Location-based Environments and Technologies

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INTRODUCTION

Location-based services (LBS) and location-based environments (LBE) exist at the intersection of three separate technologies: information and communication technology (ICT), geographic information systems (GIS) with spatial databases and the Internet (Steiniger et al., 2006). Location-based technologies – such as mobile phones, mobile networks and global positioning systems (GPS) – can be employed in order to deliver information that is relevant to one's location or to use one's location as an information resource. Users can, then, interact with these location-based environments (LBE) for social (e.g. checking in to a restaurant), educational (e.g. exploring a science-based augmented reality world) or informational (e.g. checking the traffic on Google Maps) purposes. With continually evolving advances in mobile technology, users do not merely use their device in a specific location; rather, location, as Gordon and de Souza e Silva argue, sets the 'conditions for interaction and provides the

context from which information is interpreted and used' (Gordon and de Souza e Silva, 2011: 11).

In a fiction piece from *Wired Magazine*, Bruce Sterling (2007) writes from the perspective of a 'hyperlocal' blogger – an 'early-adapter webceleb in the hyperlocal biz' – in the year 2017. He breaks down the definition of hyperlocal for his readers: 'Hyper, as in linked and local, as in location'. All of the databases of this 'new Web', he explains, are 'stuffed with geographic coordinates. Real positions. Real distances'. In this hyperlocal future, corporations have 'used their skills and capital to weld the virtual world firmly to the actual world'. 'Hyperlocality', he writes, 'is transforming our lives at every scale: bodyware, roomware, streetware, cityware, nationware, and global ware'. In 2017, bodyware, for instance, is the stuff carried in pockets and bags that broadcasts its location to nearby devices; roomware maintains rooms, the sensors that control temperature and remotes that control locks; streetware is his 'mobile's navigator,

plus social tags, ad filters, and all those black-and-white barcode blotches painted on walls like graffiti'.

Today, we witness the early predecessors of Sterling's hyperlocal future: smartphone applications such as FourSquare, SCVNGR and Facebook Places have earned popularity by allowing users to 'check-in' to their current location, share information, stories and even participate in location-specific activities; food trucks broadcast their location via Twitter and consumers seek them out; applications such as Yelp and Urbanspoon determine nearby restaurants based on a user's location; photos uploaded to Flickr and Google Photos can be geotagged and mapped by location; computer chips in key fobs can even communicate with billboards for personalized advertisements (Scholz, 2011). In a more nuanced view of location, popular applications for smartphones use the accelerometer, for instance, to wake a user as the phone senses a certain degree of movement in the morning; IP addresses are tracked and provide location-based advertisements; and power consumption can be monitored and altered by mobile devices. Location-based services (LBS) as a whole are forecast to increase their overall profits from $515 million in 2007 to $13.3 billion in 2013 – making them the fastest-growing Web technology sector (ABI Research, 2009 as cited in Gordon and de Souza e Silva, 2011: 9).

This chapter will draw on examples from research using location-based technologies and environments. We will consider at length the general problem of tracking and understanding users, focusing first on how researchers have collected and analyzed aggregate data on users and locations, then turning to approaches to collecting and analyzing data on individual users. Of course, these larger categories of aggregate and individual are not tightly bound, yet they offer a means of organizing the different research goals, technologies employed and perspectives on the relationship between locations, human activity and digital tools and spaces. We then shift to a more in-depth consideration of sensing technologies as a way to suggest how technologies are opening up opportunities to embed rich environmental and human data within location data, even offering real-time feedback loops. A discussion of sensors provides a variety of ways to use location-based technologies as well as a variety of research questions to pursue. While a number of research fields and contexts have drawn on location-aware technologies and have designed location-aware environments, we focus in the following section on two exemplary contexts: health research and research on education and game-based learning. Finally, we will discuss the issues and challenges in conducting research with location-based technologies and within location-based environments.

The research surveyed here ranges from studies using early location-based technologies and environments to more contemporary work and technologies. Its goal is to probe some of the over-arching questions revolving around research with location-based technologies and within location-based environments: how have such technologies pursued issues surrounding individual and group mobility? How have researchers used them to learn more about the movement within space, changes to space or ways to improve space? What can such technologies tell us about human behavior? How do such technologies interface with the human body for the collection of data? By seeking to answer such questions, this chapter aims to better understand the gradual shift from, as Sterling's blogger suggests, the local to the hyperlocal.

