Compared to Specialized GPS Devices, How Good are Smartphones for Measuring GPS Coordinate Data?

Authors: Stuart Clark and Evan Levy
Information Technology Services Branch, CalRecycle; June 2013

Abstract

As new technologies are constantly appearing, GPS tracking has become more integrated into mobile devices to allow users to incorporate an additional feature into the smartphone realm. Due to the number of applications that are available for smartphones, many are questioning the need to purchase a second device for tracking location rather than using the smartphone that they already possess. To assess if smartphones are a viable replacement for a dedicated GPS device, it is important to consider the following question: compared to specialized/dedicated GPS units, how effective are smartphones for measuring GPS coordinate data? To answer this question, it is vital to study previous research that has already looked into the accuracy of smartphones in comparison to dedicated GPS devices. Based on analysis of four articles discussing smartphone GPS accuracy, it is evident that smartphones are becoming viable as a substitute for a dedicated GPS device. Currently, as of the writing of this article in June 2013, smartphones are not quite as accurate as dedicated GPS devices but are accurate enough to provide reliable location services for most practical uses.

Problem/Opportunity

Global Positioning Systems (GPS) have become the leading technology for providing location-based information that has provided many organizations with methods of tracking geographic position and recording data about places of interest. With new technologies constantly surfacing, GPS tracking has been integrated more and more into mobile computer devices, such as tablets and smartphones. Due to advances in these technologies, workers are now inclined to use smartphones rather than a dedicated GPS device. Many people already possess a smartphone and obtaining a dedicated GPS device adds more costs to their budgets, and it would therefore be beneficial to use a smartphone instead. To assess if a smartphone is a viable replacement for a dedicated GPS device, it is important to consider the following question: compared to specialized/dedicated GPS units, how good are smartphones for measuring GPS coordinate data? In other words, can smartphones be used as a practical and accurate tool to collect geographic data?

GPS calculates locational positions anywhere on Earth by the use of a global satellite system. There are currently twenty-four GPS satellites that orbit Earth and in order for GPS devices to acquire positional data there needs to be a connection with at least three satellites to calculate 2D coordinates, such as latitude and longitude. If a GPS device connects to four or more satellites, it can also obtain altitude information for the position. GPS devices are very useful for gathering location-based points and routes when the user is offsite from the workplace, and the devices are able to include attribute data about each of those features. Due to rapid technological advances in the recent past, mobile phones have incorporated location-based applications and infrastructure to offer essentially
Compared to Specialized GPS Devices, How Good are Smartphones for Measuring GPS Coordinate Data?

the same characteristics as a GPS device provides. Consequently, using smartphones as a GPS device has become a popular method of gathering geographic data and navigating routes.

Most current smartphones are GPS-enabled and use a technology called Assisted GPS (A-GPS) (Zandbergen, 2009). A-GPS, unlike a full GPS receiver, employs functions performed by a remote GPS location server, which provides the smartphone with satellite orbit and clock information, the initial position and time estimate, satellite selection, range and range date, and position computation (Zandbergen, 2009). Some current smartphones come equipped with a true GPS chip, which gathers satellite data to calculate exact positioning similar to a dedicated GPS device. The Apple iPhone and Google Nexus One are examples of devices that utilize this type of chip, and have proven to be more like a dedicated GPS device in regard to accuracy (Ionescu, 2010 - http://www.pcworld.com/article/192803/geolo.html). The U.S. Federal Communications Commission (FCC) requires that mobile devices locate the caller to within 50 meters for 67% of emergency service calls and to 150 meters for 95% of calls in order for emergency services to acquire locational data (Zandbergen, 2009). Many cellular service providers adopted A-GPS to meet the requirements of the FCC. Some downsides of using Assisted GPS include an inability to acquire position when indoors and when in high density urban regions due to satellite visibility and signal obstruction. A way to counteract the issues involved with signal obstruction when indoors has been to use WiFi signals to determine location. According to Zandbergen, the WiFi locating software recognizes the existing WiFi signals within range of a WiFi-enabled smartphone to compute the current location of the mobile device (Zandbergen, 2009). WiFi has proven to be fairly accurate and within 20 meters of accuracy indoors and outdoors. Another method of tracking location within a cellular device is through cellular positioning. This technique involves tracking a mobile client as it moves through the network based on the cellular towers. The Cell ID, or cellular identification, is the most common way that cellular positioning is accomplished and is done by using the known location of the base station, or cellular tower (Zandbergen, 2009). The positional accuracy of cellular positioning is dependent mostly on the density of cellular towers, or base stations, but it can prove to be useful when A-GPS and/or WiFi positioning is unavailable. According to the MIT Technology Review, most smartphones have GPS location signals from satellites with cartographic software capabilities, by using either a GPS chip or cellular towers (Leber, 2013 - http://www.technologyreview.com/news/511786/a-shrinking-garmin-navigates-the-smartphone-storm/).

