

Improved methods to measure and generate 3D road profile in concerning with simulation errors

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Abstract

The main goal of this presentation is to provide some studies upon the latest methods of measure and generate the 3D road profile. The issue comes for all the experts to have a more precise view on minimum equipment necessary to measure the road and to know from the beginning the estimation of error in simulation and reconstruction of the scene. This will be a helpful image on the estimation of total error induced in obtaining the final position. In our activity it is very important to have an overview from the beginning which method and equipment of measure will be used and also we have to estimate the costs of this equipment and time regarding the results and the error obtained.

Zusammenfassung

Das Hauptziel dieser Präsentation besteht darin, einige Studien zu den neusten Methoden zur Messung und 3D Streckenprofil Generierung, vorzustellen. Die Problematik betrifft alle Experten, die ein genaueres Bild zur Wegstrecke, mit Minimum von Vermessungsausstattung zu haben und von Anfang an die Beurteilung der Genauigkeit bei der Beurteilung der Ereignisses. Dieses gestattet ein hilfreiches Bild bei der Ermittlung des gesamten Fehlers bei der Berechnung der Endposition. In unserer Tätigkeit ist es wichtig von Anfang an einen Überblick zu den benutzten Methoden und Ausstattung zu haben, um auch die Kosten- und Zeitaufwand betreffend der Ergebnisse und Fehlerursachen zu ermitteln.

Acknowledgement

In time, we have made some measurements on the dynamic behavior of cars using different devices and establish in some way the error level induced by the system, taking into account also the time needed for setup and after measure data post-processing.

The results at that moment have been focused on the accuracy of the measuring system and the volume of data acquired.

When measuring using classical methods we got a good approximation. In the opposite picture (Fig. 1) is shown the 3D road profile generated in PC-Crash, of the road presented in the same picture. The simulation on this 3D profile for different system braking functionality of the car is shown in Fig. 2.



Fig. 1: The road and his profile generated on the computer



Fig. 2: Simulation of the road profile for different braking functionality

In this paper we intend to estimate the error found in simulation caused by improper measurement due to different methods and equipment, and we propose a simple method for measuring the road gradient with good accuracy.

Introduction

The goal of the study was to identify a method for ascertaining the gradient of a road section with minimal costs, in time and money.

For that, it was considered a road segment for which it was available the design project for road rehabilitation and also the geodetic survey made using a total station. The equipment used for dynamic measurement of the road were two professional GPS devices: Vbox III from Racelogic and DS-5, an in-house developed system based on the GPS 18x-5Hz sensor from Garmin.

Devices and methods used for data acquisition

Racelogic Vbox III (Fig. 3) is a professional device with a recording rate of up to 100 samples per second, able to compute speed and acceleration; it is

designed especially for measuring the position and velocity of a moving vehicle.



Fig. 3: Racelogic VBOX

The parameters that can be measured by VBOX, based only on GPS signal and without any other external sensors are: speed or velocity, distance, time, position, heading, altitude, lateral and longitudinal acceleration, vertical speed, turning radius, position on a road, track (record), coasting down distance.

Recorded data are stored on a *CompactFlash* card, as text files, in a specific format (.vbo).

DS-5 is a data acquisition system designed at *Transilvania University*, based on the sensor GPS 18x-5Hz (Fig. 4). This is a GPS sensor manufactured by Garmin, designed for machinery operation, guiding and different agricultural applications, where are required very precise position and velocity information.



Fig. 4: GPS 18x-5Hz

GPS 18x-5Hz has 12 parallel channels and is WAAS enabled (can process the differential radio signal when available). It has a permanent memory for storing the configuration information, an internal clock (independent by the satellite signal) and measured raw data, for high precision and dynamic applications.

The sampling rate is 5 Hz, much less than the rate of VBOX, but the sensitivity is very good. The GPS 18x-5Hz device cannot work independently; it must be connected to a computer. The DS-5 system consists in the 18x receiver, a small, ultraportable computer (*Asus Eee*) and an adapter between receiver and computer, and the software application developed especially for this system (Fig. 5). The acquired data are stored as text files on the computer. Optionally, the receiver can be connected to a logger instead of a computer, to save data directly on a micro-

SD card.

The useful data taken from the receiver are: time (with a rate of 0.2 seconds and the accuracy given by satellite), latitude, longitude (both in degrees, with 7 decimals accuracy), altitude (accuracy of 0.1 meters) and velocity (accuracy: 0.01 km/h).

In addition, as coordinates accuracy information, there are known: the satellites number (in good receiving condition there are 8-10 satellites visible) and *HDOP* (*Horizontal Dilution of Precision*) – usually less than 1.5 (with differential signal: < 1).

