Quality of Map-Matching Procedures Based on DGPS and Stand-Alone GPS Positioning in an Urban Area

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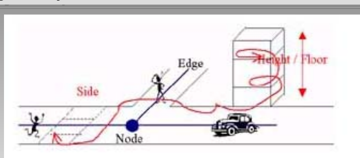
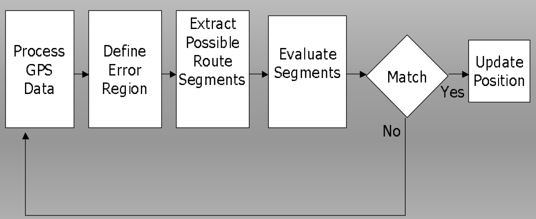
- A major problem for land navigation systems in urban areas is the quality of spatial and temporal data along the different road segments.
- The accurate positioning of a vehicle is very important for all kinds of land navigation applications, such as fleet management systems, in-car navigation systems etc.
- Usually, fleet management systems operate by using GPS technology (Stand-Alone GPS or Kinematic DGPS methodology) to initially determine the position of each vehicle. GIS software platform is used to make available digital cartographic data and network analysis capabilities.



- Stand-Alone GPS can provide a horizontal positional accuracy of approximately 15 m when Selective Availability (S/A) is turned off.
- Differential GPS (DGPS) can significantly improve GPS accuracy down to 1 to 5 m when using data collected by a reference GPS station.
- Real-time Differential GPS provides similar accuracy when the vehicle GPS receiver corrects its position by using differential corrections radio-transmitted by a reference GPS station in real-time.
- In an urban built environment, both techniques may face certain limitations (lack of visibility to satellites (GPS and DGPS) and poor or blocked continuous reception of differential corrections (DGPS).
- Other navigation systems can be used for improving the accuracy of GPS positioning.

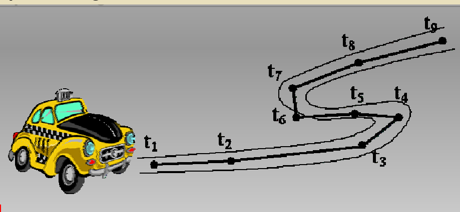
- Road network in an urban area is known in the form of a digital map.
- Special computer algorithms can be employed to correlate the computed vehicle location with the road network segments and translate the vehicle raw positions onto the road network, matching the calculated position to the nearest digital road.
- This vehicle tracking on a given road segment is known as Map-Matching.
- Many times, the level of positional accuracy obtained is insufficient to ensure that the estimated position of a vehicle's location corresponds to the certain digitally mapped road on which the vehicle is actually travelling.



Conventional Map-Matching

- An interesting question is <u>how the accuracy of the measurements can affect the map-matching algorithms when using Stand-Alone GPS receivers instead of DGPS now that SA (Selective Availability) has been turned off</u>.

- In this presentation, the developed statistical models for map-matching are being tested on the basis of DGPS and Stand-Alone GPS positioning.



▸ The basic model used for processing of the measured Stand-Alone GPS and DGPS points and computing the accuracy of the best-fitted curve is a **linear regression model**.

▸ For every road segment, the corresponding GPS points are being fitted to the linear equation:

$$Y = \alpha + \beta X + \varepsilon .$$

The confidence interval or prediction zone for $\hat{Y}_0$ is given by:

$$\hat{Y}_0 - t_{\alpha/2} \cdot s_{\hat{Y}_0} \leq Y_0 \leq \hat{Y}_0 + t_{\alpha/2} \cdot s_{\hat{Y}_0} .$$

The reliability zone of model parameters α and β is

$$\hat{\alpha} - t_{\alpha/2}\, s_{\hat{\alpha}} \leq \alpha \leq \hat{\alpha} + t_{\alpha/2}\, s_{\hat{\alpha}} \qquad \hat{\beta} - t_{\alpha/2}\, s_{\hat{\beta}} \leq \beta \leq \hat{\beta} + t_{\alpha/2}\, s_{\hat{\beta}} .$$

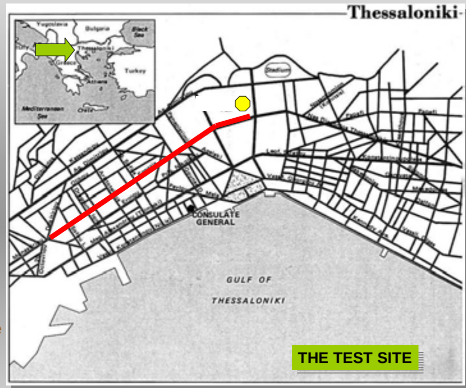
- The straight lines described by the linear regression model can produce the digital map.
- The regression models have as base the data-clouds produced from the GPS points, one cloud per road segment and direction.
- These linear models can be tested upon the spatial digital map of the road network (if available – otherwise the computed lines themselves gradually built the digital map).
- These statistical models can work as prediction tools, capable to offer the map-matching:
  - The prediction zone for the regression model can be used as the criterion to attribute each point to the corresponding line.
  - The reliability zone of the linear model parameters can be used for the determination of the most reliable linear model.

