characteristics. First, these maps include animals, humans and non-animate objects in the same map. For example in the figure 2.2 we can see animals as deers and dogs,



Figure 2.2: Titled: Diwali celebrations at the royal palace at Kotah, Rajasthan. *This map and many others like it were commissioned by kings for decorative, commemorative and utilitarian purposes, circa 1600* Source: [3].

royalty and the common folks, trees and garden and building and roads. Although drawn in an awkward perspective, both figure 2.1 and figure 2.2 are drawn in so simple a manner that any novice user can look at the map and understand important aspects of the landscape.

These maps from the past try to convey more than just location information - with one glance at these maps, the user can infer social relations, agricultural behavior etc. of the actors being depicted in the map. Moreover, with maps like those shown in figure 2.3 and figure 2.4, the authors of the map are not making objective, quantifiable statements but are trying to portray their subjective feeling towards locations and people.

## 2.2.2 Maps in the age of technology

As societies got more organized into city-states, more and more effort was put into demarcating physical space. With the wave of colonization, the need for accurate maps for taxation, for battle planning and navigation grew stronger. Figure 2.5 shows the map of India produced by the British empire in preparation of colonization, figure 2.6 shows India after colonization and figure 2.7 shows India after the British left. Accurate political map in modern times, it seems, are a by product of wars.

However, in this project we are concerned not with political maps of the world but with local maps -



Figure 2.3: Titled: Africa. *The Africa shown in this map forms a part of an eclectic world map from India, circa 1700.* Source: [3].

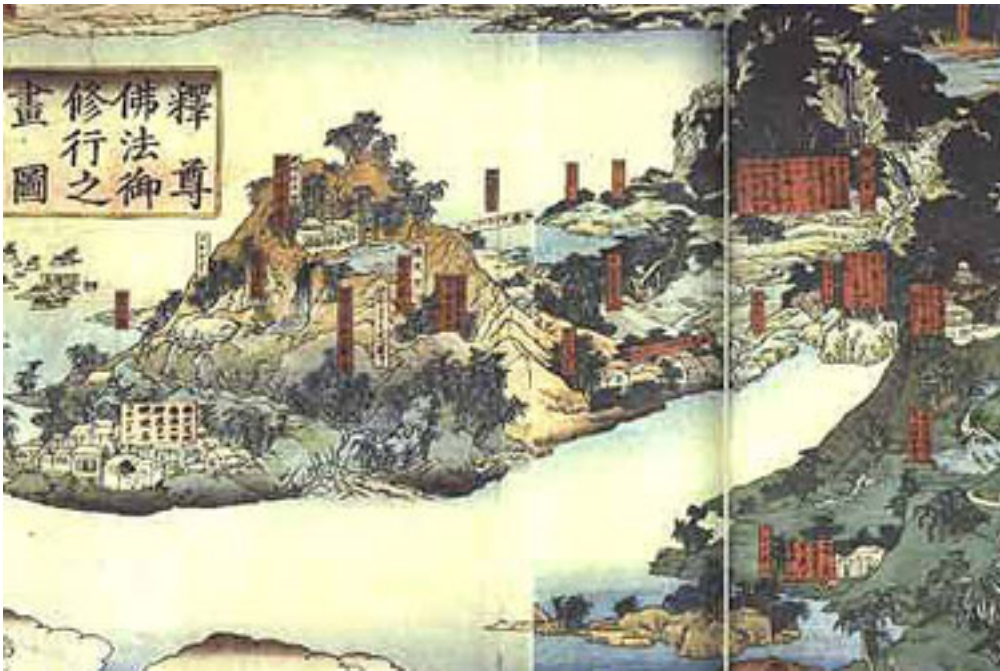


Figure 2.4: Titled: Panoramic Map of Buddhist India. *This is a map drawn by Hashimoto Sadahide in 1860 depicting his conception of India* Source: [39].



Figure 2.5: Titled: A description of East India. *This is a map drawn by William Baffin and Thomas Roe of the Mughal empire in India, circa 1600* Source: [3].



Figure 2.6: Titled: Hindoostan. *This is a map of India drawn by James Rennell for East India Company, 1778.* Source: [3].



Figure 2.7: Titled: Map of India. *This is a modern political map of India. Disputed regions have been shown as parts of India.* Source: [21].



Figure 2.8: Titled: Google map. *This map shows the location around the author's university campus shown in figure 3.1.* Source: [17].



Figure 2.9: Titled: Satellite map. *This map shows satellite image of the same location as seen in figure 2.8.* Source: [17].

maps that might cater to the needs of an individual. Figure 2.8 shows a popular online digital map from Google [17]. The map is highly accurate and many “mashups”, a term to be described in later chapters, use it as a substrate. A satellite image of the same location is shown in figure 2.9 and a hybrid version is shown in figure 2.10.

Although highly accurate, the digital maps as shown in figure 2.8 lack a few key features that old maps provide:

- They do not have location specific information. Because most digital maps are often used for navigational purposes, they don’t show much else than roads. Since most cities are structured in a grid-like structure, their digital maps end up looking featureless rectangular grid.
- Landmarks, historical or otherwise are absent in modern maps. As discussed in the earlier section on cognitive maps, landmarks play a crucial role in navigation - but digital maps, despite posing purely as navigational maps, don’t have them.
- People, animals, trees etc. are missing in the landmark. One could argue that the hybrid map of figure 2.10 does have greenery and roads shown at the same time, the old maps do a much better job of showing social information in maps. In fact, if we treat maps as being representations of physical spaces, the hybrid map doesn’t count as a map. If definitely is a high tech picture with overlaid roads,

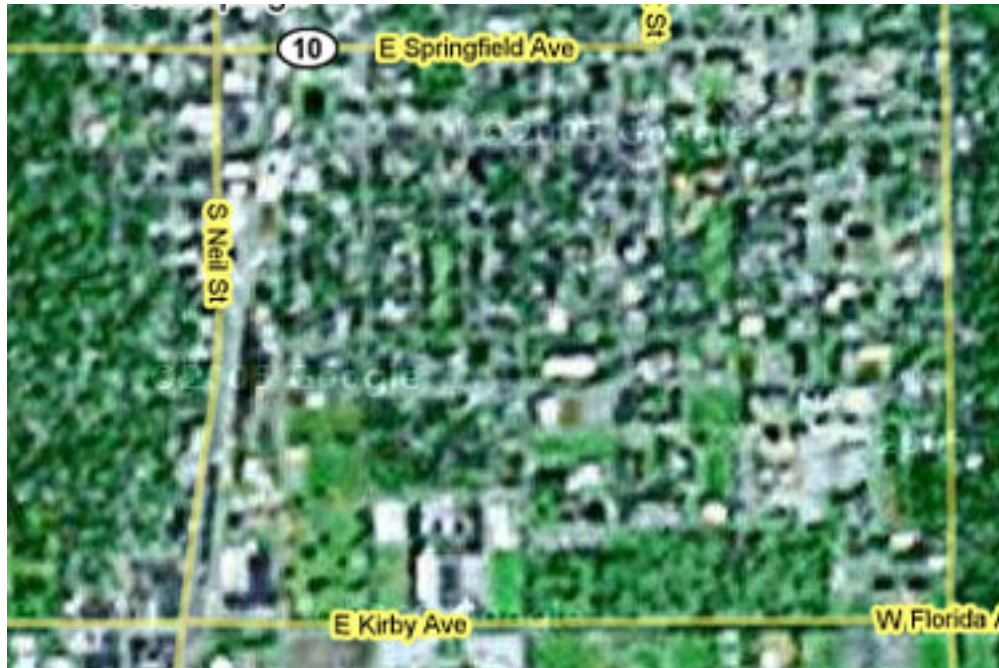


Figure 2.10: Titled: Hybrid map. *This map shows information of both figure 2.8 and figure 2.9.* Source: [17].

but not a map.

The section on landmarks, section 3.1 details the components of the map of this project.

### 2.2.3 Sketch maps

If landmarks are represented as frames in our mind and the directions are represented by direction names, what kind of maps would most closely match our cognitive maps? Figure 2.11 shows a Nineteenth century Korean map that shows real and imaginary places as encircled text. One of the text represents the “Land of the white people” and another represents “Land of Japan” and yet another “Land of refined elegant ladies”. Based on both mythology and facts, this map is “accurate” only by a large stretch of imagination. However, its scientific inaccuracy should not be equated with its usefulness. (After all, it would indeed be nice to have a “Land of refined elegant ladies” in any map!)

Sketch maps like those shown in figure 2.12 or figure 2.11 which fail to pass the scientific accuracy test can still be useful if they pass the following criteria:

- The shape of the landmark, whether it be a photorealistic painting or a text with a circle around it, is important to the user to the extent that the user is able to form a mental model of the object it is trying to portray.

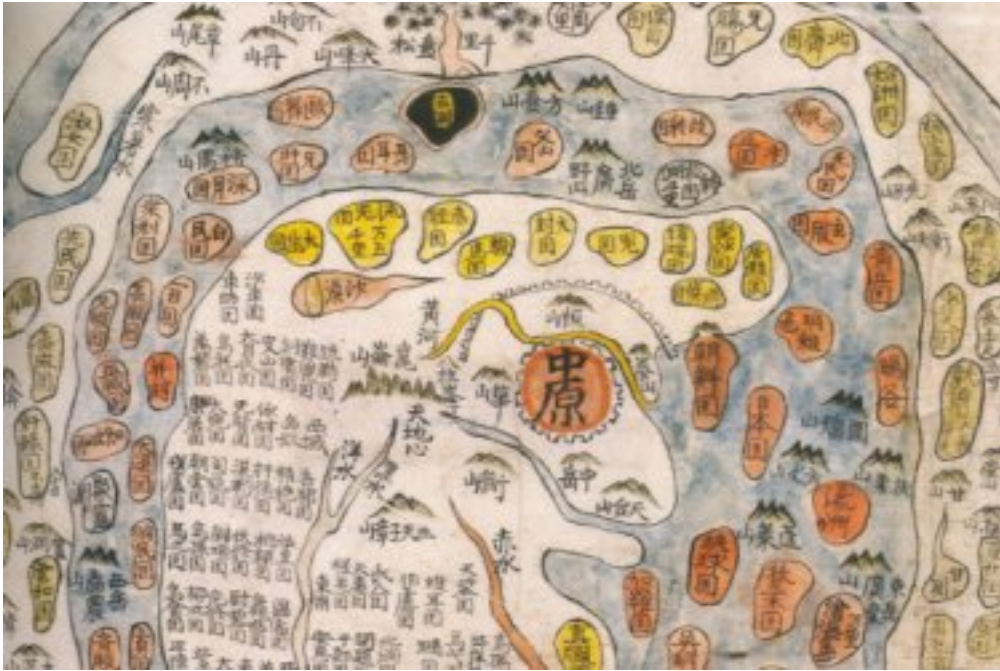


Figure 2.11: Titled: Ch'onhodo: 'All Under Heaven'. This map from the year 1800 maintains China at the center of the known universe and shows both real and mythical places. Source: [3].