RESEARCH

There have been several studies that examine the advantages and disadvantages of using a GPS-enabled smartphone device versus a dedicated-GPS device. Most of the studies that examine the differences between the two types of devices conclude that dedicated-GPS devices will be more accurate, but smartphones appear to be becoming more accurate as time progresses. These studies will assist in determining whether or not smartphones are accurate enough to be feasible replacements for dedicated GPS devices.

HTC G1 DREAM VERSUS TRIMBLE JUNO SB

A study written by Anna Klimaszewski-Patterson compares an HTC G1 Dream smartphone to a Trimble Juno SB dedicated-GPS device based on intuitive use and accuracy of the GPS readings meant for geographic fieldwork. The author points out that less expensive stand-alone GPS devices exist but the Trimble GPS was chosen for the study because of the similarities to the HTC G1 Dream device. The HTC G1 Dream was chosen because it has a GPS-enabled chip and uses the same GPS protocol as the Juno (Klimaszewski-Patterson, 2010).
According to Klimaszewski-Patterson, two free GPS mapping applications were used to ensure the smartphone device was tested to the best of their ability – Maverick 1.1.7 and OruxMaps 2.0.0. The Trimble device used ArcPad 8.0.0.88 (based out of ESRI’s ArcGIS) and TerraSync 4.00 for each test. For each device and application, the following evaluations were made: the ability to navigate, record and load specific geographic coordinates; the ability to record, read and load a track, or polyline; ability to record, read and load a polygon; and calculating the error between reported and actual accuracy. ArcGIS 9.3 with an ArcView license and Google Earth 5.1.3533.1731 were used to analyze the results for each device test. The G1 applications exported the data as KML (Keyhole Markup Language) files through OruxMaps and GPX (GPS Exchange Format) for Maverick, while the Juno device exported data as ArcGIS SHP (Shapefile) files.

The researcher surveyed students who used the GPS and smartphone in the field to find out preferences of the uses, and concluded that the G1’s applications were most preferred due to ease-of-use for waypoints and tracks/polylines, while the results were more mixed for polygons. ArcPad was preferred for loading and visualizing polygons, while the combination of OruxMaps and OruxMapsDesktop was preferred for navigating along/within polygons with less positional slow-down than was experienced with ArcPad. The G1 smartphone was also favored when navigating to pre-loaded waypoints with either of the used applications.
Compared to Specialized GPS Devices, How Good are Smartphones for Measuring GPS Coordinate Data?

![Figure 2: Geographic coordinates collected at sampled control points.](image)

After reviewing the device accuracy and user experience, Klimaszewski-Patterson concludes that the G1 could be used as a capable GPS device. The author states that the “G1 compared favorably against a dedicated GPS device, and was found to be just as accurate as Juno, if not more so, regarding GPS positioning...a smartphone may be a viable alternative to an expensive dedicated GPS device for small-scale research and educational applications where the functionality of enterprise-level GIS integration is unnecessary” (Klimaszewski-Patterson, 2010).

