Augmented GPS Tracking for Sport Applications

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1 Introduction

Those are interested in cycling, mountain biking, skiing, running or hiking might have used any GPS tracking device to record their positions and to analyse their training results. The position accuracy of these devices lies within an accuracy range of +/- 15 meters. - The altitude error is generally 1.5 times higher. This is appropriate for most applications, particularly if the user is only interested in his position or the distance covered. In contrast, various aspects of physical performance like top speed, power, acceleration or the difference in altitude are not very reliable because the GPS device reacts quite erratic.

Hence we have tested a common tracking device for sport tracking applications and show its characteristic as well as different methods to augment, i.e. to improve its accuracy.

2 Equipment

The following tracking devices have been used:

1. Sony Ericsson XPERIA ST17i - a Smartphone including a GPS single frequency receiver and a barometric sensor. It is operated with the Black Tusk mobile application (see http://blacktusk-sports.eu). Output: Position in NMEA-format and air pressure values.

2. **UBlox Evaluation Kit EVK-6** - an advanced GPS single frequency receiver. Output: Position in NMEA-format and C1/L1 observations in RINEX 2.11.

Black Tusk, http://www.blacktusk.eu, 04/2013

Ublox, http://www.u-blox.com, 04/2013

3 Test track

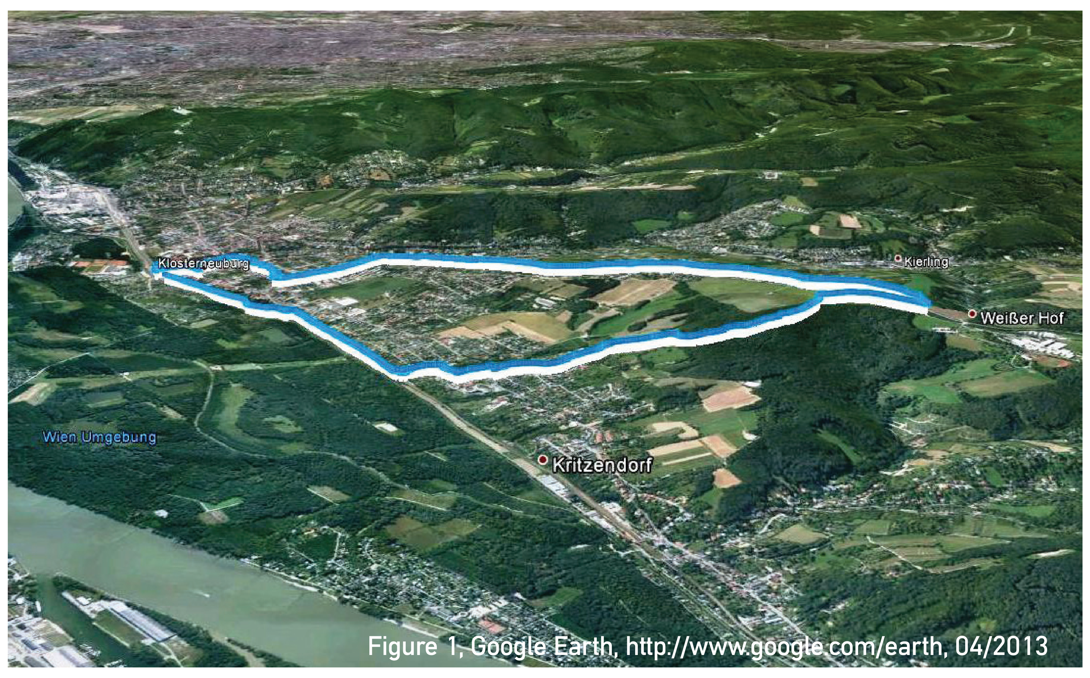


Figure 1, Google Earth, http://www.google.com/earth, 04/2013

To test the performance of the tracking devices a test track near Vienna was defined. The track starts in Klosterneuburg and is curling up into the Wiener Wald through small streets, fringe areas and woodland before it is falling back to the start point (see Figure 1).

