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Smartphones and Tablets as Scientific Tools for Georeferencing Measurements

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Abstract - *The identification, study, or monitoring of any environmental problem frequently requires georeferencing measurements. Fieldwork has frequently been constrained by the availability of global positioning system (GPS) navigation devices. However, many current portable devices can perform georeferencing measurements. We therefore analyzed the potential use of two common portable devices (smartphones and tablets) to take low-resolution georeferencing measurements. We compared the georeferencing measurements from a low-resolution standalone GPS navigation device (Etrex 10, Garmin) with the corresponding measurements from a smartphone (with an assisted GPS system) and a WIFI-enabled tablet (with a standalone GPS system). The results show no statistically significant differences in latitude or longitude measurements between the low-resolution standalone GPS navigation device and the smartphone or WIFI tablet. A comparison of measurement precision showed statistically significant differences between all the devices studied. The standalone GPS, smartphone, and tablet achieve mean precision values of 3 m, 4 m, and 5 m, respectively. These results show that georeferencing measurements from a smartphone or WIFI tablet can be useful in low-resolution studies.*

Keywords — *GPS, smartphone, tablet, georeferencing measurements.*

I. INTRODUCTION

In fieldwork for scientific research, georeferencing is an important tool. However, this tool has not always been readily available, because of both the cost of autonomous dedicated global positioning system (GPS) navigation devices, and the number of devices required for studies with broad coverage (e.g., national biological or environmental surveys). New mobile devices (smartphones and tablets) are potential tools for georeferencing measurements, perhaps complementing the main scientific tools, and they may resolve the limitations described above.

Some recent studies have utilized georeferencing measurements from mobile devices for scientific research, such as teaching physics [1], studying bikers' movements [2], road inventories [3], vehicle tracking [4,5], geological investigation [6], and opportunistic data collection [7]. However, no studies have tested whether the new portable devices with GPS capacities could replace a low-resolution GPS navigation device in either planned research activities across extensive regions (e.g., a national biological survey or definition of water-sampling zones in a watershed) or unplanned situations (e.g., detection of endangered species, soil erosion, cyanobacteria bloom, or chemical or pesticide spillage).

Wan and Lin (2013)[8] assessed the georeferencing accuracy of smartphones for low-resolution measurements, and quoted accuracy ranges of 15–75 m in urban conditions. It is clear that the urban zone can produce distortion of signals, but this level of accuracy is not useful for precision work. However, in environmental or ecological studies, an accuracy better than 10 m can be acceptable for the definition of a sampling point in a river, or a position in a crop field for pesticide or soil sampling. In such nonurban conditions, it is possible that the precision of smartphones and tablets will be similar to that of a low-resolution GPS navigation device. Further, these georeferencing measurements can frequently be complemented with other information about the vicinity, for example by local maps, satellite images, or customized maps (i.e., Google Maps, Map Engine Lite). These allow the fieldworker to understand the local situation better, allowing improved performance of scientific field studies.

The georeferencing capacities of different portable devices (e.g., smartphones and tablets) are provided by trilateration calculations based on: (1) cell ID positioning, through the network utilized by the GSM smartphone (accuracy of 65–134 m) [9]; (2) intensity of the received signal from a WLAN, based on measuring the proximity to wireless access points (accuracy of 5–54 m) [10]; (3) the civilian version of the GPS (accuracy of 5–10 m) [11], called standalone GPS (S-GPS) (accuracy 18–91 m) [12]; and (4) S-GPS complemented by IP information, called assisted GPS (A-GPS) [12,13]. These georeferencing measurements can be accessed using application program interfaces; these are currently focused on outdoor recreational activities (e.g., sports) [2,10,14], but are not limited to them.

In this work, we compare georeferencing

measurements by two common portable devices (a smartphone using A-GPS and a WIFI-enabled tablet using S-GPS) with those by an autonomous dedicated GPS navigation device (Garmin Etrex 10) to determine whether these new devices could be useful for scientific research requiring low-resolution GPS measurements (> 3 m) in outdoor conditions for environmental studies (e.g., definition of river sampling zones).