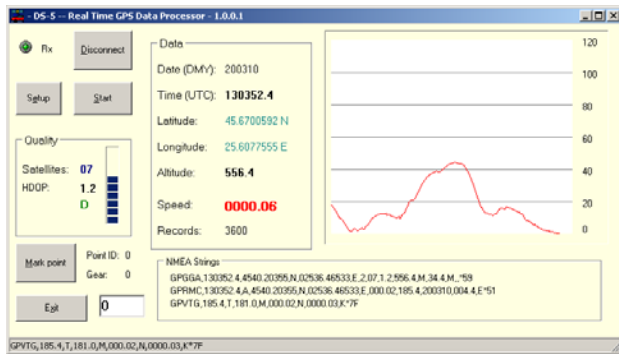


Fig. 5: User interface of the GPS data acquisition software

In order to collect data from the analyzed road, it was used a vehicle instrumented with the two systems described above. The antennas were both placed on the roof of the vehicle, in a central location (Fig. 6). Both systems were powered from an external battery.



Fig. 6: Preparing of the instrumented vehicle

The road was traveled four times in both directions. One of the registered tracks is shown in Fig. 7, on Google Earth and also on mapping software (recorded data were exported in the standard *gpx* format using the custom CAD application described further in this paper).

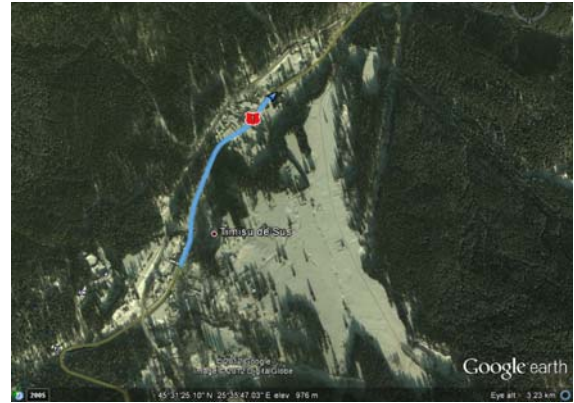


Fig. 7: Visualisation of the track using specialized software

The reception condition is not very good, since the road is bordered by hills and forrests. Even so, the number of satellites received was 5 to 6 with VBOX and 7 to 9 with DS-5.

Data processing

Data recorded on the road (text files) were processed further using a special application developed under AutoCAD; the CAD environment offer the advantage of using functions already developed for processing geometry, so that the new application can be focused on data processing. The interface of a CAD software is much flexible than the interfaces of the software dedicated to mathematic calculation.

The recored tracks were imported and drawn on AutoCAD as shown in Fig. 8.

In this picture are represented all the tracks, for both acquisition systems. The track is composed by points and lines, as geometric entities.

Each point of a track is a line in the source file. In order to draw the track in AutoCAD, the geographic coordinates recorded from the GPS receiver should

be converted into cartesian coordinates (from WGS84 Datum to the local projection system, which in Romania is Stereo 70).

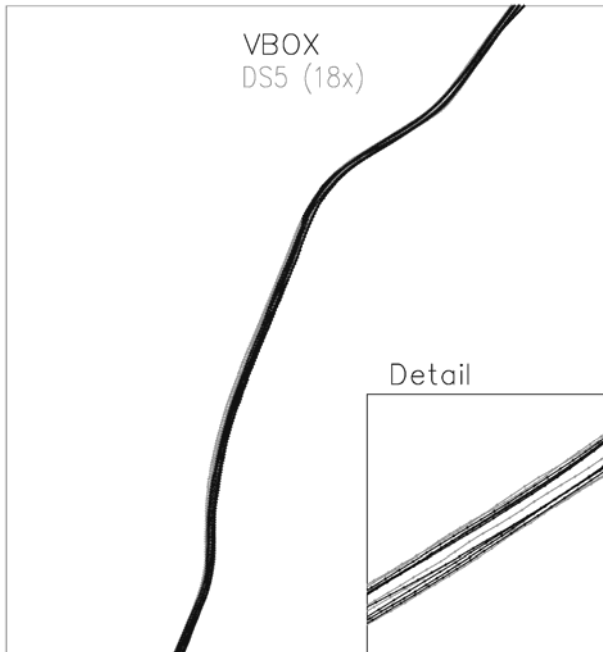


Fig. 8: Tracks represented in AutoCAD

Beside the data already stored for a regular entity in AutoCAD, the custom application can attach additional information (metadata) like the geographic coordinates, time, altitude, speed and acceleration.

