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VELOCITY FLOW ESTIMATION IN NATURAL EPHEMERAL AND UNGAUGED CHANNELS FROM LIDAR AND GPS-RTK DATA

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I. INTRODUCTION

In the last several years, numerous studies about the potential of the LiDAR technology as a new source of geographic information for geomorphological and hydrological studies have been generated. Several authors, such as Cavalli et al. (2008) used very high resolution digital elevation models in order to recognize mesophorms in riverbeds. Gilveart et al. (2004) successfully characterized the morphology of a part of the River Tummel channel in Scotland (8 km) using multispectral imagery, colour aerial photography and LiDAR data, obtaining an accuracy above 99% in the classification of islands, exposed rocks and water surfaces. Recently, Colmenárez et al. (2010) calculated the n Manning using a digital roughness model (DRM) generated from a digital elevation model (DEM) that was obtained using high-resolution LiDAR data.

In ungauged rivers, Manning's formula has been traditionally used to calculate the mean flow velocity (Giogia and Bombardelli, 2002). By means of this formula, the velocity is obtained from the slope of the water surface (S), the hydraulic radius (RH) and the roughness coefficient n. The measurement of these parameters in ungauged or inaccessible rivers is difficult. To solve this problem, we try to calculate the velocity of water flow in a semi-automated manner from airborne LiDAR data and GPS measurements, comparing the level of quality with field velocity measurements.

II. STUDY AREA

The study area is located in the central sector of the Palancia river, (a 976 km^2 basin with about 90 km length), which drains the southern part of the Iberian Range, between the towns of Algar de Palancia and Torres Torres. In this sector, the river has a braided pattern, with numerous bars and fluvial islands formed mainly by coarse sediment (cobble and pebble). Five sub-areas were selected, and a total of 43 plots were located inside of them, taking into account some topographic factors (relief and slope), as well as hydraulic factors (flow, depth, channel sinuosity and turbulence).

III. METHODOLOGY

In order to implement the study, the following information was used:
- ✓ LiDAR data of the dry riverbed.
- ✓ GPS-RTK data about the channel geometry and height.
- ✓ Field data to calculate the mean flow velocity (Vc).

1. Field measurements

The velocity was measured in the plots using floats (Whiting, 2003), and measurements of channel geometry and water height level were performed using a GPS-RTK Leica Smarth Rover, applying real-time differential corrections via internet. The hydraulic radius was obtained from cross-sections automatically generated (RHMed) using specific software designed for that purpose.

2. Obtaining Manning's coefficient *n* from LiDAR data

The *n* Manning's coefficient is traditionally obtained from tables (Chow et al., 1994), resulting in a subjective parameter. We used the methodology proposed by Colmenárez et al. (2010) in order to estimate the roughness coefficient. The procedure was the following:
1. The coefficient Manning's *n* was calculated from field data measurements (n_Campo) and the average hydraulic radius (RHMed) automatically obtained;
2. Five first order histogram texture variables were generated using texture analysis (data range, mean, variance, entropy and skewness), and an additional variable from the gradient vector.(Álvarez et al., 2002);
3. The Manning coefficient *n* (n_D) was deduced from a multiple regression analysis, using the six texture features as independent variables, and «n_Campo» as dependent variable. The statistical analysis showed that the variance (V) from the texture analysis was the most relevant variable in the model. The linear relationship between n_Campo and the Variance (V) was 55.81% and using a 2nd order adjustment 56.51%, therefore the value of Manning's n deduced by the model of 2nd order polynomial will be used.

3. A tool for automatic extraction of the morphometric parameters

A specific software application was created using ArcMap © as programming and visualization environment. The initial data were a LIDAR digital elevation model (DEM-LiDAR) in raster format, the study channel, and the channel axis, both in vector format. The tool consists on three modules:

1. The first module creates the cross sections

2. The second module generalizes the original channel to avoid intersection between the cross sections.

3. The third module determines the length of the study plots, generating a table containing a summary for the profiles involved.

With the information generated, we proceed to calculate the rate of water flow estimated (Ve) from the empirical formula of Manning, using the mean hydraulic radius (RHMed), the slope of water surface measured in the field with GPS (S), and the deduced Manning coefficient n (n_D).

4. Velocity flow map generation. The map is generated calculating flow depth (d) for each pixel in the study plot, the slope (S) (measured directly in field using GPS) and applying the 2nd order polynomial model based on the variance to derive the coefficient n in Manning's formula for every pixel. Then, the formula proposed by Manning-Limerinos is applied to map the velocity flow.

IV. CONCLUSIONS

A semi-automated methodology to obtain the average velocity of water flow in ungauged natural channels, from LiDAR data and GPS-RTK field measurements has been proposed, implemented and validated. The results obtained suggest that this methodology has a high potential for application to obtain the velocity of water flow, mainly in situations where a first and fast approximation of this value is required. This method is also interesting in those cases where the application of traditional procedures is difficult, or when working in very large areas. Since LiDAR technology facilitates the acquisition of data in large areas, the velocity of water flow will be obtained in a faster and more efficient manner. Future work should be focused on the rigorous assessment, using field measurements, of the water surface slope automatically obtained in this study. The proposed method also opens the possibility to produce 3D information that allows mapping the spatial variability of the velocity of water flow. A comparison of these results with those obtained by means of hydraulic models should also be done in the future.