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MAPPING THE SPACE OF LOCATION-BASED SERVICES

Abstract

This paper is an attempt to both summarize the current state of Location Based Services (LBS), and to unpack and problematize the underlying assumptions on which they operate. Location based services — including applications for mapping and navigation, social networking, gaming, and tourism and information services — are all based on the idea that information about a user's location can be used to adapt the content and user interface of a service, improving it. However, the "location" used by these systems is usually restricted to data-poor representations such as geographic coordinates, and as such provides an insufficient cue for the rich and culturally contingent context embodied in the notion of a "place". I will argue that developers should consider both the salience of the particular place- or space-based context to their application domain, and the potential impacts the application will have on a user's sense of place when designing location based services.

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1

Introduction: Location, Location, Location

Location is a deep component of how we experience the world — it encapsulates not only a mathematical abstraction for our positions in space, but also a rich set of cultural meanings that we associate with particular places, which bound and contextualize our experience. The concept of "place" combines both geography and sociality — one has a "place" in relation to other people (and deviant behavior is "out of place"). By reperforming the socially accepted behavior associated with a place, we retain the familiarity and boundedness of experience, and avoid the chaos of the unknown. Location provides the phenomenal background that constrains our experiences and defines possibility. It is perhaps for this reason that anarchistic provocateurs of the latter half of the 20th century held such a fondness for the notion of the *nomad*[1]: a nomad transcends not just spatial territory, but also social territory, expressing a freedom to transgress and transcend the constraints of institutions.

[1] Notable 20th century theorists of nomadism include Deleuze and Guattari [Deleuze and Guattari, 1987], the Situationist Internationale [Sadler, 1999], Hakim Bey [Bey, 1991], and Ant Farm (particularly via the Truckstop Network)[Lewallen et al., 2004, p 102].

In contrast with 20th century radicals' vision of anarchistic nomadism, the current vogue is a techno-boosterist rhetoric about mobility of the workplace. Rather than enabling personal autonomy that transcends institutional constraint, "digital nomadism" of the workplace is an institutional pervasiveness that transcends personal constraint. No longer do the boundaries of the office protect you from the need to work: the office follows you wherever you are — be it your home, the coffee shop, or the beach.

> Sell the house and the car. Put up all your possessions on eBay. Pack your bags and buy a one-way ticket to some exotic location. The plan? "Telecommute" from wherever you happen to be. Earn an American salary, but pay Third-World prices for food and shelter.
>
> The digital nomad, location-independent lifestyle once seemed so impossible, exotic and unlikely that only a few people dared even attempt it. But now, a lot more people are doing it, and it

> seems like everyone else would like to. Could it be? Is the digital nomad lifestyle about to go "mainstream"? . . .
>
> A perfect storm of micro-trends are colliding before our very eyes to facilitate the lifestyle of traveling while working, and working while traveling. These include the usual suspects, such as the declining price of electronics and bandwidth and of an increasingly globalized economy. . . . These are digital nomad-enabling trends, but everybody is participating in them. It will get to the point where the only difference between an ordinary white-collar worker and a digital nomad is an airplane ticket. [Elgan, 2009]

While this rhetoric is framed in the glowing perception that one is now free from the dreary constraint of the fluorescent-lit cubicle (and the commercials show the happy 30-something relaxing in the beach house with his ever-connected tablet), the flip side is that now the workplace has entered the beach. What was perhaps most attractive about the exotic travel destination — the ability to absorb oneself in a completely different set of cultural or situational affordances — has now been diminished by electronic media that brings the familiarity, boundeness, and banality of institutional constraint along with you.

The double-edged sword of digital nomadism is a result of a collapsing (or perhaps complicating) of territorial boundaries that electronic media facilitates. The rise of electronic media in the last century has certainly led to dramatic changes in the way we regard appropriate behavior in places. This has led to a host of cultural jokes about inappropriate cell phone conversations, perpetually texting teenagers, and bluetooth headset-adorned people loudly talking to themselves. These violations build on a tradition of conservative complaints about the impacts of computers, television, and radio on cultural relations. One can be in a physical space, but have one's attention directed outside of it, and thus become temporarily oblivious to the prior norms of one's physical space. The territorial violations can be extreme: in prisons, the proliferation of contraband cell phones threaten to destroy the sacrosanct isolation of the incarcerated. Electronic media don't just inhabit physical *space*; they also inhabit and alter cultural *place*.

Traditionally, theorists (e.g. [Harrison and Dourish, 1996]) have distinguished "space" and "place" as separate understandings of location — "space" consists of the physical and geometric properties of a location, while "place" consists of the cultural meanings, rules, norms, and social structures that govern it. These simplistic definitions aren't entirely adequate, as the geometric relations of space are themselves contingent on particular cultural understandings. [Dourish, 2006] Even so, a distinction between particularly spatial and relational aspects of a location on the one hand, and the social-

behavioral affordances the other, is useful to help contextualize the design assumptions of location-based services.

When mobile devies are location-aware, they are almost always exclusively situated in *space*, and not *place*. Whether by GPS, radio signal triangulation, radio fingerprinting, or dead reckoning, the means that location-based services use to determine "where" you are almost always refer to a spatial notion of "where" rather than a social notion. Where they are treated at all, the social affordances of a place are usually assumed to be tied to a physical location — users of a device might tag a spatial location as having a meaning (such as "work" or "home"), and the device might alter its behavior accordingly. But this is both data-poor and insufficient: home can become an office, an office can host a party, a party can follow a funeral, and in each case the social affordances change in ways that may be significant to a mobile application's function.

Often, the spatial context used by location-based services is not actually used for its spatiality — it is used as a proxy for other meanings. For example, a location-based social network might notify you about nearby friends. Location in this case is a proxy for "opportunity to socialize". The effectiveness of this is limited insofar as the proxied meanings don't map cleanly to spatial coordinates — nearby friends aren't always available to meet (and far away friends aren't always unavailable). The argument here is not that "place" is more important than "space", nor that GPS is inadequate for LBS. Rather, the argument is that there are many rich possibilities for space that go beyond GPS, and that there are many rich possibilities for place that can't be captured by space alone. Designers need to approach their use of "location" with a critical understanding of what is meaningful about location for the application's needs, and choose models of place and space accordingly. And given the power of electronic media to alter social practice, designers need to consider the extent to which they wish for their applications to work as agents for social change, rather than accessories to current practice.

In the following sections, I will provide a discussion and problematization of the meanings *space* and *place*. I will follow this with a survey of the ways that space and place inform current LBS, and close with a discussion of the impacts of LBS design on social and spatial practice.

2 Space: the geometry of location

> Do not jump into your automobile next June and rush out to the desert hoping to see some of what I have attempted to evoke in these pages. In the first place, you can't see *anything* from a car; you've got to get out of the goddamned contraption and walk, better yet crawl, on hands and knees, over the sandstone and through the thornbush and cactus. When traces of blood begin to mark your trail you'll see something, maybe. Probably not.[Abbey, 1985, p xii]

What is "space"? When we think of "space" in relation to physical geography, we usually think of latitudes, longitudes, areas, volumes, and other geometric measurements. These characteristics tend to be regarded as inherent properties of the real world — there *is* a physical world out there after all, and it has certain geometric properties which we might want to regard as existing beyond culturally contingent meaning. But the representations that we're used to thinking in — North, South, East and West, latitudes and longitudes, miles and bearings — all are culturally constructed ways of representing the spatial properties of the world. Different representations of space are not only possible, but might be more valuable depending on the application domain. These alternate representations aren't different because of differences in *place* (the social affordances and context of a location) — they are fundamentally different ways of regarding the physical relationality of things in the world.

Even for the committed positivist, the limitation of latitudes and longitudes as a description of "how things really are" is clear if we consider an effort to render the mathematical geometry of our world in greater precision. The Earth becomes not spherical but elliptical (and not a perfect ellipse, but one with variation from mountains, tectonics, ocean currents, and the gravitational bulge from the moon). Distances become skewed by the gravitational curvature of space. Measurements become confounded by the fuzzy mollecular boundaries of objects. We are forced to sacrifice the simplicity of euclidian

dimensions for the probabilistic precision of quantum mechanics. At best, the positivist would have to regard the loose approximations of latitudes, longitudes and linear distances as culturally useful approximations of the more precise underlying mathematical reality. For the less committed positivist, the same principle might be learned by taking Edward Abbey's advice above: instead of regarding the path of a trail as a line in space, try approaching it from a crawl, and experience the rock, sand, dirt and thorns directly. Experience the rise and fall of a hill, and the confusing turn of a canyon. The smooth curves of a topographic map fade into the rough grit of the boulder field; mathematical simplicity fades to the messy and approximate. None of this has to do with the cultural understandings of place; it remains manifestly physical — a property that mathematical geometry lacks.

But beyond mathematical geometry, how else can we regard "space"? Historically, measurements and representations of land took very different forms. It wasn't until 1538 that the practice of measuring the extent of land in terms of geometric area was first described in English:

> If there is a single date when the idea of land as private property can be said to have taken hold, it is 1538. In that year a tiny volume was published with a long title that began, "This boke sheweth the manner of measurynge of all manner of lande..." In it, the author, Sir Richard Benese, described for the first time in English how to calculate the area of a field or an entire estate.[Linklater, 2002, p 10]

Prior to this, land holdings were traditionally measured not in terms of space, but in terms of yield. The Domesday Book, a survey of land and livestock of England completed in 1086, measured taxable land in terms of virgates (enough land to supprt one person) and hides (enough land to support a family, four virgates to the hide). The size of a hide would change depending on the quality of the land — if soil quality deteriorated, the same plot of land would consist of fewer hides. Rather than extent, the culturally important metric of land was yield. Again, this did not describe what constituted appropriate use or social behavior in a field (it's "placeness"); a field would be the same size regardless of whether or not it was plowed, so long as its *potential* for yield remained the same — a hide was a metric of space.

Navigation, too, was not always based on universalizable geometry as a representation of space. Ancient mediterranean mariners developed a navigation aid called a *periplous*, which consisted of detailed descriptions of steps, from the perspective of the mariner. It would describe ports of entry, coastal features, and navigational aids in a linear fashion from start to finish.[Kish, 1978] Pesudo-Skylax circumnavigated the "inhabited world" (the Mediterranean and Black

Seas) and recorded the journey as a periplous in such a manner, describing distances of travel in terms of a mariner's day: "And the Pagasetic gulf's length is, from the mouth to the inner end of Pagasai: a voyage before the midday meal." [gjs, 2008] This format was later developed by the Romans into the *itinerarium* — literally, an itinerary of stops, roads, and dangers to be avoided — describing journeys as a declarative algorithm from the perspective of a Roman footsoldier. [Kish, 1978]

History records a diversity of other navigational techniques, each suitable to the culture and situation of the time. Micronesian navigators undertaking long sea journeys were able to travel without maps or Western navigational principles, by using representational systems that relied on local features and precise knowledge of conditions of water, weather, and their craft. Australian Aboriginies considered spatial paths to include built-in obstacles due to ritual exclusions, leading to at times cicruitous routes, despite no visible barriers. These alterations in path are encoded in the spatial description of the journey — travelers recited "songlines" which identified the physical features in sequential order, without an encompassing birds-eye perspective. [Dourish, 2006]

The idea of mathematical geometry as the canonical representation of space is an effort to gain perspective of the world "as it is", rather than inconsistent and contingent considerations such as farm yield, journey time, and emotional response. But the perspective of the world-as-it-is, paradoxically, is no perspective at all — as Merleau-Ponty writes in *The Phenomenology of Perception*:

> Our perception ends in objects, and the object once constituted, appears as the reason for all the experiences of it which we have had or could have. For example, I see the next-door house from a certain angle, but it would be seen differently from the right bank of the Seine, or from the inside, or again from an aeroplane: the house itself is none of these appearances: it is, as Leibnitz said, the geometrized projection of these perspectives and of all possible perspectives, that is, the perspectiveless position from which all can be derived, the house seen from nowhere. [Merleau-Ponty, 2002, p 77]

A representation of space as pure geometry, a mathematical abstraction, is an attempt to construct a representation of space from *all perspectives* (or "infinite" perspective), which is the "view from nowhere". This is not a representation that we can actually see and use — this is a purified abstraction, a model. Usable representations, however, are always "sullied" by perspective: they come with mercator projections, political lines, selective display of features, selective approximations — all of which, through their selectivity, become

usable[1]. But in so doing, the representations also constitute acts of power — they will be usable for particular purposes, or by particular individuals, at the expense of other possible uses. They embody, both physically and socially, a point of view.

