What Have You Done with Location-Based Services Lately?

Beverly Harrison and Anind Dey

Editors’ Intro

When IEEE Pervasive Computing last published an issue on technologies supporting location detection and its applications, this capability was in its infancy. Developers focused on integrating multiple radio technologies such as GPS, Wi-Fi, and cell towers/Global System for Mobile Communications (GSM). Much of the benchmarking determined how accurately this could work and whether such accuracy could support useful applications, but there was debate about whether users’ privacy concerns would limit the propagation of such applications. Today, location-based services are now a basic user expectation on most cell phones, and applications abound. In this column, we look at how far we’ve come and ask experts what they believe are the coolest location-based applications and what’s in store for the future.

—Beverly Harrison and Anind Dey

Sitting in my rental car at the San Francisco airport during morning rush hour, I’m trying to figure out how to make my 9:00 a.m. meeting in San Jose. The rental car GPS isn’t much help because I used to live in the Bay Area, and I know the routes—the trick is deciding which one to pick at rush hour today. And then I remember my shiny new iPhone (the now impoverished version 1, predating the App Store), so I poke in my current location (pinpointing doesn’t exist yet). Up comes a real-time traffic map. Even with its limitations, I’m still doing a happy dance for the real-time traffic feed that I keep pushing along with my finger as I progress toward my destination. I thought I would be more skeptical and hard to win over on something so seemingly simple. Sometimes simple is just really good.

A version or two of software downloads later, I start hearing murmurings from colleagues about finding restaurants using search words such as “steaks nearby.” And after overeating to my heart’s content in Pittsburgh on this hot tip, there are a dozen applications to track my (non)fitness to help get me back on track. Although I couldn’t quite face them, there are also calorie-counting applications for those whose dedication and courage are beyond mine. I personally rely on the guilt induced by activity-based applications that sense the extent of couch-potato behavior I’m indulging in and get out the exercise wear.

In thinking about this special issue, I wondered how often I used location-based services or applications without even thinking about it anymore. So I kept a log over a week during which I used some form of location-based application. —Beverly Harrison

My first experience with location-based systems was the CyberGuide system (www.cc.gatech.edu/fce/cyberguide) from Georgia Tech. It was one of the first location-aware tour guide systems, of which there are now many. At the time, it was both very expensive and technologically challenging to build an indoor location system. The clever folks at Georgia Tech had built a very low-fidelity but effective positioning system: they bought a bunch of surplus infrared remote controls on the cheap. Then, on each one, they taped down a button, so each remote sent out a unique signature. They hung the remotes from the ceiling, spread out enough to create a cell-based location system that covered several rooms. Infrared receivers connected to Newton MessagePads completed the system. For a few hundred dollars and some batteries, they built a simple location system.

Although I had a lot of experience with research and cutting-edge location-based systems in grad school, my first real experience with a commercial location-based service wasn’t too long ago. I had just graduated in December 2000 and was traveling all over the US and Canada for various interviews. I had an interview at the University of Colorado, Boulder, and was flying
into Denver when I decided to indulge myself and rent a Hertz car that had the new NeverLost system. I was already one day late for my interview because of weather conditions, and as it was, I landed a few hours late due to more weather issues, so I picked up the car, entered the university’s address in the NeverLost system, and was excited to see a complete list of directions that would get me into Boulder in about an hour—still in time to make my job talk.

Of course, the NeverLost system got me completely lost. For a while, it had me going in circles—I went through the same toll booth so many times that I ran out of change and resorted to stuffing dollar bills in the operator-less toll basket; eventually, I ended up just driving through the tolls without paying. Needless to say, I missed my scheduled job talk and about half my interview. Not a good first experience.

Despite that, I continued to research location-based and context-aware systems, and have recently been using the more commercial and widely available mobile phone location applications. Like Beverly, I kept track of how many times I’d used a location-based service over a fairly typical week. Between Yelp, Google Transit, my Garmin nüvi, and a bunch of other applications, the total was 32.