**CAN A SMARTPHONE REPLACE A DEDICATED GPS?**

One article, written by Aaron Miller, assessed four devices and recorded waypoints at known locations visible in satellite imagery and aerial photographs in order to compare the relative error for each device. The reasons behind this research were to compare two iPhone devices to two dedicated GPS devices to examine the accuracy of each. The devices used in this study were as follows: an AT&T iPhone 4S, a Verizon iPhone 4S and two Garmin GPSmap60CSx. After recording the waypoints on each device, the locations were loaded into ESRI’s ArcMap in ArcGIS. The actual locations where the points were obtained were also loaded into ArcMap to be compared and to calculate the accuracy of each device.
The author concludes that iPhones are less accurate than a dedicated GPS, but not significantly so. In general positions, the iPhone was sufficient with single-digit meter errors. However, if it is necessary to be within a meter or two of accuracy, a dedicated GPS would be the best choice. The author averaged the error for each device to represent the majority of the sample. The first point was not included in this, though, due to the fact that the location information that the iPhones received was from WiFi triangulation and did not have information from more reliable sources, like cellular towers and GPS signals. Miller determined that smartphone location is “good enough for projects that are ‘campus-sized.’” Depending on the desired precision of the location collection, a smartphone can serve as a viable option to collect locational data.

**ACCURACY OF IPHONE LOCATIONS**
Another research article by Paul Zandbergen looks at a comparison of assisted-GPS, WiFi and cellular positioning in regard to iPhone locations. Zandbergen briefly discusses the positional accuracy of the 3G iPhone for each of the three methods based on an article from Wired Magazine as follows: within 10 meters for A-GPS; within 30 meters for WiFi positioning; and within 500 meters for cellular positioning (Zandbergen, 2009). Zandbergen’s study aimed to calculate the performance of the hybrid system of A-GPS, WiFi and cellular positioning in the 3G iPhone. The research aims to compare the positional accuracy of each method. A-GPS locational data was collected at outdoor sites under conditions that allowed for the best satellite visibility. WiFi and cellular positions were collected at indoor locations where A-GPS positioning was unavailable. In order to switch between WiFi and cellular positioning while A-GPS was unavailable, the WiFi receiver would simply be switched off. When WiFi is off and A-GPS is unavailable, cellular positioning becomes the default method of collecting locational data.

There were ten benchmark locations and at each location 240 points were recorded. In comparison to a consumer-grade GPS receiver, the Garmin GPSMAP 60Cx unit, the accuracy of the A-GPS on the iPhone at outdoor locations was significantly less (Zandbergen, 2009). Zandbergen states that the performance of the A-GPS could be “attributed to the concessions that are made in the design of the A-GPS hardware on the iPhone, including antenna, power and other considerations” (Zandbergen, 2009). The results from WiFi positioning demonstrated substantially less accuracy on the iPhone at indoor locations in comparison to the A-GPS usage. The results from WiFi positioning were much lower than anticipated, according to Zandbergen. On 57 observations of WiFi positioning, a median error of 74 meters was calculated, which contradicted the potential 30 meters accuracy that was stated earlier (Zandbergen, 2009). The availability of cellular positioning at indoor locations was 98.5%, which was much higher than WiFi (Zandbergen, 2009). The median error of cellular positioning resulted at 599 meters, which is not very accurate. Zandbergen stated that the “spatial pattern of cellular positions suggest that relatively simple positioning algorithms are employed, which do not perform as well as other more complex algorithms” (Zandbergen, 2009). Zandbergen’s 2009 findings concluded that there is promise with the hybrid system, but the positional error found in WiFi and cellular positioning was substantial. Zandbergen goes into more detail about why the WiFi was so unexpectedly low in accuracy and states that it is important to determine factors that contribute to WiFi positioning to find ways to improve the WiFi positioning accuracy.

ACCURACY OF POSITIONING DATA ON APPLE MOBILE DEVICES

Another research study examined comparisons of various apple iPhone and iPad products to test how accurate as a whole these products are. According to the authors, GPS technology, positioning by WLAN, and Cell-ID based positioning are used in combination to determine the position of a smartphone (Watzdorf and Michahelles, 2010). Smartphone devices vary in accuracy due to the WLAN (Wireless Local Area Network), GPS and Cell-ID based location technologies that are incorporated into almost all smartphones currently. As long as a phone is connected to a mobile network, it can receive positioning based on the Cell-ID. Watzdorf’s and Michahelles’s study consisted of a total of 2,289 locations using a marketed Apple application on an iPhone 3G, iPhone 3GS, iPod Touch 2G, iPod Tough 3G and iPad (Watzdorf and Michahelles, 2010). The researchers used an application provided by an insurance company in Switzerland that supplied services relying on location for finding agencies, assistance services, etc. (Watzdorf and Michahelles, 2010). The locational data was collected between April 2011 and August 2011 for this study. This study looks at three different aspects of accuracy amongst the devices: (1) How the accuracy of location information differs among smartphone devices; (2) the different levels of accuracy for location information that are reported by smartphones; and (3) how much does accuracy information differ in populated and rural areas (Watzdorf and Michahelles, 2010).
Compared to Specialized GPS Devices, How Good are Smartphones for Measuring GPS Coordinate Data?