Figure 2.12: Sketch map of a portion of the university campus of the author.



- The direction of a landmark with respect to another is more important to be displayed accurately than the distance between them.
- There are certain landmarks that are universally recognized by a large group of people and inclusion of them helps in sketch maps.

As a form of representation of maps, sketches play an important part to emphasize certain aspects of the landscape and deemphasize others. A central concept for cognitively adequate representations of environmental knowledge is that of a schematic map [22]. In this project, we look at how sketch maps can be used to intentionally simplify complex landscapes and reduce them into collection of landmarks that can be displayed in a map. It is our hope that such maps will put less cognitive load in the user than traditional maps while delivering richer content to the user.

## 2.3 Commonsense

“Common sense is the collection of prejudices acquired by age eighteen.” - Albert Einstein

The word commonsense is often thought of as sound judgement that is not based on specialized knowledge. It is commonly assumed that as people grow older, they accumulate myriad of facts, called commonsense facts, that allows them to perform some sort of default reasoning. In this section, we will investigate commonsense in detail as it relates to myMap.

### 2.3.1 Overview of commonsense

*We can get soup in a Chinese restaurant. A gym is a place where people go to exercise. There are computers in an office. Children play in parks.*

Each of the short sentences in the last paragraph is presented as a fact - and yet, in a strictly mathematical sense, none of them qualifies as a fact. We may not get soup in a Chinese restaurant and some offices do not have computers in them. To assert that we get soup in a Chinese restaurant as a mathematical fact, we need to define what soup is and what eateries qualify as Chinese restaurants. Unless we strictly define millions of other facts, the sentences presented above can never be treated as mathematically true.

A positivist outlook of the world requires that sentences like those presented above be objective and quantitative in nature allowing for precise mathematical manipulation. In contrast, phenomenological theories are subjective and quantitative in orientation. Phenomenology turns analytic attention away from the idea of a stable external world that is unproblematically recognized by all, and towards the idea that

the world, as we perceive it, is essentially a consensus of interpretation [12]. Thus, if all of the people I know agree that a certain restaurant is a Chinese restaurant and if all believe that one can get soup in that restaurant, then the sentence “we can get soup in a Chinese restaurant” can be treated as a useful fact.

There are a lot of other facts as the ones presented above that are universally treated as true - a consensus of interpretation, if you will - that are collectively called commonsense facts. Minsky in his book *The Society of Mind* suggests that as we grow older, we learn generalized facts about the world around us [33] and learn to use them for default reasoning tasks [37]. A more in-depth analysis of these commonsense facts can be found in Minsky’s new book *The Emotion Machine* [34]. Commonsense facts are rarely without exceptions and can often be wrong but their usefulness (and what interests us most) stems from the fact that they represent a consensus of interpretation among a large number of social actors. Below, we introduce two commonsense related projects, ConceptNet and WordNet, that are used in myMap.

A lot of research has been done under the commonsense umbrella. One of the earliest papers in the field was written by McCarthy [31]. Douglas Lenat’s Cyc was the first large-scale attempt to catalog and codify commonsense knowledge [24]. The Cyc project tries to formalize commonsense knowledge into logical sentences so that (variations of) predicate logic can be used to *reason* about the world around us. Each commonsense fact is entered by individual experts in unambiguous logical formulations in a specialized language called cycL.

In contrast to hard-coding commonsense knowledge in predicate logic by experts, the Open Mind Commonsense (OMCS) database collects commonsense facts from the general public [43]. Internet users with no special training can enter a commonsense fact in the OMCS web page in natural language (or alternatively using a fill-in-the blank approach). The OMCS database is then mined for commonly occurring concepts to form a semantic network of commonsense knowledge called ConceptNet [27]. ConceptNet is provided as a freely downloadable package with interfaces for language as Java.

ConceptNet has a network structure with concepts as nodes and various relations as edges between nodes. Each concept could be a single noun or a noun phrase and the relations between concept nodes are grouped under various thematic. The *LocationOf* relation between two concepts for example illustrates the spatial relationship between two concepts.

In addition to ConceptNet, another relational semantic network called WordNet is used for this project. WordNet is a lexical reference system whose design is inspired by current psycholinguistic theories of human lexical memory [32]. English nouns, verbs, adjectives and adverbs are organized into synonym sets, each representing one underlying lexical concept. Different relations link the synonym sets. WordNet’s repertoire of semantic relations consists of triplet of “synonym”, “is-a” and “part-of” relations. As in ConceptNet,

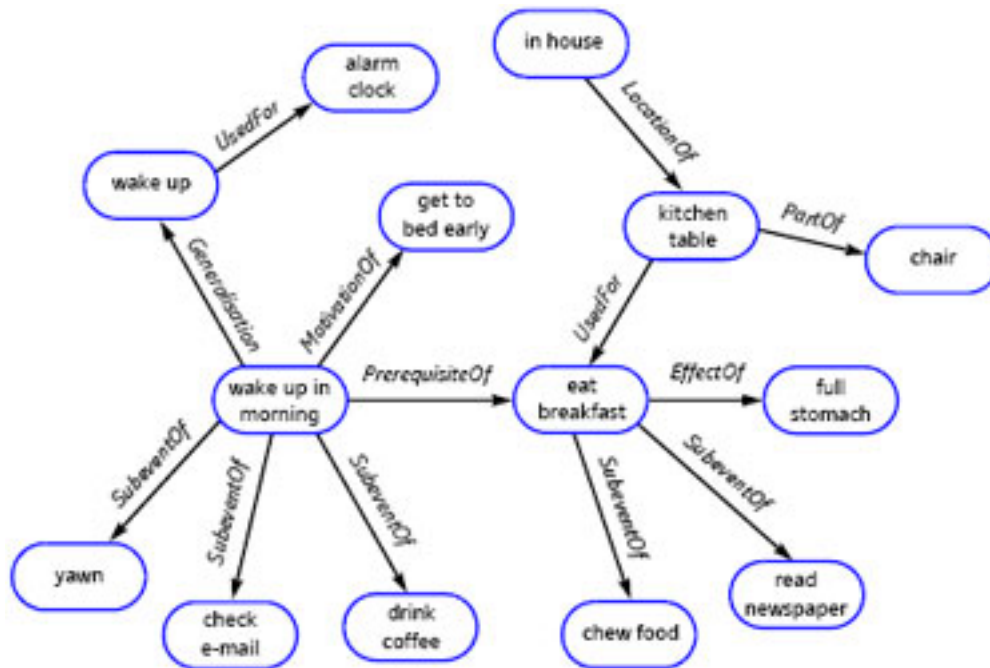


Figure 2.13: An excerpt from ConceptNets semantic network of commonsense knowledge. Compound (as opposed to simple) concepts are represented in semi-structured English by composing a verb (e.g. drink) with a noun phrase (coffee) or a prepositional phrase (in morning).

noun phrases are represented as nodes in WordNet but unlike ConceptNet, the relations between the nodes are optimized for word similarity determination.

### 2.3.2 Commonsense knowledge for maps

As discussed in the cognitive maps section earlier, we don't yet have a clear understanding of how places and things are represented in our brains. Although it is not yet proven, it is plausible that all humans share some basic "vocabulary" that describes our interactions with spatial entities. It is also possible that different individuals represent spatial entities with similar language - based on the entities' form, function or location.

It is thus likely that two city dwellers will describe a public park in similar language. The individual words they use will be different but the overall intent would be the same. Both would probably include major descriptions of a park - that it has trees, benches and green grass - and minor descriptions are likely to vary widely. In fact, the majority of the common elements in their description would be what we commonly refer to as commonsense facts about a public park.

Landmarks are described in more detail in section 3.1 but in short, we can treat each building, park etc. in a map as a landmark. Given commonsense facts about various landmarks and some natural language description of a previously uncategorized landmark, we can categorize new landmarks as being a building,

park, office etc. This process allows for automatically assigning a landmark to be in categories like restaurant or library or park etc.

Additionally, the commonsense approach to map allows us to infer relationships between different landmarks and calculate conceptual nearness between landmarks. For example, a Chinese restaurant is conceptually nearer to a burger drive-through than it is to a children’s playground because a Chinese restaurant is functionally similar to a burger drive-through. Conceptual nearness is discussed in more detail in section 3.2.2.

### **2.3.3 Inherent inaccuracy**

We almost never find rules that have no exceptions and commonsense knowledge, being a large set of generalized rules itself is no exception. The commonsense fact that “birds can fly” is useful only when the bird in question is not a penguin or an ostrich and is alive, has functional wings, is not confined in a cage, doesn’t have its feet stuck in cement, or has undergone no dreadful experience that has rendered it psychologically incapable of flight [33]. Any system that uses commonsense facts, including humans, must take into account this issue of inherent inaccuracy of commonsense knowledge.

Continuing our example of Chinese restaurants and soup, it is possible that there exists a Chinese restaurant somewhere that indeed doesn’t serve any soup. However this shouldn’t prevent us from using the commonsense fact that “we can get soup in a Chinese restaurant.” If we had only a limited number of commonsense facts about each landmark, then the inaccuracy inherent in them could adversely affect our calculations. However, when large numbers of facts are involved, the exceptions don’t play a significant part in the final result.

Another source of inaccuracy arises from inaccurate input description of landmarks. As detailed in section 3.2.2, a few paragraphs of natural language text is collected for each landmark in the map from the internet. Some of the information in these texts might be factually wrong. Others might have disproportionate descriptions of particular features of the landmark instead of an overall description of the landmark. For example, suppose we have some text that purports to describe a gym - but instead of details about the facility, the majority of the text talks about a cafeteria inside the gym. In this scenario, each calculation that pertains to that gym is going to be heavily influenced by the description of the cafeteria. This source of error is much harder to trace and eradicate.

### 2.3.4 Speculations on personalized commonsense

Commonsense facts are generalized rules and most members of a society often share a wide variety of such facts. It is in fact these shared common beliefs that make many human enterprises as communication possible. However, each individual with a unique learning history must have a unique sense of what counts as commonsense knowledge. How can a map application respect this individualized sense of commonsense?

Although myMap doesn't attempt to personalize commonsense, one approach would be to assign different confidence level to each commonsense fact and see if those match with the user's confidence level. This thought exercise is carried out in more detail in section 3.3.

## 2.4 Context

### 2.4.1 Maps as tools

*A saw is used to cut wood. A pen is good for writing. A thesaurus can help find synonyms.*

Each of the above tool could be used differently - it is possible to use a saw to cut meat or a thesaurus to find the meaning of a word - however, such usage will be inefficient at best. The form and function of any tool are closely related. The original design of a pen and subsequent re-designs has made it a superb tool for writing. For any other function, a pen is useless. Even tools like axe that have evolved through long periods of time work best in niche application domains. Thus, when we think about maps, we have to ask, "What is the function that a map as a tool serves"?