Many of these applications now seem commonplace: in fact, location awareness and meaningful applications in mobile devices have become a basic expectation. However, this fundamental contextual cue opens the door to much more than simple applications based on moment-to-moment location coordinates or point-based queries about restaurants or traffic.

We experimented with several new applications and spoke with experts who were pioneers in mobile device location detection and context-aware applications to see what they thought were the best new applications and the more interesting future areas for location-based research.

**LOCATION CAN DEFINE YOUR LIFESTYLE**

Many applications use location and time stamps to track physical fitness; they often combine them with accelerometer sensor data to differentiate walking from running and determine exercise intensity. Such applications can also collect activity patterns over time for monitoring long-term health and tuning specialized training programs, such as marathons or physical rehabilitation. Suddenly, location isn’t just about map-based information anymore: it can track distance covered, derive exercise pace, and show trends over time (for example, see the Nokia Sports Tracker in Figure 1). In this way, location is subtly supporting a seemingly different user goal in overall lifestyle and health.

When Jeffrey Hightower at Intel Labs Seattle first worked on the PlaceLab project (www.placelab.org/publications/pubs/pervasive-placelab-2005-final.pdf), it was about accurately representing a person’s location with a dot on a map. Although the project pushed fundamental technologies in integrating different wireless radios to triangulate user position, the aspiration was to migrate to “less obvious stuff.”

Hightower explained, “You have destinations that define your life and go beyond just being coordinates on a map. Long-term health, activity, and fitness are not just showing that you move from here to there. These are more than point queries.

“Even the best location applications seem to have location as a less and less visible element—it’s tied to other databases and information. For example,
Other Latino community members later used these routes to encourage increased healthy physical activity to reduce incidence of obesity in the local Latino population.

At Carnegie Mellon University, we’ve been studying dual-income families with school-aged children (http://smarthome.cs.cmu.edu). We gave six families GPS-enabled smart phones for six months to track their location and communication. We also interviewed these families daily to understand their schedules for the next day, how they deviated from their schedule, and which deviations were particularly stressful. We have an amazing data set that we’re only now in a position to mine. We certainly see how valuable location is when combined with children’s activity schedules. We can learn whose responsibility it is to pick up a child from band practice on Thursdays, find out how long it usually takes to get from work to school to pick up a child and get to the doctor’s office, and even predict whether a parent is on his or her way to pick up a child.

PARTICIPATORY SENSING

As Facebook and Twitter have become part of our lives (or at least our kids’ lives), perhaps it’s not surprising that location applications have also gathered momentum around social networking and group interaction. This isn’t about where you are, but rather where your friends are, where others are gathering, and how ad hoc location-based communities spring up. In this context, location sensing depends on information from many possible participants for the applications to have meaning.

Location-Centric Participatory Sensing

Many new applications rely on users tagging, rating, or otherwise posting information about specific locations so others can view these tags—for example, mapping and describing bike routes or walking trails, monitoring environmental hot spots and reporting violations, reporting crime data for neighborhoods, geocaching games, or organizing rallies. In these applications, the value isn’t about who the participants are but rather the event or location itself.

According to Gaetano Borriello at the University of Washington, such participatory sensing is a significant future direction for location-based services that is “not yet out there in the large but will be soon. … Such systems might have fewer privacy issues because they are aggregating data over larger groups and populations. Also, these applications tend to be more tied to specialized interests (versus generic applications). They reflect sensing on a concentration of people, but at a much larger scale than current applications have done.” One simple example of such a system is a location-specific listing of people’s fruit trees that are available for anyone to pick fruit from or harvest.

Yelp (see Figure 2) is one of the more popular examples of location-centric participatory sensing. It lets users search for nearby places to eat, hang out, and shop. Users provide recommendations for the places they like (and don’t), letting other users discover new places to visit.

Participant-Centric Location Sensing

We’ve described applications in which participants’ identities weren’t of primary importance but the information they provided and their locations were. We now look at applications in which both location and participants’ identities matter. Typically, these applications identify and track a limited number of predefined buddies, friends, or family members over time to enable various social networking applications. At the simplest level, the applications might feed labels for specific locations into instant message status indicators to reflect when someone’s at work, at home, in a café, and so forth. More sophisticated applications track multiple people, predict estimated arrival times, and coordinate schedules.

