Journal of Hydrology 509 (2014) 150–162

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Geomatic methods at the service of water resources modelling

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ARTICLE INFO

Article history:
Received 29 July 2013
Received in revised form 19 November 2013
Accepted 22 November 2013
Available online 28 November 2013
This manuscript was handled by Geoff Syme, Editor-in-Chief

Keywords:
Water resources modelling
Geomatics
Suitability assessment
Hydrology
Hydraulics
Guidelines

SUMMARY

Acquisition, management and/or use of spatial information are crucial for the quality of water resources studies. In this sense, several geomatic methods arise at the service of water modelling, aiming the generation of cartographic products, especially in terms of 3D models and orthophotos. They may also perform as tools for problem solving and decision making. However, choosing the right geomatic method is still a challenge in this field. That is mostly due to the complexity of the different applications and variables involved for water resources management. This study is aimed to provide a guide to best practices in this context by tackling a deep review of geomatic methods and their suitability assessment for the following study types: Surface Hydrology, Groundwater Hydrology, Hydraulics, Agronomy, Morphodynamics and Geotechnical Processes. This assessment is driven by several decision variables grouped in two categories, classified depending on their nature as geometric or radiometric. As a result, the reader comes with the best choice/choices for the method to use, depending on the type of water resources modelling study in hand.

1. Introduction

The studies related to water resources management comprise multidisciplinary approaches due to its wide range of dimensions and applications: flood analysis, erosion, hydraulics, numerical models, hydro-economy, water supply, water quality and contamination, etc. In order to minimize the initial uncertainty, these studies require accurate and reliable field measures for the subsequent analysis.

Acquisition of spatial data is a key factor as it is the base for further calculations and analysis. However, it is necessary to bear in mind that the application field for water resources management is so wide that looking for the most suitable geospatial technique for each case study become essential. According to the Oxford dictionary definition of Geomatic: "The mathematics of the Earth; the science of the collection, analysis, and interpretation of data, especially instrumental data, relating to the Earth's surface" (Deshogues and Gilliéron, 2009). This definition emphasizes the fact that Geomatic is responsible for not only the data collection techniques and technologies, but also for the management of geospatial data by GIS (Geographical Information System) and SDI (spatial data infrastructure).

Both branches (data acquisition and management) have suffered a quick development during the last decades towards a higher efficient and completion. However, there is always a trade-off between the instrumentation, sensor integration and the degree of automation achieved by new algorithms and numerical methods. Within the capture methods, the modernization has been focused on terms as precision, exhaustiveness and the miniaturization of sensors. Since the amount of information generated is still growing, it becomes vital to choose the correct method in terms of a right posterior processing and management. Consequently, classical instruments have not completely set aside, and could be a good choice for some scenarios in terms of precision or budget which do not require a massive data acquisition.

Since the spatial data plays a key role for water management, the final hydraulic/hydrology results will be affected by the uncertainty contained in the data itself (Chaubey et al., 2005). In this sense, it is important distinguish among the possible causes of uncertainty in a spatial data for a management system, which are resumed in positional and attribute accuracy (Chrisman, 1991). Whereas the latter refers to the attribute attached to the points, lines and polygons features of the spatial dataset, and thus to whether nominal variables or labels are correct or not, the former falls into the geomatic application field. Consequently, this is highly related to the instrument and capture methodology used, and not only in terms of improving field data quality but also of reducing error propagation. Since all measurements contain errors, it is unavoidable that the quantities computed from them also contain errors (Ghilani and Wolf, 2011). Within the parameters which characterizing them (from the metrology field), it is necessary to

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0022-1694/$ - see front matter
http://dx.doi.org/10.1016/j.jhydrol.2013.11.034

clarify three that will be used through this paper, and may be subject to confusion: *precision*: closeness of agreement among replicate measured quantities under specified conditions (VIM, 2008). This concept is the used to characterize the instrumentation and it is expressed by measures of standard deviation. Then, *accuracy* represents the discrepancy of measurements of a quantity to the ground truth (VIM, 2008). Last but not least, the *geometric resolution* is defined as the size of the smallest spatial measurement that can be detected by a sensor. This concept can be given in terms of the GSD (Ground Sampling Distance) for spatial image resolution (Reulke et al., 2006). It is define as the pixel distance with respect to the projection on the ground.