As discussed in the historical overview of maps in section 2.2, maps in modern times have primarily been used for navigational purposes. The task at hand is to find directions and the tools are maps. Road-centric maps like google maps [17] or those from the early twentieth century have been designed with navigation in mind. Hence, it is no accident that modern maps are limited in their usability outside the navigation domain.

myMap attempts to re-think maps. What functions can maps play in social settings and what forms would they need to take to fulfill those functions? What restrictions do medium of representation - a stone slab, a map-book, a desktop client or a mobile phone - present? How are static maps different than dynamic maps like myMap? Efforts to answer these questions will allow us to design better maps.

Our spatial behavior is a huge part of our identity. Each day, we choose to go to certain restaurants or certain parks or choose to walk one route over others. There are temporal patterns in our spatial behavior - one may be at a gym from 5 pm to 6 pm each Monday and Friday of the week. And there are anomalies in

our spatial behavior - once in a blue moon, we choose to go to see a movie or sleep over at a friend's place. A map as a tool would need to respect this identity that is part of each of us - our spatial identity.

As a personal tool, a map should help us better understand our own spatial identity and show us ways to diversify and augment it. If one so much loved Chinese food that they went to only Chinese restaurants during lunch, it would perhaps please the user if the map showed more Chinese restaurant locations. Or perhaps for a change, the user would be interested in trying some places that served something close to Chinese food. As another example, in a map aimed at children, parks and playgrounds would be nice to display; adult movie stores would be a bad idea.

As a social tool, a map should help us connect with the spatial identities of our friends and family and show us ways to expand our circle of influence. If one of our friends is in a coffee shop and if we are nearby, it should show the coffee shop in the map - perhaps, by accident we will chance upon this friend. The map should also display landmarks that our social circles frequent - they later can become important conversational topics. However, this sharing of social data should be respectful of the privacy issues involved.

There are many recent map-based applications that are popularly called "map-mashups" that try to address some of these issues. For example, Gawker Stalker is a google map mashup that shows celebrity location in real time [16]. Users can email the location of celebrity sightings to Gawker Stalker and the celebrity location is updated in an interface built upon google map. There are more map mashups than that can be listed here but a comprehensive list can be found at [googlemapsmania blog](#) [18].

Due to technical difficulties of building spatially accurate map in large scale, most of the mashups use an existing digital map as their substrate. This "feature" seriously constraints any creative re-thinking of maps. However, by not trying to show directions, celebrity sightings and rainfall data in the same map, mashups are a step in the right direction - they work as tools that are expected to solve particular problems.

myMap expands on this one-task approach of mashups to build a social map. Additionally, since myMap is a small-scale experiment, a proof of concept if you will, it is not limited by the constraint of having a digital map as its substrate. As described in section on sketch maps, section 2.2.3, and in the implementation chapter 4, myMap explores a new sketch-based substrate for the map.

We want myMap to be a map that respects and enhances our spatial identity. However, it is not entirely clear in what scenarios users will use such a map and to solve what kind of problems. If the relative success of map mashups is any indication, users do want to know more about their own and other people's spatial behavior. Also, many people are interested in discovering landmarks of interest that others have visited and likely to use a map like myMap both in the desktop and mobile setting.

## 2.4.2 User Context

*I drink tea early in the morning every day. Jane likes to go hiking on Sundays. If I go early, I can meet Mike at the gym.*

As alluded in the previous section, our spatial identity consists of our spatial, temporal and social behavior. However, to capture every spatial, temporal and social behavior of a human would be a monumental task - with methods unclear to isolate behaviors that would be useful for projects like myMap. Instead of trying to capture all sorts of behaviors, myMap focuses on some aspects of the spatial, temporal and social behavior useful for map creation/display. We will call these behaviors the context of the user. As will be explained in the next section, researchers in the field of context aware computing have used the word context very differently.

Everyday events can be visualized as sequences of activities done in different spatial, social or temporal settings. Spatial and temporal settings give rise to location/time context indicating where a particular user was at different times. Social setting comprises of a user's friends, family and social acquaintances and their location/time context comprises the social context of the user.

This simple formulation of a users' context is quite easy to capture. Mining the GPS location data of the user at different places can capture a user's location/time context. Mining the GPS location data of her friends, family and social acquaintances can capture her social context. In myMap, in the interest of time no actual GPS data have been collected - instead the user's location are hand-recorded with accurate time stamps and the location of the user's friends are simulated for various times.

The formulation of context as presented above perhaps seems simplistic if one were to look at it from a representational point of view. As a representational problem, the central concern with context is with the questions, "what is context and how can it be encoded?" [12]. The answer to both those questions is indeed answered poorly by the above formulation. However, we are not interested in context itself - we are interested in having an interactional model of context that treats context as an outcome rather than a premise to activities.

myMap is inspired by this alternative view of context put forward by Paul Dourish. Dourish [12] puts forward following four characteristics, which form the basis for our understanding of what context, entails:

1. Contextuality is a relational property. Instead of treating context as information, context should be treated as a property that holds between objects or activities.
2. The scope of contextuality is determined dynamically. We cannot establish context apart from or in advance of any activity.

3. Context is an occasioned property. Context is not stable but rather is particular to different settings, different instances of action and particular to parties to that action.
4. Context arises from the activity. Context is actively produced, maintained and enacted in the course of the activity at hand.

### 2.4.3 Context awareness in literature

Traditionally, context has been thought of from a positivist point of view with emphasis on accurately defining and encoding it. Positivist theories derive from rational, empirical, scientific traditions that seek to reduce complex observable phenomena to underlying idealized mathematical descriptions. Thus, it is not unusual to find context being defined as “location, identity, environment, and time” [38] without much regard to social actors and their activities.

Context in literature is often thought of as consisting of categories [41]:

1. Computing context, such as network connectivity, communication costs, nearby resources etc.
2. User context, such as the user’s profile, location, people nearby and social situations.
3. Physical context, such as temperature, noise levels, lighting etc.
4. Time context, such as time of a day, week, month, etc. [8].

Abowd et al., who perhaps provide one of the most popular definition of context in the literature define context as “any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves” [2]. This idea that context consists of a set of features of the environment surrounding generic activities and that it can be modeled, encoded and put into software underlies following four assumptions about context [12]:

1. Context is a form of information - it can be known, modeled, encoded etc.
2. Context is delineable - what counts as context is known prior to execution of activities that give rise to the context.
3. Context is stable - the determination of the relevance of any potential contextual element can be made once and for all.
4. Context and activity are separable - activities happen within contexts but the activities can be defined and described separately from the context in which they happen.



Context aware computing seems to have arisen in response to the rigidity of traditional interactive systems. Context is often used, as in the case of myMap, to dynamically tailor the behavior of the system in response to changing environments. However, by treating context as a representational problem, the positivist formulation of context is more concerned with modeling and encoding *context* than responding to immediate human needs. It is often assumed that most users of a context aware system will face consistent interactional problems, even after repeated usage. Moreover, as context is treated as a static property of the world divorced from all activities, it does not evolve. Most criticism of popular context aware systems is based on this positivist attitude towards context and is humorously illustrated by Thomas Erickson [14].

The alternative phenomenological formulation, which treats context as an interactional problem, puts the *human* element into context awareness. As described in the previous section, context depends on the system's interactions with the user and as will be discussed in section 3.3, there exist possibilities for evolution of context with user activities.

#### 2.4.4 Context awareness in maps

With the formulation of context as static properties of objects in the popular literature, it is hard to see how context can be directly incorporated into maps. Sensor data can perhaps be overlaid in a map - making its description richer over time - but this approach is as divorced from the user as are traditional maps. Given our formulation of context as a relational property with the representation itself consisting of nothing more than location/time data of the user and her social acquaintances, how can we re-think maps?

In the section 2.4.2, we said that context was actively produced, maintained and enacted in the course of activity at hand. When a user goes to a coffee shop at noon, for example, through her activity, she is producing "context" - her location/time data can now be treated as having some value in defining her spatial identity. Furthermore, if she goes to coffee shop every day at noon, this sustained activity produces another kind of "context" - one of the patterns in her spatial behavior, namely that she goes to a coffee shop around noon every day, is known. Context is not only produced and maintained but is also enacted in the course of an activity. We know that as the day passes, around noon, the user will enact the context that refers to her going to a coffee shop. A map capable of showing a user's spatial identity would display that coffee shop in some form around noon time.

myMap is a dynamic map, continually updated to reflect the user's past habits and hint possible future actions. As the location and/or time of the user changes, the map updates itself - hiding landmarks that are not relevant to current context and showing new ones that are. Details on how the map is updated can be found in the section about nearness in chapter 3.

# Chapter 3

## Map Components

### 3.1 Landmarks

As was discussed in the section on cognitive maps, humans (and animals) often use some locations as reference points during navigation or social interaction. These locations usually have some salient features associated with them that is universally recognized by a group of people. But more often the salience of a landscape is evaluated and used by each individual differently. In this chapter we give a tentative definition of landmark as they apply to maps and ponder on what (and how many) landmarks should be displayed in a map.

#### 3.1.1 What is a landmark?

A landmark is often defined as a prominent identifying feature of a landscape. When people talk about landmarks in general, they usually mean historical buildings or tourist destinations. We use the term landmark more loosely to refer to locations that has some significance to the user of myMap.

Figure 3.1 shows a part of a regular map of a university campus. Such maps are better designed than online road-based maps but still are crowded with buildings and roads - indiscriminately showing all buildings to all willing to look. If one were looking for a specific building, it would be almost impossible to spot it without looking at an index.

What would happen if we started with a regular map as shown above, and one by one removed all those buildings that the user has never been to, remove all those roads the user has never traveled and put in some locations that the user frequents, yet are absent in the map? We would invariably end up with a much less crowded map - a map that would display only those buildings, roads, parks, pathways etc. the user was concerned with. These would be our ideal landmarks - these are indeed the prominent identifying features of a complex landscape - as seen through the eyes of the map user.