[1] Indeed, this is precisely what the concept of a "map" is – a selective, compact representation of a more complicated reality, suitable for a particular purpose.

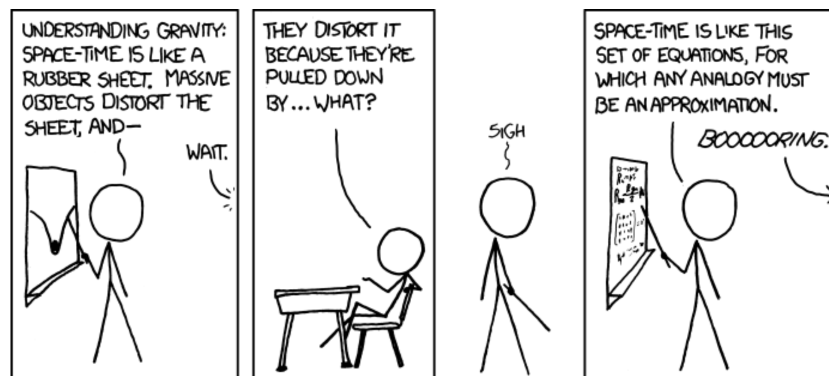

Figure 2.1: xkcd comic describing the limits of mathematical geometry as a comprehension of space. [Munroe]

As spatial representations enter use, they both reflect and construct the ways we understand space and the world. As Berg argues in [Berg, 1997], a “map” and the “terrain” are not cleanly conceptually distinct — rather, the map becomes the lens by which we construct our understanding of the terrain. As knowledgable agents who then operate in the world based on this understanding, we alter physical aspects of the world to suit the map. A straight line drawn on the map becomes a highway, a clearcut, a political boundary, a smooth modernist structure. These formal systems evolve through a “chain of re-representations”, where the construction of new formal systems builds on the existing formal systems and the reflexively altered terrain which in turn creates new maps. The choice of a representational system, then, is not just a descriptive act — it can also be creative. We might imagine how the layout of our cities would change if we were raised in a hegemony of polar coordinates rather than cartesian.

Stewart Brand famously campaigned for NASA to release a picture of the Whole Earth, selling buttons that read “Why haven’t we seen the whole world yet?” [Turner, 2006, p 69] Brand believed that seeing a picture of the whole earth would “change everything”; that it might inspire a greater sense of shared humanity. It was with this in mind that a picture of the whole earth adorned the cover of the first edition of the *Whole Earth Catalog*. Presumably Brand had hoped that those who saw a photograph of the Earth in its entirety would come to understand the fragility and closeness of our human condition on Earth, and how much we share in common. But from the cold distance of space, one can’t see with sufficient detail to make out individual peo-

ple — one can forget that they are there, reducing them to landmass, climate, political boundaries, or other abstractions. Just as Merleau-Ponty's neighbor's house looks vastly different from the airplane or from the kitchen, the Earth from space is only one of several perspectives, and not the "view from nowhere". To believe that the bird's eye perspective is the most correct conception of spatiality is ahistorical hubris.

Figure 2.2: On the left, the whole Earth from the first Whole Earth Catalog, 1968. On the right, a 1989 reconstruction of the Pomponius Melas map of the world from 43 C.E.[Mela and Romer, 1998]

3
Place: the interpretation of location

What is a "place"? In contrast with the purely spatial or proximal, a "place" is understood as something that consists of a social context. As Harrison and Dourish describe it, "Space is the opportunity; place is the understood reality."[Harrison and Dourish, 1996] A "place" is more than just its location — it also encapsulates the social codes that define acceptable behavior. Whether a church, a playground, an office, a coffee shop, a bus stop, or one's living room, each place is defined less by its spatial characteristics than by the codes of conduct that it requires.[1] Spatial cues can demarcate places — for example, the steeple demarcates a church; the swingset demarcates a playground. Sometimes spatial features will be necessary for the social activity that constitutes a space (for example, a sports field requires a relatively unobstructed expanse), but more often than not the spatial characteristics are only important to the "placeness" of a space insofar as they act as cues for the structural codes for behavior.

[1] Christopher Alexander's "A Pattern Language" goes further, to suggest that a certain catalog of place types is necessary for smooth functioning of dwellings and towns.[Alexander et al., 1977]

Beyond physical markers of space, the informational context of a place also contributes to our social understanding of it. Knowledge that the priest has been seeing a mistress in the chapel would decrease our sense of its sanctity, just as knowledge that a drug dealer was operating out of a playground would alter its codes. But digital media takes this a step further: by providing an information link to an alternative context, an a-spatial place can be superimposed on a physical space. A television doesn't care about the context of the room in which it is placed — it will display the titillating, educational, sexually charged, prayerful, or violent programming just the same, whether it is placed in a church, on a playground, or in a living room. It is this character of place-transcendence that Meyrowitz, author of the highligh influential *No Sense of Place*, implicates in a set of massive cultural changes beginning with the first electronic media. Meyrowitz intends for the words "sense" and "place" in the title of his book to be bivalent:

> The phrase is an intricate—though very serious—pun. It is intricate because the word "sense" and the word "place" have two meanings each: "sense" referring to both perception and logic; and "place" meaning both social position and physical location. The pun is serious because each of these four meanings represents a significant concept in the theory... that social roles (i.e. social "place") can be understood only in terms of social situations, which, until recently, have been tied to physical place, and ... that the logic of situational behaviors has much to do with patterns of information flow, that is, much to do with the human senses and their technological extensions. [Meyrowitz, 1986, p 308]

In *No Sense of Place*, Meyrowitz argues a position (echoed by other late 20th century critical theorists [Wilken, 2008]) that electronic media have had a powerful effect on social relationships through the ways that they intrude in places, and combine the affordances of different social places into the same physical space. These changes are not always deleterious — Meyrowitz implicates television and radio in bolstering the civil rights movement of the 1950's and 1960's. Groups that would previously be seen as an "other", whether powerful (as in presidents) or disempowered (as in black people), would become more familiar and less frightening (or awe inspiring) as a result of TV and radio that provided a glimpse into their formerly backstaged inner lives. Meyrowitz credits electronic media as leading to a merging of formerly more disparate notions of masculinity and femininity, childhood and adulthood, as well as a diminution in the reverence of authority.

Later theorists, particularly in light of the rise in prevelance of mobile telephony and computing, have argued against the stronger formulation of Meyrowitz's position that electronic media *destroys* place. Harrison and Dourish describe how electronic media environments can create alternative, virtual places, which embed their own social codes and affordances, effectively "spaceless" places:

> One obvious source of such examples are USENET news groups and Internet mailing lists. The technology of each USENET group is exactly the same, and yet the resultant groups exhibit very different notions of place. It's not simply that they separate discussion into topics, making certain postings appropriate to one group or another; but that they also make distinctions between styles of posting. Neophyte queries may be more or less appropriate, depending on the culture of the group; so are flames. These styles are relatively independent of topic. [Harrison and Dourish, 1996, p 72]

Even a spaceless venue for communication, by having social norms and criteria for use, can exhibit the cultural criteria for the constitution of a place. One could argue that the usenet addresses are virtual

"spaces" (we even use terms like "namespaces" to demarcate them). Far from being unbounded place-less free-for-alls, electronic media spaces acquire codes of conduct that turn them into places of a particular character. Still, with the existence of mobile communication media which can bring the newsgroup (or facebook, twitter, email, SMS) to the office, playground, or the mountain top, the potential for those electronic places to conflict with and obstruct physical places remains strong.

Changing places

As a site for the performance of social norms, "place" is also an important site for social change. Civil rights protests such as Woolworth's lunch counter sit-in of 1960 and Rosa Parks' refusal to give up her bus seat in 1955 were explicit violations of place (both in the sense of physical and social place). Street protests involve the physical obstraction of space and violation of norms of place in an effort to get one's voice and position heard. Physical places as sites of power take imposing forms such as grand columns, foyers, and bunker-like security. The Critical Art Ensemble describes this "bunker" or "fortress"-like construction as a means of limiting the possible behavior in a space:

> The bunker is the foundation of homogeneity, and allows only a singular action within a given situation. For example, in a mall one may only consume. The mall is a bunker of perpetual discomfort. There is no place to rest, unless one is consuming (usually in the food court), and in this situation only the most uncomfortable of accommodations are provided so that the consumer will hurry, finish, and rejoin the dynamic flow moving from shop to shop.[Ensemble, 1996]

Hakim Bey argues for cultural resistance in physical space in the form of a "temporary autonomous zone" — people can intentionally, and temporarily disolve the usual social structures that constitute a place, creating instead a temporary chaotic site for creative energy and release. [Bey, 1991] And just as places can exist in both virtual/electronic spaces and in physical space, sites of power exist both electronically and physically — and electronic communication media can become a site for cultural resistance, including virtual-sit-in denial of service attacks, which mimic the function of a real-world sit-in in virtual space.[Ensemble, 1996]

Some recent theorists have argued for a more nuanced perspective which characterizes the evolution of place as a result of human-technology-environment interaction. The micro-practice of everyday mobile phone use can't be adequately described as a simple super-

Figure 3.1: A panel from Packard Jennings' "Business Reply Pamphlet", a how-to manual for transforming the office environment into a primitivist anarchist utopia, illustrating a transformation of place. [Jennings]

position of electronic and physical places — rather, the multiple social constraints of various places and modes create a "bounded but open and contested site, a complex product of competing discourses, ever-shifting social relations, and internal (as well as external) events."[Wilken, 2008] Rather than being composed of purely structural elements, places are relational: it is the various relations between the participants in a space (including those electronically-connected) that constitute the "place". At a bar, one might simultaneously have a conversation with a neighbor, check text messages, and watch a sports game. All of these activities and potentials come to constitute the "place" of the bar. Wilken argues for the use of Lefevbre's notion of "textural analysis" and "rhythmanalysis" as a more productive metaphor for understanding the relations and norms that constitute a place.

As agents for social change, electronic media are especially powerful due to their allure. Some theorists have modeled the behavior of mobile device users with an "ontology of everyday distraction"[Wilken, 2008]. Mobile technology functions as an escape for the mobile phone user from tedious physical spaces — an escape with all the connotations that carries, including the maladaption of addiction. This is especially notable in "non-places" [Auge, 1995], spaces such as bus stops, train stations, or other liminal spaces that are only partially coherently perceived. These spaces afford an explicit isolation from other people in them, and thus distraction and electronic escape becomes especially attractive. The expected behavior in a "non-place" — non-action — is harder than active but non-locally directed absorption. Mobile phones are in some ways a more accessible tool of distraction than older alternatives such as books, in the same way that television is more accessible. In Meyrowitz's terms, the opera-

tional mode of electronic media trends towards the *expressive* rather than *discursive*[Meyrowitz, 1986, p 108]; this greater accessibility and the fecundity of micro-rewards provided by electronic games and short communications can make the transfer of phone habits out of liminal spaces more irresistable. As this happens, the expected patterns of behavior in places that would formerly regard phone use as taboo may shift.

4
Technology of space and place

Fundamentally, location based services are a subset of context-aware computing. The intuition is that devices which are able to detect their location will be able to use that context to provide improved service. However, as discussed above, the meaning of location is complicated by the different notions of *space* and *place*. The following describes technologies for sensing space and place that are usable by LBS.

