Automation of DEM Cutting for Hydrologic/ Hydraulic Modeling

tech transfer summary

The proposed enforcement method can provide relatively accurately enforced digital elevation models (DEMs) with relatively little effort.

Objective

Develop a method for hydrologic enforcement using digital elevation models (DEMs) created from raw light detection and ranging (LiDAR) data that both respects natural depressions and correctly enforces flow in areas that are drained.

Background and Problem Statement

As a critical part of transportation design, hydrologic analysis helps ensure that roads are not frequently inundated and that hydraulic structures are able to accommodate the flow regimes they will likely see. LiDAR technology is now commonly used in hydrologic analysis to create high-resolution DEMs that help model the flow of water across a landscape.

However, such technologies introduce challenges that must be solved before these data can be commonly used as a model input. High-resolution DEMs capture many high-frequency manmade features and some natural features that create hydrologic obstructions during the hydrologic enforcement process. Moreover, some landform regions have significant amounts of natural depressions that are not handled well by traditional DEM enforcement.

Research Description

The method proposed for depressional analysis and enforcement involves three steps.

1. Creating a DEM from the Raw LiDAR Data

Elevation points are imported into a terrain, and unnecessary resolution is reduced. The terrain is then converted into a DEM, and elevation differences smaller than 1 centimeter are truncated. The resulting DEM is then analyzed for flow characteristics to remove depressions of one-cell extent.

2. Hole Punching

Depressions significant enough to warrant analysis via the enforcement algorithm are defined. This involves iteratively filling the DEM, defining regions where the DEM was filled, and calculating the maximum fill depth and total area filled of each region. The deepest point in any significant depressions is set to “null” so that water can “flow” out, and the filling process is repeated until no significant depressions remain. The depressions drained via channelized flowpaths are then removed.

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RESEARCH PROJECT TITLE
GIS Automation of LiDAR DEM Cutting for Hydrologic/Hydraulic Modeling

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3. Cutting

Depressions are identified that are likely created via an embankment and would drain if the embankment were removed. Depressions where the distance from the depression's deepest points to the local watershed boundary is greater than a 5 percent slope have the embankment removed and are tested for a decrease in the filled DEM elevation. The depressions that are provisionally drained are then tested for enforcement by trying to connect the deepest points in the depression to lower points outside the depression. Successful linear connections are then used to modify the DEM elevation appropriately, creating the final enforced DEM.

This procedure was evaluated at a 3 meter resolution on a small watershed in central Iowa, Walnut Creek of the South Skunk River watershed, HUC12 # 070801050901.

Key Findings

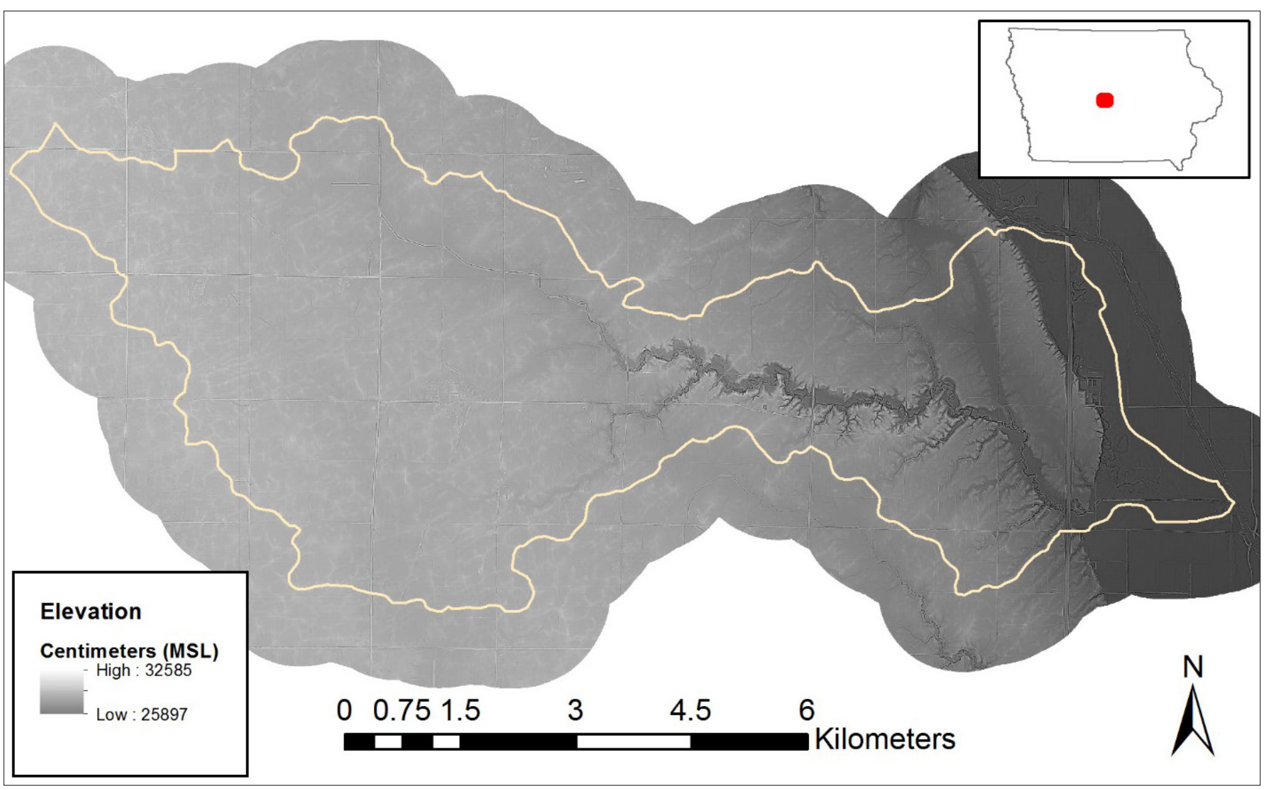
- The procedure was found to accurately identify 88 of 92 drained depressions (about 95 percent) and then place enforcements generally accurate to within two pixels.
- Enforcements were often placed where none are necessary, with approximately four times as many enforcements as actual hydraulic structures.
- The method often tried to drain prairie pothole depressions that are bisected by anthropogenic features. Most of these enforcements reconnected a depression bisected by a road or cut across a road when the enforcement should have paralleled the road.