The track is 9 km long, overcomes approximately 290 m difference in altitude and characterises a challenging environment for every tracking device.

4 Methods

Several tests on bike and by foot are carried out. Three different solutions have been derived from the recorded datasets.

Solution	Parameter	Source	Description
GPS	lat, lon, altitude	NMEA (Ublox)	on-chip solution
DGPS	lat, lon, altitude	RINEX (Ublox)	server solution
Barometer	altitude	Pressure (Sony)	on-chip solution

Table 1, Overview of the different solutions carried out to obtain the position and altitude along the test track

The GPS solution is a readout of the NMEA-message. The DGPS solution is estimated with GPS observations recorded from the Ublox receiver and data from a GNSS reference station close-by. Afterwards a moving average filter is applied.

The barometric heights are calculated from the air pressure values by utilising the isotherm barometric formula under the assumption of a standard atmosphere.

For validation we recorded the coordinates of 34 waypoints along the test track using RTK equipment (Ref1). In addition we digitalised the test track using georeferenced satellite images (Ref2). In the following both solution are used as reference.

5 Results

Altitude: The altitudes and its differences (dH) with respect to the RTK measured waypoints are plotted in Figure 2.

Solution	Bias dH [m]	Sigma dH [m]	Diff altitude [m]
GPS	-10.7	14.4	1007 (-1011)
DPGS	-3.0	6.3	410 (-420)
Barometer	19.5	3.4	361(-355)
Ref1 (RTK)	---	---	**226 (-226)**

Table 2, Statistical Information - Bias and sigma refer to the height differences dH (Figure 2) and describe its mean value and its variation. The difference in altitude is the sum of all positive (negative) height differences of neighbouring points along the test track.