Sensing space

Humans (and, indeed, the entire animal kingdom) depend on spatial senses for survival. The most basic human sense of space is the combination of vision, balance, and memory: by seeing and recalling where we have been, we are able to reconstruct spatiality with a precision adequate for basic survival. Other position sensing techniques used by animals include echolocation (bats), magnetic field sensing (birds, turtles), and chemical sensing (ants). Humans have extended the sense of space through a variety of technologies — generally these enhancements fall into three categories:

- Tools for improving spatial memory and communication (e.g. narrative structures such as Aboriginal songlines, itineraries, maps)
- Tools that add new sensible signals, or augment existing ones (e.g. signs, light houses, radio transmitters, GPS satelites, QR codes)
- Tools for more precisely measuring sensible phenomena, or sensing phenomena beyond human senses (e.g. sextants, compasses, radio sensors)

The advent of electronic sensors has made the use of spatial location especially convenient in mobile applications. The following is a

brief description of the major locative technologies used in modern location-based services.

GPS: Of the technologies for sensing space, none is more widely discussed in reference to LBS than the Global Positioning System (GPS). GPS consists of a network of satellites which broadcast timing signals which are detected and correlated by a receiver on the ground. Based on the phase differences of the timing signals received, a receiver can calculate its position. The accuracy of its determination varies depending on the number and strength of signals available — a limitation which makes GPS unreliable indoors or inside canyons (either urban or natural) which obstruct line-of-sight views of the satellites or reflect signals causing multipath propagation errors. The system was developed by the US Department of Defense starting in 1973, became fully operational in 1994. In 2000, restrictions on civilian access were lifted, removing technical limitations that restricted civilian GPS accuracy to 100 meters. [Wikipedia] GPS accuracy varies from none in conditions where satellites are not visible, to 5 meters in the best case. [Wing et al., 2005] GPS receivers can provide estimates for their accuracy based on the number and strength of satellite signals they are able to detect. It can take several minutes for a GPS receiver to register sufficient satellite signals to estimate a location (the "time to first fix") — this time can be reduced by using outside resources such as a nearby network server. This technique is used by "Assisted GPS" in most recent mobile phones to improve the time to first fix. [Jariven et al., 2002]

Radio Fingerprinting: The prevelance of stationary radio transmitters with unique signatures makes it possible to sense location by detecting the mix, strength, or content (including MAC addresses or cell tower IDs) of radio signals available at any given moment. Any stationary radio transmitter could be used for this — including WiFi and bluetooth base stations, mobile phone transmitters, or even FM radio or TV stations, though lower frequency and higher power sources will provide less locative accuracy. Where databases exist which correlate transmitter signatures with geographic coordinates, radio fingerprinting can provide global positioning — but even without such databases, an application can store locally meaningful signatures for particular users (Hightower et al. [2005] describes a system that uses WiFi and GSM signals to provide personally meaningful locations without a global correlation). Unlike GPS, radio fingerprinting can function indoors if there are radio transmitters detectable from the indoor location. Companies such as Skyhook Wireless, Google, and others have undertaken the task of mapping radio transmitters in urban areas worldwide to assist the use of radio fingerprinting in geolocation. The accuracy of radio fingerprinting

varies considerably depending on the density and quality of available signals — where available in dense urban environments, Skyhook claims accuracy of 10–20 meters. [Skyhook, 2011]

IP Geolocation: Knowledge of the centralized distribution of IP address blocks can be used to obtain rough estimates of geolocation. When a device connects to the Internet, its IP address (or the IP address of the Network Address Translator that it communicates through) will belong to a block of addresses assigned to the service provider by the Internet Assigned Numbers Authority. Databases of the geographic location of service providers that have been given particular IP blocks can correlate an IP address with a rough geographic area. Such databases have been collected by companies such as MaxMind and Google. MaxMind claims to be able to locate an IP address to the country level with an accuracy of 99.8%, and city with an accuracy of 81.5%. In general, MaxMind accuracy does not exceed 25 miles. [MaxMind, 2011] As with radio fingerprinting, an application could construct a local database which collects IP addresses and associates meaningful context with them, even without global registration.

Dead reckoning: Given some starting position, a system can infer subsequent positions based on inertial sensing. If a system is able to accurately detect speed and bearing, the system can determine subsequent position. The challenge with dead reckoning systems is that without an updates from an external reference, errors will tend to accumulate over time. This can be mitigated by quantizing against known references (e.g. turn counting) or regular recalibration. Well prior to the public availability of GPS, dead reckoning was used as the positioning technique in [Davis and Schmandt, 1989]; [Randell et al., 2003] used modern accelerometers and three dimensional compasses to achieve accuracy of 2 to 20 meters depending on the length of test. Mixed method sensing that combines a global location sensor like GPS with dead reckoning can result in highly accurate positioning.

Computer Vision: tracking object or scene movement to infer local position, or matching landmarks against global databases. This has been widely used for local positioning in robotics (e.g. [Hager, 1997]). The task can be made considerably simpler with the use of machine-readable markers, such as QR codes or AR codes; these techniques have been widely used for tourist and museum information and advertisements.

Magnetic sensing: Using perturbations in the Earth's magnetic field caused by natural or human-made features (such as the structural steel of buildings), highly accurate positioning is possible. Chung et al. [2011] use magnetic perturbations to do indoor posi-

tioning with an accuracy as high as 1m.

In general, any phenomenon that either varies predictably in space, or varies relatively with movement, can be used to detect position. Each sensible phenomenon requires additional knowledge to register a position: the frequencies and predicted positions of the satellites are needed to make use of GPS signals; the geographic allocation of IP addresses is needed for IP Geolocation; the prior positions and history of movement is needed for dead reckoning. Given any sensible phenomenon, three fundamental questions can be used to assess whether the phenomenon is useful for positioning for a particular application:

- What is availability of the sensible phenomenon? (e.g. indoors/outdoors, daytime/nighttime, selected geographies)
- What precision is feasible? (e.g. TV broadcasts will never be as precise as WiFi signals for geolocation, due to constraints of radio frequency and power)
- If global registration is needed, what knowledge outside of the sensed phenomenon is required for it? (e.g. frequencies of satellites, positions of WiFi base stations, positions of the stars)

Depending on the application's needs, any or a mix of several locative technologies might be adequate. In particular, global registration, which can be technically challenging and costly, is not always necessary for an effective location-based service. Even a dead-reckoning system without calibration may be adequate — a sequence of inertial movements may suffice to represent a consistent commute, for example.

Sensing place

Sensing place is considerably more challenging than sensing space. Rather than the simple question of where in space you are, place is a question of *what sort of place* you are in, and what this means in terms of the place's social affordances. Given the huge diversity of types of place and social affordances that they present, techniques for sensing place must take a more narrow perspective which senses only places of a particular sort or social situations of a particular sort.

Association with space: To the extent that a place is correlated with space, data about a place can be attached to spatial coordinates. Spatially registered place data exists on a continuum of public to private meaning — for example, the place where my favorite tree grows is privately meaningful, but the location of a public business is

publicly meaningful. Systems exist for the collection and spatial association of both kinds of meaning. The space of publicly meaningful place data is a subset of the general class of Geographic Information System (GIS) data. Companies such as NavTeq and Google have invested considerable resources in collecting GIS data which associates businesses, addresses, and general points of interest (POIs) with spatial coordinates. Open source competitors such as Open Street Maps have emerged, producing data which is often competitive with commercial providers. [Goodchild, 2007] Privately meaningful data can be recorded in private databases carried by a mobile user. Zhou et al. [2007] presents a thorough summary of techniques for automatically detecting locations that are frequented by users carrying position tracking devices; users can be prompted to give frequented locations semantic labels. In the case of both public and private data, locally consistent but not globally registered spatial signals can be used in association with place data (this principle could even be applied to mobile places, such as the inside of a bus or airplane).

Detecting social circumstances directly: Place has as much to do with the social affordances of a space as its spatial properties. Some social criteria might be detectable without any spatial registration. Sawhney and Schmandt [2000] describes a mobile messaging system that detects conversation, and adapts its delivery of messages to avoid interuption. Mahato et al. [2008] discusses a bluetooth-based signaling application that broadcasts a user's musical preferences, allowing a cooperating music player to adapt a public address system's playlist to suit the present users' preferences. In both cases, social criteria of a specific type are detected by a system to adapt the system's performance to the social situation. Given the diversity of possible social situations and criteria, a universal solution is not likely.

Detecting other circumstances: Other sensible phenomena that may correlate with place-based concerns include things such as the time of day and the user's personal context (calendars, sleep state, etc.). Marti and Schmandt [2007] describes a system which selectively delivers messages to a device based on the time of day, the sender, the volume of messages a user is currently receiving, and other signals such as calendar entries. The Android app *Locale*[Locale, 2011] allows the user to set different device profiles for features such as the device's volume according to sensed parameters such as spatial location, and calendar events.

5
Space, place, and location based services

Based on the discussion above, we can now characterize location based services according to the ways that they employ notions of space and place, and what limitations they have as a result of these technical choices. Below, I will describe a selection of location-based services, divided into 5 application categories: social networking, messaging, tourism and information, mapping and navigation, and gaming. These are by no means mutually-exclusive descriptions of any particular application's function, but they are useful genres with which to consider the use of space and place, and the social impacts of the application domain.

Social Networking

One of the more popular classes of location based services is location-based social networking applications — popular at least among developers, as evidenced by the over 170 different products from the last five years listed in Appendix A. The intention of location-based social networks is to create and discover opportunities for social interactions through knowledge of location. One might learn that one's friends are in a nearby restaurant, that a long-distance friend has just arrived in town, or that a particular venue in town is having a party. Here, I will discuss three applications: "Linked Public Spaces" [Jancke et al., 2001], Dodgeball [Humphreys, 2007], and City Sense [Networks, 2011], and comment on the wide proliferation of similar applications.

Location as a proxy for where friends or associates are able to meet and socialize is an imperfect match: even if one knew the location of one's friends precisely, nearby friends may be unable to meet up, while far away friends may be willing to travel. The disconnect between the two is wide enough that location alone is an imperfect indicator. This problem is compounded by network effects from the fragmented usage space of these applications. If a friend doesn't use

the same location-based social networking service (or doesn't use one at all), the friend will not be discoverable even if they are close by. The first challenge of a social networking application is to overcome the inertia of network effects to get enough users to make usage of the app worthwhile. Application authors seek to encourage everyone to report their spatial location, improving the quality of the proxy of space-as-socialization.

This desire to increase usage pulls against persistent user concerns of location privacy, which every location-based application is forced to address. Jancke et al. [2001] describe a location-based social networking installation which linked three different public spaces used by members of a single organization with a full-duplex audio and video channel. Public kitchen areas in a building were outfitted with video screens and cameras which allowed conversation with people in the other spaces, or ambient awareness of the activity there. The designers hoped to increase informal interaction among collaborators who might otherwise not often see one another within the organization. Based on early feedback that indicated that users might desire privacy, the designers installed a button on the outside of the space which would disable video and audio recording temporarily. Even so, the designers reported substantial controversy, and even efforts at sabatoge, among kitchen visitors who did not wish to have their images or audio transmitted to the other spaces. The authors report that even though the kitchens were "public" spaces, there was still a sense of violation when a conduit would transmit their presence to another location.

