A simple method for the enhancement of river bathymetry in LIDAR DEM

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ABSTRACT

The preparation of an accurate bathymetry is of paramount importance for flood modeling. A recurrent flaw of LIDAR-derived Digital Elevation Models (DEM) is a wrong representation of bed bathymetry due to the presence of water along rivers, that prevents a careful reproduction of the actual bed morphology and consequently an incorrect estimation of the conveyance. This contribution provides a simple algorithm designed to tackle this problem that can be applied when land surveyed cross sections are available to complement DEM data. The proposed algorithm, that requires the coupled use of both a 2D Shallow Water Equations solver and a GIS software, is successfully applied to a 37 km long stretch of the Mella river (Northern Italy).

1. Introduction

The European legislation 2007/60/EC prescribes the review of the hazard maps and flood risk maps every six years in order to take into account the impact of climate change, availability of new data and the increasing knowledge on hazard computation and flooding risk. There is a fundamental agreement on the procedure to compute hazard maps using suitable mathematical models (typically, the Shallow Water Equations, SWE) and the quality level that can be obtained is potentially very good provided that the description of the floodplain, watercourse and hydraulic structures present along the area of interest is accurate. Accordingly, DEM produced with LIDAR survey provides a detailed description of the floodplain topography but, on the other hand, the description of the river bathymetry could be unrealistic, mostly as consequence of the use of lasers based on red light, unable to penetrate water bodies. The consequence of the poor description of the riverbed is an unrealistically low conveyance that can be measured in correspondence of the surveyed cross sections where the riverbed elevation is known, thus suggesting the need of the correction of the bathymetry. In the literature, several methods are proposed to tackle this problem as a function of the data available; for instance, when only the DEM is available, typical procedures are based on the estimation of the water normal depth using Manning equation with simplified cross sections and a reasonable guess on the discharge value (e.g., Roub et al., 2012; Bhuyan et al., 2015). When both surveyed cross section and DEM are available, a different kind of interpolation can be done in order to reconstruct the bathymetry of the river to be substituted into the original DEM (Dysarz, 2018; Merwade et al., 2008; Caviedes et al., 2014). In this contribution we provide a simple method to improve the description of the river bathymetry in a DEM, that can be used when the data is properly filtered from vegetation and a set of topographically-surveyed CS_{sur} are available. The method uses the information obtained by a low-flow simulation with a 2D SWE solver.

2. The Algorithm

The proposed algorithm for the improvement of a river bathymetry within a raster DEM (DEM_{ori}, in the following) requires the use of a GIS software and of a 2D SWE solver along with a set of *n* rectilinear cross section (CS_{sur} in the following) of the watercourse. The steps that compound the algorithm can be summarized in the following points:

1. In order to identify the subset of cells of DEM_{ori} representing the bed of the river a 2D simulation is performed with a suitably chosen low flow Q, such that the riverbed only is flooded by water. Using the results of this simulation, the shapefile of the outline of the flooded domain (SHP_{fld}) is obtained.
2. A set of *n* cross sections (CS_{DEM}) is extracted from DEM_{ori} in correspondence of the available CS_{sur}, limiting their transversal extent l_j (where *j* is the index of the CS) to the outline of the previously identified flooded domain. Then, for each cross section, the average vertical offset Δz_j is computed.

3. A fictious channel is built, made up of rectangular cross sections of depth Δz_j with the same width L_j and position of the CS_{sur} set. Then, the geometry of the fictitious channel is converted to a raster file, called DEM_{offset}.
4. DEM_{offset} is clipped using the polygon SHP_{fld}. Then the final corrected DEM (DEM_{corr}, in the following) is built as the difference of elevations between DEM_{ori} and the clipped DEM_{offset}.

3. Application to the Mella river

The Mella river is a pre-alpine Italian watercourse in the province of Brescia, one of the most strongly urbanized areas of northern Italy. This area is covered by a 0.8 m grid LIDAR DEM surveyed in 2009. In our test, a 37 km long stretch of the river was considered. Along the same stretch of the river, 120 CSs were surveyed in 2002, with a lateral extension that typically covers the floodplain for a width 4 times larger than the river bed. The proposed algorithm was applied with a positive result, as shown by the comparison of the cross sections extracted from DEM_{ori} and DEM_{corr} (CS_{DEM} and CS_{corr}, respectively) in correspondence of CS_{sur} (see Fig. 1). The geometry of CS_{corr} is very close to the corresponding CS_{sur}, leading to stage-conveyance curves that are in very good agreement.