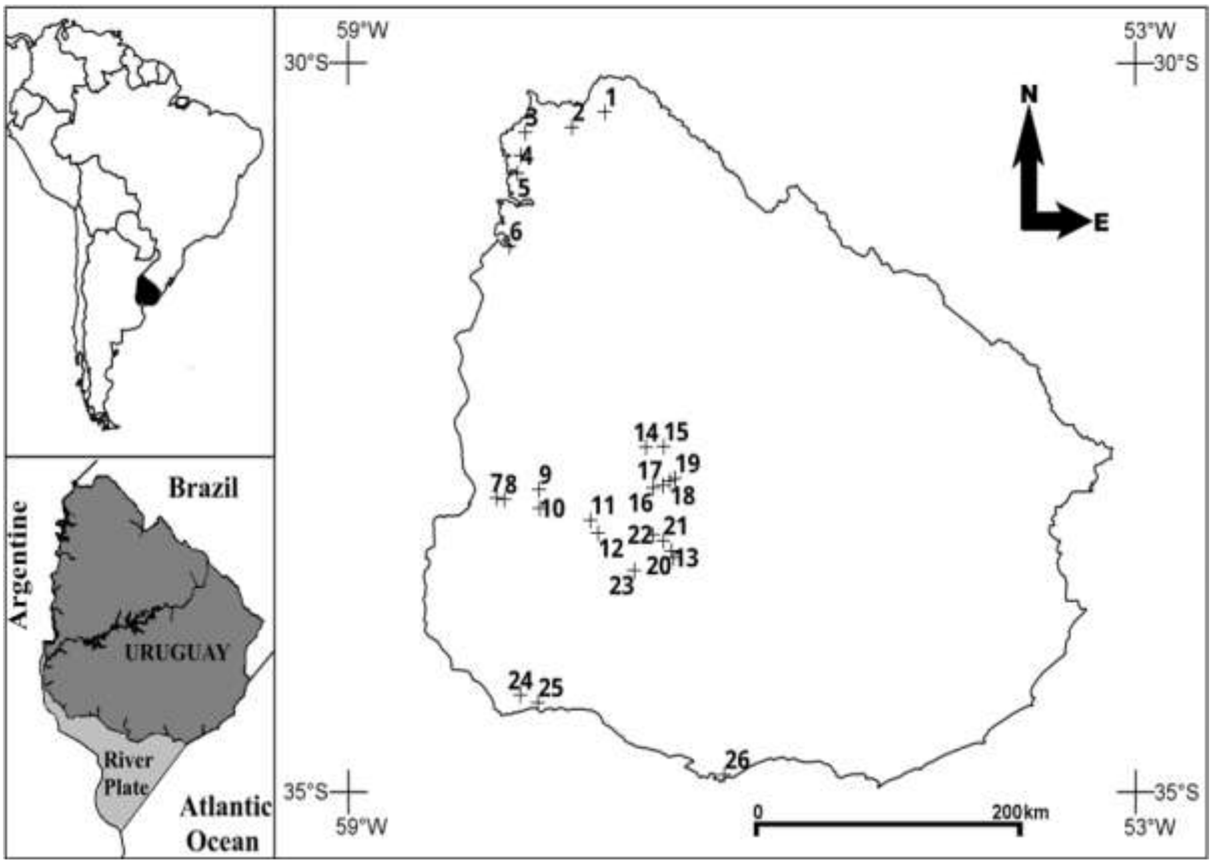

Fig.1. Locations of measurements

II. MATERIALS AND METHODS

A. Devices

The following devices were used in this research:

Autonomous GPS unit: Etrex 10 (Garmin International, Inc., Kansas, USA), with an S-GPS system with access to GPS and GLONASS satellites.

WIFI-enabled tablet: Nexus 7 Asus Wifi (ASUSTeK Computer Inc., Taiwan, China), with an S-GPS system with access to GLONASS satellites, Android 4.3 (Jelly Bean) operating system, wireless connection by 802.11a/b/g/n, and Bluetooth.