The "privacy" or "publicness" of a space is a powerful contributor to the sense of place and the social affordances it has. "Public" and "private" are not binary, but rather expressed as a range of different levels of publicness which depend in part on who is watching. As an example, there is a wide rift in the "privacy" of being at a sporting event (an extremely public venue), versus being shown on the jumbotron at the same event. Piping someone's image or sound allows a level of voyeurism which can be uncomfortable, even if there is no expectation of privacy anyway. Humans have evolved very finely attuned local spatial sense — one can easily tell the direction and approach of a person from down the hall based on sound, movements of air, and shadows. Even very high quality audio and video systems remain restricted to point sources, which impede this type of ambient spatial sense. It would be difficult to have high enough resolution of all the sensable phenomena that contribute to the sense of spatial layout of a space such that one could have a phenomenal sense of presence or spatial connectedness the way one does in real connected spaces. Indirect gaze introduced by off-angle cameras also decreases

people's ability to make eye contact, resulting in an impeded sense of social propriety with respect to staring. The combined intimacy of seeing associates in the same organization with a system that increases a sense of being watched can bring discomfort. One has neither the privacy of public anonymity (e.g. walking down a street), nor the privacy of a more private space (e.g. a bedroom or office), nor the reciprocity of truly shared space where all share a common spatial and place-based sense.

In contrast to the relatively concerned response that Jancke et al. [2001] found in their effort to link public spaces, Humphreys [2007] describes a case which led to a much more welcomed alteration of a sense of place. Humphreys provides an in-depth case study of the use of Dodgeball, an SMS-based service which existed from 2000 to 2009. Dodgeball allowed users to "check in" to a location, chosen from a menu of pre-existing venues within supported cities, and to broadcast these check-ins to subscribing friends. Since users were always in control of where and when they checked in, privacy became less of a concern for them. Indeed, some users reported a sense of freedom in their ability to subvert the expected privacy concerns over disclosing their location. As one of Humphrey's informants describes:

> I think [Dodgeball] is a really interesting subversion. For years and years, people have been like, "Oh don't tell anyone on the Internet about yourself. Don't tell 'em where you are." Well, this is something that is trying to broadcast exactly where you are. So it kind of subverts that notion that everyone is a sexual predator and that everyone online is evil. [Humphreys, 2007, p 213]

In contrast to the users of Jancke's spaces with public video links, who had the link brought into their own space, users of Dodgeball are able to self-select and choose whether or not to use the service. One could always choose not to check in, or to only check in to particular places, and thus retain control over the projection of their location identity.

Humphreys also reports changes in users' sense of public places. Drawing from Lofland [1998], she describes three kinds of urban social space: public, parochial, and private.

> Public spaces are territories characterized by strangers, while private spaces are territories characterized by intimates and personal networks. Lofland suggests a third kind of urban space exists which is somewhere between the public and private spaces, namely, the parochial. Parochial spaces are territories characterized by 'a sense of community among acquaintances and neighborhoods who are involved in interpersonal networks

> that are located within the communities' [Lofland, 1998, 10]. Neighborhoods are examples of parochial places.[Humphreys, 2010, p 6]

Humphreys argues that use of Dodgeball can lead to a parochialization of space, where public spaces become more familiar and intimate as a result of shared experience. The "place-ness" of a space is altered as a result of awareness of who is there, and what social interactions that configuration affords. Friends who gather informally in a space may feel a greater sense of ownership and commonality over that space than they would by either chance encounters or formal gatherings.

In contrast to the low spatial resolution of Dodgeball, *citySense* [Networks, 2011] is a mobile phone application which continuously senses and records detailed spatial movements of its users using GPS, wifi and cell network triangulation, in an effort to give a sense of the overall "activity level" of a whole city with high granularity. Users can see "activity" (as proxied by detected movement) of people who are "like them" in that their movements follow similar patterns. The application operates inherently spatially — it only senses spatial coordinates, and does not seek to correlate those with other social meanings or places. The assumption is that users who follow similar spatial patterns will have similar interests, and that by detecting this similarity, it might be possible to positively influence people's choices of where to go. It remains to be seen what feedback effects might emerge if users began altering their movements in response to visualizations of the interpreted aggregations of their movements — whether this would increase flash-mob style gatherings, lead to less variety of social interaction, or other effects. The developers of citySense approach privacy primarily through the display of only aggregated data; but in so doing, they also eliminate the possibility of parochialization of the type that Humphreys reported, as one only gets a sense of aggregate rather than socially familiar activity. Even if one goes to a venue of people "like them", the people are still unknown strangers until one gets there.

Given the huge number of mobile social networking applications released in recent years (see Appendix A), and the relatively limited breadth of variation in functionality, it seems likely that many developers are following a "me-too" strategy of copying other designs, or reaching for the low-hanging fruit afforded by open APIs for social graphs and embedded GPS chips in smart phones, and potential opportunities to monitize local business deals. Most of these applications depend on a critical mass of users for efficacy — with the paucity of novelty in the space, one would expect the majority of these efforts to fail. To provide exceptional utility, an applica-

tion would have to express high salience between its employment of sensed space and place and the application domain, in order to alter one's sense of place in a constructive way.

Messaging and annotations

One of the most persistent problem domains for location based services is the attachment of messages, notes, tags, photos, or other content to the physical world. Among the plethora of messaging applications is *comMotion* [Marmasse, 1999] (among the earliest), *Yellow Arrows* [Todras-whitehill, 2006] (among the most successful), and a host of others.[1] In general, these applications can be thought of as facilitating the construction or use of spatially-indexed databases of content, where the user's proximity to a location is an integral part of the experience of the content.

[1] Lassey [2004] provides a good summary of previous location-based messaging applications, including "Hanging Messages", "E-Graffiti", "Active Campus", "Location Linked Information", and "GeoNotes".

There have been many efforts to identify personally meaningful places (such as "work", "home", "store", etc.) based on GPS tracks. Hightower et al. [2005] presents a summary of algorithmic approaches to segmenting spatial coordinates into frequented locations using various sensors and timing data, building on earlier efforts including [Marmasse, 1999]. Once a location has been identified as a frequented location, the user can be prompted to tag the location with a semantically meaningful name. Casey et al. [2008] presents an interface that allows users to share personally meaningful place tags with friends, and studies the motivations that users have for doing so.

The notion of "place" that tagging schemes represent is thin. Any point in space will have multiple different places that it represents, on varying levels of granularity — I am currently at my desk, in my office, in the Media Lab, in Cambridge, in Boston (which is only loosely true, as Cambridge is not inside the Boston city limits, yet is still more understood by out-of-towners than "Cambridge" is), in Massachusetts, and in the US. All of these levels of description are appropriate depending on the context of use. None of these places are adequately represented by a point in space — they all extend in space, with non-circular shapes. While there is value to knowing that my nearness to a particular latitude and longitude indicates that I am probably "at the office", this value is limited to application domains where that level of granularity and accuracy is adequate.

Messaging applications that use geographic coordinates as a spatial index for messages face a similar challenge of salience: does the "location" being employed by the application actually correspond to appropriateness of message delivery? The designers of comMotion described it as a way of dealing with information overload —

by distributing messages spatially in locations where they might be more useful, one could more effectively discover and recall important and timely information. [Schmandt, 1999] If one attaches a shopping list to a spatial coordinate (say, a store), one might only be presented with that list when one goes to that particular location, and otherwise not have it cluttering up one's todo list. However, this strategy works only insofar as the spatial distribution actually maps to use. If one goes to a different store at a different location, the shopping list could be missed. comMotion addressed this by supporting attachment of reminders to place types, so that multiple stores could be associated with a single message, as long as the user had previously tagged the alternate locations appropriately (comMotion predated the wide availability of public point of interest databases). Even in a completely tagged environment where every "store" is known, this approach is limited to spatially linked places rather than movable places — a road-side farm stand which changes locations would be missed. The point here is that the "place" notion required for a shopping list is not a coordinate, but whether the place affords shopping. Other considerations of place that might be just as important as location are whether it is open, or whether it sells the items on your list.

The Yellow Arrows project [Todras-whitehill, 2006] presents a different approach to location-based information tagging, which is both far less technically ambitious, and more limited in scope. Users simply attach stickers to the world, which are marked with an SMS code for creation and retrieval of text messages describing personal experiences about the place where the sticker is affixed. Visitors who find the stickers can also reply anonymously to the original author of the sticker message. Because the application's framing is as a service for leaving messages about personal histories and private meaning that is associated with a particular place, the salience of the application context to the location-message mapping remains high, even if the spatial resolution and broader applicability of the platform outside of that domain is reduced.

A location-based messaging application might also bypass spatial notions altogether, and instead attempt to directly sense something about a place which determines the appropriateness of particular content. Nomadic Radio [Schmandt, 1999] is an example of a messaging application which employs notions of place in its delivery of messages, but without any particular notion of space. Nomadic Radio consists of a wearable device which plays audio message ambiently for the wearer, allowing for hands-free message delivery. The device detects ambient sound in order to choose appropriate times to deliver a message, with the assumption that ambient conversation should

take precedence over recorded messages. Marti and Schmandt [2005] presents another approach to this problem, where wireless finger rings worn by members of a group vibrate when any of them receive a call. If any group member "vetoes" the call by touching the finger ring, the phone call is sent to voicemail. Both applications attempt to preserve a precedence of local place over remote place in messaging.

Tourism and information

Tourism presents a unique set of requirements around the design of place-based services. Historical information is usually all about notions of place — one of the aspects that is the most compelling is how different a place the same space was in the past. Layouts of cities, buildings, and the ways people used spaces and interacted with one another in those spaces change over time, and these differences are compelling narratives.

Personal multimedia tours have long been part of tourism services: many museums or historical venues offer headsets which provide audio tours. Some museums have begun to offer phone numbers that provide audio comentary about particular pieces when dialed from a cell phone, alleviating the need for dedicated hardware. Smartphones open up further possibilities with their ability to sense location using GPS, and their ability to present rich audio and video as well as textual information and maps.

GUIDE [Cheverst et al., 2000] was an early attempt at building a location-aware platform for multimedia tourism. GUIDE predated wide availability of GPS-enabled smartphones with fast data connections, and so was developed with tablet PCs, PDAs, and WiFi data links. The devices sensed location using wireless network IDs, and also used these networks to retrieve information relevant to that location. The user interface included both information contextual to the location, and general information that could be accessed via a directory or table of contents. The designers found in the iteration of their design that while some context-relevance was useful for discovery of information, users would find overly context-constrained interfaces to be too limiting. For example, one might want to find information about non-local venues that one had seen earlier in the day, but one could also benefit from adaptive estimates of tour times based on the user's walking speed. The device also connected to local services such as hotels and restaurants to facilitate reservations.

The same basic principle employed by GUIDE — combining a tour guide, a map, and a guidebook into one device — has now been employed by a large number of other tourism applications specific to particular venues. Parkman Murder is a mobile phone application

which provides a guided mixed-reality audio and video tour that uses the phone's GPS to determine the user's location, presenting the story of a famous 1849 murder trial. Time Travel Explorer presents historical maps, pictures, and venues around London. Chicago Gangland Tour guides visitors around venues important to the history of organized crime in Chicago. Boston Freedom Trail offers a multimedia tour following the historical sites along an established walking tour in Boston. Medical London Walk (the first from a company intending to produce more tourism applications) presents the history of the development of medical practice around Bloomsbury, London. Hollywood Star Walk does similar service for Hollywood celebrities along the established tour in Hollywood. The World Park was a tourism event in New York's Central Park which used barcodes placed throughout the park to connect to videos, photos, and trivia questions and other information about the history of the park. The relative success of these and many other similar applications, combined with the relatively low barrier to entry provided by widely available smartphones and public mapping APIs, likely ensures the continued proliferation of apps of this type.

Figure 5.1: The augurscope: place- and space-based information. [Schnädelbach et al., 2006]

In contrast to these relatively simple phone-based devices, Augurscope [Schnädelbach et al., 2006] was a large, dedicated mobile platform intended to augment open-air museum experiences. The device used a screen mounted on a movable tripod-like platform which displayed overlays of the structures and artifacts that formerly

occupied the space. Visitors could point the device in different directions and push it around, providing a rich immersive experience of the former structures. The designers were particularly concerned with providing an experience that could be shared among multiple museum visitors simultaneously, to encourage a social engagement with the place. This would allow conversation and critical engagement between friends and families that came to the museum with the former modes of social use of space — something missing from exclusively personal guided tours. In order to achieve this, the designers put considerable thought, energy and resources into designing a custom physical form of the device that most easily afforded movement and shared use. GPS accuracy was found to be problematic — even a best-case resolution of 5–6 feet was large enough that small movements of the device would not translate into movements of the virtual scene — a problem that has plagued other augmented reality platforms that utilize GPS as their locative technology.