Often, maps are used not to look at places we already know but to explore places that we would want to know. The crowdedness of a map is reduced by not showing any buildings that the user has never been

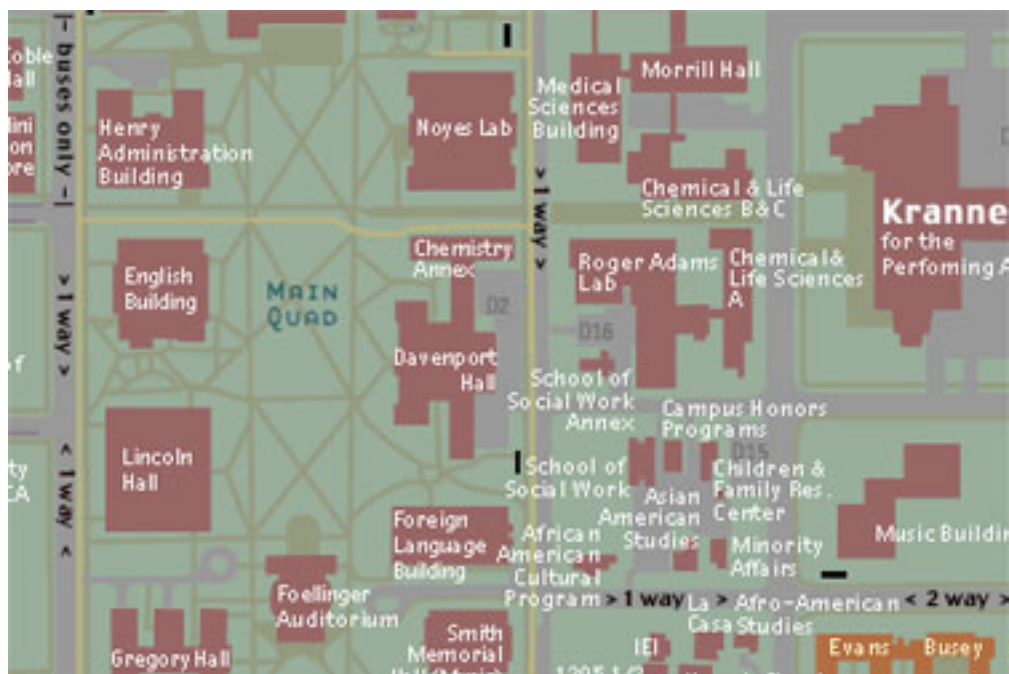


Figure 3.1: A small portion of the campus map of the author's campus.

to but in doing so, we also fail to impart any new information to the user. The usefulness of a building in a map is determined not only by whether a user has previously been there but also by whether she would want to be there in the future. Thus, our definition of landmark includes all those locations that a user has been to and also those that she would want to go to. In short, landmarks are those locations that are of interest to the user.

### 3.1.2 Personalized landmarks

Each of us travels different routes, are affiliated with different buildings and visit different places at different times. All of this data can be collected in an experimental scenario that has a user carrying a mobile GPS device capable of recording the location and time information throughout a period of time. A wealth of information can be found from GPS information as described by Eagle et. al [13] but since we are interested in only very basic location/time information, we don't make use of a GPS device. Instead, we hand-record the user's location at different times resulting in raw data as presented in sub section 6.1.1.

A week's worth of such data for the author is collected and is presented in the appendix. Equivalently, with more time, we could have used a GPS unit to get exactly the same data about the author's location at different times.

The list of landmarks that appear in such data is unique to particular users. Using concepts of nearness

as described in 3.2, we could find other landmarks that are related to this list. The original list of landmarks from the raw data and the related list of landmarks are personalized in the sense that they reflect the spatial identity of the user.

### 3.1.3 Universal landmarks

There are a few landmarks that are common to everybody how belongs to particular groups. For example, the computer science building will be known by most, if not all people who study computer science. We call these landmarks that are common to a large group of map users universal landmarks. Inclusion of such landmarks in a map helps different people from a group find a shared point of reference when talking about their personalized landmarks.

It should be noted that some universal landmarks are group specific. Thus, a history student might not know a computer science lab building and its inclusion in her map would serve no purpose. However, most people living in a locale share some landmarks that are popular destinations. In a university setting, for example, the quad or the student union building are often universal landmarks across a large number of people irrespective of the smaller groups they belong to.

### 3.1.4 Landmarks in maps

Given that current maps are crowded with too many buildings (or roads etc.), a natural question to ask is what can we do to reduce the crowdedness - which buildings do we keep, which buildings do we discard from the map? With our definition of landmarks as those locations that are relevant to the user, we can perhaps reduce the crowdedness of the maps by displaying only landmarks in the map.

However, the list of landmarks may itself be too large to display in a regular map. If a user has a list containing a hundred landmarks, then it is impossible to neatly display all these landmarks in a regular A4 size paper. We need some structured way to limit the number of landmarks displayed in any map.

Often, when humans draw sketch maps, the size of the maps and the number of landmarks in them depends greatly on the medium of representation. Thus, if the map is being drawn on a large black board, many landmarks can be put and if it is drawn on a dollar bill, only two or three landmarks make it to the map. For digital maps too, the medium of representation is important when deciding how many landmarks to display. In a desktop computer, perhaps five to ten landmarks, depending on the screen resolution may be comfortably displayed. In a mobile device with limited screen size, perhaps three to five landmarks could be displayed without the map being too crowded.

Finally, what exactly are the kind of landmarks we need to display in a map? Universal landmarks, as

a common reference point for a large group of people are useful to display in any map. Personalized list of landmarks should also be appropriately displayed in a map. In addition, as we discussed in the section in context, a map should display all those landmarks that are relevant to the user's context. Thus, if it is lunch time, then the user's context usually involves finding food. Restaurants of the type the user visits may be displayed in such scenarios.

### 3.1.5 Mining data about landmarks from the web

In a traditional map as shown in figure 3.1 all landmarks are represented with a polygonal shape and a name. The information inherent in these maps are inadequate for us to differentiate between a coffee shop and a fine arts theater except perhaps to infer functionality of a landmark from the rudimentary information that we can glean from the landmark's name. Thus, before we can display a restaurant in response to the user's context, we have to positively identify a landmark as a restaurant.

In a university campus setting, with limited number of landmarks, a viable approach to identifying landmarks is to manually tag them. Thus, a library building can be tagged with keywords like "books", "library", "study rooms" etc. A few map mashups called "geo-taggers" attempt to do exactly this - they overlay tagged location information on traditional digital map in the hope that searching for landmarks will be efficient.

While these attempts of tagging may work for a limited number of landmarks, it is virtually impossible to tag large number of landmarks manually. In an attempt to find an automated solution that allows for discerning between two landmarks reliably, we turn to the internet and its vast collection of location-specific information. However, location-specific information in the web, as much of the web itself, is unorganized - making it nearly impossible to organize landmarks in clear-cut categories. Landmark-specific text are found at multiple sites, often with conflicting information about the landmarks themselves, making the task of creating categories even trickier.

For this project, we look at about thirty landmarks and collect information about them from various sources with no particular regard to the accuracy or quality of the data. All of the information collected is written in natural language by various authors. For example, information for most restaurants are taken from restaurant reviews written by novice reviewers. Some of the descriptions of academic buildings was retrieved from Wikipedia and some were collected from notes from different department websites. Overall, the data collection process and the data itself reflect what one would typically get if one were to collect these data using an automated algorithm from the web.

The menu had typical Chinese and Thai dishes. I was curious about the almond chicken. They

also have some ho fun, pad Thai and noodle dishes. Yes, the curry chicken is there also. I will have to try that sometime. The place is bit pricey than Sing Ma. I guess they need few weeks to settle down. I would give it another try in a week or so.

The above paragraph shows a typical paragraph of data - the text describes a restaurant and is taken from a restaurant review done by a novice reviewer. As can be seen, the text collected from the web is highly unorganized and often it is hard to see what, if any, location specific information such text contains. However, even with unorganized text as above, we can find basic relationship between different landmarks as discussed in the next section.

## 3.2 Nearness - concepts and calculations

In a dynamically changing map, what are the landmarks that we should display? The previous section hinted that we should display universal landmarks and personalized landmarks that are relevant to the user's context. In this section, we will explore how we can reliably detect universal landmarks and find landmarks that are relevant to a user's context. We will see that the landmarks that are finally shown in the dynamic map are related to each other by the concept of "nearness".

Two landmarks are said to be "near" one another if

- They are spatially near to each other,
- They share the same functionality,
- They are visited by the user at around the same time or,
- They are visited by user's social circle.

Nearness is not a quality of a single landmark - it is instead the relationship that exists between two landmarks. The formulation of the concept of nearness allows us to put numerical values to the commonality between two landmarks in the spatial, conceptual, temporal and social dimensions. The next four sub sections describe the four types of nearness and the last two sections describe how the nearness calculated can be used to display relevant landmarks in a map.

### 3.2.1 Spatial nearness

Suppose a user who is at her office currently has a choice of going to one of four identical coffee shops in the mid-day afternoon. These coffee shops are located at a distance of fifty, hundred, five hundred and a

thousand feet away from the user’s office. All things being equal, the most likely coffee shop the user will end up going to is the one nearest to her office.

We can model the user’s behavior of going to the nearest coffee shop by introducing the concept of spatial nearness. The spatial nearness between two landmarks is inversely proportional to the Euclidean distance between those landmarks. Of course different users have different preferences resulting in different willingness to go to coffee shops that are farther away. Thus, a proportionality constant of  $\alpha$  is required to model this preference.

For two landmarks  $L_i$  and  $L_j$ , with spatial coordinates of  $(x_i, y_i)$  and  $(x_j, y_j)$ , we have spatial nearness  $S_{ij}$  as,

$$S_{ij} = \frac{\alpha_{ij}}{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}} \quad (3.1)$$

It should be noted that the constant  $\alpha$  doesn’t accurately model user preference over time since a user might be more willing to travel the distance if it was a nice day than if it was hot and humid. Modeling this user behavior is much more complex and is not attempted in this project.

### 3.2.2 Conceptual nearness

In the previous section, we put the user to the hard task of choosing between four identical coffee shops. In real life these tasks are even harder - coffee shops are rarely identical. Sure, all coffee shops sell coffee, perhaps most have some sitting spaces but similarities end there. Some are sparsely furnished large rooms with abstract art painted over walls - soft melodies and fresh smell of certain Jamaican herbs fill the air. Others overflow with aristocracy - leather couches, flower vases and heart shaped chocolate fudge decorate the interior.

However, even with these differences between coffee shops, a coffee shop is functionally much more similar to another coffee shop than it is to a jewelry store. All coffee shops serve some “commonsense” function like serving coffee. This can be modeled as conceptual nearness with the nearness between two landmarks being directly proportional to their functional similarity.

A priori, we do not know the function that any of the landmarks serve. What we have instead is some text written in natural language associated with each landmark. No guarantees are made about the accuracy and relevancy of such text - hence we should not expect to extract precise function for any landmark. Attempts to categorize the landmarks into clear cut groups as restaurants and parks are clearly futile.

In this context, we need a more robust way to find conceptual relationships between landmarks. The method needs to be accurate to the degree of being able to distinguish between functionally related and non-related landmarks. Since we are not attempting classification of landmarks, we do need to know predefined characteristics of landmarks. All we are interested in is knowing how similar one building is to another conceptually.

As an example, consider two landmarks and suppose that the text associated with both contains the word *chicken*. Just with one word, we are already able to draw some inferences about the relationship between these two landmarks - both are probably related to food. Direct match of keywords in text is a very straightforward way to gauge the relationship between two landmarks.

Care should be taken to not include commonly occurring words as *for*, *the* etc during matching. In this project, we only consider noun phrases for the direct match of keywords. However, each noun phrase itself can have multiple senses with cross-sense match providing us with ambiguous results. For example, the word *chicken* has four sense as a noun phrase - as *meat*, as *fowl*, as *a person who lacks confidence* and as *a foolhardy competitor*. Comparing across senses will result in noisy results. Fortunately, only the first or second sense of a word is often used in casual writing. For this project, we only look at the first sense of a noun phrase.

