A geostatistical approach to estimating river bathymetry in near real-time.

Sanjeev Jha, National Center for Supercomputing Applications, 217-244-0076, jha.sanj@gmail.com

1. Sanjeev Kumar Jha, National Center for Supercomputing Applications, Urbana, Illinois
2. Barbara Bailey, Department of Mathematics and Statistics, San Diego State University, California
3. Barbara Minsker, National Center for Supercomputing Applications, Urbana, Illinois
4. Ron Cash, Department of Geology, University of Illinois at Urbana-Champaign, Illinois
5. Jim Best, Department of Geology, University of Illinois at Urbana-Champaign, Illinois

Understanding of spatially-distributed bathymetry at a range of spatial scales is important to understanding river and sediment dynamics. Most river sand dunes are 10-100m long but man-made features such as pipes, groynes, and piers can be less than a meter wide. Therefore it is necessary to conduct high-resolution survey measurements to accurately capture the spatial variation in bed profile. With rapidly changing bathymetry in large rivers, detailed surveys must be done frequently to capture short and long term changes in the river bed, but this is challenging for manually-intensive and expensive high-resolution surveys. In this paper, we propose the use of geostatistical models to update measurements from a periodic detailed survey, which is used as a baseline morphology, with less dense data collected from routine boat traffic equipped with less expensive sensors.

Our study area is a six-kilometer reach of the Mississippi River. We obtain measurements of depth at different spatial and temporal resolutions from two types of data sources: detailed surveys using a multi-beam echosounder (MBES) bed profiler and routine depth data from two sensors installed on a boat making a single pass down the Mississippi River. The MBES measurements consist of latitude, longitude, and depth at a spatial resolution of 0.5m*0.5m, collected during three surveys over a period of one year. These three surveys were conducted immediately after seasons when the river experiences large variations in bed bathymetry. While conducting Survey3 measurements, we also measured latitude, longitude, and depth once per minute (approximately every 140 m) along the boat route using two single-beam depth sensors. A four-step methodology was then developed to rapidly update the baseline morphology and provide a near-real-time estimate of the bathymetry: (i) use Survey 2 measurements to estimate the variance structure and develop a geostatistical model; (ii) use boat measurements during Survey 3 to update the estimated variance structure; (iii) use the updated variance structure to predict the bathymetry; and (iv) validate the model prediction using Survey 3 measurements.

For step (i), a geostatistical model was developed using ordinary and Bayesian kriging with the geoR package within R statistical software. The results obtained from both approaches were less than 2% different from each other, hence ordinary kriging was used for further analysis as it is less computationally demanding. For steps (ii) and (iii), the algorithm proposed by Barnes and Watson (1992) is used for updating kriging variances and depth estimates. The model was used to predict the depth at 2,000 randomly sampled points among the Survey 3 measurement locations. We performed this analysis five times using 2,000 different randomly sampled points each time and calculated the root-mean-squared error (RMSE) between the model predictions and the actual Survey 3 measurements for each analysis. The average normalized RMSE of the updated bathymetry was around 0.15 with respect to the Survey 3 measurements. The developed method holds promise for improving bathymetry estimates at low cost, but more boat passes may be needed to bring errors to sufficiently low levels.