- Measurement campaign: December 1 to December 14, 2003 (14 days).
- The measurement-route constantly was on Egnatia Street, at a distance of approximately 2 Km (both directions: EW & WE)
- On every-day basis, there were two periods of measurements per day, during morning (2 hours, from 10:00 to 12:00) and during afternoon (2 hours, from 16:00 to 18:00).
- Totally, there were 83 passes along this route: 41 during morning hours (21 in the EW direction and 20 in the WE direction) and 42 during afternoon hours, respectively (21 in the EW direction and 21 in the WE direction).

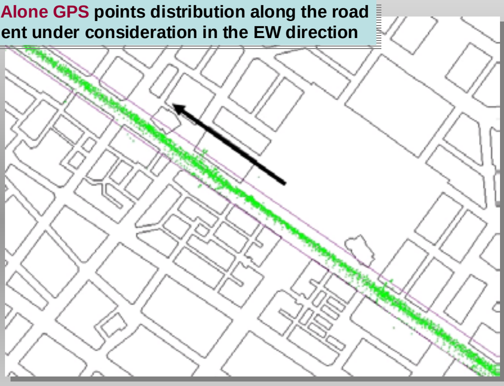
THE FIELD OBSERVATIONS

- GPS data were collected with the help of the VECON system by using a portable Ashtech GPS (L1/L2) model Z-Surveyor receiver on a vehicle (Recording interval 1 sec, minimum satellites 1, elevation mask 10°).
- GPS data were also collected by the Continuous GPS Reference Station of the Laboratory of Geodesy, for differential post-processing (DGPS).

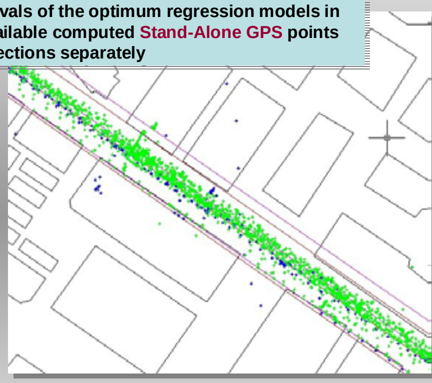
Continuous Operating Reference GPS Station (Laboratory of Geodesy – since 1999)



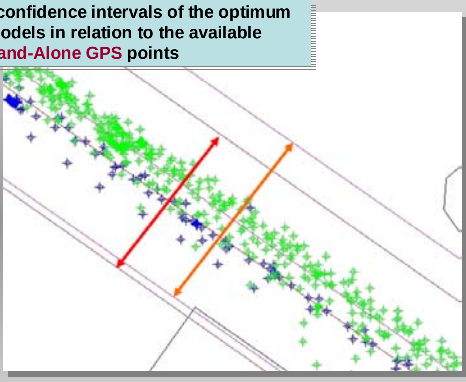
Stand-Alone GPS points distribution along the road segment under consideration in the EW direction



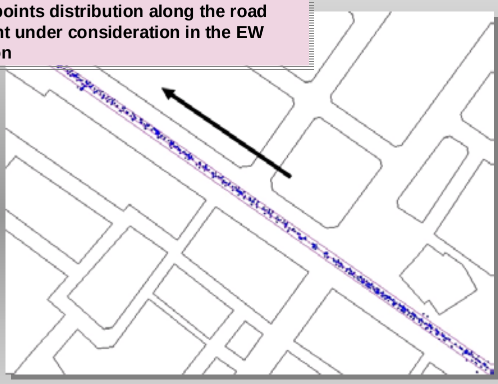
Confidence intervals of the optimum regression models in relation to all available computed Stand-Alone GPS points for EW & WE directions separately



Detail of the confidence intervals of the optimum regression models in relation to the available computed Stand-Alone GPS points



DGPS points distribution along the road segment under consideration in the EW direction