Mapping and Navigation

Mapping and navigation apps include the broad category of spatial problem solving. They help to answer questions like, "How do I get from A to B?", "Where is X?" or "Where is something like X?", and "What does the layout of Y look like?". This domain is perhaps the most successful for location based services: every smartphone ships with a mapping application. Mapping and navigation were the original uses for which GPS was intended, and where it has had its main commercial success. In contrast with the other categories, for mapping and navigation, space is the domain of inquiry rather than just the context — however, through the choice of which features of space to represent, maps enter the domain of place: they define the social use of a space through highlighted features, boundaries, and juxtaposition. Mapping is, at its core, a process of selecting a repeatable subset of the features of the world and displaying them in a usable context. Maps are valuable because of what they *don't* show as much as what they do — superfluous details are hidden, allowing the user to more easily comprehend a place at the level of detail needed. Of course, the precise definition of "superfluous" is exactly what is at issue when one considers the political power of maps. By carving out a particular set of features of the world as important, other features are rendered unimportant.

Maps function in several different ways: directive (telling us how to accomplish something or get somewhere), informative or analytic (teaching us about aspects of the world), and aesthetic (expressing viewpoints or information as art). These modes are not mutually

exclusive — a single map could do all three. Issues critical to the producers of maps which cut across all of these modes include:

- Choices of representation
- Strategies for data acquisition

These critical issues both draw from and contribute to cultural understanding of place. The widespread availability of geographic infromation systems and low cost public APIs for geographic data has led to a tendency for services to focus on geographic "accuracy" (proportional relationships between entities on a map to distances in the world) over representational utility. Further, the database-centric approach to geographic data privileges universalizable global formats for information over local knowledge.

Representation

Perhaps the most widely recognized location based service is a GPS enabled device accompanied by a map. This might be further accompanied by facilities for providing directions between places, as well as the locations of nearby points of interest or services, collected from GIS databases. Commercial GPS navigation devices such as those made by Garmin or TomTom, services such as Google Maps, as well as road atlases and topographical maps all fit into this category.

The wide availability of Geographic Information System databases makes it easier than ever to combine layers of information with a common coordinate system, allowing easy comparison of widely disparate information types. However, strict spatial accuracy is not always desirable in directive representations — as a common and familiar example, public transit diagrams frequently give up spatial accuracy for conceptual simplicity and compactness. Subway maps often bear only a loose relationship to the spatial geography of their tracks. This is good visual information design — from the perspective of a navigating passenger, the only opportunities to make decisions are at stations and intersections, and thus the full detail of roads and geographic features would only add clutter. Showing only the needed relationships between rail lines captures the *place* of the transportation grid itself. It allows reasoning about space in a non-globally coordinated, but locally effective manner.

Tufte [1990] cites the necessity for information designers to escape from the tyranny of a coordinate-locked flatland, in order to better describe the three-dimensional world we inhabit. Tufte provides the example of a visitor's map for the Ise Shrine of Japan, which seamlessly shifts between a 3D projection of the area around an island and

Figure 5.2: The Massachusetts Bay Transit Authority's subway system map only loosely adheres to the geography of the rail system. Despite (or perhaps because of) its geographic inaccuracy, the map is able to adequately represent all of the stops on five different subway lines and their handicap accessibility, a dozen bus lines, the Boston-based sections of 10 commuter rail lines, and three ferry lines.

Figure 5.3: An even more compressed representation of one rail line, representing only the needed information for a single journey: the sequence of stops, and major interconnections to other rail lines.

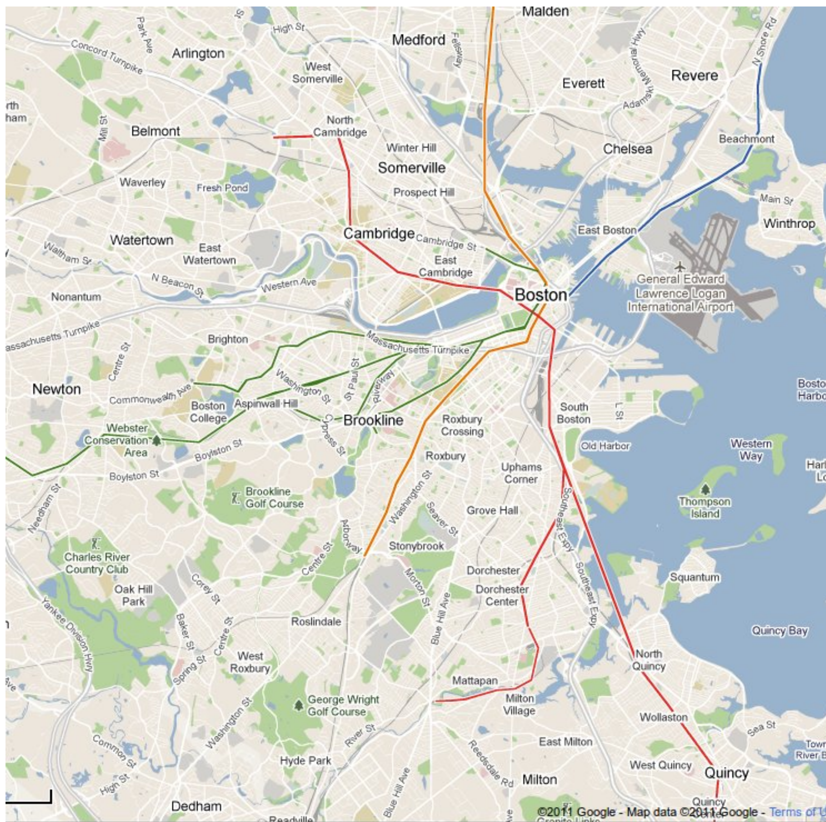

Figure 5.4: A more geographically "accurate" representation of the Boston transit system, which is harder to read for the purposes of travel within the transit system, but easier to relate to other things outside the transit system.

a compact 2D representation of the transportation network used to access it.

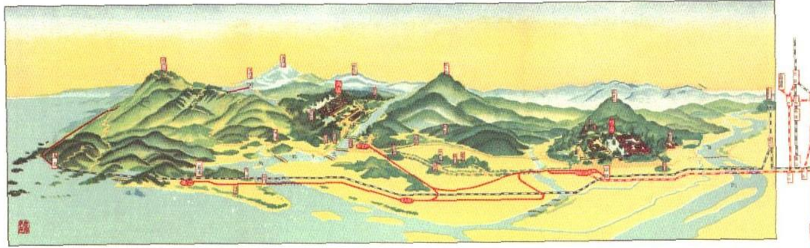

Figure 5.5: A map displaying a path around the Ise Shrine in Japan, which combines a 3D projection view with a compact transit view, representing the perspective of a visitor. [Tufte, 1990]

Neither the stylized transit-map view nor the mixed projection view of the Ise Shrine is possible using the dominant GIS-based map providers — to achieve a refined representation like this, one must forgo precise coordinate systems to introduce intentional and artful distortions which simplify the needed information at the appropriate level of detail. Strict adherence to a globally synchronized representation biases us to relate local geographic features to a larger global structure rather than focusing on the needed local detail.

Beyond representational simplicity, distorted representations that take into account a local perspective can be easier to reason about. As another simple example, printed maps of Manhattan, New York almost always represent the island in the vertical — avenues and streets are parallel to the edges of the paper. However, since the grid of Manhattan has an approximately 30 degree tilt with respect to North, this requires forgoing the convention of keeping North to the top of a map. Maps which depend on seamless movement between a global and local perspective, however, tend to adhere to the convention of keeping North on top, thus representing the island with a tilt. To preserve the intuitive and more locally useful representation which places North 30 degrees to the West in a map, it is necessary to retain *local knowledge* of the geography of a space, rather than resorting only to globally synchronized views.

The city of Boston is notoriously difficult to navigate. Even with the aid of navigational tools, the byzantine layout of streets which eschew rectilinearity, repetition of street names among disparate streets in disparate neighborhoods, and unclear boundaries between sections of town present a daunting task for the uninitiated. However, there *is* a local logic which can be used to help navigate — it is the network of "squares". A square in Boston is not square in shape nor is it always visually distinctive from other intersections, but it represents a named hub in the network of streets that can be used to navigate to other parts of town. As MIT's student publication "How to Get

Figure 5.6: Google Map of manhattan with a 30 degree tilt on the left, and a map more typical of printed maps which keeps North 30 degrees to the West. Map on right from http://www.accessmaps.com/

Around MIT" notes:

> The streets in the older sections were planned by Betsy the Cow and follow ancient land-filled shores, so make very little sense to newcomers. Occasional grids exist, e.g., in the Back Bay and South Boston, but even here confusion reigns — the numbering changes from street to street. To really understand Boston's street layout, you need to realize that its roads run from "square" to "square". Learn where each square is, and the streets just fall into place. [Sims, 2007, p 178]

Despite this, the squares of Boston carry no special prominence in mapping services such as Google Maps. Squares exist only as additional points of interest, no different from a Starbucks or a gas station. The historical sense and conceptual simplicity that they provide to the task of navigation in Boston is ignored.

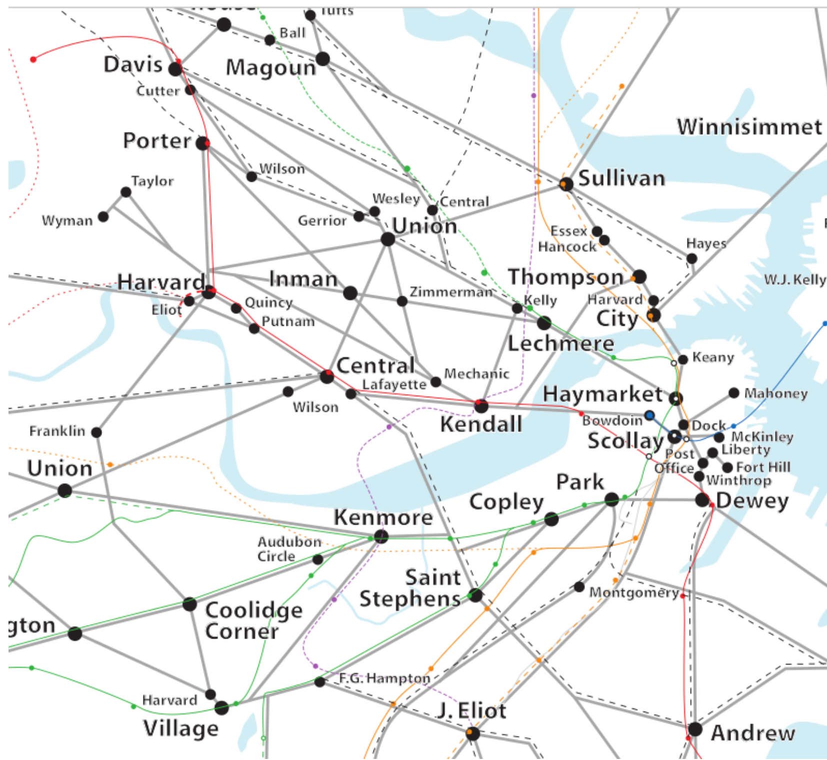

Figure 5.7: A map showing the squares of Boston, and transit lines which connect to them. From http://www.radicalcartography.com

A navigational system which does not convey the existing local knowledge for how to spatially reason about a place is less likely to impart a clear understanding in the user of how to best conceptualize and recall the layout. A mapping application such as Google Maps can provide detailed directions for how to get from point A to point B, but it is less likely to teach a user how to conceptualize the layout

of a city, and how to lose dependence on the application. Navigational applications can thus suffer more from the impact of *decontrol* — users who become reliant on an "intelligent" tool to make choices for how to travel will be less likely to develop the skill to navigate on their own without the tool. This can lead to disastrous results where the intelligent tool errs, and users obliviously drive on [Rotman, 2011]. As one approach to making better use of existing local knowledge, Jaewoo Chung developed an application which takes an interrogative approach, using databases of points of interest to reduce the complexity of turn-by-turn directions presented to a user. The application would ask users if they are familiar with particular points of interest near the destination, and give turn-by-turn directions from there. [Chung and Schmandt, 2009]

Future navigational work might benefit from seeking to collect and represent local knowledge for navigational strategies in particular places. While the seamless transition in zoom levels between global and local levels in a tool such as Google Maps is useful in gaining a global perspective such as that required by an airline pilot, it often falls short where it fails to capture the local logic of a place. A more variegated system which could shift perspectives from a global view to a local view with an accompanying shift in adherence to strict global coordinate systems might improve conceptual clarity of navigational tasks.