TRACKING AND UNDERSTANDING USERS

Aggregate Users and Locations

Research focused on aggregate users and locations tends to be interested in questions of large-scale patterns of use and distribution, such as the distribution of online activity in/ with physical space or the ways in which

virtual and physical worlds overlay and intersect with one another. This area also includes research that has taken new directions through new technologies and, theoretically, the 'spatial turn' (Soja, 1996) to forge new forms of analysis.

GIS and spatial humanities

Scholars in the humanities have begun to use geospatial tools for their research. A *New York Times* article (Cohen, 2011) highlighted the research of those working in the 'spatial humanities' who are using GIS 'to re-examine real and fictional places like the villages around Salem, Massachusetts., at the time of the witch trials; the Dust Bowl region devastated during the Great Depression; and the Eastcheap taverns where Shakespeare's Falstaff and Prince Hal 'caroused'. Knowles (2008) has used GIS to recreate Robert E. Lee's vantage point during the battle of Gettysburg; Cunfer's (2008) investigation of the causes of the Dust Bowl used GIS to drastically shift the time/space scale from 'an intense two-county case study to a broad two-hundred-county region at a coarser resolution, but one which allows for systematic analysis and a broad context' (2008: 118). Ray's mapping (2002) of the accusations made during the Salem Witch Trials emphasized its epidemic-like qualities. As evidenced here, GIS technologies provide a way to investigate time and space from new vantage points and scales as well as ways to visualize data from previously unexplored perspectives.

WiFi

A number of early location-based studies explored behavior and spatial and computational dynamics afforded by wireless Internet (WiFi) and wireless local area networks (WLAN). Tang and Baker (2000) sought to better understand the ways in which users on a college campus took advantage of wireless networks by examining overall user behavior, network traffic and load characteristics. They found users were primarily generating

Web traffic by using synchronous chat applications. Henderson and colleagues (2004) expanded upon this work to trace the kinds of computer-mediated actions taking place over WiFi, such as peer-to-peer sharing, the streaming of multimedia and voice over (VoIP) traffic. They found that, despite the increase of mobile devices – PDAs and mobile VoIP clients – users were not nearly as mobile as predicted, remaining close to home nearly 98 per cent of the time. Sevtsuk and colleagues (2008) probed the intersection between work and mobility on a college campus. They then mapped the spatial patterns of WiFi usage in real time, provided the visualization and allowed the university community to act on that knowledge.

Geo-referencing Digital Activity

Location-based technologies can also be used to track 'digital footprints' (Girardin et al., 2009). By exploring geo-referenced photos shared publicly by individuals, as well as records generated by mobile phone users placing calls and sending text messages, Girardin and colleagues (2009: 128) explored the 'attractiveness of the urban space over time'. By summing aggregate data of mobile calls, texts and AT&T satellite traffic within the proximity of a specific location, they were able to measure overall cellular network activity. This data was then coupled with information gathered from the public photo-sharing website Flickr – specifically, photos anchored to their location by latitudinal and longitudinal coordinates. The mapping of this data allowed Girardin and colleagues to 'detect the main areas of photographic activities in New York because the accumulation of georeferenced photos over a period of time reveal[ed] the boundaries of areas of interest in a neighborhood' (2009: 131). In the end, the study allowed the team to trace the development of the attractiveness of major points of interest by following the density of digital footprints. When combined with the flows of visitors at popular locations, the data supplemented traditional measures, such as surveys

and manual counts, to quantify the impact of a public space or event.

Similarly, Currid and Williams (2010) mapped 'the geography of buzz'. They used Getty Images to geo-code over 6000 events and 300,000 photos taken in Los Angeles and New York City. In other words, they provided a digital footprint to images through their geo-codes. All events were affiliated with the art, fashion, music, design and film industries – creators of social 'buzz'. Then, they conducted a macro-analysis of geographical patterns through GIS and spatial statistics. Through such an analysis, they observed 'particular nodes within the city' (2017: 3) at which cultural events often occurred, drawing connections between specific places and goods, and achieving a better understanding of the specific places that attract the media.