Smartphone: Galaxy Duos GT-S6802B (Samsung, Seoul, South Korea), with an A-GPS system with access to GLONASS satellites, Android 2.3 (Gingerbread) operating system, wireless connection by GSM 3G/HSDPA/EDGE/GPRS/802.11a/b/g/n, and Bluetooth.

The georeferencing information and its precision of measurement were obtained in the Android devices with the app “GPS coordinates and location” version 1.71, free from Tappi Apps company, from Google Play™ (digital distribution platform operated by Google™).

B. Experiment design and raw data

We took georeferencing measurements at 26 different places (Fig. 1) between 56° and 59° W and between 30° and 35° S, in the continental national territory of the Eastern Republic of Uruguay. In each place, each device registered the latitude and longitude in degrees–minutes–seconds, as well as the precision reported in meters for each measurement. The information was organized in a LibreOffice spreadsheet [13], transformed to decimal degrees, and exported as a CSV file.

The geographic coordinates were projected in a modified Gauss–Krüger coordinate system, called ROU–USAMS, used by Eastern Republic of Uruguay. This projection system is based on the Hayford 1909 ellipsoid (International 1924, a = 6378388 m, b = 6356912 m, f = 1:297) with a Gauss projection in meters, an ordinate origin 500 km west of the 62° S meridian, an abscissa origin at the South Pole, and a horizontal datum at 30° 35¢ S, 57° 25¢ W (a point called Yacaré). For this projection, we used QGIS 2.4 software [14] in a GNU/Linux operating system [15] using a customized coordinate reference system. At QGIS software, it was done with the addition of following string in Customized CRS window under Configuration menu,

+proj = tmerc +lat 0 = –90, +lon 0 = –55.8 +*k* = 1 +
*x*_0 = 500000 +y_0 = 0 +ellps = intl +towgs84 = –
155,171,37,0,0,0,0 +units = m +no_defs

The CSV file with the geographic coordinates was imported to QGIS software and saved as a shape file with ROU-USAMS as the coordinate r*eference* system. With this shape file, we calculated the respective values of ordinates (*x*-values) and abscissas (*y*-values) for each georeferencing measurement. Then, the *x*- and *y*-values were retrieved from the dBase file of the shape file with LibreOffice Base, and this information was saved as a LibreOffice spreadsheet [15].

C. Data analysis

Every set of Cartesian coordinates (xy-value) from the smartphone or tablet was compared with the corresponding Cartesian coordinates from the GPS navigation device. For this task, we calculated the respective differences of the ordinate (Δx) and abscissa (Δy) values measured by the smartphone and tablet from the corresponding coordinates measured by the autonomous dedicated GPS navigation device. In addition, we determined the absolute distance (D) between the GPS's measured position and the positions measured by the studied devices.

The normal distributions of the Δx, Δy, and D values were evaluated using the Shapiro–Wilk test, before assessing whether $\mu = 0$ through a one-sample t-test or the Wilcoxon signed-rank test with continuity correction [18]. The normal distribution (Shapiro–Wilk test) and homogeneity of variance (Levene test) of the precision data were evaluated before using one-way ANOVA [18]. All statistical analysis was performed using R [19].

III. RESULTS

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The smartphone's D values and the tablet's D values showed homogeneity of variance (F = 0.4977, p = 0.4838) but did not follow a normal distribution (W = 0.9232, p = 0.0025). Therefore, the D means were compared using the Wilcoxon signed-rank test; its results showed no statistically significant difference between the D values of the two devices (V = 156, p = 0.6294).

The autonomous dedicated GPS navigation device, smartphone, and tablet precision values had a mean and standard deviation of 3.0 m and 0.0 m, 4.46 m and 1.03 m, and 5.38 m and 1.58 m respectively. These data did not follow a normal distribution (W = 0.7572, p = 4.976 x 10^{-10}) or show homogeneity of variance (F = 38.511, p = 3.11 x 10^{-12}). For these results, a Kruskal–Wallis rank sum test was used. The results showed statistically significant differences between the devices' precision values (chi-squared = 60.6655, df = 2, p = 6.71 x 10^{-14}). The Wilcoxon rank sum test with continuity correction was used for the mean pair comparisons, which showed statistically significant differences between all the devices' precision values (Fig. 2).