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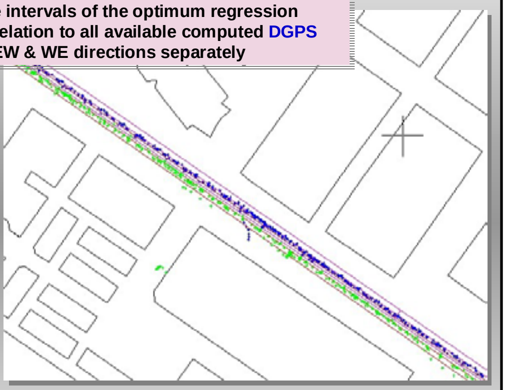

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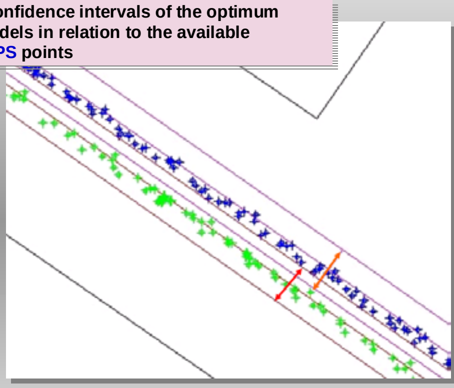
Detail of the confidence intervals of the optimum regression models in relation to the available computed DGPS points



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DATA PROCESSING AND RESULTS

- **The whole set of the measurements was finally classified into twenty seven (27) data samples for each type of processing (DGPS or Stand-Alone).**
- **There are fourteen (14) <u>simple</u> data samples for Stand-Alone GPS and thirteen (13) <u>simple</u> data samples for DGPS. Each one of them is related to a particular day of measurements, respectively.**
- **After this classification, the other thirteen (13) data samples have a <u>cumulative</u> character each. In simple words, each one contains the data of its related day plus the data of all the previous days.**

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The optimum Regression Models and their basic elements (Confidence level 0.950)

GPS Day / Direction	Type of Processing	Models	Points	STD (m)	STD $\hat{\beta}$ (m)
340 / WE	DGPS	Y = 4787210.62029-0.7029971105 * X	395	1.28480	0.00014
335-338 / EW	DGPS	Y = 4785974.32888-0.6999752004 * X	3651	1.46259	0.00005
335-345 / WE	Stand-Alone GPS	Y = 4786796.28955-0.7019892268 * X	12193	8.72290	0.00017
335-348 / EW	Stand-Alone GPS	Y = 4784998.22137-0.6975968949 * X	25091	10.10034	0.00013

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The prediction (map-matching) zone of the optimum models of Stand-Alone GPS processing for three confidence levels (0.950, 0.975 & 0.995)

GPS Day / Direction	X Min Max Mid	$\hat{Y}_0$	Map-Matching zone [m] (0.950)	Map-Matching zone [m] (0.975)	Map-Matching zone [m] (0.995)
335-345* / WE	409884.8650	4499061.5301	14.3523	17.1007	22.4751
	411593.0850	4497862.3780	14.3511	17.0993	22.4733
	410870.7161	4498369.4732	14.3498	17.0976	22.4712
335-348 / EW	409864.6440	4499077.9184	16.6163	19.7981	26.0204
	411655.0620	4497828.9284	16.6166	19.7986	26.0210
	410669.5814	4498516.3965	16.6155	19.7971	26.0191

* (without day 336)

The prediction (map-matching) zone of the optimum models of DGPS processing for three confidence levels (0.950, 0.975 & 0.995)

GPS Day / Direction	X Min Max Mid	$\hat{Y}_0$	Map-Matching zone [m] (0.950)	Map-Matching zone [m] (0.975)	Map-Matching zone [m] (0.995)
340 / WE	410034.0960	4498957.8356	2.1257	2.5327	3.3287
	411569.1110	4497878.7245	2.1212	2.5275	3.3218
	410919.6883	4498335.2668	2.1162	2.5214	3.3138
335-338/ EW	409905.5750	4499050.5919	2.4071	2.8680	3.7695
	411587.8060	4497873.0719	2.4075	2.8684	3.7700
	410677.4865	4498510.2730	2.4063	2.8671	3.7682

CONCLUSIONS

- Differential GPS gave much better results than Stand-Alone GPS, as expected.
- Stand-Alone GPS could follow the trajectory of the vehicle along bigger parts of the road segment under consideration, because it does not face the limitations of DGPS positioning.
- The resulting accuracy of Stand-Alone GPS positioning is not enough for reliable map-matching procedures.

- Concerning an organisation with a significant fleet of vehicles, it can be said that the time and money that can be earned by using Stand-Alone GPS systems soon enough can be minimized, because of the many problems and the deficiency of the map-matching models, in the intersections of the road segments and also the extending overlay of the map-matching zones.

- In time depth, DGPS positioning will be proven more cost-effective for map-matching applications.