Michael Batty posits that this kind of work maps 'the pulse of the city' (2010: 576). Tracing 'buzz' or digital footprints, like Flickr photos, though, does not allow information to be processed in real time. Geo-located messages from Twitter (Tweets) and FourSquare 'check-ins' have begun to be mined as data and can provide real-time figures. Fabian Neuhaus (2010) detailed the ways in which new 'landscapes' were formed through the topographic visualization of such data by geographic location – plains, for instance, in areas of little usage and hills and peaks in areas of high usage. The digital landscape changed throughout the day: from the morning, to lunch, rush hour and so on. Such an understanding of the pulse of the city, Batty argues, will 'provide us with new views of urban structure and pattern that could well demonstrate to us that cities are much less stable structures than we have previously perceived' (2010: 576).

Individual Users and Locations

While location data on individual activity – whether virtual or physical – is fascinating data, on its own such data is relatively thin and telegraphic to interpret. Researchers therefore have found an increasing array of ways to augment the collection of geo-referenced data with ethnographic data, with participatory data collection and other approaches. Following this, we give a sense of the augmentation of location data by moving stepwise through a range of technologies or ensembles of technologies that have been used in order to augment location data and embed it in other means of understanding social and cultural lives. We survey, in sequence, research on individual users and locations with mobility kits, GPS, participatory GIS and mobile phones.

Mobility Kits

Studies of mobility have sought to better understand the portable objects people carry with them and the ways in which such objects have allowed them to interface with their local environment. Nippert-Eng (1996) investigated notions of privacy through the contents of participants' wallets. Strickland's 'Portable EFFECTS' (2001) project prompted participants to consider the ways in which they were 'nomadic designers' through the objects they carried with them on a daily basis. Other studies have focused on the urban routines established through mobility and the 'mobility kits' (Ito et al. 2009; Mainwaring et al., 2005) that fostered them.

Roth and colleagues (2010) took a major component of a Londoner's mobility kit – the Oyster card – to analyze patterns of urban movement throughout London. The Oyster card is used as an electronic ticket to access public transport services in Greater London. In their study, Roth and colleagues collected data from the Transport of London documenting 11.2 million trips from 2.03 million Oyster cards. Their analysis led to the conclusion that intra-urban movement was primarily organized around specific activity centers. Such a study provided an example of inferring individual movement and mobility patterns through the aggregation of location-based data generated by physical artifacts.

The work on mobility kits acts as a precursor to current location-based research conducted through pervasive, ubiquitous computing devices, like mobile phones. In their study, Mainwaring and colleagues detail the ways in which the mobile kit signaled the participants' interaction with the urban environment in three cities: Los Angeles, London and Tokyo. Through the kit, along with the way the users networked with personal contacts and sought their own private spaces, or 'cocoon', and the researchers mapped the travel patterns of the participants through their 'collecting places' (Mainwaring et al., 2005: 281), in the form of business, loyalty, transit and ID cards.

Okabe et al. (2005) analysis extended the discussion of mobility kits through their further emphasis on location within data collection. The participants in each city, however, captured their own personal diaries through different media: Los Angeles through an audio diary; London through paper-and-pencil; and Tokyo through a GPS-enabled mobile blogging system (moblogging). Participants using the moblogging device could choose to document their personal diary by taking pictures, recording a movie or writing a text message. When doing so, they also provided contextual information, such as whom they were with and what they were doing. The device logged the GPS coordinates, time and date after each entry. Ito and Okabe's study provides a strong example of the analysis of location, both through movement through space via physical artifact and the digital tracking of data entries.

GPS

Evolving technologies have led to similar tracking studies conducted through the use of GPS. Van der Spek and colleagues (2009) explored the possibilities of using GPS as sensor technology in measuring the activities of people. Their study observed the patterns of tourists in historic cities in order to improve the visitor experience. They developed tools to measure the overall impact of city improvements – such as city beautification, additional street furniture and lighting – on visitors. Street interviews coupled with the tracking technologies allowed the team to develop maps of 'great public spaces' (Van der Spek et al., 2009: 3044).

GPS has been employed in order to understand the connection between travel, activity and location. In an early study, Wolf and colleagues (2001) sought to eliminate the travel survey through the use of GPS data loggers. Their research sought to use GPS point data and GIS to derive trip purpose. Kochan and colleagues (2010) developed PARROTS (PDA system Activity Registration and Recoding of Travel Scheduling) to collect activity and travel data as well as location data through GPS during trips. PARROTS automatically recorded location data and allowed users to document the activities they performed at each location. When response rates with PARROTS were compared with those of a paper and pencil survey, Kochan and colleagues found fewer dropouts during the survey period. They also reported a greater number of executed trips, higher-quality data and the convenience of immediate access to electronic data (Kochan et al., 2010: 103).

