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Accuracy assessment of georectified aerial photographs: Implications for measuring lateral channel movement in a GIS

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Abstract

Aerial photographs are commonly used to measure planform river channel change. We investigated the sources and implications of georectification error in the measurement of lateral channel movement by testing how the number (6–30) and type (human versus natural landscape features) of ground-control points (GCPs) and the order of the transformation polynomial (first-, second-, and third-order) affected the spatial accuracy of a typical georectified aerial photograph. Error was assessed using the root-mean-square error (RMSE) of the GCPs as well as error in 31 independent test points. The RMSE and the mean and median values of test-point errors were relatively insensitive to the number of GCPs above eight, but the upper range of test-point errors showed marked improvement (i.e., the number of extreme errors was reduced) as more GCPs were used for georectification. Using more GCPs thus improved overall georectification accuracy, but this improvement was not indicated by the RMSE, suggesting that independent test-points located in key areas of interest should be used in addition to RSME to evaluate georectification error.

The order of the transformation polynomial also influenced test-point accuracy; the second-order polynomial function yielded the best result for the terrain of the study area. GCP type exerted a less consistent influence on test-point accuracy, suggesting that although hard-edged points (e.g., roof corners) are favored as GCPs, some soft-edged points (e.g., trees) may be used without adding significant error. Based upon these results, we believe that aerial photos of a floodplain landscape similar to that of our study can be consistently georectified to an accuracy of approximately $\pm$5 m, with ~10% chance of greater error. The implications of georectification error for measuring lateral channel movement are demonstrated with a multiple buffer analysis, which documents the inverse relationship between the size of the buffers applied to two channel centerlines and the magnitude of change detected between them. This study demonstrates the importance of using an independent test-point analysis in addition to the RSME to evaluate and treat locational error in channel change studies.
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Keywords: Channel change; Channel migration; Georectification; Aerial photographs; Geospatial error; GIS

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1. Introduction

Aerial photographs are rich sources of information on historical river conditions (Trimble, 1991; Lawler, 1993) and have been widely used to track the historical planform evolution of river systems (e.g., Lewin and Weir, 1977; Petts, 1989; Gurnell, 1997; Surian, 1999; Graf, 2000; Winterbottom and Gilvear, 2000; O'Connor et al., 2003; plus many others). Historical planform channel analysis typically involves the co-registration of aerial photos and maps from different years so channel positions can be analyzed in overlay. Since the 1980s, the development of desktop GIS software and improvements in remote sensing and digital scanning technology have enabled users to more efficiently scan and co-register aerial photos; however, spatial error in digital imagery (including scanned aerial photos) is inevitable and can impart inaccuracies in measurements of lateral channel movement.

While there is widespread recognition in the GIScience community of the sources, types, and implications of locational error in geospatial data sets (Chrisman, 1982, 1992; Goodchild and Gopal, 1989; Unwin, 1995; Leung and Yan, 1998), fluvial geomorphologists have generally ignored the magnitude of geospatial error in relation to geomorphic change or have used only Root Mean Square Error (RMSE) as a measure of this error (e.g., Urban and Rhoads, 2004). Only recently have fluvial geomorphologists begun to embrace geospatial error as an independent research topic (e.g., Mount and Louis, 2005). Consequently, despite the development of approaches for measuring positional accuracy of linear features (e.g., Goodchild and Hunter, 1997; Leung and Yan, 1998) and recognition of the inherent problems of positional error on maps of rivers (Hooke and Redmond, 1989; Locke and Wyckoff, 1993) and lakes (Butler, 1989), there is no widely supported conceptual framework for evaluating and treating positional error on digital imagery in the measurement of lateral channel movement.

In this article, we seek to identify the magnitude and controls of geospatial error in georectified aerial photos and to address the implications of this error for measuring lateral channel movement. Accordingly, we raise the following questions:

(i) How is the locational accuracy of georectified aerial photos affected by the number and type of ground control points (GCPs) and the order of polynomial transformation used in georectification?
(ii) Is root-mean-square error (RMSE) a good proxy of overall georectification error?
(iii) What are the implications of georectifcation error for quantifying lateral channel movement and how can such error be minimized?

We address these questions using repeated georectification of an aerial photo showing the Umatilla River in northeastern Oregon. The quality and scale of this imagery is typical of those used throughout North America and many other parts of the world to reconstruct river histories. This article is the first phase of a broader study to evaluate channel and floodplain change resulting from large floods in selected rivers of the U.S. Pacific Northwest.

2. Background

GIScience and remote sensing play an increasingly significant role in geomorphological studies. Some recent examples of topics that have benefited from advances in the generation and handling of digital geospatial data include (but are not limited to) mapping and modeling of: fluvial erosion (Finlayson and Montgomery, 2003), complex terrain (Wilson and Gallant, 2000), mass wasting (Roering et al., 2005); mountain topography (Schroder and Bishop, 2004), historical channel change (Leys and Werrity, 1999; Collins et al., 2003), and river habitats (Marcus et al., 2003) and depths (Fonstad and Marcus, 2005). While many studies have developed methods for using digital data (e.g., aerial photos, satellite images, historical maps, and digital elevation models) to address traditional research topics, relatively few studies have rigorously addressed the effects of geospatial data quality on the results of geomorphic analyses (although see Holmes et al., 2000; Mount et al., 2003; Mount and Louis, 2005). Therefore, geomorphologists currently using digital geospatial need to better understand how the quality of geospatial data may affect analyses of digital data sets and to understand what factors control such data quality. Development of error-sensitive change detection methods depends on this knowledge. As GIScience continues

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