This paper is aimed to tackle a review and analysis of the different available geomatic methods that are useful for the different dimensions and applications of water resources modelling. Also, this paper aims to provide the reader with the best choice/choices for the method to use, depending on the type of water resources modelling study in hand.

After this introductory section, the paper is structured as follows: a description of the geomatic techniques in the context of their application to Water Resources Modelling is developed at Section 2, then, a suitability analysis of each technique per case study is shown. Finally, some conclusions of this review are provided in Section 4.

2. Geomatic methods at the service of water resources management and modelling

Spatial information acquisition in hydrology and hydraulics has been supporting by classic topographic instruments as a method for discrete representation of the terrain. But, until the apparition of the EDM (Electronic Distance Measurement), there was not possibility of reducing the field time used with the previously steel tape and/or stadia rod. There was a consequent precision and work range increase.

Nowadays, and although the apparition of newest technologies, the survey instruments are kept in use, due to the possibility of increasing the spatial resolution and the surveying of singular points in the critical regions of the study scenario, since are human operated. As for example, Gómez et al. (2009) where use of reflectorless total station for cross-sections for gully erosion, or Anderson et al. (2009) who generate digital elevation model of a hill slope, which is part of a calculation to determine the morphology and spatial pattern of a preferential flow network over a large scale.

The classic survey is kept using, as for example in Young (2008)where a topographic level is used together with a stadia rod for hydrologic studies in artic regions. It is necessary to point out that the topographic level is the most suitable instrument for leveling heights since is reached the highest precision (0.7–0.3 mm of error per km). The main disadvantage is the low range of the instrument and the leveling method (up to 25 m in favorable situations, flat terrain). The survey levels are also uses for the establishment of the vertical datum based on orthometric heights (Meyer and Baron, 2010). If the precision requirements are lower, there is always the possibility of using the total station for long range leveling, by the known technique of trigonometric leveling (in contrast with the geometric carried out by the automatic level) where by the measure of geometric distance and vertical angle solve the height difference.

2.1. Global Navigation Satellite System (GNSS)

The GNSS (Global Navigation Satellite System) appears in 1970s and it refers to the entire scope of satellite systems used in positioning (Ghilani and Wolf, 2011). The GNSS was an effective alternative to the total station surveying avoiding the indivisibility constraint between station and the measured element (difficult in wide and/or abrupt watershed) and providing oriented measures. Nevertheless, the GNSS system is affected by several error sources from atmospheric ones to relativistic (Hofmann-Wellenhof et al., 2008). There are also significant differences among different type of receptors, since they use the phase difference to obtain the highest precision (in contrast with the use of pseudorange by the consumer grade receivers). The GNSS survey protocol with two dual frequency receivers allows eliminating biases and obtaining the highest precision of the method. This is a relative positioning, because of the coordinates of unknown point are determined with respect a known one (which is usually stationary).Regarding the GNSS positioning techniques, they can be grouped as static relative positioning with horizontal precision of 5 mm + 0.5 ppm) and vertical precision of 10 mm + 0.5 ppm good to check-points, but with long observation times (20 min + 2 min/km) and as kinematic relative positioning where the unknown point in moving (Fig. 1).

By using this method a larger amount of points can be determined, but it requires a continual satellite contact, and the precision decreases if more epochs for point are not collected, getting a horizontal precision of 5 cm + 5 ppm and a vertical precision of 20 mm + 1 ppm (Hofmann-Wellenhof et al., 2008).

Some remarkable examples of GNSS applications related to enviromental management can be the monitoring and measurement of landslide displacement, using a real-time kinematic technique (Rawat et al., 2011). Another application has been for accuracy assessment, by establishing ground control points, to evaluate an algorithm for stream mapping and watershed analysis (Metz et al., 2011), in this sense, in Harrower et al., 2012, the water flow patterns are studied. Also, measurement of wrack marks with differential GNSS (in addition to gauge data) was applied for flood inundation modelling (Neal et al., 2009). Another newer application of GNSS instruments, not related to coordinate capture, is

Fig. 1. GNSS-RTK (Real Time Kinematic) positioning.