Reconstruction of a digital elevation model in a lab-scale urban drainage facility applying LiDAR and SfM techniques

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ABSTRACT

The use of visualization techniques for obtaining elevation maps with simple and relatively low-cost procedures, apart from conventional topographic methods, is widespread. In the field of urban drainage systems, numerical models require greater grid detail to solve complex hydraulic problems. This study presents the use of Structure from Motion (SfM) and Light Detection And Ranging (LiDAR) techniques to obtain the roof and pavement elevations of an urban drainage experimental module. The digital reconstructions obtained are both satisfactory, in terms of the detail of the elements, and similar between each other, with a mean vertical error for both surfaces less than 2 mm. The main discrepancies between both procedures lie in collecting and processing point clouds and meshes.

Keywords: urban drainage; photogrammetry; Structure from Motion (SfM); Light Detection And Ranging (LiDAR).

1 INTRODUCTION

Urban runoff-rainfall models are commonly used to study the performance of urban drainage systems. High spatial resolution models, such as detailed grids of the surface elevations, should be used as input geometries in numerical models to accurately analyse the hydraulic processes that occur in these systems. As the computational capabilities of commercial computers increase, they will make it possible to solve more complex problems with larger mesh sizes. Visualization tools are a suitable mechanism to obtain a better approach to the model elevation map, assessing surface macro-roughness (e.g., roofs and pavers within urban drainage systems). A comparison of the elevation map acquisition with LiDAR and SfM procedures in part of an urban drainage experimental module is shown in this study. The use of photogrammetric techniques to obtain elevations by the authors is noteworthy, especially on impervious surfaces and accumulation of sediments in sewer pipes. Further information regarding these applications can be found in Naves et al. (2019) and Regueiro-Picallo et al. (2020).

2 MATERIAL AND METHODS

This study was carried out in a water-sensitive urban design (WSUD) facility located in the Hydraulic Engineering Laboratory of the Center for Technological Innovation in Construction and Civil Engineering (CITEEC) at the University of A Coruña (Spain). This facility is included in the WSUD experimental models of the laboratory, which were built mainly for research as well as high-education purposes (Puertas et al., 2020). For the present study, one of the roofs of the WSUD experimental model and part of the paved surface have been selected. The elevation map of these surfaces was obtained by applying SfM and LiDAR techniques (Figure 1). To obtain the elevations with the SfM technique, the surfaces were first photographed with a conventional digital camera (Canon EOS 2000d, EF-S 18-55mm f/3.5-5.6 IS). Since these are surfaces with uniform textures, it was necessary to project a texture onto the surfaces so that the SfM technique could detect the pairs of points between the photographs. VisualSfM software was used for the digital reconstruction of the model and MeshLab software was used for point cloud processing and mesh generation. On the other hand, an Intel RealSense LiDAR Camera L515 together with the commercial software RecFusion have been used to directly obtain the digital reconstruction of the installation using the LiDAR technique.

3 RESULTS

The final products consist of two Digital Elevation Models (DEM) with a 5 mm spatial resolution. Differences between Digital Elevation Models (DEM) obtained with each technique were quantified using the Root Mean Square Error (RMSE) using the LiDAR topography as reference. The RMSE obtained between roof topographies was 8 mm while for paved topographies was 5 mm. In addition, the mean vertical error obtained for roof and paved surface topographies was less than 2 mm. These differences agree with the results in Naves et al. (2019) where a topography with a similar resolution was used and validated in a hydraulic numerical model. Therefore, no significant differences can be considered regarding DEM resolution and accuracy between both techniques for this research scope.