Loopt (www.loopt.com) is a commonly used site for location-based social

![Figure 2. Typical Yelp blog postings and reviews. Location helps users find nearby restaurants, which link to basic information and reviews.](image-url)
networking (see Figure 3). Loopt’s map overlays let users see where the people in their social networks are and keep tabs on what they’re doing. Friends can share their location changes as well as photos and comments about particular locations.

PERVASIVE LOCATION AWARENESS

A critical element in many of the newest and most interesting applications is the assumption that location-based data is continually collected as part of a background process. Although it’s technically possible to use the combined wireless radios (GPS, Wi-Fi, BlueTooth, GSM) in today’s mobile devices to get reasonably accurate location data, few of these devices can optimize the use of near-constant “radio pinging.” Location technology must either turn on/off a radio or keep it running continuously to exploit wireless radio capabilities. Systems that don’t include standby mode must power on the entire device, including the display. There’s no “closed lid” or low-power mode for running sensors in the background; thus, while software development kits seem adequate and fairly low effort, developers must still resolve critical technical issues to fully realize the potential of location- and other sensor-based applications.

The assumption of pervasive technologies is that they’re always on, always available, and work anywhere. Location-based sensing is now accurate enough to enable a huge range of applications, particularly outdoors. Indoor location sensing is more problematic, but ultimately, as wireless networking propagates, this is expected to improve. Cell phone towers are getting wider coverage and stronger signals, which might also help indoor localization.

PRIVACY, SHARING, AND PLAUSIBLE DENIABILITY

As the range of possible applications increases, so do privacy concerns in various forms. Location data about individuals, at any moment in time, might reveal they aren’t where they’re supposed to be (for instance, teens aren’t at the library studying or a spouse isn’t working at the office late). It might also facilitate unwanted tracking or stalking behaviors. One of the beneficial affordances users advocate is plausible deniability—the ability to use technical data ambiguity or technology failure in a useful explanatory capacity. A classic case is claiming there was no cell phone signal when missing, not returning, or hanging up on a call (whether or not there really was no signal).

Beyond this instant location awareness, many of the more advanced applications can build lifestyle patterns of behavior. Again, such behavior patterns might expose highly sensitive information about people’s preferences, diet or entertainment choices, or activities that they wouldn’t want shared, hacked, or seen by others.

Finally, for larger groups or participatory sensing, there could be serious ramifications if it were possible to determine who had attended certain political rallies or protest marches or who had posted tags or messages at certain locations.

In a very nonscientific poll of colleagues around the world who do research on and use location-based services, we asked what their favorite location-based application or service was. By far, the favorites were navigation aids and location-based search, such as Yelp. Many of the respondents seemed almost apologetic for liking something so simple. This shows how far location-based services have come from the days of Active Badge and remote controls in the ceiling. We take these kinds of...
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applications for granted, not just as consumers but as researchers as well. To test out our latest and greatest location-based application, we don’t need to roll out custom hardware anymore. Potential subjects carrying their preferred smart phone are all around us. The ease of deployment has made our lives easier; however, it has also made it harder to stay ahead of industry.

Although the next location-based “killer app” is unclear, as is whether we’ll see the next major innovations coming from academia or industry, location-based services are now fundamental expectations. The creation and propagation of new services are faster than we ever anticipated. We’re already living the future envisioned only a few short years ago. Mel Brooks might have put it best in Dracula: Dead and Loving It, when he said, “it all comes down to location, location, location.”

Beverly Harrison is a senior scientist and manager at Intel Labs Seattle and affiliate faculty in the University of Washington’s Computer Science and Engineering Department and Information School. Her research interests include designing and evaluating novel interaction technologies and designing context-aware systems. Harrison has a PhD in human factors engineering from the University of Toronto. Contact her at beverly.harrison@intel.com.

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