Direct keyword matches are hard to come by. But variations of a word are often used to describe similar things. For example, *roaster* and *chicken* describe almost the same thing. To account for cases as these, it will be fruitful to find synonyms and hyponyms of keywords.

A hyponym is a word whose extension is included within that of another word. For example, the first five hyponym of the word *chicken* are *broiler*, *capon*, *fryer*, *roaster* and *spatchcock*. A broiler is flesh of a small young chicken not over two and half pounds suitable for broiling. Similarly, a spatchcock is flesh of chicken split down the back and grilled.

We usually call the set of hyponyms of a word, as given in the example above, its first order inherited hyponym. If we were to find hyponyms of all the words in the first order inherited hyponym, then the resulting set would represent the second order inherited hyponym of the original word. For example, *roaster* is a hyponym of the word *chicken* and the noun phrase *oven stuffer* is a hyponym of the word *roaster*. Thus, the phrase *oven stuffer* would be an element in the second order inherited hyponym of the word *chicken*. Third order inherited hyponyms are similarly defined.

Given original text  $Text_j$  for landmark  $L_j$ , we can find out the sets of its noun phrases, the synonyms of the noun phrases and first, second and third order hyponyms. The chapter on implementation explains how this is exactly achieved using WordNet. The four sets are:



1. Noun phrases of text of landmark.

$$Set_j^1 = NounPhrase(Text_j) \quad (3.2)$$

2. Synonym set of the first set.

$$Set_j^2 = Synonym(Set_j^1) \quad (3.3)$$

3. First order hyponym of the first set.

$$Set_j^3 = Hyponym(Set_j^1) \quad (3.4)$$

4. Second and third order hyponym of the first set. To get the second order hyponym, we just get the hyponyms of the first order hyponym. To get both the second and third order hyponyms, we get the hyponym of both the first and second order hyponyms.

$$Set_j^4 = Hyponym(Set_j^3) \cup Hyponym(Hyponym(Set_j^3)) \quad (3.5)$$

The reason we create four distinct sets instead of lumping all keywords, their synonyms and hyponyms into one set and doing a comparison matching is we want to assign different weights to matches between different sets. If there is a direct match between the noun phrases of two landmarks, it is registered as having more influence than match between third order hyponyms of the landmarks.

Suppose we have two landmarks  $L_i$  and  $L_j$  then we can create  $Set_x^y$  where  $x = i$  or  $j$  and  $y = 1$  through 4 as described above. We will use values  $\beta_{ij}^y$  to weigh the number of matches between the set  $Set_i^y$  and  $Set_j^y$ . The value of conceptual nearness  $C_{ij}$  is then:

$$C_{ij} = \sum_{y=1}^4 \beta_{ij}^y * Size \left( Set_i^y \cap Set_j^y \right) \quad (3.6)$$

The match using keywords, synonyms and hyponyms still falls short of capturing the full location specific information about different landmarks. For example although the words *chicken* and *french fry* both

refer to food products, we will get no matches between these words or their synonyms or hyponyms. The commonsense fact that *chicken* and *french fry* both relate to locations as *restaurant* can be inferred from a commonsense database. As explained in the section on commonsense, the *LocationOf* relation in ConceptNet provides commonsense locations of different objects. For example, the *LocationOf* relation of the word *chicken* consists of *at dinner*, *at fast food restaurant*, *egg*, *in freezer*, *in oven*, *in pizza*. The *LocationOf* relation of the word *french fry* consists of *at fast food restaurant* and *in fast food restaurant*.

As can already be seen from the example in the last paragraph, the commonsense database doesn't have very robust *LocationOf* relation for every word. Moreover, some of the relations that are present are of little value - the "fact" that *chicken* can be found in an *egg* is not very useful, if not simply wrong.

Despite these shortcomings, a commonsense approach will definitely improve our conceptual nearness calculations. Thus, we further define these sets for landmark  $L_j$ .

$$Set_j^5 = LocationOf(Set_j^1) \tag{3.7}$$

$$Set_j^6 = LocationOf(Set_j^2) \tag{3.8}$$

$$Set_j^7 = LocationOf(Set_j^3) \tag{3.9}$$

$$Set_j^8 = LocationOf(Set_j^4) \tag{3.10}$$

Finally, we also assign  $\beta$  values to the match between these sets to obtain the final equation for calculating the conceptual nearness between two landmarks  $L_i$  and  $L_j$ :

$$C_{ij} = \sum_{y=1}^8 \beta_{ij}^y * Size(Set_i^y \cap Set_j^y) \tag{3.11}$$

### 3.2.3 Temporal nearness

We go to work in the morning, have lunch around lunch time and return home in the evening. Each of us has unique temporal patterns in our activities. In association to these activities, we visit different landmarks at different times. Although the exact times that we go to work in the morning varies, we can still make general observations like "I go to work around 9 in the morning".

If we knew, for example, that a user goes to landmark  $L_i$  at around 1 pm and to landmark  $L_j$  around 3 pm, we should display these two and other landmarks related to these in the map. In all likelihood, the user will follow her routine and a map that displays the places she is expected to be next is certainly helpful.

Landmarks that are visited within a time window, as in the example, are said to be temporally near to each other. If landmarks  $L_i$  and  $L_j$  are visited within a time window of 3 hours, then the temporal nearness between them is higher than if they were visited within a time window of 5 hours - the less the time difference between the visits of two landmarks, the greater the temporal nearness.

Temporal nearness in a sense is trying to predict the next landmark that will be visited by the user. It also takes into account where the user has recently been. By finding temporal nearness between landmarks, we are trying to model the evolving set of landmarks that are likely to be in a user's mental model at different times.

Suppose a user visits her office at 10 am, a coffee shop at 11 am and a library at 12 am. Although no empirical study has been done to find out how much importance the user assigns to going to the coffee shop versus going to the library, we make an assumption that the user assigns at least twice as much importance to going to the coffee shop than going to the library. That is, we assume that temporal nearness is an inverse function of the *difference in time* between the visits to the landmarks concerned. In the implementation section, we choose the following non-linear function:

$$f(y) = \frac{1}{2 + y} \quad (3.12)$$

Suppose the user visits the landmark  $L_j$  in a period of time, say a week, at times  $t_j^1, t_j^2 \dots t_j^x$  for a total of  $x$  times. Let the current time and current location of the user be  $curTime$  and  $L_i$  respectively. We can calculate the temporal nearness  $T_{ij}$  between landmark  $L_i$  and  $L_j$  at time  $curTime$  to be

$$T_{ij} = \max_y f(|curTime - t_j^y|) + \frac{\sum_{y=1}^x f(|curTime - t_j^y|)}{x} \quad (3.13)$$

The first term above makes sure that the nearest landmark is given more consideration than those farther away. Alternatively, we could have used weighting constants to weigh different time differences differently. More details on how the temporal nearness is calculated from the raw GPS data can be found in the chapter on implementation.

### 3.2.4 Social nearness

If a landmark is visited often by a friend or a family member then such landmark has some relevance to a user even if the user has never been there. If the user happens to be in the vicinity of the landmark where

her friend/family are currently located, then perhaps it is a good idea to show this landmark in a map.

A landmark  $L_j$  is said to be socially near another landmark  $L_i$  if at time  $curTime$  the user visits landmark  $L_i$  and a friend or family member of the user visits, has visited or is about to visit landmark  $L_j$ . Put another way, social nearness is temporal nearness not of the user but of her friends and family. Let  $T_{ij}^1, T_{ij}^2, \dots, T_{ij}^x$ , be the temporal nearness of  $x$  number of acquaintances of the user. The social nearness  $A_{ij}$  ( $A$  for acquaintances) between  $L_i$  and  $L_j$  is proportional to each of these temporal nearness values. However, each of these acquaintances will have different relationship with the user introducing the need for a weighing constant  $\gamma$ . Thus,

$$A_{ij} = \sum_{y=1}^x \gamma_y T_{ij}^y \quad (3.14)$$

In the interest of time, we simulate the GPS data for the acquaintances of the user without making attempt to determine its correctness.

### 3.2.5 Putting it all together

In the preceding sections we calculated the spatial, conceptual, temporal and social nearness between two landmarks  $L_i$  and  $L_j$  to be  $S_{ij}$ ,  $C_{ij}$ ,  $T_{ij}$  and  $A_{ij}$  respectively. One way to find total nearness  $N_{ij}$ , is just to add these nearness-es together using weights  $W$ :

$$N_{ij} = W_s S_{ij} + W_c C_{ij} + W_t T_{ij} + W_a A_{ij} \quad (3.15)$$

The weights  $W$  have to be determined experimentally so that the total nearness is not unfairly skewed by any of the nearness values. Alternatively, in some future version, it could be learned as described in the next section.

As described in the section on landmarks, the number of landmarks displayed in the map is dependent on the type of display. Suppose, the map displays  $x$  number of landmarks in total. Using the current time, temporal nearness values are calculated for each landmark with respect to the current landmark.  $x$  number of landmarks that have the highest temporal nearness values are chosen. With these landmarks as the basis, spatial, conceptual and social nearness are calculated for each landmark. Then,  $x$  number of landmarks that have the highest total nearness are chosen for display in the map.

### 3.2.6 Accuracy in calculations

The nearness calculated above will not be cent percent accurate. Spatial calculations will be accurate but rest of the nearness values will be approximations. Because of the very nature of conceptual nearness, there will be a lot of room for ambiguity as described in the section on conceptual nearness. Temporal nearness and social nearness will also be inaccurate because the GPS data collected might be inaccurate, the temporal function,  $f$ , might be inaccurate or the model we have used for social nearness might be incorrect.

Despite all these sources of inaccuracy, the calculation of nearness is necessary if we are to find the right landmarks to be displayed in a dynamic map. If the user is concerned with exclusion of a landmark, she can always choose to display more landmarks in the map, making it more likely the map that she expects to see will be displayed. Moreover, if due to some error a crucial landmark is not displayed, a user can consult the map in the background (please refer to the screenshot for details) that includes all landmarks.

## 3.3 Learning components

This section describes possible learning components that could improve on the accuracy of nearness calculations. The learning mechanisms presented in this section have been explored in the field of artificial intelligence but due to lack of time, they are not implemented in this project.

In the previous section, we performed nearness calculations that allowed us to display different landmarks in the map. However, there was no mechanism to check if the set of landmarks displayed in the map were useful to the user. We will assume that upon display of certain landmarks in the map, if the user consequently visits those landmarks then those landmarks were useful to the user.

Thus, algorithmically, we would want a system that would

1. Look at past behavior of the user and predict a set  $S$  of landmarks.
2. Look at current user behavior and see if the user goes to landmark  $L \in S$ . If yes, the predictions were correct. Increase the nearness values between  $L$  and landmarks in  $S$ . Otherwise, the predictions were incorrect so decrease the nearness values between  $L$  and landmarks in  $S$ .
3. Repeat steps 1 and 2 with the updated nearness values.