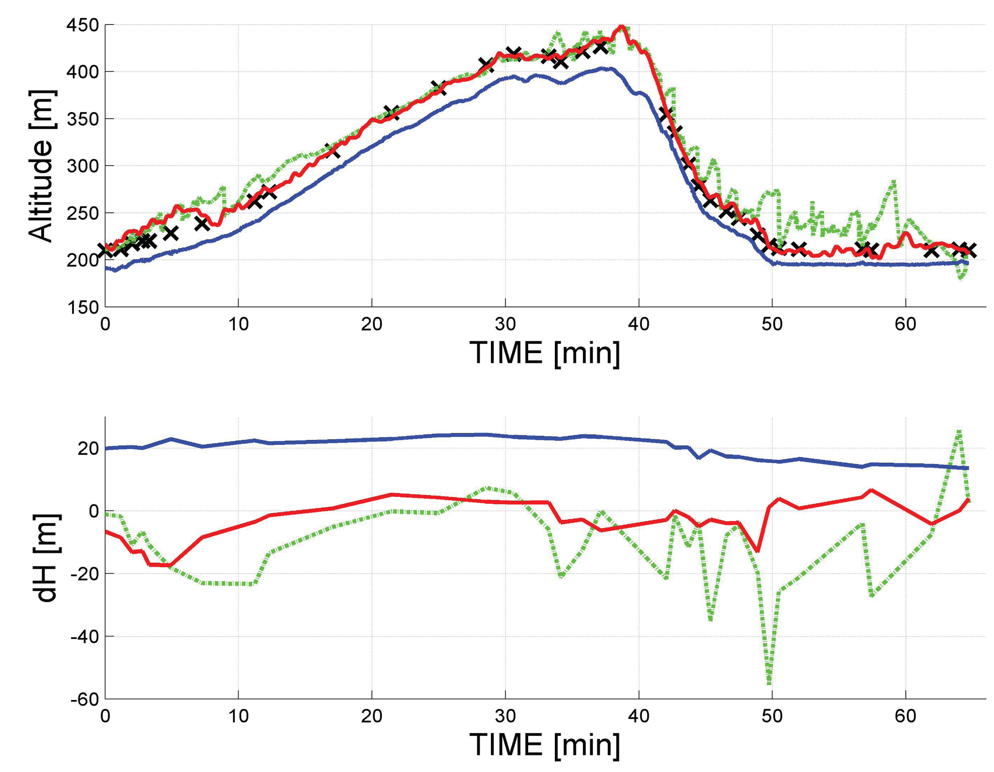
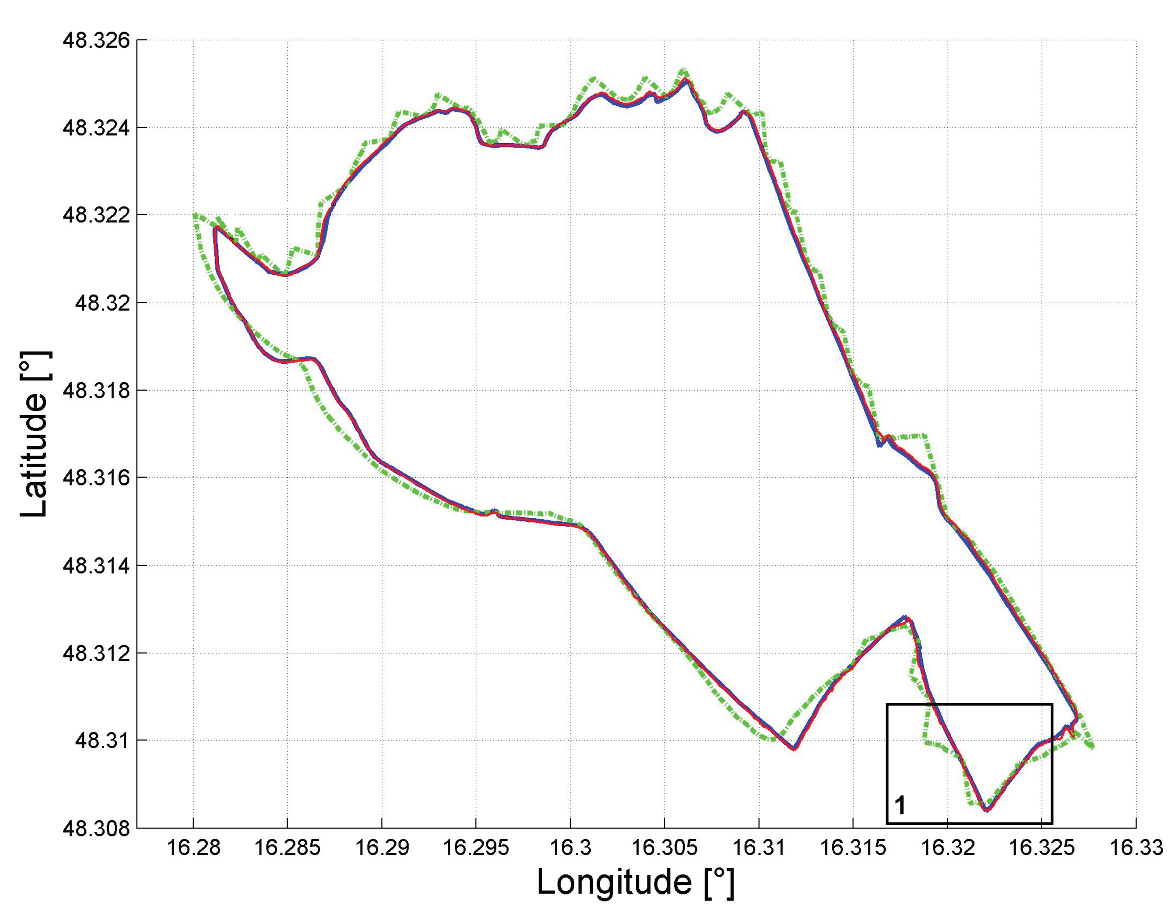


Figure 2, Top: Altitudes from different devices; Ref1 (black crosses), GPS (green line), DGPS (red line) and Barometer (blue line) **Bottom:** Differences in altitude; RTK minus GPS (green line), RTK minus DPGS (red line) and RTK minus Barometer (blue line).