GPS capabilities extend beyond tracking, or sensing, human activity – toward predicting it as well. Krumm and Horvitz (2004) implemented 'Predestination', a method developed to predict where a driver is going as a trip progresses. Ashbrook and Starner (2003) collected GPS data from a single user and then 'developed algorithms to extract places and locations from that data' (2003: 283). Such a method, they concluded, 'may be able to find locations that are semantically meaningful to the user' (2003: 283). Liao and colleagues (2007) detailed a system that could create a probabilistic model of a user's travel patterns through GPS data. Using GPS data, they sought to infer a user's mode of transportation and predicted when the user would shift to a new mode. Their research also predicted future movements and inferred when a user had deviated from his or her

typical routine by error. GPS, as such, has primarily been used as a means to understand human movement through, and within, specific spaces.

Participatory GIS and Urban Tomography

Similar research has provided users with data-collecting tools – or employs the users' own devices – to collect location-based data. Walker and colleagues (2009) used a mixed-methods approach by combining qualitative methods and GIS in order to learn more about the regular journey that students took to school. To do so, they provided young teen-agers with a mobile phone. A previously installed application, GeoBlog, allowed par-ticipants to write text, take pictures and anno-tate their image. The phone was wirelessly connected to a Bluetooth-enabled GPS device in order to track participants' journeys. Through their research, Walker and col-leagues found it was really the qualitative component – 'the talk' – that truly established the narrative surrounding the student's jour-ney and the interesting things captivating them during it. Such an approach allowed learners from all levels to 'engage in the research process in different ways and their involvement provided a richness to the data set and to our understanding of the school journey as contingent and complex' (Walker et al., 2009: 120).

Urban tomography (Krieger et al., 2010) imbues individual users with agency as data-collectors. With current smartphone technology, urban tomography 'makes use of multiple media records of city life to provide a multi-aspectival view of urban activity' (2010: 22). In other words, users document city life by providing a multitude of 'slices' (2010: 22) of activity. Urban tomography depends on the most recent affordances of smartphones: high-quality video documentation, time/location tagging, 3G wireless and uploading capabili-ties. Once videos are uploaded to a server, they can then be displayed on a webpage. Kreiger and colleagues also note that urban

tomography captures the flows of people within a given location. Each of these exam-ples demonstrates the individual, participatory nature of data collection with location-based technologies.

Mobile Phones and Networks

Mobile phones and networks have been lev-eraged to research human behavior and the daily locations that structure individuals' lives. Ratti and colleagues (2006: 737) used the 'pervasiveness of cell phones to capture extensive urban dynamics'. They sought to make sense of the 'unlimited flow of data from the cell phone infrastructure' in order to better visualize the flowing nature of urban life. Through their research, they questioned the ways in which pedestrians moved through the city; the ways people self-organized in response to disturbances; and the 'critical points of urban infrastructure' (2006: 728).

In their reality mining study, Eagle and Pentland (2006) exploited the use of short- and long-range networks of mobile phones. By tracing the connections that mobile phones made to these networks, Eagle and Pentland then used their data to reveal the structures of behavior that guided actions by individuals and organizations. Using an information entropy metric, they quantified the amount of 'predictable structure in an individual's life' (2006: 258). They analyzed the large-scale dynamics of human behavior by continually logging a user's activity, location, and prox-imity to other people (2006: 263). Such a method of data collection could provide, they argue, a wide range of possibilities – ranging from the ability to predict the locations of col-leagues at specific times to aiding research in computational epidemiology as it seeks to 'build more accurate models of airborne pathogen dissemination' (2006: 263).

In later studies, the reality mining dataset (2006) was used to identify repeating struc-tures in human behavior (Eagle and Pentland, 2009). Eagle and Pentland called these characteristic behaviors of people *eigenbe-haviors*. With such a 'behavioral caricature'

(2009: 1058) in place, predictions could be made about the subsequent behavior of an individual. Eagle and Pentland then demonstrated the ways *eigenbehaviors* could be applied to whole groups as they moved through a 'behavior space' (2009: 1058) as well as 'to extract the underlying structure in the daily patterns of human behavior, infer group affiliations, and predict subsequent user behavior' (2009: 1059).