Table 1. Location coverage, average accuracy, and technology for different smartphone devices

<table>
<thead>
<tr>
<th>Platform</th>
<th>Overall Locates</th>
<th>Failed Locates</th>
<th>Successful Locates</th>
<th>Coverage (Share of Successful Locates)</th>
<th>Average Accuracy per Location</th>
<th>Employed Location Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>iPhone 3G</td>
<td>492</td>
<td>122</td>
<td>370</td>
<td>75.20%</td>
<td>655</td>
<td>WLAN, GPS, Cell-ID</td>
</tr>
<tr>
<td>iPhone 3GS</td>
<td>1406</td>
<td>331</td>
<td>1075</td>
<td>76.46%</td>
<td>582</td>
<td>WLAN, GPS, Cell-ID</td>
</tr>
<tr>
<td>iPod Touch 2G</td>
<td>167</td>
<td>98</td>
<td>69</td>
<td>41.32%</td>
<td>174</td>
<td>WLAN</td>
</tr>
<tr>
<td>iPod Touch 3G</td>
<td>127</td>
<td>53</td>
<td>74</td>
<td>58.27%</td>
<td>129</td>
<td>WLAN</td>
</tr>
<tr>
<td>iPad</td>
<td>97</td>
<td>30</td>
<td>67</td>
<td>69.07%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5: Location information derived from the study for each separate device (Watzdorf and Michahelles, 2010).

It was found that the iPhone devices could calculate the position in about 75% of the study, while the rate of data collection for the iPod and iPad devices were at 41% to 69%. Even though the coverage rate was less for iPad and iPod devices, the average accuracy was 108 to 174 meters. The average accuracy for the iPhone was 582 to 655 meters, however. Due to the additional uses of GPS and Cell-ID in the iPhone devices, those smartphones were able to have a higher coverage rate. Employing Cell-ID for positioning data collection allows for much higher coverage rates, but produce significantly reduced accuracy. The researchers found that any data collected that had an accuracy of above 500 meters originated from Cell-ID based positioning, and also discovered that accuracy is much less for locations with more than 500 meters distance from the next populated region (Watzdorf and Michahelles, 2010). The authors end the article by stating that “particularly during the development of mobile applications this fact [using Cell-ID based positioning increases coverage while accuracy is significantly reduced] needs to be considered” (Watzdorf and Michahelles, 2010). It becomes evident through this study that the use of GPS and WLAN in mobile devices is a much more accurate method of collecting locational information.

CONCLUSIONS

Based on the studies that have been researched for this article, it is evident that smartphones are becoming a viable option as a substitute for a dedicated GPS device. Due to advancing technology and capability of smartphones, GPS location services on mobile devices should continue to increase in accuracy as time progresses. At this time, smartphones are not quite as accurate as dedicated GPS devices, but are accurate enough to provide useful location services for most practical uses.

This assessment has illustrated that the benefit of using GPS on a smartphone is very dependent on how accurate the user needs the geographic data to be. Each smartphone has shown to vary slightly in accuracy, so it is important to research the accuracy of specific phones before using them for location tracking. If employing the use of smartphones for uses other than GPS tracking in the workplace, it may be very beneficial to use the smartphone for location tracking rather than purchasing a separate device for GPS. As technology continues to advance, mobile devices will likely demonstrate increased accuracy in gathering locational data and may soon take control of the Global Positioning Systems world.

WORKS CITED

Compared to Specialized GPS Devices, How Good are Smartphones for Measuring GPS Coordinate Data?


