The Autonomous Detection of Tree Position with Different GPS Devices for the Need of Early Apple Yield Forecast

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Abstract. The accuracy of different GPS devices for sampling of trees required for the early yield forecast was studied in two years' campaign. In our experiment March II, PDA ASUS P565 and Nokia 5800 XpressMusic were used. To determine the positions and their accuracy, 245 randomly trees were selected from 245 orchards. We found out that the measurements made in two years with MARCH II deviated in average in diagonal for 16.72 m, in ASUS P565 for 15.41 m and in Nokia 5800 XpressMusic for 46.14 m. ASUS P565 was found to be the most accurate device because the two season's measurements deviated in average in diagonal only for 1.31 m from MARCH II, but there was no significant difference. Despite the fact that discrepancies in individual trees were minimal (0.33 m) in particular measurement, those two devices are not precise sufficiently to identify unequivocally the position of sample trees.

Keywords: GPS / positioning / orchard / sampling

1 Introduction

In the European Union (EU-25), about 10 million tons of apples are harvested yearly, but with great fluctuations from year to year and from orchard to orchard.

Yield prediction is hence a pre-requisite for all partners in the food chain; orchard owners, trade, shippers and retailers all require data on fruit quantity at different fruit growth stages, since a tree bearing an excessive number of fruits will yield small, undersized fruits. Thus, modelling of fruit growth with an emphasis on tree variability is a crucial step in the management of fruit quantity and quality through horticultural practices (Lescourret et al., 1998) with a great impact on yield prediction per hectare in every growing region. Oriade and Dillon (1997) investigated the variability of fruit growth by using a stochastic approach of fruit growth rates and considering the sink strength of the fruit. However, all these models simulate the environmental conditions in the orchard, which can significantly vary from the real values. To overcome these disadvantages, Welte (1991) refined the original Bavendorf model (Winter, 1986) by introducing orchard measurements in

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the mechanistic models. However, fruits were still manually counted on the tree in the orchard by visual inspection on a few selected sample trees, which was a labour intensive and time consuming procedure, hence leaving this method inappropriate for modelling fruit yield in an individual orchard as required by the fruit industry (Stajnko et al., 2004).
Due to time-consuming counting and the lack of experts a lot of inaccurate forecasts appeared in Slovenia from 1998-2004. From these reasons the Bavendorf method was changed by the method of image analysis introduced by Stajnko et al. (2004, 2009). However, even though the method itself was very accurate for forecasting the yield on particular parcel, the small number of sample orchard made it rather vague for entire country. It happened in the individual years that the estimated yield differed from the actual production for 5 to 25%.
Therefore it was decided in 2009 to increase the sample population to 245 orchards selected form the register of orchards. However, for accurate forecasting, in which 'in situ' samples are used for predictions, it is essential that they are always taken at the same location. Then we can talk about the real data with which we can design the organization in advance.
The main advantage of image analysis method is its possibility to capture a lot of images in a variety of orchards in a short time in order to improve forecast accuracy. However, it is desirable very much that each year the images are captured from the same trees. Everyone who was already sampling the trees from the orchards is aware that it is very difficult to locate the positions without any additional marks, as it requires a lot of walking.
The solution of these problems should represent a global positioning system (GPS) as the most frequent method for localization (Panzieri et al. 2007), which enables the user to have access to selected trees for the taking of samples quickly and easily. Since in the sampling method of image analysis we already have camera, we were interested in researching the smart phone with built-in GPS receiver as a substitute for professional GPS equipment.
The objective of our research was to determine whether three different GPS devices (March II, ASUS P565 and Nokia 5800 XpressMusic) lead us to the same position of sample tree, even one year after the first measurement was taken. Another aim was also to determine whether the hail network that are installed on the new plantations affect the signal reception and accuracy of measurements.

2 Material and Methods

From the Slovenian register of intensive crops, owned by the Ministry of Agriculture, 245 locations of the orchards were selected in June 2009 according to the different apple varieties, planting year and growing form. In the same time when the samples of tree images were taken from the particular orchard four tees were additionally marked by the plastic label (Fig. 1). One year later in June 2010 the samples of images were captured again and the position of particular mark tree on all three devices was checked.

