2014 IGS Research Grant Final Report: Empirical Testing of Perceptually Shaded Slope Maps

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Introduction
Perceptually Shaded Slope Maps (PSSMs, Figure 1) are a novel approach to rendering lidar-derived Digital Surface Models (DSMs) of human-influenced terrain. The portion of the project supported by the 2014 IGS grant included rigorous empirical testing of the visualization (described below). A full description of the PSSM visualization, as well as the results of an exploratory analysis of data collected prior to the IGS award has been accepted for publication in *Cartographica* (Pingel and Clarke, in press). A second paper is in preparation describing the application of the lidar filter SMRF (Simple Morphological Filter; Pingel, Clarke, and McBride, 2013) coupled with the PSSM visualization to the ancient Maya settlement of El Pilar in Belize and Guatemela (Ford, Clarke, and Pingel, in preparation).

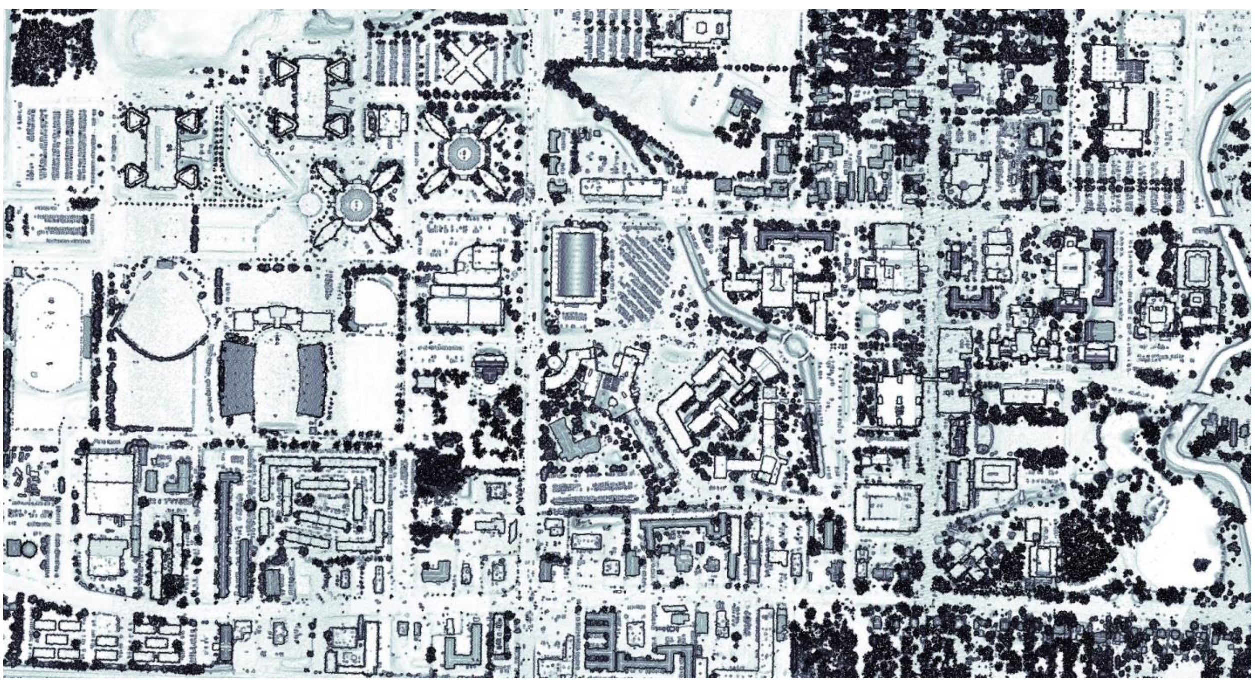

Figure 1. Perceptually Shaded Slope Map (PSSM) of the area near Northern Illinois University.

Methods

Participants in the study completed a randomly ordered series of four computer-administered tests. Two of these involved map-based tasks (profile estimation and map rotation), while two others involved tests of non-geographic spatial ability (card rotation and perspective taking). Following the administration of these four tasks, participants completed a short questionnaire consisting of (1) the Santa Barbara Sense of Direction Scale questionnaire (Hegarty et al., 2002), (2) two demographic questions (age, sex), and (3) two questions in which they expressed (on a 5-point scale) their familiarity with geography in general and topographic maps in particular.

We were primarily interested in testing the effectiveness of the PSSM against the standard hillshade visualization as measured by response time and accuracy rate in representative map reading tasks. The alignment of maps (i.e., mental rotation) with the environment is a common problem for many types of maps (Artez and Wickens, 1992; Levine, Marchon, and Hanley, 1982) and profile estimation is a commonly used task to test user understanding of topographic maps specifically (Potash, Farrell, and Jeffrey, 1978). Map rotation assesses map *saliency* while profile estimation tests map *intelligibility* more broadly.

Participants

One hundred six individuals participated in the experiment; all were drawn from introductory geography or geology courses and participated in exchange for extra credit. Forty-six of these were male, and the mean age was 20.5 (range: 18-58). Written informed consent was obtained according to the provisions set by the Northern Illinois University Institutional Review Board.

Profile Estimation Task

The profile estimation task required the participant to correctly identify the profile (from three alternatives) that matched a transect drawn across an image, appearing as either a PSSM or in shaded relief (Figure 2). All of the images were drawn from a one-meter resolution DSM of DeKalb, Illinois created from 2009 lidar data. Participants were shown 251 pixel diameter extracts from this image at a size of approximately 10 cm. The transects (shown in red, green, and blue) were drawn on the screen at a size of approximately 40 cm wide by 10 cm high. This larger size of the profiles enabled viewers to detect more subtle changes in the surface that would have been otherwise difficult to see.

