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USE OF LOCATION REFERENCING SYSTEMS IN PAVEMENT MONITORING

Best-practice guide on how to link surface parameters to location

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1 Introduction

1.1 Role within SILENCE

Subproject F of the SILENCE project is concerned with the role of road surfaces in the generation of road traffic noise. The project focuses especially on noise abatement in urban areas, and consequently urban road surfaces and their noise emission properties are the main interest of subproject F. The work packages within subproject F deal with the following topics:

- WP F1: New production technologies for surfaces on urban streets
- WP F2: New production technologies for surfaces on urban main roads
- WP F3: Improved systems for the maintenance of quieter surfaces
- WP F4: Noise classification methods for urban road surfaces
- WP F5: Testing of novel road surfacing materials

Within the subproject, work package F3 focuses on the influence of maintenance activities on the noise emission properties of pavements and suitable monitoring methods for acoustic and related non-acoustic road surface parameters. Within F3, the tasks are distributed as follows:

- Task F3.1: State-of-the-art pavement monitoring
- Task F3.2: Acoustic pavement monitoring
- Task F3.3: Detection systems for pavement discontinuities
- Task F3.4: Use of location referencing systems in pavement monitoring
- Task F3.5: Systems for preventative maintenance
- Task F3.6: Rejuvenation of pavements
- Task F3.7: Fast repair systems for urban streets

This document is the output of the work in task F3.4 and deals with the issue of linking the results of measurements and examinations of pavement properties to specific locations in a reproducible and accurate way. The work in this task relies on results from task F3.1. In addition to more traditional methods, modern location referencing systems like GALILEO, GPS or dGPS are used in many applications to pinpoint exact positions also in residential and urban areas. The limitations and possibilities of existing systems will be compared to the requirements of providing exact position information as a basis for maintenance planning.

1.2 Aim

The aim of this document is to

- Discuss the advantages and disadvantages of existing methods for location referencing on roads
- Point out the restrictions and special considerations that result from the application in urban surroundings
- Provide recommendations for providing road surface characteristics linked to locations to the partners in SILENCE and for future use

2 Location referencing systems on the road network

2.1 Mileposts and milestones

The classical location referencing on roads is based on road designation and distance marking relative to fixed starting points. This is achieved by placing mileposts or milestones along the roadside at regular intervals, showing the distance travelled. On-site marking is usually only in place on high-level road networks.

Figure 1: Presenting position information using mileposts

Typical road position information contains the following information (with example values):

Road name: A2
Carriageway: Vienna to Graz
Position: km 108,500 (e.g. mileposts at intervals of 500 m)
Lane: 1^{st} of 3 (rightmost)

The milepost only shows the distance information (km 108,500). Road name and carriageway can be determined from road information signs, whereas the lane is defined by the road markings.

This information is derived from the road construction data and from later surveys. The distance increment is typically in the range of 100 – 500 m, which permits only a very rough location determination. When using additional distance and orientation measurement equipment like measuring wheels, odometers and gyroscopes (see BETAILLE 2000), the position accuracy can be improved down to the range of a few meters. Nevertheless this kind of positioning relies on the exact placing of the mileposts.

When mileposts are used in combination with mobile road monitoring vehicles, the task of transferring position information into the vehicle must be solved. This can be achieved by several techniques:

- Setting a manual trigger marker by an operator in the vehicle who observes the passage of the milepost
- Triggering by means of a static roadside electronic sensor like a photoelectric barrier or induction coils
- On-Board sensors, e.g. video recognition of the mileposts

The first method is rather simple, and its inaccuracy will certainly increase with higher travelling speeds. Nevertheless the achievable accuracy can still be sufficient for practical purposes. Static electronic sensors like photoelectric barriers require both pre-installation and a means of wireless data transfer to the monitoring vehicle. These solutions are not feasible for long-distance monitoring. The last approach is very versatile, but requires also sophisticated equipment and fast software to reliably detect the pass-by event of the milepost.

The main advantages of using mileposts to add location information to road monitoring results are simplicity and inexpensiveness. By using the already installed mileposts a rough position estimate can be established quickly. For monitoring information on road sections which are more than 1 km long, the achievable accuracy is often sufficient.