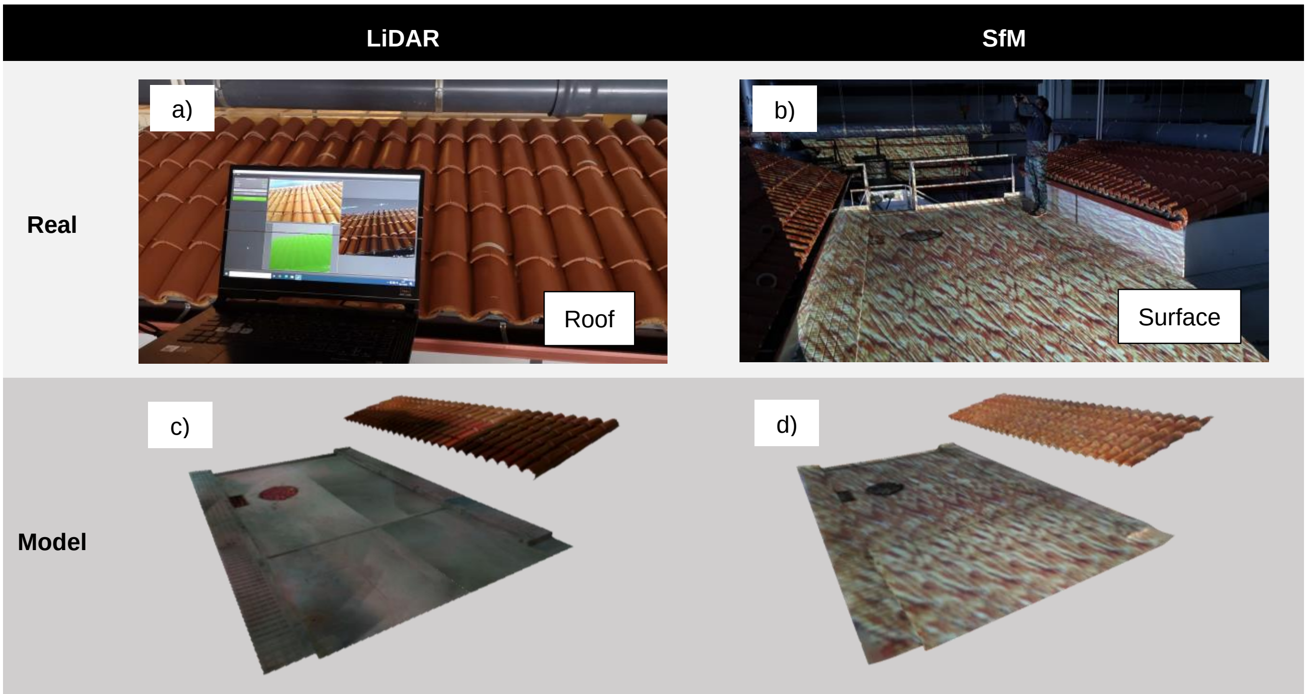

Figure 1. Snapshots of the roof (a) and the surface (b) of the WSUD facility, and LiDAR (c) and SfM (d) reconstruction models.

4 CONCLUSIONS

LiDAR and SfM techniques show significant advances in reconstructing highly detailed (mm/cm scale) urban drainage surfaces, such as pavements and roofs, to increase the performance of numerical models. The comparison of the elevations in the facility shows that the result is similar regardless of the technique used. Nevertheless, as main differences, it should be noted that the SfM technique allows to obtain a greater detail of the surface macro-roughness, such as roof tile channels, mainly due to the higher density of points. On the other hand, the LiDAR technique shows greater advantages when processing point clouds since the mesh can be obtained directly by using the sensor-software combination, and within a known coordinate system and scale.

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REFERENCES

Naves, J., Anta, J., Puertas, J., Regueiro-Picallo, M., Suárez, J. (2019). Using a 2D shallow water model to assess Large-Scale Particle Image Velocimetry (LSPIV) and Structure from Motion (SfM) techniques in a street-scale urban drainage physical model. *Journal of Hydrology,* 575, 54-65.

Puertas, J., Hernández-Ibáñez, L., Cea, L., Regueiro-Picallo, M., Barneche-Naya, V., Varela-García, F.-A. (2020). An Augmented Reality Facility to Run Hybrid Physical-Numerical Flood Models. *Water,* 12, 3290.

Regueiro-Picallo, M., Suárez, J., Sañudo, E., Puertas, J., Anta, J. (2020). New insights to study the accumulation and erosion processes of fine-grained organic sediments in combined sewer systems from a laboratory scale model. *Science of The Total Environment,* 716, 136923.