In his discussion of 'human sensing' – the use of aggregative data from mobile phones to track human activity – Shoval (2007) points to Ahas and Mark (2005) as the first to undergo such a method of data collection. In their study, Ahas and Mark introduced the social positioning method (SPM) in order to study the flows of mobile phone users in time and space through the analysis of the location coordinates of a mobile phone and the social identification of its user. In each of these studies, the primary impetus for using mobile communication was to create lightweight, low-cost systems that could track the mobile patterns of users through their own mobile phones.

ENHANCED LOCATION AND HUMAN DATA THROUGH SENSING

Sensors automatically detect, measure and observe events – motion, pressure, temperature, sound and pollutants, for instance – within close proximity. The spectrum of sensors stretches from, at one end, opportunistic sensors to, at the other end, participatory, human-driven sensors (Lane et al., 2008). Current applications use sensor-based technology in order to collect, process, share and visualize sensed information (Parker et al., 2006). An early opportunistic sensing application, Jetsam (Paulos and Jenkins, 2005), for instance, sought to visualize urban public trash through an augmented trash can in order to illustrate to city dwellers the ways in which they participated in their 'newly emerging digital city landscape' (2005: 350). Such work preceded the rise of mobile

devices. The ubiquity of mobile devices, and their evolving sensing capabilities, have made them ideal for people-centric sensing systems – where humans are the focal point of sensing activity – in urban and social settings (Campbell et al., 2006; Eisenman et al., 2006). Mobile devices, then, provide new opportunities for participants involved in data collection to interact with their local environments in ways that are 'uniquely relevant to the interests of individuals, groups, and communities as they seek to understand the social and physical processes of the world around them' (Reddy et al., 2011).

SENSEable City

MIT's 'SENSEable city lab' (Martino et al., 2010) has employed a variety of data collection methods, including pervasive systems, like mobile phone networks and crowdsourced materials, as well as participatory and opportunistic sensing. Specifically, the lab sought a better understanding of the flow of bodies through urban spaces and how such systems could lead to more efficient and sustainable living situations. Through the collection of information by 'smaller urban actors' with 'localization tags' – like GPS, WiFi spots and Bluetooth – the researchers at the SENSEable Lab then created visualizations of 'dynamic localized flows' (Martino et al., 2010). Such visualizations, they argued, effectively depicted human behavior once overlaid on top of traditional maps.

The Copenhagen wheel study (Outram et al., 2010), for instance, used environmental sensors to detect carbon monoxide, nitrogen dioxide, temperature, noise and humidity as the bicyclist rode through the city. The Copenhagen wheel, including sensors located in a hub-controller, was linked to a smartphone on the handlebars of the bike. While the Copenhagen wheel offered health benefits for the user – and encouraged frequent rides – Outram and colleagues noted other potential benefits of such a device, ranging from helping determine routes to measurements of heat, noise and pollution

fluctuation within the city. Key to the project, though, was the visualization created and overlaid on top of traditional maps. Such a visualization translated the data into a form that could lead to change in the mobility patterns and energy consumption once viewed by the participant.

Other studies used visualizations of data to explore the relationships between place, behavior and interaction in real time. They questioned the ways in which such real-time information altered the mobility choices made by people. Real Time Copenhagen (Martino et al., 2010) and WikiCity Rome (Calabrese et al., 2008) displayed the 'pulse of the city' (Martino et al., 2010: 8) or the real-time mapping of urban flows during an evening. The visualization, broadcast for passers-by on a large screen in an accessible area of the city, detailed the movement of people through the city based upon the intensity of mobile phone use. Viewers could alter their routes based on the available information. By doing so, they factored into the ever-shifting nature of their surrounding urban environment.

The SENSEable City Lab also noted other projects with a similar ethos. The Amsterdam Real Time project by the Waag Society and Esther Polak (2002) examined the movements of citizens through GPS and created a map of the city based solely on their mobility. The Real Time Rome Project (Rojas et al., 2008) analyzed the 'emotional landscape' (2008: 4) of Rome through the aggregation of cell phone logs during the 2006 World Cup Final between Italy and France, as well as a Madonna concert. Nold's 'Bio mapping' (2007) used galvanic skin response to measure people's psychological reactions to different areas within a city. This work, in many ways, helps posit urban areas as flowing, fluctuating entities, altered by human movement and affective intensities.