The GPS device shows the typical erratic behaviour. Both, DPGS and the calibrated barometric sensor deliver a smoother and a more realistic solution. The DGPS heights are closest to the reference; the barometric sensor describes the characteristic of the track best. The difference in altitude is still over-estimated but 5-6 times smaller compared to the GPS only solution.

A combination of DGPS and barometric heights would help to reduce the drift and the offset of the barometric sensor and in return to capture periods with a high PDOP (position dilution of precision). - The PDOP is used as indicator to validate the quality of the GPS solution.

Position: The erratic behaviour of the GPS device can be seen in the lateral position too. In consequence an error in the distance of 15% is obtained (Table 3). The DGPS ground track is smoother, without artificial jumps and in 95% closer to the reference (Ref2). Especially in challenging environment it helps to improve the accuracy of the GPS device. Figure 3 shows the ground track and the typical characteristics of the two different solutions.



Solution	distance covered [m]
GPS [km]	10.20
DGPS [km]	9.07
Ref2 [km]	**9.02**

Table 3, Distance covered

Figure 3, Left: Ground track from Ref2 (blue line), GPS (green line) and DGPS (red line) **Down right :** Screenshot from a characteristic part of the test track, http://www.google.com/earth, 04/2013

6 Outlook

To make use of the strengths of different augmentation methods and to further improve the accuracy of a GPS tracking device - especially in altitude, a combination of these methods is contemplated.

Therefore a set of parameters has to be defined which allows to validate the performance of each technique at every point in time.

One parameter to validate the GPS solution could be the PDOP (see Figure 4).

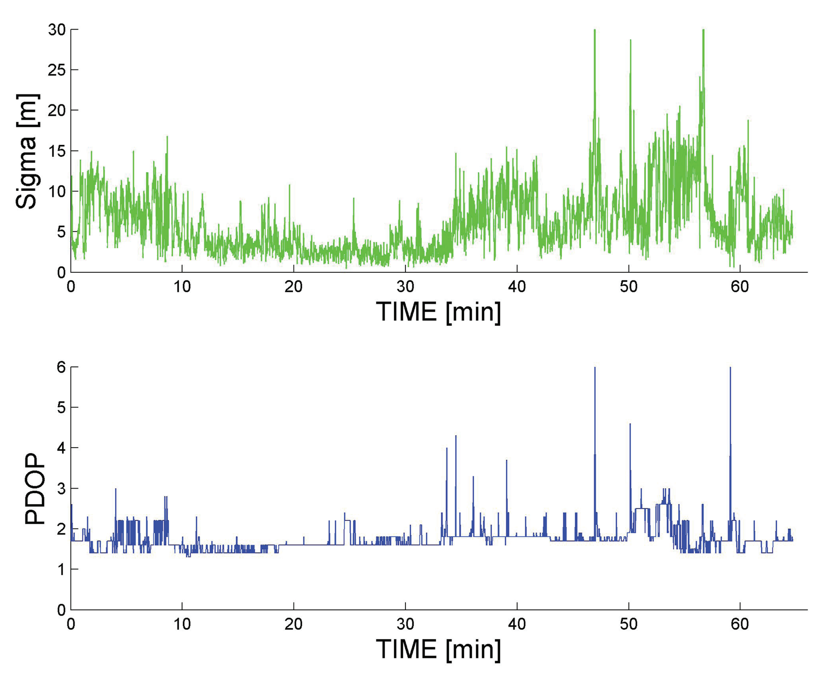


Figure 4, PDOP and its correlation with the standard deviation of the GPS heights.

A combination method is developed which takes these parameters into account and delivers a combined altitude solution without drifts, jumps and smaller biases. Then further aspects of physical performance can be derived more reliable.