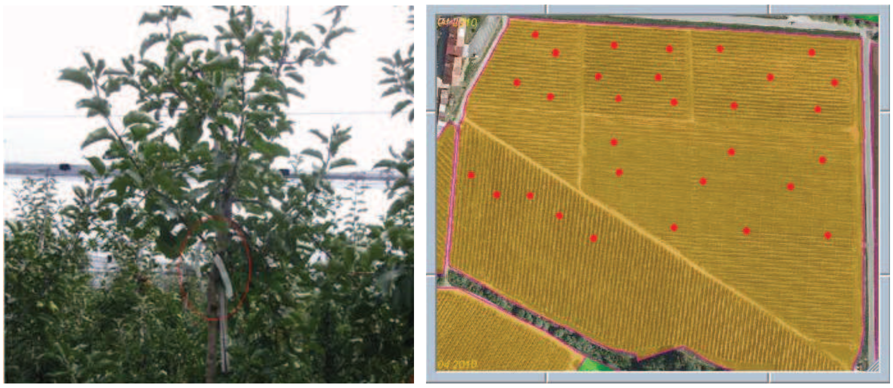

Fig. 1. A sample of marked tree (left), the orto-photo image of selected orchard with sampled trees (right)

For our research three different GPS devices were used according to the price and accuracy reference.

2.1 Description of Devices

March II is a professional hand-held GPS receiver for field data capture. It uses a Motorola integrated 8-channel GPS receiver whose referencing provides a horizontal accuracy of less than 3 m. Its main characteristic is a compact unit, which integrates the receiver, antenna, computer and software that is designed to easily capture the spatial data. Data were gathered in the field based on a pre-established list of objects that we want to record (map) and their properties.

ASUS P565 is also called a ‘smart phone’ driven by an 800 MHz processor and operates on Windows Mobile 6.1 environment and built-in digital camera with a resolution of 3.0 mega pixels. It has got good sensitivity (<-159 dBm), a positioning accuracy (<2.5 m), quick start (standby <1 s), small size (3.12 x 3.17 x 0.4 mm) and the ability to track the frequency L1 (1575.42 MHz). For this handheld PDA in 2008 software Garmin Mobile XT was uploaded and a program FK mobile was developed by Šinjur et al. (2008), which enables autonomous guiding to the marked trees by integrated compass function.

Nokia 5800 XpressMusic is a music-oriented GSM phone, which boasts a modern attractive design, but also is practical and user friendly. The phone has a touch screen and built-in digital camera with a resolution of 3.2 mega pixels. It supports GPS for car navigation and pedestrian navigation and Nokia Maps 2.0 Touch. The device also supports Assisted GPS (A-GPS), which is used to provide packet data connection, which assists in the calculation of the coordinates of the current location when your device is receiving signals from satellites.

2.2 Procedure for Calculating the Differences

All devices used in the experiment operate in a coordinate system WGS84 which refers the position in the usual geographical coordinate format (Lat. 13 ° 39'48.7'', Lon. 45 ° 57' 41.1''), however a direct subtract for calculating differences in position is not possible. Therefore, we applied the Excel forms (Fig. 2), which first record the geographical coordinates of degrees, minutes, and seconds in the decimal representation (column E) and in coordinate form (column F). Once we got the difference in decimal format we had to convert it again back in the geographical coordinates (column G). Finally, the difference in meters was calculated from geographical units so that the φ (latitude) was multiplied by 31 m and λ (longitude) by 22 m (column H).