Sound Sensors

Sound sensors have also been deployed for a variety of research purposes (Peltonen et al., 2002; Choudhury, 2003). SoundSense (Lu et al., 2009) used the microphone of the Apple iPhone to distinguish both general sounds, like music and voices, and sounds specific to individual users. It differentiated itself from previous studies through the real-time classification of sounds as opposed to offline analysis and classification. Through its Audio Daily Diary capability, SoundSense used opportunistic sensing to produce a log of acoustic events throughout the user's daily activities. SoundSense also acted as a music detector. In this application, when it detected music, the device prompted users to take a picture of their current location. That image, then, was uploaded to a Web portal where other users could view the stream of images connected to music and location. Users then witnessed the locations of music and could choose whether or not they wanted to go to that event based on the provided visuals. This emphasis on sound highlights foundational work on opportunistic sensing connected to popular mobile devices.

Sensing Proximity through CenceMe

CenceMe (Campbell et al., 2006; Miluzzo et al., 2008), used sensor-enabled mobile phones to infer the actions of users and then shared those actions with their selected social networks, like Facebook or Twitter. It collected sound samples through the microphone and motion through the accelerometer; it scanned Bluetooth and MAC (Media Access Control) addresses in the user's vicinity; it also took GPS readings, as well as 'random' pictures when a keypad was pressed or a call was made. CenceMe classifiers used specific algorithms to categorize audio, motion and images. The phone classifier retrieved audio bits, both voice and background noise; the activity classifier captured data from the accelerometer and classified it as, for instance, sitting, standing, walking, or running. Further, social context was inferred based on sensed conversations with a group of other CenceMe users, and could also recognize when the user

was alone. With training, CenceMe could classify the user as attending a party based on ambient sounds. The accelerator could also determine if the user was dancing at that party.

Musolesi and colleagues (2008) sought to extend the capabilities of CenceMe by uniting it with the virtual world of Second Life. In Second Life, users interact with one another through digital representations of themselves called avatars. When creating an avatar, though, as Musolesi and colleagues noted, users could nearly mirror their physical appearance, but they could not translate their real-world actions into the virtual realm. Musolesi and colleagues sought to bridge real-world actions with virtual world representations through the use of mobile phones. Through the activity inference capabilities of CenceMe, physical actions in the real world were mapped into the virtual world. For example, when a user was running in the real world, his avatar was running in Second Life.

EXEMPLARY RESEARCH CONTEXTS

Perhaps it comes as no surprise that we might select as exemplary research areas for new directions with location-aware technologies, work in health and environmental research on the one hand and education and games for learning on the other. Both areas involve broadly distributed systems and the use of technologies to change human behaviors and human learning. Of course, as of writing, these technologiea are becoming more ubiquitous in daily life: 'bodyware' like the Fitbit and Nike's Fuelband are increasingly common. Moreover, it is also noteworthy that these broad areas are undergoing 'spatial turns' (Soja, 1996) in their own right, including the intersection of physical and virtual spaces. Both areas, for instance, are becoming increasingly interested in studying the individual outside of the laboratory and in the context of everyday, mobile life. How does one live a healthy life across space and time? How does one learn across space and time or how might such learning contexts be designed? Such expanded visions of living on the move, and life as distributed, inform new directions in health, environmental and education research.

Health and Environmental Studies

The nexus of location-based technologies and health information exemplifies data collection at the individual level. Such forms of data collection employ location-based technologies, ranging from the use of mobile networks tracking and sensing technologies. Anderson and colleagues (2007) extended the tracking of mobility to include the tracking of exercise habits through mobility. With their implementation of the application Shakra, they sought to design a system that would motivate adults who were not achieving their daily levels of physical activity by tracking and categorizing daily activity. Such activity was inferred through fluctuations in GSM signal strength.

Other studies have used commercial pedometers in order to motivate users towards a more active lifestyle. Lin and colleagues (2006) created 'Fish'n'Steps', a program that used the step-count gathered by a pedometer to determine the growth of a virtual fish displayed on a monitor. Users could then compete with one another as they witnessed fitness growth through the visual of their respective fish's growth. Similar programs, such as 'Houston' (Consolvo et al., 2006) and 'Chick Clique,' (Toscos et al., 2006) emphasized the social component of fitness as they used data collected by a pedometer to monitor users' step-counts and to share that data with other participants via mobile phone.