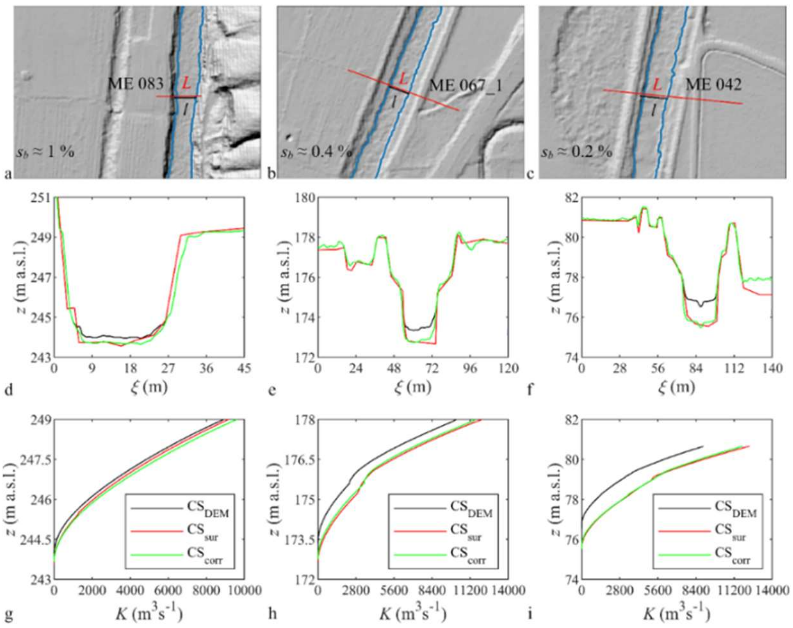

Fig. 1. Plan view of CSs ME 083 (a), ME 067_1 (b), and ME 042 (c) from the Mella river test case with indication of the flooded area and of the part of the CS representing the river bed. The CSs geometry extracted from DEM_{ori} and DEM_{corr} and the stage-conveyance curves are compared to the data from CS_{sur} (d, g: CS ME 083; e, f: CS ME 067_1; f, i: CS ME 042).

4. Conclusions

The proposed simple methodology relies on the availability of surveyed CSs and of a DEM filtered from vegetation. In particular, the methodology takes advantage of the information obtained by a 2D flood simulation that is also the final goal of the DEM improvement activities. Accordingly, this step is not to be considered as an overburden but as a preliminary activity (to be possibly performed with a simple parabolic model) that anticipates a necessary step of the overall workflow. On the contrary, the 2D simulation gives a physical basis to the methodology and captures automatically the possible river planimetric width variability or the presence of islands between two consecutive CS_{sur}, providing a careful reconstruction of the river bed. On the other hand, a 1D reconstruction of the watercourse, based on the interpolation of the CS_{sur} set only, could miss this aspect.

References

Bhuyian MNM, Kalyanapu AJ, Nardi F (2015) Approach to digital elevation model correction by improving channel conveyance, J. Hydrol. Eng., 20(5)

Caviedes-Voullième D, Morales-Hernández M, López-Marijuan I, García-Navarro P (2014) Reconstruction of 2D river beds by appropriate interpolation of 1D cross-sectional information for flood simulation, Environ. Modell. Softw., 61 (0), 206-228

Dysarz T (2018) Development of RiverBox - an ArcGIS toolbox for river bathymetry reconstruction, Water, 10(9), 1266

Merwade V, Cook A, Coonrod J (2008) GIS techniques for creating river terrain models for hydrodynamic modeling and flood inundation mapping, Environ. Modell. Softw., 23, 1300–1311

Roub R, Hejduk T, Novák P (2012) Automating the creation of channel cross section data from aerial laser scanning and hydrological surveying for modeling flood events, J. Hydrol. Hydromech., 60(4), 227– 241