This method of giving rewards when predictions of a system are correct and discounting the predictions when they are wrong are generally studied under the umbrella of re-enforcement learning [37]. By adjusting the nearness value - either increasing them in the positive case or decreasing them in the negative case - we

are basically traversing an error landscape to find the minima. A gradient search method as neural network could be used for such a task.

Our final nearness function has four weight variables  $W$ :

$$N_{ij} = W_s S_{ij} + W_c C_{ij} + W_t T_{ij} + W_a A_{ij}$$

We can adjust these weights so that upon many iterations, the map “learns” the correct nearness values that will result in the set of landmarks that reflects user behavior.

# Chapter 4

## Implementation

This section explains the implementation of the framework developed in the previous chapter. Since we don't intend myMap to be an end user product, the visual interface still needs a lot of polishing. The map application is designed with couple of design requirements in mind:

1. Portability. The application should be portable across different computers and with a little bit of work across devices.
2. Fun. The application should be fun to use.
3. Lowered expectation of accuracy. A sketch-based map ensures that the user's expectation of spatial accuracy is lowered.
4. Dynamic update. With no zoom or scroll feature, the user can not navigate around the map - the idea is to have the map dynamically change in anticipation of user's scroll or zoom.

As input, we provide

1. The user's location information at different times. A sample of such information can be found in section 6.1.1.
2. One to three paragraph of natural language text about each landmark from the web. A sample of such information can be found in section 6.1.1.
3. Simulated data on the location of the user's acquaintances at different times. This data is similar to the one presented in 6.1.1.
4. Raw data on the location of different landmarks. An one time effort is needed to encode the relative location of all landmarks that will be used in the project. This data can be found in section 6.1.3.

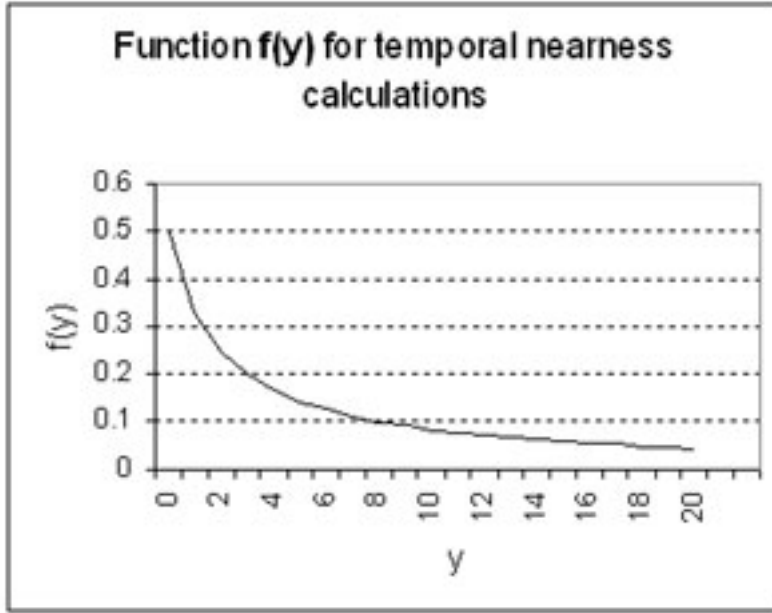


Figure 4.1: Function  $f(y) = \frac{1}{2+y}$ .

## 4.1 Implementation details

The general structure of the program can be found in section 6.2.1. First, temporal nearness is calculated using the user’s location data, a sample of which can be found in section 6.1. The function  $f$  has the following form as shown in figure 4.1.

If the user never visits a location within a time window, then the temporal nearness between that landmark and the current landmark is zero. The temporal nearness between the user’s current location and four landmarks - *beckmanInstitute*, *bombayGrill*, *DCL* and *goldenWok* - is shown in figure 4.2. One can easily notice the periodic visit to *DCL* and since *bombayGrill* is never visited, its temporal nearness with respect to all landmarks is zero. The calculations of temporal nearness is performed in the *MapObjects* and *ParseEvents* classes.

A limited number of landmarks that have the highest temporal nearness to the current landmark is selected for calculation of conceptual nearness values.

The calculation of conceptual nearness is described in section 3.2.2. First, the unstructured text of a landmark is parsed to find all noun phrases. The result is stored in the first set. WordNet is used to find the synonym, first, second and third order hyponyms. These results are stored in the second, third and fourth sets. OMCS database is then used to find the *LocationOf* relations of the first four sets, resulting in four new sets. An example of the content of the eight sets can be found in appendix section 6.2.2. The code for



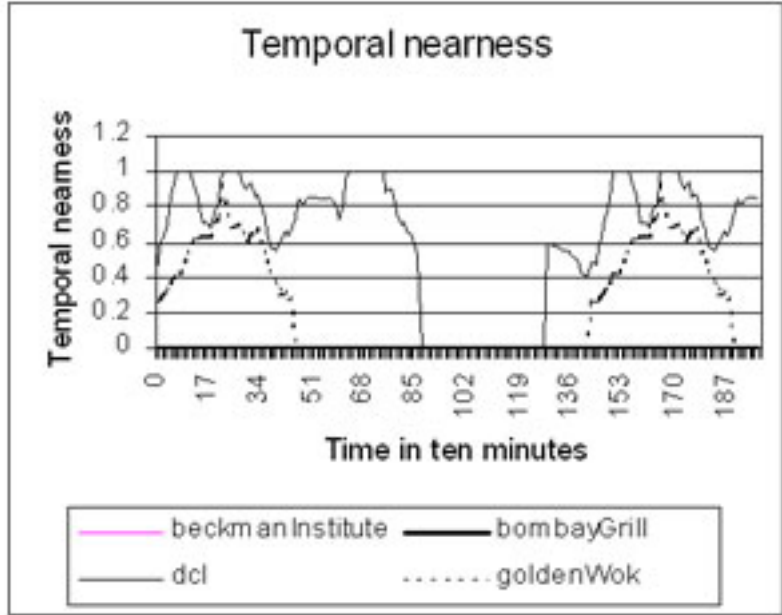


Figure 4.2: *Temporal nearness of four landmarks at different times.*

creating these eight lists is in class *ListCreator*.

Once these eight sets are created for each landmark, we compare identical-numbered sets of all landmarks to find out how many of the terms match. Thus, we compare the first set of a landmark with the first set of all landmarks, counting the number of direct keyword matches. The number of matches is then normalized such that

1. A landmark compared to itself - a case of conceptual nearness with itself - should return a one.
2. The number of keywords in the raw data should not heavily influence the number of matches.

A sample of the final conceptual nearness values is given in appendix section 6.2.2. The number of synonym and hyponyms generated from the first list determines the size of subsequent lists. However, as can be seen from figures 4.3 and 4.4, the number of hyponyms does not seem to make major difference in the value of conceptual nearness. The figures show the conceptual nearness of *bombayGrill* and *beckmanInstitute* with other landmarks for different values of the maximum number of hyponyms and maximum number of lemmas for each keyword. A lemma is a WordNet specific concept and refers to the hypernym of a hyponym.

Once all the nearness values have been added up to get the final nearness values as described in section 3.2.5, we display the landmarks with the highest nearness values. The number of landmarks that are finally displayed is dependent on the display type and can easily be changed. The displaying of the landmark is done by the GUI code base.

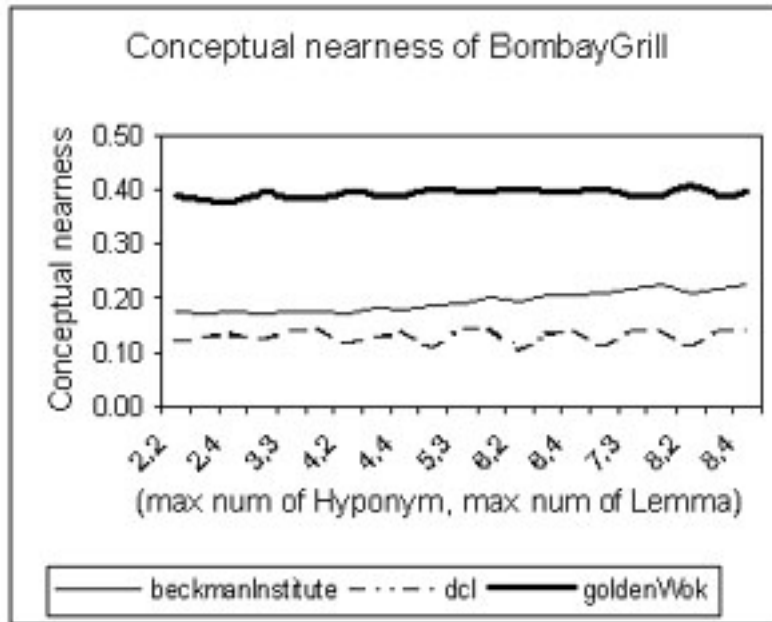


Figure 4.3: Conceptual nearness value of *bombayGrill* for different values of maximum number of hyponyms and maximum number of lemmas.

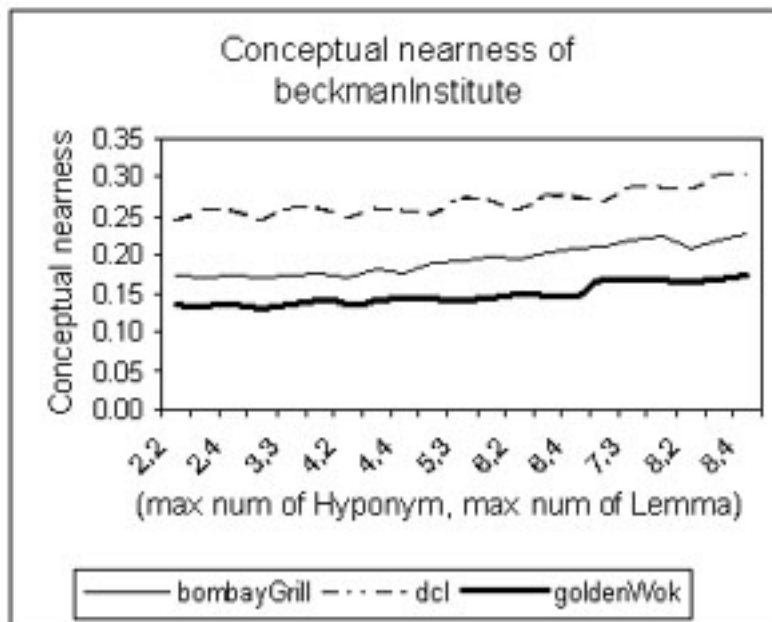


Figure 4.4: Conceptual nearness value of *beckmanInstitute* for different values of maximum number of hyponyms and maximum number of lemmas.

## 4.2 Graphic component

We started with a traditional map as our beginning point. It was used to locate the  $x$  and  $y$  position of the 27 landmarks given in table 6.1. The screen shot shown in 4.5 shows the first version of the program.

