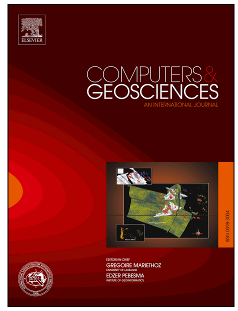
Accepted Manuscript



Uncertainty modelling and analysis of volume calculations based on a regular grid digital elevation model (DEM)

Chang Li, Qing Wang, Wenzhong Shi, Sisi Zhao

PII: S0098-3004(16)30732-4

DOI: 10.1016/j.cageo.2018.01.002

Reference: CAGEO 4075

To appear in: *Computers and Geosciences*

Received Date: 29 November 2016

Revised Date: 17 November 2017

Accepted Date: 10 January 2018

Please cite this article as: Li, C., Wang, Q., Shi, W., Zhao, S., Uncertainty modelling and analysis of volume calculations based on a regular grid digital elevation model (DEM), *Computers and Geosciences* (2018), doi: 10.1016/j.cageo.2018.01.002.

Uncertainty modelling and analysis of volume calculations based on a regular grid digital elevation model (DEM)

CHANG LI [1] *, Qing Wang [1] Wenzhong SHI [2] and Sisi ZHAO [1]
1 Key Laboratory for Geographical Process Analysis & Simulation, Hubei Province, and College of Urban and Environmental Science, Central China Normal University, Wuhan, China.
2 Joint Spatial Information Research Laboratory, The Hong Kong Polytechnic University and Wuhan University, Hong Kong and Wuhan, China.

The accuracy of earthwork calculations that compute terrain volume is critical to digital terrain analysis (DTA). The uncertainties in volume calculations (VCs) based on a DEM are primarily related to three factors: 1) model error (ME), which is caused by an adopted algorithm for a VC model, 2) discrete error (DE), which is usually caused by DEM resolution and terrain complexity, and 3) propagation error (PE), which is caused by the variables' error. Based on these factors, the uncertainty modelling and analysis of VCs based on a regular grid DEM are investigated in this paper. Especially, how to quantify the uncertainty of VCs is proposed by a confidence interval based on truncation error (TE). In the experiments, the trapezoidal double rule (TDR) and Simpson's double rule (SDR) were used to calculate volume, where the TE is the major ME, and six simulated regular grid DEMs with different terrain complexity and resolution (i.e. DE) were generated by a Gauss synthetic surface to easily obtain the theoretical true value and eliminate the interference of data errors. For PE, Monte-Carlo simulation techniques and spatial autocorrelation were used to represent DEM uncertainty. This study can enrich uncertainty modelling and analysis-related theories of geographic information science.

Keywords: Volume calculation; DTA; Uncertainty modelling; Truncation error; propagation; Terrain complexity; DEM

1 Introduction

For many disciplines, uncertainty has been recognized as an important part of basic theory. Goodchild (1992) identified GIScience as a set of fundamental scientific issues that are stimulated by or surround the use of digital computers to handle, process, analyse, store or access geographic information. Data serve as the carrier of information of an objective entity; approximately 70% of phenomena in the real world are position-related and can be described by spatial data (Shi 2009). Thus, the need for spatial data has increased in a rapidly changing world due to the widespread development and application of GISs (the major research and application tool of GIScience) (Li et al. 2012). However, the quality of geospatial data cannot be guaranteed because information gathering and processing suffer from various man-machine limitations (Goodchild and Jeansoulin 1998). These limitations create uncertainty in spatial data and these uncertainties may produce unforeseeable spatial analysis errors. Therefore, studying the uncertainty of spatial data is very important.

In past two decades, the study of the uncertainty of spatial data has achieved fruitful results, especially the study of the uncertainty of a digital elevation model (DEM) for digital terrain analysis (DTA) (LI, et al. 2005). As the focus of the study of spatial data uncertainty, the study of the uncertainty of a DEM is primarily concentrated in two aspects: a) the uncertainty modelling and analysis of DEM data sources (Carlisle 2005, James et al. 2007, Wheaton et al. 2010) and b) the uncertainty modelling and analysis of DEM interpolation (Shi et al. 2005, Shi and Tian 2006). Although some studies of the uncertainty of DEM applications have also

* Corresponding author, E-mail: lcshaka@126.com and lichang@mail.ccnu.edu.cn