IV. DISCUSSION AND CONCLUSION

Historically, GPS georeferencing measurements for civilian use were offered with reduced precision from the USA. This condition gradually changed, with improved resolution for nonmilitary users. Although these improvements expanded the use of GPS measurements in field experiments in civilian scientific research [12], this option was only available to those research groups that could afford at least a basic model (low resolution, 3–5 m) of an autonomous dedicated GPS navigation device (e.g., Garmin basic models costing 250–380 nominal USD in 2007 and 180–300 nominal USD in 2014, according to the database of the National Agricultural Research Institute).

Environmental studies normally require georeferenced measurements, because environmental impacts can cover extensive regions (e.g., pesticide pollution, land cover changes, and freshwater pollution). Both governmental and research institutions have central roles in such studies, but studies must not be limited to them. Nongovernmental and educational institutions have important functions, because they can offer complementary views, allowing both governmental and citizen participation in the environmental management process. Increasing use of GPS information by research groups and citizens has been constrained by the availability of GPS sensors; this situation can potentially be solved by new portable devices with GPS functions.

The results of this work showed that smartphones or tablets could be used for low-resolution studies, because the measurement precision was in the range of 4–8 m for the devices evaluated (Fig. 2). This precision was better than that reported previously, i.e., 10–60 m [14]. This difference could originate in the electronic component quality of the devices tested, or it could be because the earlier studies related to urban applications of georeferencing, where signal reception has many problems [8]. Moreover, there were no statistically significant differences between Δx, Δy, and D and zero, when comparing the devices' measurements with those of the autonomous dedicated GPS navigation device, and there were no significant differences in the D value between the smartphone and tablet. From these results, we can conclude that there are no important differences between the tested devices (smartphone and tablet) and a commercial low-resolution autonomous dedicated GPS navigation device. We can therefore recommend the use of smartphones and tablets as complementary tools for low-resolution environmental surveys in nonurban zones and for teaching activities, as was suggested by Gabriel and Backhaus[1]. Future improvement will derive from two approaches: technological developments similar to those of Hedgecock et al. [20], which achieved submeter accuracy with a smartphone arrangement; and replication of the National Agri-Environmental Standard Initiative (Canadian experience) for sustainable development in developing countries, where georeferencing measurements must not be a limitation. Because theirs necessity and utility as widely had been demonstrated on precision agriculture with wireless sensor networks [21].

TABLE I

COMPARISON RESULTS OF MEAN VALUES OF ORDINATE'S DIFFERENCES AND ABSCISSA'S DIFFERENCES WITH A μ = 0.

Parameters	Smartphone	Tablet
Δx' mean	–1.23 m	0.62 m
Δx' SD	3.08 m	5.15 m
Statistic value	t=–2.0394	t=0.6144
p	0.0521	0.5445
Δy' mean	–0.29 m	–0.72 m
Δy' SD	4.11 m	2.95 m
Statistic value	t=–0.3655	V= 144
p	0.7178	p= 0.4374
D	4.52 m	4.95 m
D' SD	2.61 m	3.26 m
Statistic value	t=8.8454	V= 351
p	3.59×10^{-9}	2.98×10^{-8}

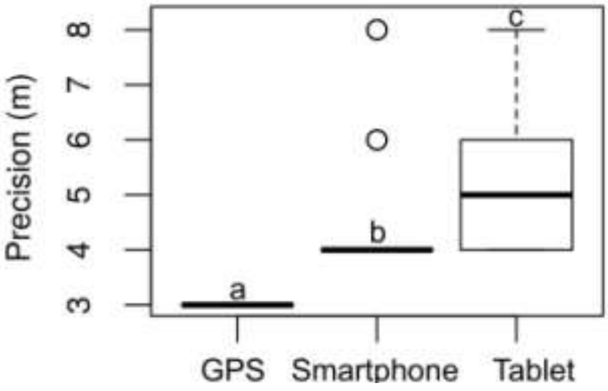

Fig.2. Box and Whisker graph of georeferenced measurement precision self defined per each device.

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