However, the spatial resolution of mileposts is limited and has to be supplemented by on-board odometers or measuring wheels to achieve positioning intervals in the range of tens of meters. The possibly inaccurate or changed location of mileposts adds to the error in absolute position values.

2.2 Satellite-based systems

Satellite-based location determination has brought a new dimension to traditional land survey methods. These systems determine the exact position of the receiver device by measuring the travel time from the satellites positioned in orbit. Every satellite emits radio signals carrying information on its identity, location and on the time of the signal emission. The receiver units on the ground compare the time stamp with their built-in clock and compute travel time and distance to the satellite. When receiving enough satellite signals, the receiver can calculate its own position using the known satellite positions and the distance information. Additional satellites may be needed to correct errors, e.g. receiver clock inaccuracies. The most important error sources of satellite-based navigation systems are clock errors, ephemeris errors (satellite trajectory errors), atmospheric effects, multiple reflections and electronic errors.

The results may be presented e.g. in the coordinates of the WGS84 (World Geodetic System 1984). The coordinates can then be transformed into arbitrary local coordinate systems.

The main advantages of these systems are:

- Independence of local reference points
- High reproducibility of measurement locations, especially for point measurements
- Easy integration with other data in GIS (Geographic Information Systems), e.g. noise maps
- Direct integration into the measurement data flow

There are also some disadvantages:

- The identification of road segments requires a GIS model of the road
- A constant good radio connection to the satellites is required – this can be difficult in cities and mountainous areas
- The spatial resolution may not be compatible with typical measurement intervals

2.2.1 GPS

The Global Positioning System (GPS) was originally developed by the United States Department of Defence with a view to military applications in the 1970s, but is now publicly accessible. It uses 24 satellites with atomic clocks covering the whole area of the earth's surface. The satellites themselves are monitored and controlled by ground stations of the US Air Force. The satellite signals can be received with commercially available GPS devices.

Figure 2: Small commercially available GPS receiver (example)

The maximum achievable location accuracy is in the range of 15 - 30 m with low-resolution signals (C/A) and in the cm range with high-resolution signals (P(Y)). These accuracies are however difficult to achieve due to the errors mentioned in 2.2 (MAURER 1998).

2.2.2 dGPS

Differential GPS Systems, abbreviated dGPS, follow the same principle as GPS, but include the signal of an additional ground station or a satellite in geosynchronous orbit with an exactly known location and its own GPS receiver system. This station can supply GPS correction data to mobile GPS receivers in its surrounding regions by comparing its position derived from GPS positioning with its actual position. The use of geostationary satellites is preferable because of the larger area that can be covered with good signal quality. The achievable location accuracy is typically in the range of a few meters (MAURER 1998).

2.2.3 GALILEO and GLONASS

GALILEO is a global satellite navigation network project run by the European Union and ESA (European Space Agency) with total of 30 planned satellites. At the time of writing, the project is in its satellite deployment phase and commercial operation is planned to start in 2008 (GALILEO 2007). The GALILEO global navigation satellite system will be the first system of its type under civilian control. It is designed to be both independent of and compatible to GPS and GLONASS. It will offer standard real-time position accuracy in the meter range and is designed with very fast error-reporting capabilities, so that it can be used even for failure-critical operations like remote vehicle control. The high-performance modes of operation will even offer horizontal and vertical position resolution of 10 cm and below using additional information from ground stations supplementing the satellites. When available, this will be the most accurate satellite-based positioning tool available for road surface monitoring, with the added advantage that it was intentionally built for high-performance commercial and civilian use.

The GLONASS System is the counterpart of the Russian Federation to the GPS system, but is currently not fully operational.

3 Requirements for localizing pavement parameter values

Road surface characteristics are properties of a certain section of the road comprising at least the surface area of one lane along a defined distance and the upper layer of the pavement. Typical road surface characteristics are skid resistance, texture, longitudinal and transversal unevenness, crack occurrence or porosity. The main acoustic characteristics would be the noise emission properties as measured by the Statistical Pass-By Method (SPB, following ISO 11819-1) and the Close-Proximity Method (CPX, according to ISO/CD 11819-2). Supplementary acoustic properties would be the sound absorption and possibly the dynamic stiffness.