Data acquisition

Beyond questions of representation, mapping and navigation systems must grapple with the issue of data acquisition. Companies like Google, NavTeq, and others invest enormous resources in the acquisition of street-level features for their mapping and navigation products. Google drives specially outfitted vehicles around cities collecting imagery for their "street view" product, GPS tracks for roads, and more. These companies must also work with governments and other data providers to collect information about the laws governing roads and interchanges to inform driving directions products. In contrast to this large investment, volunteer geographic information systems like Open Street Maps rely on unpaid volunteers to contribute data, and have become increasingly competitive with commercial map providers, especially in politically contested regions such as Georgia. Goodchild [2007] describes the ways that average people contribute data to services such as Open Street Maps, WikiMapia (a website that allows visitors to attach wiki-style articles to geographic regions), and Flickr, a photo-sharing website that allows visitors to geotag photos. By relying on interested volunteers to contribute data,

it is more likely that those who are familiar with a place and its peculiarities will be able to convey that local knowledge to the geographic information system, rather than simply applying a globally-defined lowest common denominator to the information types.

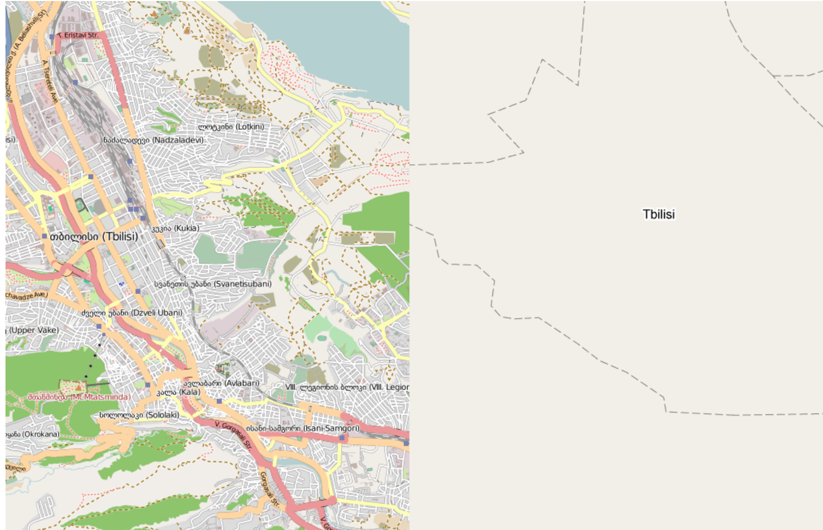

Figure 5.8: On the left, Open Street Map coverage of Tbilisi, the capital of Georgia. On the right, Google Maps for the same area, as of June, 2011

A critical question in the acquisition of map data is the choice of what sorts of data are important. A map provider may consider car navigation to be the most important feature, and invest resources developing a detailed network of roads from the perspective of a driver, thus impacting the use of and importance of cars in a community. An emphasis on public transit or bicycling would require a different strategy for acquiring and storing data. Priedhorsky et al. [2007] describes a volunteer geographic system geared towards bicyclists. Priedhorsky emphasizes the importance of allowing volunteers to not just edit the location of entities or overlays on a map, but to also edit the underlying map itself:

> However, we argue that, in a true geowiki, the geographic context itself, as well as links between geographic context and non-geographic data, enjoys wiki editing features — i.e., the structure of the map itself can be edited, not just items on the map — and this is the notion of geowiki that we extend. . . . This is challenging, as existing web mapping APIs like Google Maps provide insufficient functionality, offering only manipulation of data co-located with an unchangeable, vendor-controlled transportation network. [Priedhorsky et al., 2007]

Priedhorsky's vision is of an up-to-date map that shows details of the condition of streets (including traffic, construction, and surface quality) for bicycle navigation *now*, rather than the last time a mapping

provider surveyed the area. Priedhorsky argues for the combination of sensor-enabled users who are able to track and upload their progress, as well as on-screen map editors that allow unsophisticated users to edit the data. Doing so may make it possible for users to have much more up-to-date local knowledge of the features pertinent to their particular navigational needs.

As another example of an application which depends on local data collection, in 2001, the Institute for Applied Autonomy developed iSee, a mapping application that incorporates knowledge of the locations of closed circuit surveillance cameras to provide routing. Users specify starting points and destinations, and the application provides the "path of least surveillance" between them. An application of this type requires ground-level data collection of a type that would be extraordinarily dificult to execute on a global scale without the use of volunteers — businesses which use CCTV systems would be reluctant to publish the locations of their cameras, and cameras are often hidden or tucked away such that they would be difficult to see except by people walking near them.

Data may not always be easily fit into a universalizable taxonomy required by a geographic information system. The Situationist Internationale, under the direction of Guy Debord, developed a style of mapping called psychogeography, the intention of which is to represent spaces not in terms of their geographic position, but in terms of their emotional relationships. Trajectories or gradients of emotion would be mapped as a way of representing place rather than space. Such a representation may not be a good fit for geographic information systems that have a bias toward spatial relationships. For psychogeography, the process of data collection and construction of representations may be as important a part of the process as the produced map and analysis.

Gaming

Games are powerful motivators, important time sinks, and popuar pasttimes. Game designer Jane McGonigal describes the function of games as motivators as consisting of their providing four main elements [McGonigal, 2008]:

1. Satisfying work to do.
    - immediate feedback
    - concrete results
2. Provide the experience of being good at something.
    - compliments, praise

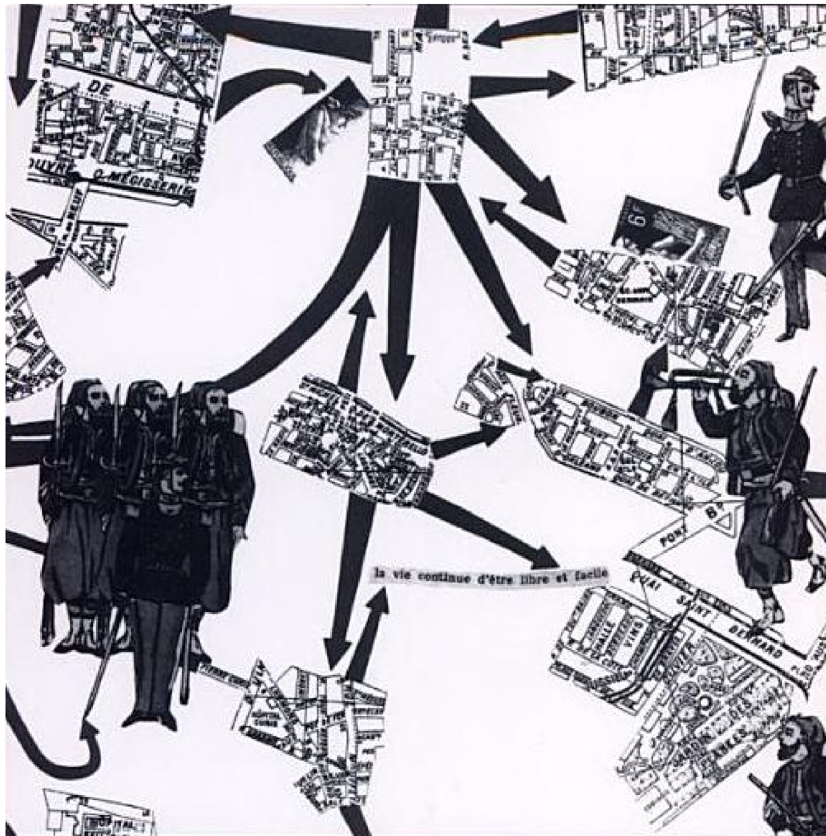

Figure 5.9: A psychogeographic map of Paris, showing the emotional relationships of places. [Sadler, 1999]

- let people feel regarded as "experts"

3. Spending time with people we like
    - Have close friends
    - Meaningful social engagement
4. The chance to be part of something bigger
    - Being told that your work matters; seeing work in context
    - Being emulated

Location-based games employ many of these strategies to motivate their use — often using space or place as the domain in which the strategies operate. A full discussion on the function of game mechanics and motivation is outside of the scope of this paper; however, the points outlined above will suffice for a discussion of how space and place inform location-based games.

Among the earliest of electronic location-based games was geocaching. Geocaching consists of people hiding a container in a particular location, publishing the location on a website. participants then use hand-held GPS units to locate the caches that others have published in order to retrieve the containers. Containers tend to have a log book in which visitors can register, as well as some form of object or treasure left by past visitors. If they wish, visitors can exchange the treasure. Geocaching has been steadily popular since the first published cache in 2000. [O'Hara, 2008] Key to the function of geocaching is the two-way interaction between producers and consumers of geocaching locations. O'Hara [2008] studied the motivations and practice of geocaching participants, and found that geocaching provided a powerful motivation for people to get out into the world — whether as an excuse to go for a walk, as a way to discover new places, as a hobby for collecting prizes, or as a competition between other geocachers to be the first to find a particular cache. O'Hara describes how even in one's local neighborhood, geocaching provides a way for participants to gain understanding about the spaces and places they inhabit:

> The discovery process also applied to the local area where people live where one might expect them to have good local knowledge. But such local knowledge is often built upon particular routines of their everyday life. . . . Geocaching helped people break out of a routine way of experiencing their local environment to discover places they never new existed. [O'Hara, 2008]

As a game, geocaching uses the spatial limitations of GPS as the basis for its challenge. Latitude and longitude coordinates describe an

abstract point on the surface of the Earth, but without any of the detail necessary to find a small hidden object. Their spatial resolution can be limited in the best case to 5 meters; and finding the closest approximation of the location requires negotiating local features including paths, structures, and natural barriers. The detailed on-the-ground features that must be negotiated to travel to the coordinates invoke a challenge of local spatial problem solving, while the indication provided by the GPS gives immediate feedback as to how close or far one is from the goal. If a GPS could somehow provide exact instructions for how to find a cache in the way that an expert human walking beside you could, much of the game mechanic would disappear.

Foursquare is a location-based social networking application for mobile phones which incorporates a game mechanic based on how frequently users visit particular venues. Users "check in" to a venue, and by doing so, earn points with respect to that venue. The user who earns the most points in a particular place can become the "mayor" of that place; mayorship thus becomes competetive. Additional "badges" provide micro-rewards for users who exhibit certain check-in patterns. Participating businesses provide discounts or offers to users who check in frequently, incentivizing usage further, and providing a revenue model for the service. Foursquare advertises their service as one which "increases awareness" of the world around you — "With foursquare, you can unlock your world, and find happiness just around the corner."[Foursquare, 2011] Advertising hyperbole aside, based on analysis of similar social location sharing services by Humphreys [2007] (described above), we would expect the mechanic provided by Foursquare to lead to a parochialization of space, where users have an increased sense of familiarity and ownership over a location. Additional social features such as notifications when out-of-town friends arrive in town and personal record-keeping of travel patterns can lead to an altered sense of familiarity of place.