Upon subsequent redesigned, we decided to make following changes to the map:

- Use simple playful icons for landmarks. Since one of the objectives of the map was to make it playful, we included simple icons that look like sketches for each landmark. There are a total of 11 landmarks for the 27 landmarks.
- Include a background map in addition to the foreground landmarks shown. Since the foreground landmarks don't particularly impart location information visually to the user, we decided to incorporate a background map so that the user will have a sense of the overall landscape.
- Drop support for scrolling or zooming in the map. We decided that as a dynamic map, the user shouldn't have to scroll to certain sections of the map to look at things important to her - the map should do that for her. It remains to be seen if this feature will be well received by the user since most users are already use to maps which allow for zoom and scroll.

The latest version are shown in figures 4.6 and 4.7. Figure 4.6 shows the map displaying five landmarks at time 9:30 am. As time progresses, the context of the user slowly changes. The map changes dynamically in response to 4.7.

## 4.3 Improvements

The scope of the project is massive and only a fraction could be achieved in the limited time. With more time, the following improvement could be desirable for a project like this:

1. As briefly explained in the section on learning, 3.3, a future version could include some form of reinforcement learning.
2. Instead of hand-coding the location of the user and simulating the GPS data of her acquaintances, we could use GPS devices to collect the data and mine location information from the data. In such cases, privacy issues become important and showing social nearness without giving away the exact location of the user's acquaintances will pose interesting challenges.

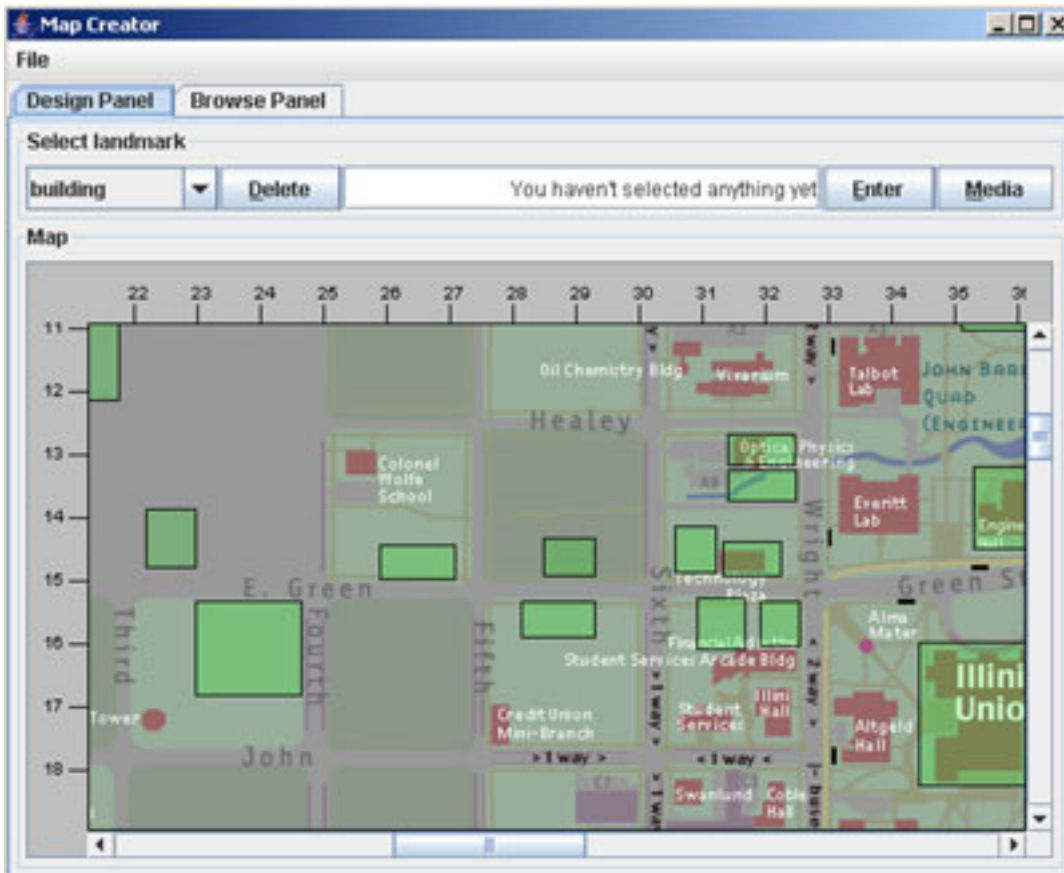


Figure 4.5: Old version of the program.



Figure 4.6: The map as displayed at time 9:30.



Figure 4.7: The map as displayed at time 9:40 am.

3. The interface of the map neither has zoom control nor slider functionality. Those were design choices that were consciously made given that the nature of the map is dynamic. However, it remains to be seen if such features are actually desirable in a project like this.
4. It will be nice to enable users to draw their own icons for landmarks since this increases the level of participation of the users and even allows for sharing sketches of different landmarks at different places. Moreover, since the user is the best person that understands the user's own cognitive model, allowing users to take control of the map reduces the cognitive load on the user and truly personalizes the map.
5. With a more revised version of the program, perhaps some user study could be done, incorporating the feedback in an iterative design process.

# Chapter 5

## User comments and Conclusion

### 5.1 User Comments

As explained in the introductory section, myMap wasn't intended to be a full fledged end-user application. The screen shots shown in section 4.2 thus should not be judged with the same scrutiny as those of other projects which have a visual interface as their final product.

However, even with the shoddy user interface, the concept of a dynamically changing map that updates itself according to time of day, a user's habit and her social acquaintances excited many friends of the author. No rigorous user study was done, but the author showed it to everybody at every opportunity. Many users had difficulty in interpreting the visual interface and some even complained about the lack of zoom or scroll feature. However, once they were explained that the map dynamically changes based on previously collected GPS locations, they often used the term "cool".

The author's officemate was intrigued about the implication such a map would have for mobile devices exclaiming that the idea was "ahead of its time". Another friend explored the possibility of such ideas used by big map companies as google who also are in the process of providing free wireless services. Location and social information would be readily available to these companies and the ability to influence the user's choice would be greatly enhanced with the formulation of nearness given in this project.

Perhaps the most unexpected usage of myMap was when the author showed it to a group of friends in a lab who were quarreling about which restaurant to go for lunch. The map, using the author's GPS behavior and sensing that it was lunch time showed a choice between Taco bell and Chipotle - which pretty much ended the discussion since everybody decided Chipotle wouldn't be a bad place to go. This showed that the project had potential in social applications if it had enough knowledge about many people's behavior.



## 5.2 Conclusion

We started this project with the central research question - what is, if any, the theoretical foundation that decides what a map should look like? In the section on cognitive maps, we decided that a map that resembles the cognitive map of a human would reduce the cognitive load of a user. Furthermore, we concluded that only those landmarks that are relevant to the user should be displayed in a map.

This requirement of displaying relevant landmarks coupled with fact that relevancy depends on changing user context meant that the map displayed would be dynamic. We developed a theoretical framework for calculating the relevancy of landmarks by introducing and developing the concept of nearness. We also explored how commonsense research can be used to infer relationship between landmarks. Finally, we developed a test platform to test the dynamically changing map and made suggestions for improvements.

Thus, this project was successful in answering its main research question by developing a tentative theoretical framework of calculating nearness between different landmarks and using that to decide what a map should look like - it should be a dynamic map that displays only those landmarks that are relevant to a user's context.

# Chapter 6

## Appendix

### 6.1 Input Data

#### 6.1.1 User location

A sample of user location at different times:

```
;; monday, feb 20:  
2006:2:20:9:30::home  
2006:2:20:13:00::tacoBell  
2006:2:20:13:30::dcl  
2006:2:20:15:45::engineeringHall  
2006:2:20:17:15::IMPE
```

#### 6.1.2 Landmark text from web

Part of text on a restaurant called Bombay Grill:

Bombay Indian Grill is the new Indian restaurant on Green Street, between 4th and 5th Streets. It is a fresh new alternative for Basmati, the only other Indian place in town. Unlike the latter, Bombay grill has some great dishes in their menu and very reasonably priced. However, only one major downside – very poor service.

I already went there twice, once for lunch and then few days later for dinner. I almost had similar experiences. Both the times they were extremely busy. However the staffs were very slow and sometimes didn't seem to know what they were doing. I have heard complaints from others that some of the staff were rude. If I go next time I would try to avoid the busy lunch and dinner hour.

For dinner, I started with some vegetable Pakoras. It was freshly cooked, soft but crisp. The appetizer, drink and the main course almost arrived at the same time after some 30 minutes of

wait. I also ordered some Mango Lassi(Mango+Yogurt drink). If you want to really taste the Mango Lassi, ask it without ice. It is already chilled, the ice cubes just ruin the taste.

Part of text on an office building called Beckman Institute:

The Beckman Institute focuses on research in three main areas, Biological Intelligence, Human-Computer Intelligent Interaction, and Molecular and Electronic Nanostructures. The Biological Intelligence Center, known as BioIntel, primarily works in the fields of Neuroscience, Neurotechnology, and Cognitive Science. Combining researches from the Life Sciences, Engineering (especially Signal Processing), and other related field the BioIntel group focuses on research which leads to a better understanding of brain functions, speech recognition, vision, and other sensory information. Work from this the BioIntel center has lead to numerous advances not only in the understanding of brain, but also in the development of algorithms for processing computer vision and other sensor information, along with the development of many sensory devices used in modern robotics.

The center for Human-Computer Intelligent Interaction, or HCII includes researchers from the fields of Artificial Intelligence, Human Computer Interaction, and Psychology. Primary work done by the center includes research in cognitive abilities of humans, and the construction of hardware and software to suit human use.

### **6.1.3 Location of landmarks**

Table 6.1 shows the different relative location of landmarks.

## **6.2 Calculations**

### **6.2.1 Code Structure**

Figure 6.2 shows the general structure of the code.

### **6.2.2 Eight sets from raw data**

Table 6.3 and 6.4 shows parts of the eight sets needed for the calculation of conceptual nearness.

Table 6.5 shows the normalized conceptual nearness values of a few landmarks. Note that the conceptual nearness value of a landmark with itself is unity.

<b>Landmark Name</b>	<b>X-Pos</b>	<b>Y-Pos</b>
assemblyHall	520	1640
beckmanInstitute	1060	100
bombayGrill	728	568
chipotle	860	520
CRCE	1400	980
dcl	1140	300
engineeringHall	1100	470
goldenWok	728	524
graingerLibrary	1080	380
home	540	160
illiniUnion	1080	600
IMPE	520	1280
jerusalem	956	468
jimmyJones	840	568
kenneyGym	1040	300
krannertCenter	1340	720
legends	760	500
mainLibrary	960	1000
murphysBar	920	500
seibelCenter	1220	240
sporlockMuseum	1480	760
springfieldPark	320	380
subwaySandwich	920	700
tacoBell	1480	80
tharaThai	660	520
wholersHall	940	1080
zas	920	568

Table 6.1: *The relative location of all landmarks used in the project.*

# Basic Code Structure

## GUI

### MapObjects

The nearness values of each landmark are gathered to decide which landmarks to be displayed next.

