POST PROCESSING OF TWO DIMENSIONAL ROAD PROFILES: VARIOGRAM SCHEME APPLICATION AND SECTIONING PROCEDURE

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ABSTRACT: Road sectioning plays a crucial role in Road Asset Management Systems and High Speed laser-based devices are able to collect a huge amount of data on pavement characteristics. However this implies an high computational effort in identifying road homogeneous sections following a long and meticulous post processing analysis. The Geostatistic methodology, in terms of Variogram scheme has been applied for characterizing road surface: "Range" and "Sill" values, deriving from the Variogram application, have been proposed as macrotexture synthetic indices to characterized different road surfaces. Once that Variogram scheme has been applied a dynamic sectioning procedure can be employed to detect homogeneous road pavement sections. Preliminary results obtained by an experimental smart road, seem to highlight that the Variogram variables can be promising in identifying homogeneous sections in terms of pavement surface macrotexture.

KEYWORDS: 'Pavement Management', 'Road Surface Macrotexture', 'Dynamic Sectioning', 'Geostatistics Variogram Scheme', 'Spatial Data Analysis'.

1 Introduction

The quality and the quantity of the data collected by high speed laser-based (HSL) texture measuring devices for pavement road monitoring and programming of maintenance interventions, open new challenge to Pavement Managers in fact, in this context, new skills for filtering, analysing and interpreting of data are requested.

In order to apply the Pavement Management Systems (PMS) principles, an identification of homogeneous sections for subdividing road network is needed. These homogeneous sections can be defined as road sections in which the parameters, that generally affect the maintenance strategies, can be considered as almost constant. Usually the road profile texture data, collected by HSL (here from now on called HSL data), can be described as "time series" characterized by information on position and height with a fixed sampling frequency on a straight alignment. HSL data usually undergo to a pre-processing (filtering) procedure in order to remove noise and invalid readings (as spikes or drop-outs) according to several approaches [Losa & Leandri 2011; D'Apuzzo et al. 2015].

Relevant macrotexture descriptive indexes, such as *Estimated Texture Depth* (*ETD*) evaluated according to [ASTM E1845], can be derived from road surface filtered profiles, although more reliable macrotexture synthetic indexes have been recently proposed [D'Apuzzo et al. 2015]

In this paper an innovative approach to describe the macrotexture of road surface employing the Geostatistical method applied to characterized 2D road profiles by means of the Variogram scheme, is proposed. Transformed data so obtained undergo to a sectioning procedure, in order to identify the homogeneous pavement sections.

2 Background

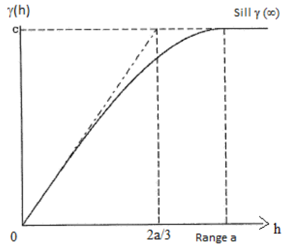
Geostatistics is a field of the Statistics focused on the study of spatial or regionalized phenomena, which are characterized by a spatial correlation. Thanks to this peculiary, several applications within environmental aspects have been performed [Chilès & Delfinet 1999; Spacagna et al. 2019] and encouraging results have been achieved from preliminary attempts for the road profiles analysis [M. Ech et al. 2007].The spatial law can be defined by means of the Variogram, which describes the relation between two point at "h" distance and it presents the following structure:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left(Z(x_i + h) - Z(x_i) \right)^2$$

Where:
$\gamma(h)$ = Variogram;
h= distance between couple of points;
N(h) = number of couple of points at h distance;
$Z(x_i)$ = value at x point;
$Z(x_{i+h})$ = value at x+h point.

In the literature, different Variogram models are presented [Chilès & Delfinet, 1999] and, in this study, the Spherical model has been used and its main features are summarized in the Figure 1. In general, the Variogram is characterized by two values the *Sill* and the *Range*. Within the *Range*, Z(x) and Z(x+h) values are related, outside are independent. For these reasons it is possible to define the *Sill* and the *Range* ("C" and "a" in the Figure 1, respectively) as the measure of the maximum variability and the distance where the variables are correlated, respectively.

Applying the Variogram to the filtered pavement profile, two new "time series", the Sill and the Range profiles, are produced and, to identify the homogeneous pavement sections, a dynamic sectioning process must be performed. Several methods, such as Bayesian methods, Cumulative Sum or Difference (CUMSUM) methods, Dichotomic method, minimum standard deviation based methods (MINRMS) and Linear models with Multiple Structural Change (LMSC), are available to identify homogeneous pavement sections from a series of measured data, and an interesting benchmarking has been previously proposed [D'Apuzzo et al., 2012]. In this paper the Dichotomic Method has been employed.



$$\gamma(h)=\begin{cases} C\left(\frac{3}{2}\frac{r}{a}-\frac{1}{2}\frac{r^3}{a^3}\right) & per\ 0\le h\le a \\ C & per\ h\ge a \end{cases}$$

Figure 1: Spherical Variogram model

3 Case Study and Data Analysis

Pavement profiles measurements have been collected at the Virginia Smart Road, (Blacksburg, Montgomery County, Virginia) where more than 15 different pavement types and mixes have been laid. HSL device, which performs dynamic measurements on a straight alignment, with a laser spot of 0.2 mm and a sampling frequency of 64 kHz, has been used for the profile measurements. An example of pavement profile collected by HSL device along the entire Smart Road track (about 2300 m) has been reported in the Figure 2a.