A similar application, *SCVNGR*, is a location-based gaming platform for mobile phones. Rather than just "check ins", SCVNGR operates with a more generic "challenge" as its basic mechanic. Challenges can consist of generic activities like "checking in", or "checking in with friends" (multiple people checking in simultaneously), but also location-specific challenges, such as "tin foil origami" (folding the wrapper for a sandwich at a specific venue, taking a photo, and sharing it). Doing challenges earns "points"; and participating businesses provide rewards in exchange for earned points. Some challenges are social (require participation of other SCVNGR players), while others are solitary; challenges can be added by any user. Challenges can be organized into "treks". Treks consist of a themed

list of places at which challenges can be completed. Treks can be competitive or non-competitive.

As with Foursquare, locations in SCVNGR are based on venues — usually a business, library, or other participating entity. GPS or other locative technologies are thus used only to identify the venue; once identified, participants are only able to earn points for the challenges for that venue. SCVNGR thus gives incentives for people to go to places that are associated with performable challenges. SCVNGR does this as part of its market strategy, which includes both location-based advertising [Priebatsch et al., 2010] and mutual offers with businesses. As a for-profit enterprise, SCVNGR is interested in pursuing those gameplay strategies that have the potential to translate to revenue.

Parallel Kingdom is a game which describes itself as a "GPS Based RPG" (Role Playing Game). The game involves a virtual world which is overlayed on real world locations. The game mechanic involves attempting to conquer territory by visiting it and claiming it in the real world, as well as battling players in the virtual world. The game only uses location as a limited input mechanism, that allows free travel of the virtual character — real world locations function as nothing more than an index to places in the virtual world. The sense of place provided by the game is thus entirely virtual — real world spaces exist only as occasional friction to character movement in the game.

In contrast with screen-based games such as Foursquare and SCVNGR, which fundamentally are incentive systems to interact with local businesses, *pervasive* or *alternate reality* games attempt to provide a much more immersive gaming experience in the real world. Pervasive games such as those designed by Jane McGonigal or the arts collective Atmosphere Industries employ multiple different media (computers, mobile phones, and actors), and often have a more ephemeral quality, existing as one-time events rather than ongoing activities.

A notable location-centric game is Atmosphere Industries' *Gentrification: The Game!*, a "transmedia" game which attempts to ellucidate the process of gentrification in a town, by asking participants to perform roles of "locals" and "developers" in the real public spaces of a city. The game play involves collecting real properties in the neighborhood and "developing" them, or altering them. Game tactics include actions such as doing protests, PR campaigns, petitions, etc., all of which are performed in the world. Each action has the potential of earning participants "money"; and the team with the most money wins. The collective runs games in places where gentrification is an actual civic issue. As such, the game functions as a pedagogical tool

for thinking about the role of public spaces. [Fono, 2010]

Games may, as Jane McGonigal asserts in her book “Reality is Broken” [McGonigal, 2011], have the potential for contributing to meaningful change in the world. As hinted at by *Gentrification: The Game!*, location-based games may have the potential for contributing to better reasoning about places in a way that improves community function. Games need not be restricted to immersive and totalizing forms like role playing games — as evidenced by Foursquare, the function of simpler, primarily socially-oriented applications can be augmented through the inclusion of a game mechanic.

6 Conclusion

Location based services are based on the idea that adding location-based context to applications can improve their function. In this paper, I have sought to show that for such applications to be successful, developers should employ a more nuanced notion of location that distinguishes *space* (physical and relational aspects of location) from *place* (social affordances and meanings of locations). Technologies for sensing space are more highly developed than technologies for sensing place; though this is in part because sensing place is a much more ambiguous problem domain. Current location sensing technology is biased towards globally registered locations, though in many application contexts, local variation more useful. Developers of location-based services should consider both the *salience* of space and place to their problem domain, and the potential *impacts* that their application will have on users' sense of space and place.

7 Bibliography

Edward Abbey. *Desert solitaire: a season in the wilderness*. Random House Digital, Inc., January 1985. ISBN 9780345326492.

Christopher Alexander, Sara Ishikawa, and Murray Silverstein. *A Pattern Language: Towns, Buildings, Construction*. Oxford University Press, later printing edition, 1977. ISBN 0195019199.

Marc Auge. *Non Places: Introduction to an Anthropology of Supermodernity*. Verso, May 1995. ISBN 1859849563.

Marc Berg. Of forms, containers, and the electronic medical record: Some tools for a sociology of the formal. *Science, Technology & Human Values*, 22(4):403 –433, October 1997. DOI: 10.1177/016224399702200401. URL http://sth.sagepub.com/content/22/4/403.abstract.

Hakim Bey. *T.A.Z. the Temporary Autonomous Zone, Ontological Anarchy, Poetic Terrorism*. Autonomedia, August 1991. ISBN 0936756764.

Sean Casey, Shaun Lawson, and Duncan Rowland. ItchyFeet: motivations for urban geospatial tagging. In *Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges*, pages 435–438, Lund, Sweden, 2008. ACM. ISBN 978-1-59593-704-9. DOI: 10.1145/1463160.1463213. URL http://portal.acm.org/citation.cfm?id=1463160.1463213&coll=GUIDE&dl=ACM&CFID=101989532&CFTOKEN=34955157.

Keith Cheverst, Nigel Davies, Keith Mitchell, Adrian Friday, and Christos Efstratiou. Developing a context-aware electronic tourist guide: some issues and experiences. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 17–24, The Hague, The Netherlands, 2000. ACM. ISBN 1-58113-216-6. DOI: 10.1145/332040.332047. URL http://portal.acm.org/citation.cfm?id=332040.332047.

J Chung, M Donahoe, C Schmandt, and I.J. Kim. Indoor location sensing using geo-magnetism. *ACM International Conference on Mobile Systems, Application and Services*, 2011.

Jaewoo Chung and Chris Schmandt. Going my way: a user-aware route planner. *Proceedings of the 27th international conference on Human factors in computing systems*, page 1899–1902, 2009. DOI: 10.1145/1518701.1518992. ACM ID: 1518992.

J.R. Davis and C.M. Schmandt. The back seat driver: real time spoken driving instructions. In *Vehicle Navigation and Information Systems Conference, 1989. Conference Record*, pages 146–150, 1989. DOI: 10.1109/VNIS.1989.98754.

Gilles Deleuze and Félix Guattari. *A thousand plateaus: capitalism and schizophrenia*. U of Minnesota Press, November 1987. ISBN 9780816614028.

Paul Dourish. Re-space-ing place: "place" and "space" ten years on. In *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work*, pages 299–308, Banff, Alberta, Canada, 2006. ACM. ISBN 1-59593-249-6. DOI: 10.1145/1180875.1180921. URL http://portal.acm.org/citation.cfm?id=1180875.1180921.

Mike Elgan. Is digital nomad living going mainstream? - computerworld. http://www.computerworld.com/s/article/9136154/Is_digital_nomad_living_going_mainstream_, August 2009. URL http://www.computerworld.com/s/article/9136154/Is_digital_nomad_living_going_mainstream_.

Critical Art Ensemble. *Electronic Civil Disobedience: and Other Unpopular Ideas*. Autonomedia, January 1996. ISBN 1570270562.

David Fono. Transforming space with play: an interview with david fono of atmosphere industries, October 2010. URL http://remotedevice.net/blog/transforming-space-with-play-an-interview-with-david-fono-of-atmosphere-industries/.

Foursquare. foursquare. https://foursquare.com/, 2011. URL https://foursquare.com/.

gjs. Pseudo-Skylax — university of leicester. http://www2.le.ac.uk/departments/archaeology/people/shipley/pseudo-skylax, 2008. URL http://www2.le.ac.uk/departments/archaeology/people/shipley/pseudo-skylax. The 'Periplous' (Circumnavigation): a provisional translation (updated 2008).

Michael F. Goodchild. Citizens as sensors: the world of volunteered geography. *GeoJournal*, 69(4):211–221, November

2007. ISSN 0343-2521. DOI: 10.1007/s10708-007-9111-y. URL http://www.springerlink.com/content/h013jk125081j628/.

G. D Hager. A modular system for robust positioning using feedback from stereo vision. *Robotics and Automation, IEEE Transactions on*, 13(4):582–595, 1997.

Steve Harrison and Paul Dourish. Re-place-ing space: the roles of place and space in collaborative systems. In *Proceedings of the 1996 ACM conference on Computer supported cooperative work*, pages 67–76, Boston, Massachusetts, United States, 1996. ACM. ISBN 0-89791-765-0. DOI: 10.1145/240080.240193. URL http://portal.acm.org/citation.cfm?id=240193.

J. Hightower, S. Consolvo, A. LaMarca, I. Smith, and J. Hughes. Learning and recognizing the places we go. *UbiComp 2005: Ubiquitous Computing*, page 159–176, 2005.

L. Humphreys. *Mobile sociality and spatial practice: A qualitative fieldstudy of new social networking technologies*. PhD thesis, University of Pennsylvania, United States – Pennsylvania, 2007. Ph.D.

Lee Humphreys. Mobile social networks and urban public space. *New Media & Society*, 12(5):763 –778, 2010. DOI: 10.1177/1461444809349578. URL http://nms.sagepub.com/content/12/5/763.abstract.

Gavin Jancke, Dan Venolia, Jonathan Grudin, Jj Cadiz, and Anoop Gupta. Linking public spaces: Technical and social issues. *IN PROCEEDINGS OF CHI 2001*, pages 530—537, 2001. URL http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.131.3765.

Jani Jariven, Javier DeSalas, and Jimmy LaMance. Assisted GPS: a Low-Infrastructure approach. http://www.gpsworld.com/gps/assisted-gps-a-low-infrastructure-approach-734, March 2002. URL http://www.gpsworld.com/gps/assisted-gps-a-low-infrastructure-approach-734.

Packard Jennings. Business reply pamphlet. http://centennialsociety.com/business_reply/businessbar.htm. URL http://centennialsociety.com/business_reply/businessbar.htm.

George Kish. *A Source book in geography*. Harvard University Press, 1978. ISBN 9780674822702.

Bradford Lassey. Etherthreads : an infrastructure for location-based messages. http://dspace.mit.edu/handle/1721.1/28425, 2004. URL http://dspace.mit.edu/handle/1721.1/28425. Thesis (M.

Eng.)–Massachusetts Institute of Technology, Dept. of Electrical Engineering and Computer Science, 2004.

Constance Lewallen, Steve Seid, Chip Lord, and Ant Farm (Design group). *Ant Farm, 1968-1978*. University of California Press, 2004. ISBN 9780520240308.

Andro Linklater. *Measuring America: How an Untamed Wilderness Shaped the United States and Fulfilled the Promise of Democracy*. Walker & Company, 1St edition edition, November 2002. ISBN 9780802713964.

Locale. Locale for android review — the gadgeteer. http://the-gadgeteer.com/2009/05/29/locale-for-android-review/, 2011. URL http://the-gadgeteer.com/2009/05/29/locale-for-android-review/.

Lyn H. Lofland. *The public realm: exploring the city's quintessential social territory*. Transaction Publishers, 1998. ISBN 9780202306087.

Hema Mahato, Dagmar Kern, Paul Holleis, and Albrecht Schmidt. Implicit personalization of public environments using bluetooth. In *CHI '08 extended abstracts on Human factors in computing systems*, pages 3093–3098, Florence, Italy, 2008. ACM. ISBN 978-1-60558-012-X. DOI: 10.1145/1358628.1358813. URL http://portal.acm.org/citation.cfm?id=1358628.1358813.

N. Marmasse. comMotion: a context-aware communication system. In *CHI'99 extended abstracts on Human factors in computing systems*, page 321, 1999.

Stefan Marti and Chris Schmandt. Giving the caller the finger. In *CHI '05 extended abstracts on Human factors in computing systems - CHI '05*, page 1633, Portland, OR, USA, 2005. DOI: 10.1145/1056808.1056984. URL http://academic.research.microsoft.com/Paper/1237254.