### LandmarkObject

Each landmark object is modeled by a LandmarkObject. It stores all attributes of the landmark.

### MapFrame

The map is displayed in a Java frame with separate layer for displaying the sketch, background and time.

## Conceptual

### ListCreator

Creates the sets of lists described in the previous chapter from raw data using WordNet and OMCS.

### ListCompare

Compares the list generated by ListCreator to find the number of matches.

### CompareLandmarks

This calculates the conceptual nearness between all landmarks by invoking the two classes above.

## Temporal

### GenerateEvents

Simulates different location of the user's friends at different times.

### ParseEvents

Parse the user's location at different times from input file.

Table 6.2: *General code structure. Only the important classes/objects are shown.*

<b>1st List</b>	<b>2nd List</b>	<b>3rd List</b>	<b>4th List</b>
Bombay	city	Algonquian	Abnaki
Indian	metropolis	Algonquin	Algonkian
Grill	urban center	Anasazi	Algonkin
restaurant	Amerindian	Athapaskan	Arapaho
Green	Native American	Athapascan	Arapahoe
Street	restaurant	Athabaskan	Blackfoot
4th	eating house	bistro	Cheyenne
5th	eating place	brasserie	caff
Streets	building	prewpub	cybercafe
a	edifice	cafe	Fifth Avenue
alternative	chromatic color	coffeehouse	Seventh Avenue
place	chromatic colour	coffee shop	frontage road
in	spectral color	greenishness	service road
town	thoroughfare	sea green	wish
latter	weekday	sage green	possible
grill	blood group	bottle green	impossible
has	blood type	chrome green	burial chamber
dishes	decision making	alley	sepulcher
menu	deciding	alleyway	sepulchre
one	point	back street	crypt

Table 6.3: *The first four of the eight lists created from the raw data of bombayGrill.*

<b>5th List</b>	<b>6th List</b>	<b>7th List</b>	<b>8th List</b>
at at hotel	in bus	in store	at state park
downtown	in country	in budapest	in big city
in big city	in county	in city	in cemetary
in building	in disarray	in large city	in cemetery
at train station	at at hotel	in london	in bank vault
in country	downtown	at airport	in china shop
in countryside	in big city	at corner of two street	in cupboard
in michigan	in building	downtown	in kitchen cabinet
at neighbor 's house	in centre of town	in behind row of buildings	in kitchen
backyard	in city	in big city	at dinner
in back yard	in room	in town	in plane
in barbeque	in town	in city or town	at grocery store
at resturant	at end of line	in france	in bean can
in advertisement	in plane	at graveyard	in bowl of chili
in application	can in kitchen cubbard	at apartment	in can
in bar	can in store	at dinner	at bar
at school	in behind big building	in cabinet	at movie
in desk	in cabinet	in cubboard	in jar
in oven	in billfold	in cupboard	in refrigerator
on table	in congress	at work	in bucket of chicken

Table 6.4: *The last four of the eight lists created from the raw data of bombayGrill.*

Landmark Index	<b>assemblyHall</b>	<b>beckmanInstitute</b>	<b>bombayGrill</b>	<b>chipotle</b>	<b>CRCE</b>
<b>assemblyHall</b>	1.000	0.238	0.170	0.211	0.306
<b>beckmanInstitute</b>	0.238	1.000	0.191	0.149	0.298
<b>bombayGrill</b>	0.170	0.191	1.000	0.458	0.241
<b>chipotle</b>	0.211	0.149	0.458	1.000	0.216
<b>CRCE</b>	0.306	0.298	0.241	0.216	1.000

Table 6.5: *Normalized conceptual nearness values for a few landmarks.*

# References

- [1] G. Abowd, C. Atkeson, J. Hong, S. Long, R. Kooper, and M. Pinkerton. Cyberguide: A mobile context-aware tour guide, 1997.
- [2] G. D. Abowd, A. K. Dey, P. J. Brown, N. Davies, M. Smith, and P. Steggle. Towards a better understanding of context and context-awareness. In *HUC '99: Proceedings of the 1st international symposium on Handheld and Ubiquitous Computing*, pages 304–307, London, UK, 1999. Springer-Verlag.
- [3] P. Barbour. *The Map Book*. Walker and Company, 2005.
- [4] L. Barkhuus and A. Dey. Is context-aware computing taking control away from the user? three levels of interactivity examined. Lecture notes in Computer Science, 2003.
- [5] A. T. D. Bennett. Do animals have cognitive maps? In *The Journal of Experimental Biology*, volume 199, pages 219–224, 1996.
- [6] P. Brown, W. Burtleston, M. Lamming, O. Rahlff, G. Romano, J. Scholtz, and D. Snowdon. Context-awareness: Some compelling applications. In *Proceedings the CHI 2000*, 2000.
- [7] J. Burrell, G. Gay, K. Kubo, and N. Farina. Context-aware computing: a test case. In *UbiComp 2002*, Ubiquitous Gteborg, Sweden, 2002.
- [8] G. Chen and D. Kotz. A survey of context-aware mobile computing research. Technical Report TR2000-381, Dept. of Computer Science, Dartmouth College, November 2000.
- [9] H. Chen, T. Finin, and A. Joshi. An ontology for context-aware pervasive computing environments, 2003.
- [10] A. Dey, R. Hamid, C. Beckmann, I. Li, and D. Hsu. a cappella: Programming by demonstration of context-aware applications, 2004.
- [11] A. K. Dey and G. D. Abowd. Cybreminder: A context-aware system for supporting reminders. In *HUC*, pages 172–186, 2000.
- [12] P. Dourish. What we talk about when we talk about context. In *Personal and Ubiquitous Computing*, 2004.
- [13] N. Eagle and A. Pentland. Reality mining: Sensing complex social systems. In *Journal of Personal and Ubiquitous Computing*, 2005.
- [14] T. Erickson. Some problems with the notion of context-aware computing. In *Communications of the ACM*, volume 45, pages 102–104. Communications of the ACM, 2002.
- [15] P. Foo, W. H. Warren, A. Duchon, and M. J. Tarr. Do humans integrate routes into a cognitive map? map-versus landmark based navigation of novel shortcuts. In *Journal of Experimental Psychology: Learning, Memory, and Cognition*, volume 31, pages 195–215, 2005.
- [16] Google. Gawker stalker. <http://www.gawker.com/stalker/>.



- [17] Google. Google maps. <http://maps.google.com>.
- [18] Google. Google maps mania. <http://googlemapsmania.blogspot.com/>.
- [19] A. Harter, A. Hopper, P. Steggles, A. Ward, and P. Webster. The anatomy of a context-aware application. In *Mobile Computing and Networking*, pages 59–68, 1999.
- [20] J. Ho and S. S. Intille. Using context-aware computing to reduce the perceived burden of interruptions from mobile devices. In *CHI '05: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 909–918, New York, NY, USA, 2005. ACM Press.
- [21] India. Embassy of india. india - states and union territories (map).
- [22] A. Klippel, K. F. Richter, T. Barkowsky, and C. Freksa. *Map-based Mobile Services – Theories, Methods and Implementations*, chapter The Cognitive Reality of Schematic Maps. Berlin: Springer, To appear.
- [23] B. Kuipers. Modeling spatial knowledge. In *IJCAI*, pages 292–298, 1977.
- [24] D. B. Lenat. CYC: A large-scale investment in knowledge infrastructure. *Communications of the ACM*, 38(11):33–38, 1995.
- [25] H. Lieberman, A. Faaborg, J. Espinosa, and T. Stocky. Commonsense on the go. In *BT Technol J*, number 22 in 4, pages 241–252, 2004.
- [26] H. Liu and P. Maes. What would they think?: a computational model of attitudes. In *IUI '04: Proceedings of the 9th international conference on Intelligent user interface*, pages 38–45, New York, NY, USA, 2004. ACM Press.
- [27] H. Liu and P. Singh. Conceptnet: A practical commonsense reasoning toolkit, 2004.
- [28] K. Lynch. *The Image of the City*. The MIT Press, 1960.
- [29] E. A. Maguire, N. Burgess, J. G. Donnett, R. S. J. Frackowiak, C. D. Frith, and J. O’Keefe. Knowing where and getting there: A human navigation network. In *Science*, volume 280, pages 921–924, 1998.
- [30] E. A. Maguire, R. S. J. Frackowiak, and C. D. Frith. Recalling routes around london: Activation of the right hippocampus in taxi drivers. In *The Journal of Neuroscience*, volume 17, 1997.
- [31] J. McCarthy. Programs with common sense. In *Proceedings of the Teddington Conference on the Mechanization of Thought Processes*, pages 75–91, London, 1959. Her Majesty’s Stationary Office.
- [32] G. A. Miller. Wordnet: A lexical database for english. In *Communications of the ACM*, volume 38, pages 39–41, 1995.
- [33] M. Minsky. *The Society of Mind*. Simon and Schuster, 1986.
- [34] M. Minsky. *The Emotion Machine*. To be published, to be published.
- [35] A. Oulasvirta. Finding meaningful uses for context-aware technologies: The humanistic research strategy. CHI, 2004.
- [36] M. Raento, A. Oulasvirta, R. Petit, and H. Toivonen. Contextphone: A prototyping platform for context-aware mobile applications. In *IEEE Pervasive Computing*, volume 04, pages 51–59, 2005.
- [37] S. Russell and P. Norvig. *Artificial Intelligence: A Modern Approach*. Prentice Hall, 2002.
- [38] N. Ryan, J. Pascoe, and D. Morse. *Computer applications in archeology*, chapter Enhanced reality fieldwork: the context-aware archeological assistant, pages 34–45. British Archeological Reports, 1997.
- [39] H. Sadahide. Panoramic map of buddhistic india. <http://www.columbia.edu/itc/ealac/moerman/japanmaps/thumbs.htm>

- [40] B. Schilit, N. Adams, and R. Want. Context-aware computing applications. In *IEEE Workshop on Mobile Computing Systems and Applications*, Santa Cruz, CA, US, 1994.
- [41] B. N. Schilit. *A System Architecture for Context-Aware Mobile Computing*. PhD thesis, 1995.
- [42] D. Siewiorek, A. Smailagic, J. Furukawa, A. Krause, N. Moraveji, K. Reiger, J. Shaffer, and F. Wong. Sensay: A context-aware mobile phone. In *IEEE Intelligent Systems*, volume 16, 2001.
- [43] P. Singh, T. Lin, E. Mueller, G. Lim, T. Perkins, and W. Zhu. Open mind common sense: Knowledge acquisition from the general public, 2002.
- [44] P. Singh and W. Williams. Lifenet: A propositional model of ordinary human activity. K-CAP, 2003.
- [45] M. Weiser. The computer for the 21st century. *Scientific American*, 94104, 1991.