Implementation Benefits

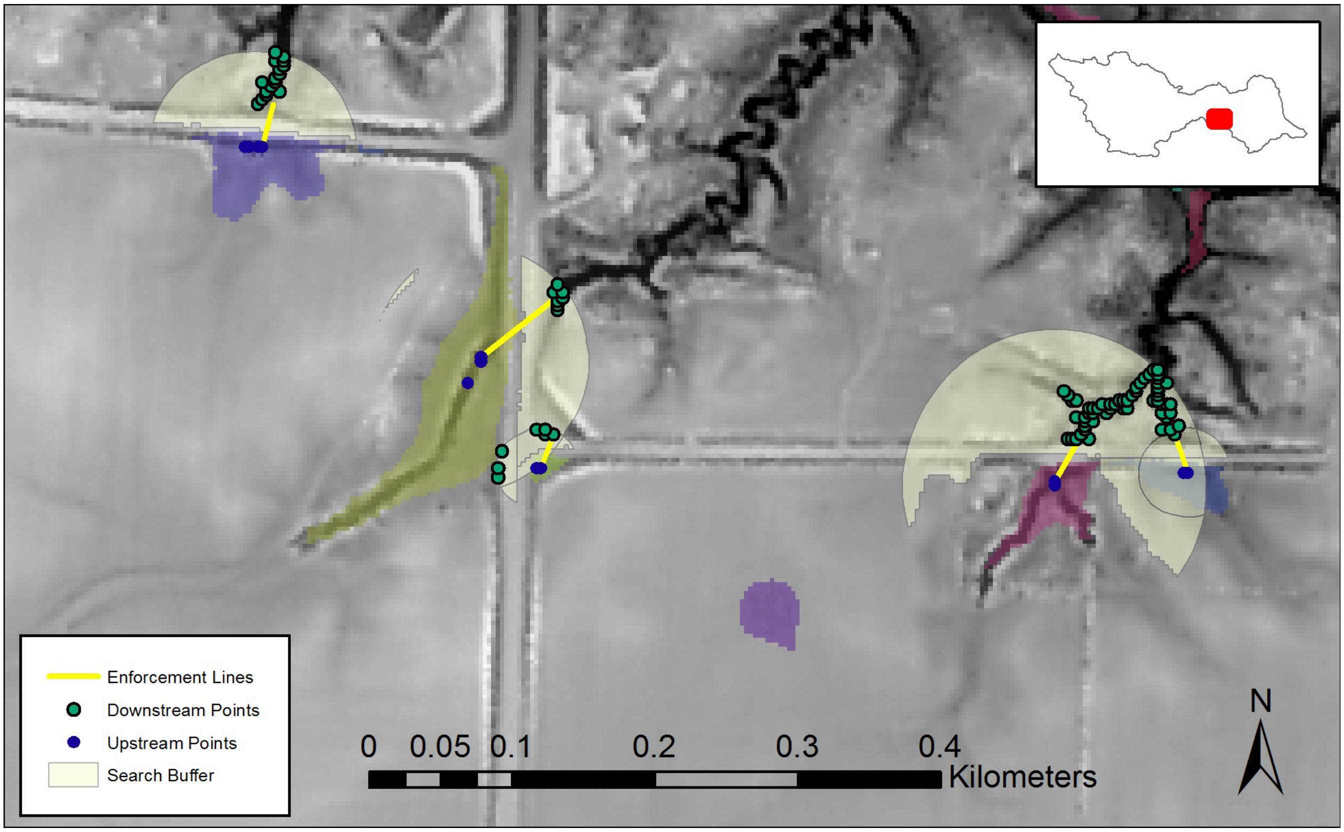
The proposed enforcement method can provide relatively accurately enforced DEMs with relatively little effort. The method does a very good job of enforcing flow where flow direction is well defined, i.e., where channelization has already occurred. It also does a good job of preserving natural and anthropogenic depressions.