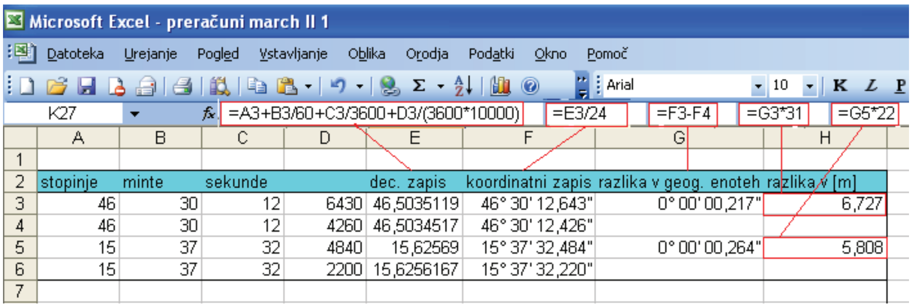

Fig. 2. A sample procedure for calculating the difference in m between two measurements

Statistical analysis was performed with a SPSS Statistics 17.0 for Windows ® as the most familiar and widespread statistical programs in Slovenian education and research field. To analyze the difference between three GPS devices a 'paired samples analysis' at $\alpha < 0.05$ was used.

3 Results

The mean differences and standard deviations between the 2009 and the 2010 measurements for the device ASUS P565 is represented in Table 1, which shows that the mean difference for X coordinate was 3.48 m and for Y coordinate 13.85 m, with standard deviations of 3.35 m for X and 17.87 m for Y. So in the diagonal the mean difference was 15.41 m with standard deviation of 17.21 m. With those results ASUS P565 was proved to be statistically most accurate only in X measurements, whereby Y measurements did differ significantly only from Nokia 5800 XpressMusic.
In MARCH II, the mean difference between 2009 and 2010 measurements was 11.41 m for X coordinate and 10.56 m for Y coordinate, respectively, with standard deviations of 9.48 m for X and 10.68 m for Y. So in the diagonal the mean calculated difference was 16.72 m with standard deviation of 12.84 m. Those

measurements did not differ significantly from the ASUS P565, but they were much better from Nokia 5800 XpressMusic.

Table 1. The mean and standard deviation between two measurements for three different GPS devices

Device	X-measurements (m)		Y-measurements (m)		Diagonal (m)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
ASUS P565	3.48*	3.35	13.85*	17.87	15.41*	17.21
MARCH II	11.41	9.48	10.56*	10.68	16.72*	12.84
Nokia 5800 XpressMusic	11.37	15.19	39.60	49.83	46.14	47.61

* statistically significant at $p \leq 0.05$ (Paired Samples Test).

The mean difference between all measurements done with Nokia 5800 XpressMusicfor showed 11.37 m difference in X coordinate and 39.60 m for Y coordinate with standard deviations of 15.19 m for X and 49.83 m for Y measurements. So in the diagonal the mean difference was 46.14 m with standard deviation of 47.61 m, which was significantly different from both devices ASUS P565 as well as MARCH II. Therefore, the Nokia 5800 XpressMusic device was found to be inaccurate for precise horticulture. For example, once standing 30 m deep in the orchard, the device would still indicate the position coordinates outside the plantation.

The main reason for not receiving declared accuracy lay in the weather conditions and the number of satellites, which was not ideal. Anyway, on the average we achieve a relative accuracy of approximately ± 10 m. It turns out that the error in measurements was most affected by the number of satellites, given in our situation. For example, when we performed measurements of 08/26/2009, we received on the average a signal from eight satellites, while on 07/01/2010 we accepted the signal from just 6 satellites, which was otherwise satisfactory to take measurements, but obviously not enough to improve accuracy.
A very important finding is also the fact that a hail network did not affect the signal quality, since the same number of satellites was detected under and outside the network.

4 Conclusions

Absolute accuracy of the declared facilities for MARCH II and ASUS P565 applied in the experiment would be up to ± 10 m, except Nokia 5800, where the producer recalls that it should not be used for very precise measurements. The manufacturer contends, moreover, that the accuracy of the MARCH II and ASUS P565 is even below 2.5 m, but in practice it was very difficult to achieve.

We can make a general conclusion that in spite of particular very precise measurements, these devices are not sufficiently reliable to indicate the position of sample trees with less than 0.7 m, which is usual space between trees in the lines. They can be applied only for determining a wider space of orchard from which the samples were taken one year before. This fact can help us or another person in finding easily the sampling zone, which is without doubt a very useful tool for saving time in locating the correct part of orchards.

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