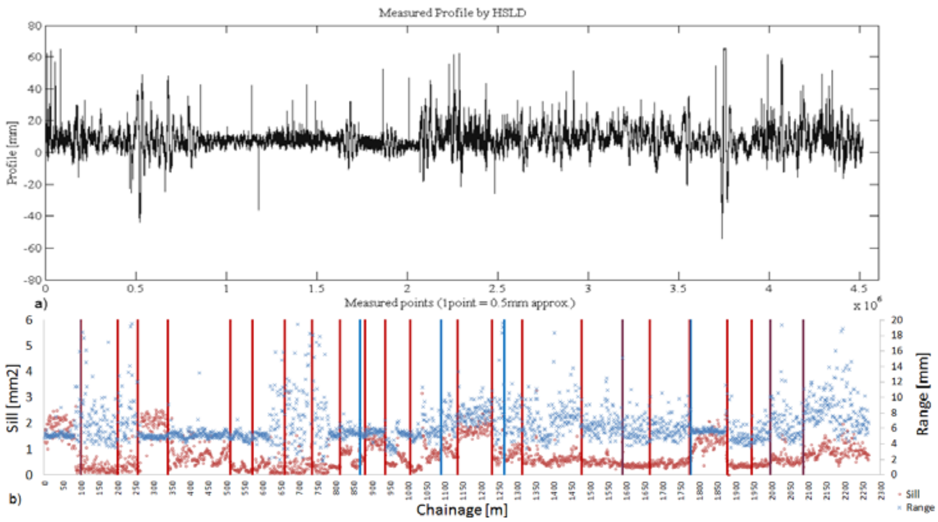


Figure 2: a) Measured profile; b) Sill and Range representation and Dichotomic sectioning restitution.

Following the profile cleaning phase, then the Variogram, with lag = 0.5mm and nlag = 40 (20mm), has been calculated, the Spherical Model has been applied and Sill and Range have been evaluated with an autofitting process (on a window of 1m). Graphical result has been summarized in the Figure 2b. As it is possible to see, the "time series" describe two different features of the same measured profile thus providing additional information on structural changes that can be used by sectioning methods. The Dichotomic method, with significance level (α) = 5% and sample size of 50, has been used for the identification of the homogeneous pavement road sections, and the results has been represented in the Figure 2b.

4 Conclusion

A Variogram scheme has been applied to the filtered road profile, measured by means of the HSL Device. Preliminary results show that Sill and Range can be considered as effective macrotexture indices since they can better highlight changes in pavement type and mixes. Dynamic sectioning by means of Dichotomic Method has been applied, yielding an identification rate of about 90% of real break points. Further studies are needed, nevertheless the developed methodology seems promising.

References

LOSA, M., & LEANDRI, P. 2011. The reliability of tests and data processing procedures for pavement macrotexture evaluation. *International Journal of Pavement Engineering*. Vol. **12**, No. 1, 59–73, Taylor and Francis. DOI: 10.1080/10298436.2010.501866.

D'APUZZO, M.; EVANGELISTI, A.; FLINTSCH; G. W.; DE L. IZEPPI; E.; MOGROVEJO, D. E. & NICOLOSI, V. 2015. Evaluation of Variability of Macrotexture Measurement with Different Laser-Based Devices. *Airfield and Highway Pavements: Innovative and Cost-Effective Pavements for a Sustainable Future*. 294-305. TRIS, ASCE. DOI: 10.1061/9780784479216.027.

ASTM E1845, 2009. Standard Practice for Calculating Pavement Macrotexture Mean Profile Depth. *American Society for Testing and Materials*.

CHILÈS, J.P. & DELFINER, P. 1999. Geostatistics: Modeling Spatial Uncertainty. Wiley, New York.

SPACAGNA, R.L., MODONI, G., SAROLI, M, 2019. An integrated model for the assessment of subsidence risk in the area of Bologna (Italy). *Geotechnical Research for Land Protection and Development- Proceedings of CNRIG 2019* - © Springer Nature Switzerland AG 2020 F. Calvetti et al. (Eds.): CNRIG 2019, LNCE 40, pp. 358–368, 2020. https://doi.org/10.1007/978-3-030-21359-6_38.

ECH M., S. MOREL, B. POUTEAU, YOTTE S., BREYSSE D. 2007. Laboratory evaluation of pavement macrotexture durability, *Revue Européenne de Génie Civil*, 11:5, 643-662. http://dx.doi.org/10.1080/17747120.2007.9692949.

D'APUZZO, M. & NICOLOSI, V. 2012 Detecting Homogeneous Pavement Section Using Econometric Test for Structural Changes in Linear Model. *Transportation Research Board 91st Annual Meeting* Paper n. 12-2125 , 0–18, Transportation Research Board, Washington DC, United States.