Examples of attached data for *POINT* and *LINE* entities, reported by AutoCAD (*rent* is a custom command used to extract metadata from a selected entity) are below:

```
Command: rent
Select object: (("vxk" . 44.31)
("type" . "gps_point") ("Time" "03"
"20" "2010" "12:57:28.4") ("Long" .
25.6258) ("line2" . "8830") ("line1"
. "881B") ("Lat" . 45.6509)
("id_traseu" . "1") ("id_point" .
1579) ("Alt" . 587.6) ("accx" .
0.0972222))
Command:
Command: rent
Select object: (("speed" . 46.4037)
("type" . "gps_line") ("TimeSec" .
0.2)
("p2" . "8811") ("p1" . "87FC")
```

```
("id_traseu" . "1"))
Command:
```

Data associated to a track can be exported in *gpx* or *txt* format, to be processed by other programs. In the *gpx* files are saved the point geographic coordinates (latitude, longitude). The *gpx* files can be loaded in mapping software (like *MapSource*), GIS software or *Google Earth*. The text files (*.txt*) contain location information and dynamic data: velocity, time, acceleration and also some values determined analytical, like the force on wheel. These data can be loaded in spreadsheet programs (*Excel*) or similar.

From the data attached to two points located approximately in the same cross section of a road, it can be noticed that the lateral declivity of the road cannot be ascertained with a satisfactory accuracy.

As example:

```
Command: rent
Select object: (("vxk" . 47.09)
("type" . "gps_point") ("Time" "09"
"17" "2012" "12:32:05.2") ("Long" .
25.5811) ("line2" . "5F75") ("line1"
. "5F60") ("Lat" . 45.5333)
("id_traseu" . "3") ("id_point" .
118) ("Alt" . 837.2) ("accx" .
1.51389))
Command:
Command: rent
Select object: (("vxk" . 61.81)
("type" . "gps_point") ("Time" "09"
"17" "2012" "12:34:00.6") ("Long" .
25.5811) ("line2" . "8B25") ("line1"
. "8B10") ("Lat" . 45.5333)
("id_traseu" . "4") ("id_point" .
261) ("Alt" . 839.7) ("accx" . -
1.80556))
```

The difference between altitudes shown above is about 2.5 meters, for a distance between the two points of about 4.5 meters. This is not possible, and it is obvious that the altitude values recorded non-continuously (at an interval of about 2 minutes in the example above) cannot be used.

Since the goal of this study is to determine the gradient of the road, it was developed a special software routine for representing the altitude as function of the traveled distance. The diagrams for all the eight tracks (registered with both VBox and DS-5 devices) are shown in Fig. 9.