Implementation Readiness

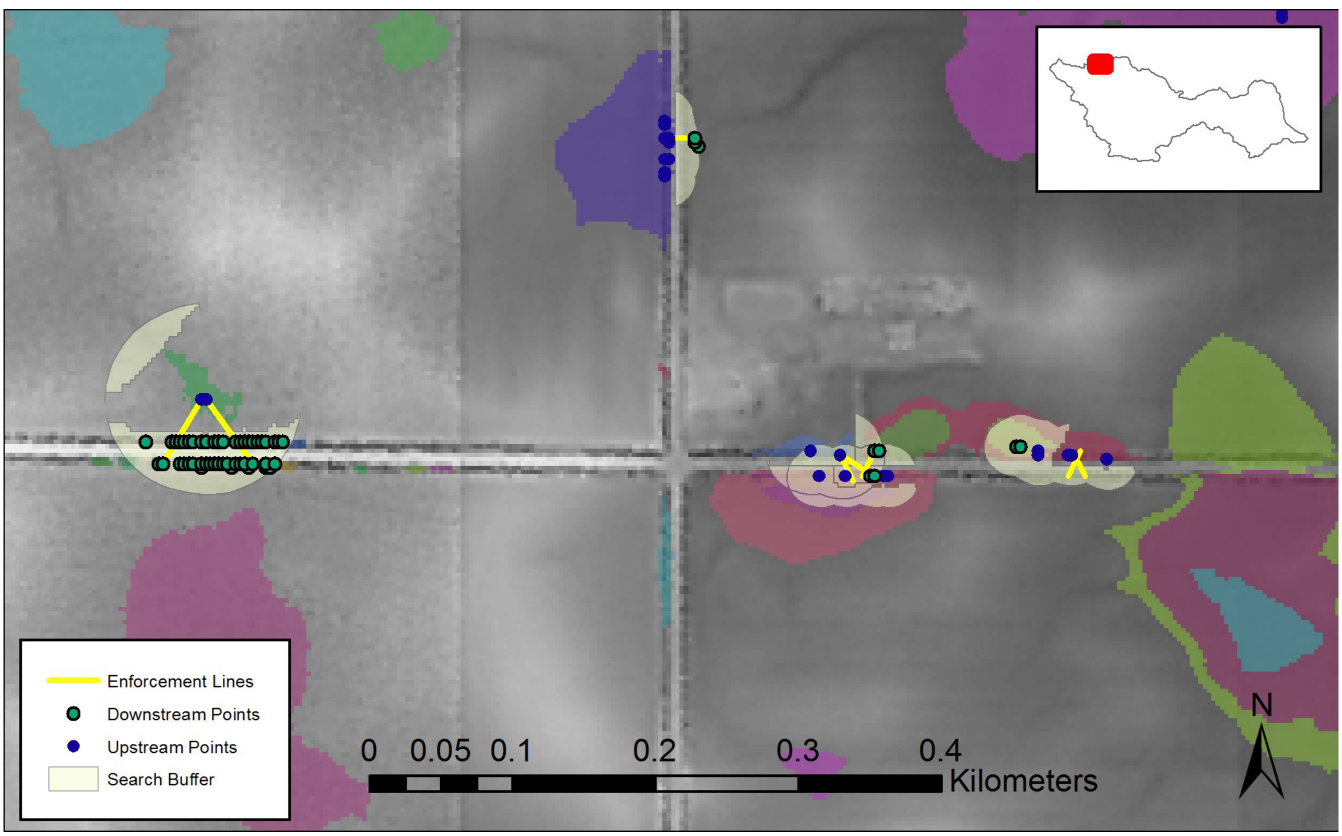
- A different interpolation method, currently used on shallow, thin depressions in areas of channelized flow, may be used in areas with no LiDAR returns to help remove as many false depressions as possible from the start. These areas then need to be enforced with a DEM inversion process to help enforce downstream flow on rivers and major streams.
- An additional step needs to be developed that classifies all non-flowing depressions as terminal depressions, e.g., prairie potholes, lagoons, and borrow pits.
- To reduce the multiple unnecessary enforcements, a new metric should be developed that can detect areas where enforcements are appropriate, such as when flow significantly leaves the channel and when it does not move downstream to the lowest points.



One kilometer buffer of Walnut Creek of South Skunk River watershed



Enforcement lines connecting upstream and downstream points



Multiple bad enforcements and one good one (northernmost)