These characteristics can be determined with either static or mobile measurement equipment. Yet due to the different measurement methods, the values are measured either at a specific point on the road or represent an average over road segments of different lengths. Table 1 shows an example for some acoustic and non-acoustic road surface parameters and the length of the road segment of which the value is considered to be representative.

Table 1: Road surface characteristics in Austria as measured by arsenal research (MAURER, 2002)

Property	**Method**	**Parameter**	**Transversal Position**	**Longitudinal interval**
Skid resistance	mobile	μ	1st lane, right wheel track	50 m
Texture	mobile	MPD	1st lane, right wheel track	10 - 50 m average 1 m measurement
Transversal evenness	mobile	P, W, S	1st lane, right wheel track	5 m
Longitudinal evenness	mobile	IRI	1st lane, right wheel track	50 m
Noise emission - SPB	stationary	SPBI	1 defined lane	Only 1 section of approx. 100 m
Noise emission - CPX	mobile	CPXI	1 defined lane	20 m
Sound absorption	stationary	α	1 defined lane	Only 1 point, circle with approx. 2 m diameter

This example shows clearly, that especially for mobile measurement methods, where correct positioning is essential, a spatial resolution down to a few meters is required. As discussed in 2, this range of accuracy is only achievable with dGPS systems or very accurate odometer systems.

Most of the road surface characteristics measured during monitoring are actually not representative of a single point in space, but actually of a certain road segment characterized by its longitudinal start and end and its lateral position. This means that determining only a single point within the measurement area is not sufficient. At least the positions of a suitable starting and ending point have to be determined and to be correlated with the geometrical description of the road in question. This means that first of all a road graph in terms of a suitable coordinate system must be determined. Then the location indicated by a satellite-based system can be compared with this road graph and the location of the road segment in question can be established. This process is called map-matching.

The following requirements for satellite-based monitoring systems can be derived:

1) Sufficient satellite signal coverage for the whole road network
2) At least sufficient longitudinal resolution to distinguish between consecutive measurement segments
3) Sufficient lateral resolution to establish the lane and carriageway (this information can also be confirmed by the operators)
4) A road graph in a supporting GIS (geographic information system) that can handle both segment- and point-based location information

Figure 3: Austrian RoadSTAR road monitoring vehicle with dGPS and gyroscope

4 Application in urban areas

The main problems of applying satellite-based positioning systems to road monitoring in urban areas are caused by insufficient signal coverage due to the high density of buildings. Satellite navigation requires an unobstructed line of sight to at least 3-4 satellites of the system. The errors due to multiple reflections are also increased in urban areas.

The most critical positions are road tunnels without any satellite contact and narrow streets lined by rows of high buildings. In these cases there will be very frequent signal losses and the trajectories have to be established by additional positioning and distance measurement tools, like road signs, combined odometer and gyroscope readings or land survey reference points. (MAURER, 1998)

5 Recommendations

The use of satellite based location referencing system in road monitoring promises easier and more accurate road monitoring results. From the preceding chapters, the following recommendations for its practical use in urban areas can be derived:

1) Only systems with a sufficient spatial resolution (longitudinal and transversal) in the rage of a few meters offer significant advantages over more traditional positioning methods.
2) The satellite-based location information should be integrated into the measurement data flow, so that the measurement crew can concentrate on the road surface parameters.
3) The measuring process should be supported by an onboard GIS navigation system including a map, so that obvious deviations from the road trajectory can be corrected.
4) The monitoring information should be processed using a GIS system with a suitable representation of the road in question. Additionally, a comprehensive database with all the measurement results linked to location data as well as road information can be built.
5) The longitudinal measurement intervals and the position information update frequency have to be synchronized for the chosen measurement speed. This enables a correct positioning of all the measurement results with respect to each other.
6) An independent backup system (e.g. an odometer) should be run in parallel to the satellite-based system to be able to complement the location data when no satellite connection is available (e.g. in tunnels or cities).
7) The measurement crew should still log also general location information (road name, carriageway, etc.) to facilitate later confirmation or correction of the position data.

6 Sources

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