Expanding on studies concerning the health of bodies, others have used location-based technologies to gather data to benefit the environment. Chamberlain and colleagues' 'Professor Tanda' (2007) collected both environmental and location-based data to first determine users' environmental footprints and then to persuade the to change their or her travel habits. Similarly, Froelich and colleagues (2010) explored eco-feedback technology, which bridges an environmental

literacy gap by automatically sensing a user's activities, like driving and showering, and providing the user with appropriate information through a computerized interface.

PEIR (Mun et al., 2009) – the personal environmental impact report – included a variety of location-based sensing capabilities – GPS location, activity classification and other contextual data – to provide personalized estimates of environmental impact and exposure for users (2009: 55). PIER focused on 'mobility-related impacts and exposures, using only the commodity sensors built into everyday smartphones' (2009: 56). Specifically, PIER provided its user with two types of her environmental impact – carbon and sensitive site – and two types of her environmental exposure – smog and fast food. The former impact stemmed from the use of transportation that left a carbon footprint and the release of airborne particulate matter emissions near sites like schools and hospitals; the latter related to the user's proximity to airborne particulate matter emissions as well as her proximity to fast-food restaurants. PIER demonstrated the 'emerging class of adaptive, human-in-the-loop sensing systems that combine the distributed processing of the web with the personal reach of mobile technology to engage people in exploring the previously unobservable relationships of their actions to the world around them' (Mun et al., 2009: 67).

Education and Games for Learning

Location-based technologies have been used to create interactive environments in (and out of) classrooms, especially through augmented reality environments. Roschelle and Pea (2002) provided an overview of the affordances of wireless devices in learning venues, including a description of the ways in which they could augment physical space through such technologies as sensors and wearable badges. In 'Savannah: mobile gaming and learning', Facer and colleagues (2004) explored how using mobile technologies could create an engaging learning experience. Specifically, students were given handheld devices that – depending on their physical location – provided information related to the Savannah (e.g. 'A lion is fifty feet in front of you, what do you choose to do?'). This allowed students 'to "see", "hear" and "smell" the world of the Savannah as they navigate the real space outdoors' (Facer et al., 2004: 400).

Klopfer and Squire (2008) designed 'Environmental Detectives', 'a multiplayer, handheld augmented reality simulation game designed to support learning' in science (2008: 5). As an augmented reality game, students used personal digital assistants that would augment the physical world by providing a virtual layer of data accessed through the device: the data on the handheld was connected to the physical location. The game itself simulated the investigation of a toxic spill and encouraged players to conduct their own desktop research and fieldwork as well as taking part in investigations constrained by time and budgets (2008: 13).

Squire and Jan (2007) created the 'Mad City Mystery' – an augmented reality game that challenged students to seek the cause of the death of a citizen. Using their devices, students traveled to various locations to interact with citizens and gain new information about the death. In the end, students had to use their evidence, as well as scientific enquiry, reasoning and logical argument skills, to decide the cause of death. Built-in opportunities for reflection as well as multilayered challenges encouraged further critical thinking. Similarly, Dunleavy and colleagues' 'Alien Contact!' (2009) established an augmented world for students to explore as they interviewed virtual characters, collected digital items and solved a variety of math, language, arts and science puzzles. Such an environment allowed the researchers to investigate the ways in which teachers and students described their learning and teaching experiences in an augmented reality space.

ISSUES AND CHALLENGES

Privacy

Of all the sources of skepticism around research involving location-based technologies, privacy stands as the dominant issue (Beresford, 2005; Dobson, 2000). Spurred to action by the recent controversy surrounding Apple and location tracking by iPhones, US representative of Minnesota Al Franken (2011) recently drafted the Location Privacy Protection Act of 2011. Fearing just what may come from such overt awareness of location, Dobson and Fisher (2003) coined the term geoslavery and asserted that it was 'a new form of slavery characterized by location control' and that it 'now looms as a real, immediate, and global threat' (2003: 47). In their discussion of the social positioning method, Ahas and Mark (2005) acknowledged privacy issues, but also noted that such fears of surveillance often correspond with new technologies: mobile positioning is simply more readily perceivable, due to its seemingly panoptic nature.