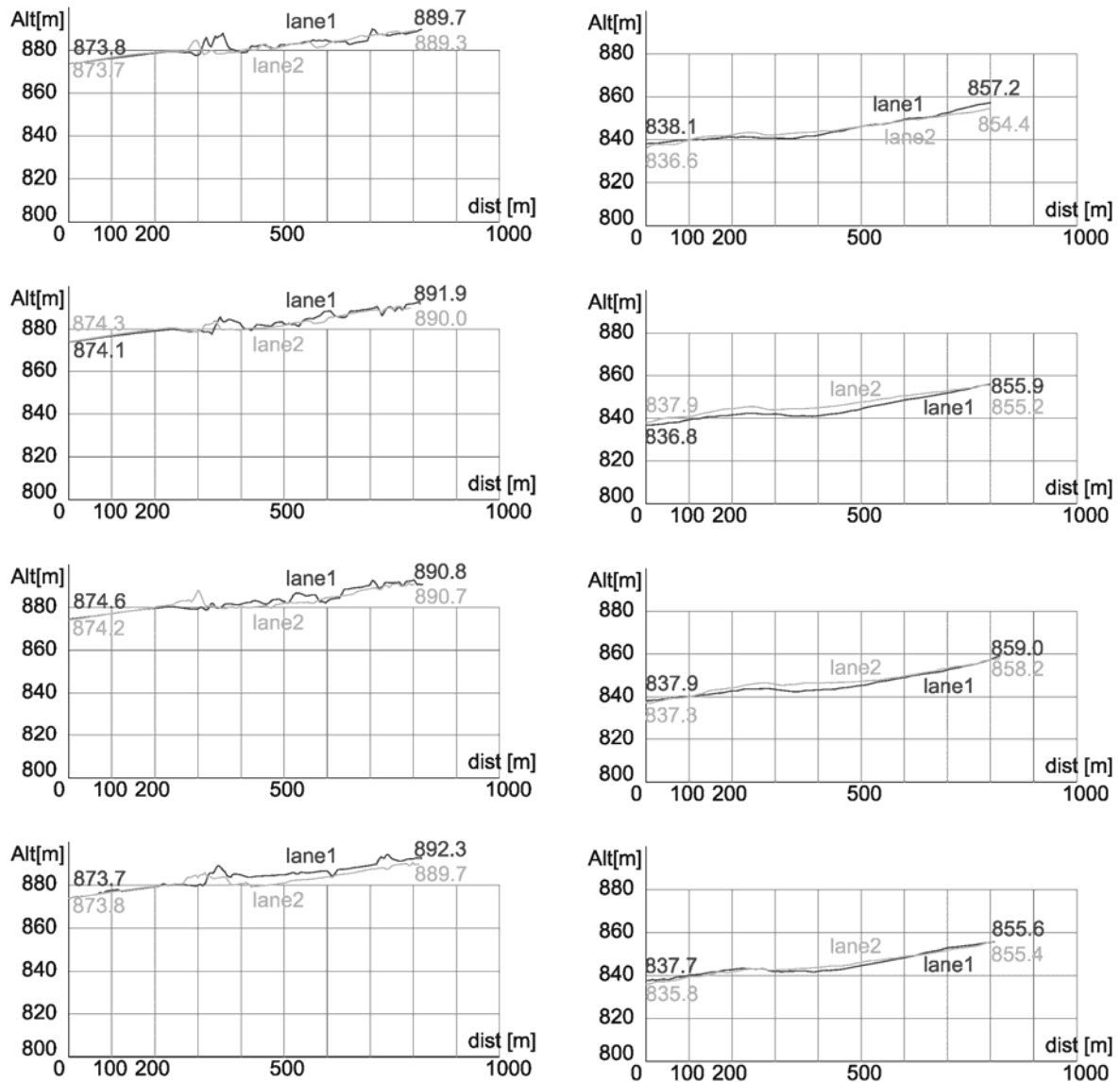


Fig. 9: Altitude versus distance: measurements with Vbox (left) and DS-5 (right)

As can be seen, the altitudes measured with Vbox are higher than those measured with DS-5. Both systems used the WGS84 datum, so that the difference (which is however consistent) may be caused by the number of visible satellites. From the existing road project we found that the altitude of the road in this area is between 831 and 854 meters. The values measured with DS-5 are close to the real values. On the other hand, it is known that the altitude reported by a GPS receiver is a relative value that depends by the reference geoid used. So the absolute values of the altitude are not as important as the relative values between minimum and maximum. The diagrams in the left column (VBox records) have also some rough variations which affect the results.

The results obtained after completely data processing are shown in the Table 1.

The average values calculated for the road gradient using the VBox measurements are 1.17 degrees and 2.05%. Based on the measurements made with DS-5, the average values are 1.36 degrees and 2.39%. The road gradient obtained with the data taken from the available project (altitudes and distances) is 1.37 degrees and 2.394%, respectively. These results lead us to the conclusion that the measurements made with the DS-5 system are accurate enough to establish the longitudinal gradient of a traveled road.

Table 1: Average road gradient

GPS 18x-5Hz		Distance 2D	Distance 3D	Road Gradient (deg.)	Road Gradient %
Trk.1	up	801	802	1.36	2.4
	down	800	801	1.30	2.3
Trk.2	up	799	800	1.38	2.4
	down	797	797	1.24	2.2
Trk.3	up	822	823	1.47	2.6
	down	821	822	1.46	2.6
Trk.4	up	809	810	1.27	2.2
	down	807	807	1.39	2.4
Average values		807.00	807.75	1.36	2.39

VBOX III		Distance 2D	Distance 3D	Road Gradient (deg.)	Road Gradient %
Trk.1	up	794	822	1.16	2.0
	down	797	805	1.13	2.0
Trk.2	up	790	819	1.17	2.0
	down	785	795	1.15	2.0
Trk.3	up	795	823	1.18	2.1
	down	790	803	1.21	2.1
Trk.4	up	803	821	1.25	2.2
	down	801	814	1.14	2.0
Average values		794.38	812.75	1.17	2.05

References

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3. ***; *GPS 18x Technical Specifications, Rev. B*, Jan. 2008, Garmin International, <http://www.garmin.com>
4. ***; *VBOX Tools Software Manual*, Version 1.4, Racelogic, <http://www.racelogic.co.uk>.
5. ***; *PC-Crash User Manual*.

Conclusion

In this study it was analyzed a road segment for which the project and also a geodetic survey were available. Considering these initial information as reference, the same road segment was traveled with a vehicle equipped with two professional GPS sensors: VBox III and DS-5.

The lateral declivity of the road was not possible to be ascertained based on the recorded GPS data.

Instead, for the longitudinal declivity there were obtained accurate results in case of DS-5 system (equipped with the sensor 18x-5Hz from Garmin). The average value for the road gradient, calculated from four passings uphill and downhill, are very similar with the values obtained from the reference project.

The main conclusion is that traveling on the road segment with a vehicle instrumented with a system based on GPS 18x sensor it is possible to ascertain the gradient of that road segment with an accuracy good enough for accident reconstruction or similar applications.

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