Stefan Marti and Chris Schmandt. Active messenger: filtering and delivery in a heterogeneous network, November 2007. URL http://citeseerx.ist.psu.edu/viewdoc/summary?doi=?doi=10.1.1.3.6861.

MaxMind. MaxMind - GeoIP city accuracy for selected countries. http://www.maxmind.com/app/city_accuracy, 2011. URL http://www.maxmind.com/app/city_accuracy.

Jane McGonigal. Alternate realities, 2008. URL http://www.slideshare.net/avantgame/alternate-realities-jane-mcgonigal-keynote-sxsw-2008.

Jane McGonigal. *Reality Is Broken: Why Games Make Us Better and How They Can Change the World*. Penguin Press HC, The, January 2011. ISBN 1594202850.

Pomponius Mela and Frank E. Romer. *Pomponius Mela's description of the world*. University of Michigan Press, 1998. ISBN 9780472084524.

Maurice Merleau-Ponty. *Phenomenology of perception*. Psychology Press, 2002. ISBN 9780415278416.

Joshua Meyrowitz. *No Sense of Place: The Impact of Electronic Media on Social Behavior*. Oxford University Press, USA, December 1986. ISBN 019504231X.

RANDALL Munroe. xkcd: Teaching physics. http://xkcd.com/895/. URL http://xkcd.com/895/.

Sense Networks. Sense networks. http://www.sensenetworks.com/citysense.php, 2011. URL http://www.sensenetworks.com/citysense.php.

Kenton O'Hara. Understanding geocaching practices and motivations. *Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems*, page 1177–1186, 2008. DOI: 10.1145/1357054.1357239. ACM ID: 1357239.

S. M Priebatsch, A. Finkelstein, and V. Karpov. *LOCATION-BASED ADVERTISING METHOD AND SYSTEM*. Google Patents, February 2010. US Patent App. 12/708,746.

Reid Priedhorsky, Benjamin Jordan, and Loren Terveen. How a personalized geowiki can help bicyclists share information more effectively. In *Proceedings of the 2007 international symposium on Wikis*, pages 93–98, Montreal, Quebec, Canada, 2007. ACM. ISBN 978-1-59593-861-9. DOI: 10.1145/1296951.1296962. URL http://portal.acm.org/citation.cfm?id=1296951.1296962.

Cliff Randell, Chris Djiallis, and Henk Muller. Personal position measurement using dead reckoning. In *Wearable Computers, IEEE International Symposium*, page 166, Los Alamitos, CA, USA, 2003. IEEE Computer Society. DOI: http://doi.ieeecomputersociety.org/10.1109/ISWC.2003.1241408.

Wilson Rotman. 'Death by GPS': could it happen to you? http://technolog.msnbc.msn.com/_news/2011/02/03/5984248-death-by-gps-could-it-happen-to-you, February 2011. URL http://technolog.msnbc.msn.com/_news/2011/02/03/5984248-death-by-gps-could-it-happen-to-you.

Simon Sadler. *The Situationist City*. The MIT Press, July 1999. ISBN 0262692252.

N. Sawhney and C. Schmandt. Nomadic radio: speech and audio interaction for contextual messaging in nomadic environments. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 7(3):383, 2000.

C. Schmandt. Everywhere messaging. In *Handheld and ubiquitous computing*, page 22–27, 1999.

Holger Schnädelbach, Boriana Koleva, Mark Paxton, Mike Twidale, Steve Benford, and Rob Anastasi. The augurscope: Refining its design. *Presence: Teleoperators and Virtual Environments*, 15(3):278–293, June 2006. DOI: 10.1162/pres.15.3.278. URL http://dx.doi.org/10.1162/pres.15.3.278.

Jessica (Eds.) Sims, Clayton; McKellar. *How to Get Aound MIT / 2007-2008, Vol. XXXVI*. (Cambridge, MA): How to Get Around MIT, 2007. ISBN 0976077930.

Skyhook. Skyhook: How it works > overview. http://www.skyhookwireless.com/howitworks/, 2011. URL http://www.skyhookwireless.com/howitworks/.

Ethan Todras-whitehill. Making connections, here and now - new york times. https://www.nytimes.com/2006/01/25/technology/techspecial2/25geo.html, 2006. URL https://www.nytimes.com/2006/01/25/technology/techspecial2/25geo.html.

Edward R. Tufte. *Envisioning Information*. Graphics Pr, May 1990. ISBN 9780961392116.

Fred Turner. *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism*. University Of Chicago Press, 1 edition, September 2006. ISBN 0226817415.

Wikipedia. Global positioning system - wikipedia, the free encyclopedia. https://secure.wikimedia.org/wikipedia/en/wiki/Gps. URL https://secure.wikimedia.org/wikipedia/en/wiki/Gps.

Rowan Wilken. Mobilizing place: Mobile media, peripatetics, and the renegotiation of urban places. *Journal of Urban Technology*, 15(3):39, 2008. ISSN 1063-0732. DOI: 10.1080/10630730802677939. URL http://www.informaworld.com/10.1080/10630730802677939.

Michael G. Wing, Aaron Eklund, and Loren D. Kellogg. Consumer-Grade global positioning system (GPS) accuracy and reliability. *Journal of Forestry*, 103:169–173, June 2005.

Changqing Zhou, Dan Frankowski, Pamela Ludford, Shashi Shekhar, and Loren Terveen. Discovering personally meaningful places: An interactive clustering approach. *ACM Trans. Inf. Syst.*, 25(3):12, 2007. DOI: 10.1145/1247715.1247718. URL http://portal.acm.org/citation.cfm?id=1247718.

Appendix A

Survey of Location-based Social Network features

The following is a summary of the advertised features in 172 location-based social networks. The initial application list was obtained from BDNooZ.com's Location Based Social Networks Links.

Heading definitions:

- defunct: the application or service is no longer available
- checkins: uses a check-in paradigm for location
- uploads: allows the upload of geotagged photos, videos, or other media
- POI: provides information about local points of interest
- Q/A: provides a local question/answer service
- nearby friends: shows people from a friends list who are nearby
- nearby strangers: shows other people who are nearby
- interests: provides filters for locations or nearby people based on a user-entered interest profile
- ratings: allows users to rate particular local businesses or services
- offers: gives business offers and other advertisements for local businesses
- geotags: allows users to name or label locations
- geotracks: records users' movement in space
- WTPA: Where's the party at? Shows local events
- mobbing: encourages ad-hoc congregation
- game: includes a game mechanic (e.g. points, badges)

name	defunct	checkins	uploads	POI	Q/A	nearby friends	nearby strangers	interests	ratings	offers	geotags	geotracks	WTPA	mobbing	game
Aka-Aki						•	•	•							
Ask around				•	•		•	•			•				
Askalo USA					•		•	•							
Badoo							•	•							
Belysio	•					•									
Bliin			•								•	•			
Block Chalk															
Blumapia			•	•	•	•					•				
Blummi		•		•	•	•					•				
Brightkite		•				•	•			•	•				
Broadcastr			•												
Buddy Beacon	•	•													
Buddy Cloud						•	•	•			•				

Buddymob	•	•													
BuddyWay		•										•			
buzzd		•		•	•	•			•						
Carticipate														•	
CarZar			•												•
Centrl		•								•	•				
CheckPoints		•								•					
Citysense	•												•		
CitySource			•	•											
CliptooMap			•	•											
Coloci						•									
ComeTogethr	•						•	•							
Dailyplaces		•		•		•									•
DeHood				•		•	•						•		
Ditto		•		•						•					
DodgeBall	•	•				•									
Dopplr						•			•						
Double Dutch															
Duzine		•													
EagleTweet		•													
Facebook Places		•		•		•		•		•					
Faysme							•	•							
Feest.je		•	•	•						•					
Findbycllick	•		•	•	•	•			•		•				
FindMe		•									•				
Fire Eagle		•													
Flaik	•		•												
Flowd		•		•		•		•							
Foodspotting															
Footprint History	•														
FourSquare				•	•	•									
Foyaje	•		•	•	•	•	•		•	•					
Fraced	•														
Friend Mapper		•													
Friends Around						•	•			•					
Friends on Fire			•	•	•	•	•				•				
FriendTicker			•	•											
Geo-Me Explore Share Connect	•		•	•	•	•					•				
Geospot	•			•	•	•					•				
Glympse		•													
goGlyph			•							•					
Google Latitude		•				•					•	•			
Gowalla		•	•	•	•	•			•	•	•				
gpsME	•	•													
Grindr							•								

Groovr	•					•									
GyPSii			•			•	•	•			•				
Icloseby							•	•							
iPling							•	•							
Ipoki		•													
IRL Connect															
Jentro				•	•	•					•				
Jentro			•			•									
Junaio				•	•	•			•		•				
Just Spotted			•	•											
karaboo							•								
Koprol (Yahoo)				•			•			•					
Lightpole	•		•	•	•	•			•	•	•				
Limbo	•	•				•				•					
Locaccino		•													
Localmind					•		•						•		
Locatik		•													
Location Fu		•													
Locatrix		•		•	•	•				•	•				
Loci						•									
Locle		•				•									
LOCR			•												
Loki		•													
loopt		•	•	•	•	•	•	•		•	•		•		
Love Clean London			•												
Map My Tracks												•			
mapme			•	•	•	•			•		•				
Match2Blue	•														
Meet Now Live	•														
Meetar							•	•							
meetMoi		•				•	•	•							
Microsoft Vine	•														
Miumeet							•								
mizoon		•				•	•	•		•					
Mobilaris															
Mobile Dead							•								•
mobiluck	•	•				•									
mologogo	•	•													
moximity	•														
Mublet				•		•		•					•		
My Adventures			•												
My Date or Hate							•	•							
MyGeoDiary			•									•			
MyGeolog			•			•									
Myrimis		•	•			•	•				•				
myWingman	•						•	•							

NAV2US				•	•	•			•						
Nearbyfeed			•				•						•		•
Nejari (in Korean)		•													•
Nowhere		•				•		•							
Nulaz		•		•	•	•									
PlacePop		•		•						•					
Plazes		•				•							•		
Pocket life		•		•	•	•							•		
Porkappolis		•		•						•					
Post by Me			•												
Pownce	•	•													
Presence			•	•							•				
Project Geoupdater															
Purpll							•	•							
Qlique	•														
Quiro	•														
Quiro	•			•											
Rally Up		•				•									
Rummble								•		•					
ScreenReach															
SCVNGR				•						•					•
Shadow Cities				•											•
Shizzow		•				•									
Situationist							•								•
Skobbler				•	•	•									
Skout							•								
SNIFF	•														
Snikkr		•	•			•						•			
Socialight			•	•	•	•									
Sparrow		•													
Spot Adventures			•	•	•	•						•			
Spotjots		•	•												
Stalqer	•														
Stickybits										•					
Street Spark							•	•							
Tackable			•		•										
The Grid			•			•									
TheHotList						•							•		
Toai	•														
Toai			•												
Tonchidot				•	•	•									
Toodalu															
Tooio				•	•	•		•							
TownKings		•					•								
Trackut	•			•	•	•									
Trapster				•	•	•									

TrioutNC			•	•					•						
tripit				•	•	•									
Troovy				•	•	•		•		•					
Tweetsii		•				•	•						•		
Twibble	•	•	•												
Twinkle		•	•			•	•								
Twittelator		•													
unsocial							•	•							
unype	•														
Vicinitymatch	•						•	•							
Waze				•	•	•									
wenear	•	•				•	•	•							
where				•	•	•				•	•				
Whereis Everyone						•									
whereyougonnabe	•														
whrrl	•			•	•	•		•							
Wizzper															
Woomark				•					•						
Yobongo							•								
Zheli		•		•						•		•			
Zhiing						•									
zintin		•	•			•	•								