Recently, Gasson and colleagues (2011) wrote of the 'privacy implications of behavioral profiles drawn from GPS enabled mobile phones'. In their short case study tracking four people, they argued that 'personal, and in some cases, sensitive information [could] be revealed' (Gasson et al., 2011: 255). By tracking four people, they were able to make inferences – but not assertions – about residence and place of work, gender, social status, family life, routine. More sensitive information, like religion, sexual orientation, and health were more inconclusive. Months, and possibly years, are needed to come to conclusions about some personal and sensitive information.

Even more recently, location-based applications on smartphones have led to concerns surrounding privacy. As mentioned, applications such as FourSquare and Facebook allow users to 'check in' to specific locations. To do so, a user actively logs into the application and notes his or her current location to a social network, which, to some critics, invites potential security risks to a user's now unprotected home. It is not only location-based apps, though, that make use of data connected to one's location. Other apps include the option for location data to be accessed. Instagram, for instance, a popular picture-taking application, can geo-tag images based on one's location. At the time of writing, a new generation of apps now interface with that data in order to provide location information for social purposes. Sonar and Banjo, as examples, integrate with Facebook, Twitter, Instagram and FourSquare to show friends, or friends-of-friends, who is nearby.

The notion of geo-fencing has some users concerned about privacy matters as well (Avalos, 2012). Essentially, geo-fencing allows companies to target consumers via their mobile devices as those users become proximate to their store. Best Buy, McDonalds and Victoria's Secret have the capability, for instance, to interface with the popular Pandora Radio app in order to deliver advertisements to a user depending on his or her proximity to their outlets.

Privacy has been a major topic of discussion in relation to many forms of new media and technologies. danah boyd (2011) has written and spoken extensively on teen privacy in 'networked publics', or 'publics that are restructured by networked technologies' (2011: 7). Teens, she argues, are managing privacy on their own accord. boyd reports that teens perform social steganography – the act of hiding in plain sight – in public messages posted on social networks. As a whole, boyd argues:

> Privacy is in a state of flux not because the values surrounding it have radically changed, but because the infrastructure through which people engage with each other has. Networked technologies introduce new challenges, particularly in environments that are public by default. Privacy cannot be assumed, especially when powerful individuals or entities are interested in leveraging newfound opportunities for access to undermine social norms. (2011: 26)

Technical challenges and limitations

Dunleavy and colleagues (Dunleavy et al., 2009) documented significant problems they faced in the implementation of their augmented reality game, 'Alien Contact'. They encountered hardware and software issues, primarily in the form of GPS error. They reported GPS failure rates of 15–30 per cent. These failures were likely a result of software instability and incorrect set-up of the handheld configuration by the research team (p. 16). Students reported being annoyed by the technical glitches, especially when it impacted other team members. Such a glitch then had a ripple effect on team members as it negatively impacted group management, learning, cohesiveness and collaboration.

When conducting experiments resulting in data collected through Bluetooth - enabled mobile phones, Eagle and Pentland (2006) detailed the issues they confronted. By using Bluetooth, which can penetrate through some types of walls and has up to a 10-meter range, people who were not physically proximate were logged as such. Further, since the device scanned for proximity every five minutes, it may have missed a person if he or she were proximate for only a short period of time. Moreover, human-induced errors occurred when the participant left his phone in a different location, allowed the battery to run out or turned off the phone completely.

Van der Spek and colleagues (2009) noted difficulties in data processing when using GPS. They noted the battery life of GPS-enabled devices as an issue confronted in data collection and the need for its preservation. They also described difficulties of gaining adequate GPS data in an urban environment, primarily from lost signals that often occur when entering buildings.

CONCLUSION

Location-based technologies and environments have played a role in ushering forth new ways for us to experience local spaces. Here, we have surveyed research that has employed location-based technologies and environments to research notions surrounding mobility, human behavior and space; digital footprints, geo-tagging and visualizations; participatory sensing systems, augmented reality, and more. As technologies continue to provide us with a further global reach, they have also enabled us to better understand our own local community and environment. How do we plan for and improve it? How do we participate in it and take part in its upkeep? How is the community continually reconfigured by new technologies? How do we work, play and learn in it? Further, as boyd notes, how does the private continue to take shape? The (networked) public? Research with new technologies will allow us to continually revisit such questions, all the while embedding us further within our local spaces.

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