The presentation was the same as previous studies (Pingel and Clarke, in press) with two exceptions. First, rather than a presentation of many types of visualization, our participants only saw images in either PSSM or shaded relief. Second, participants saw the same set of stimuli in both PSSM and shaded relief, allowing for more control compared with previous, more exploratory studies. In all, participants made 40 profile estimation judgments, 20 in each presentation type (PSSM or hillshade). The order of presentation of the images was randomly assigned to control for order effects. Participants made their profile selection via touch screen, and response time and accuracy was recorded. Median response time and mean accuracy rate were recorded for each participant.

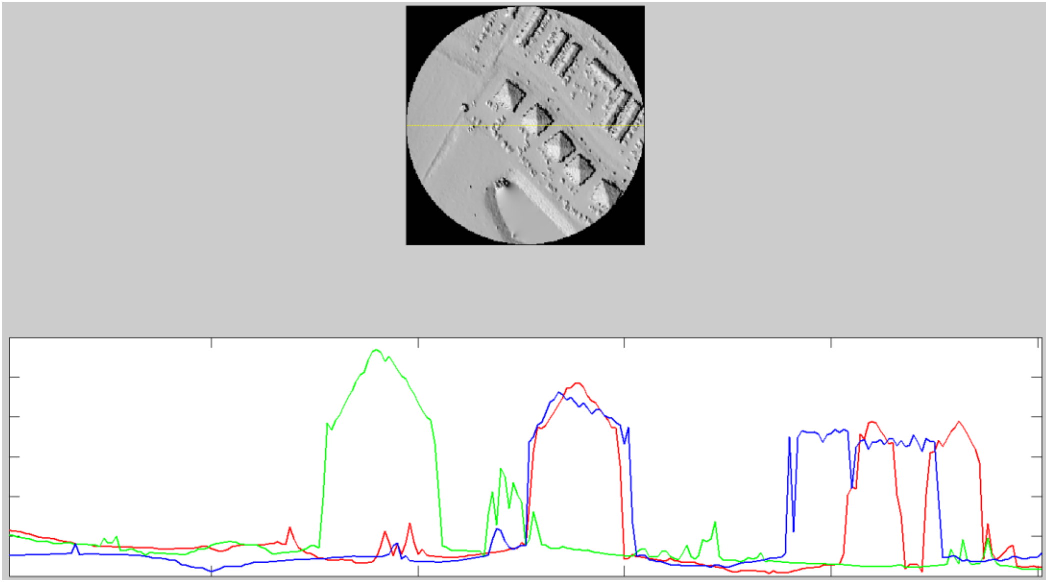

Figure 2. The profile estimation task, in which participants were asked to match the correct profile (below) to the transect drawn on the image shown at the top.

Map Rotation Task

Participants in this task were shown two images and asked to judge whether the pair of rotated imaged had also been reversed (Figure 3). The images were drawn in an identical fashion as the previous study (i.e., from a one meter resolution, lidar-derived DSM of the DeKalb, Illinois area). Participants responded “same” or “mirrored” via a touchscreen for a total of 36 images. Half of these were PSSM derived images, and half were traditional shaded relief images of the same locations with the same degree of rotation. The order of presentation of the images was randomly assigned to control for order effects. Median response time and mean accuracy rate were recorded for each participant.

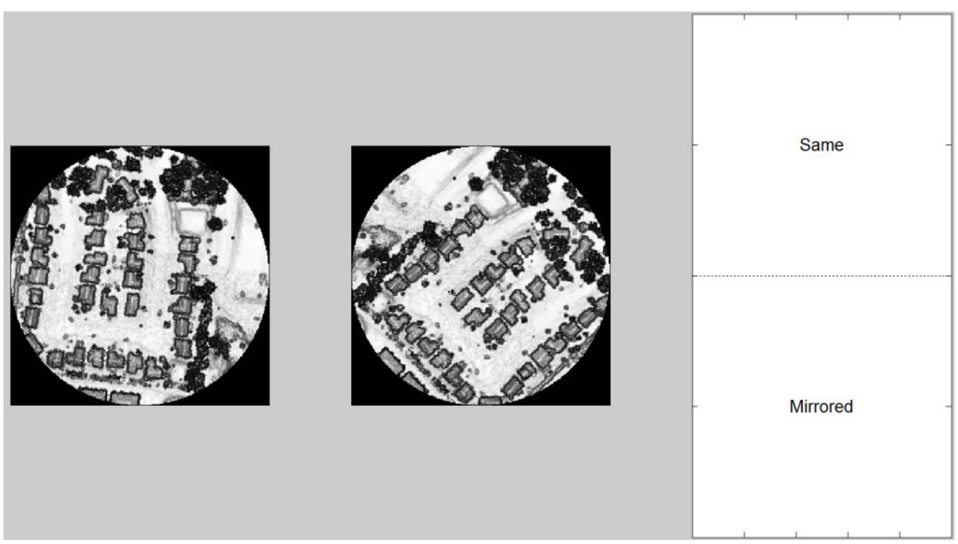

Figure 3. Screen shown to participants as part of the map rotation tasks. Participants were asked to judge whether a pair of rotated images had also been reversed (mirrored).

Preliminary Results
In both the map rotation and profile estimation tasks, the PSSM showed marked improvement over the shaded relief images (Figure 4).

For the map rotation task, the PSSM had a higher mean accuracy rate (80.2%) than the hillshaded image (76.4%), a significant difference according to paired t-test (104) = 3.05, p = 0.003, Cohen's *d* = 0.25. Mean response time was also lower for the PSSM (M = 6.1s) than for the hillshaded image (6.3s), though this difference was not statistically significant, t(104) = 1.29, p=0.20.

For the profile estimation task, the PSSM had a higher mean accuracy rate (M = 75.9%) than the hillshaded image (M = 71.3%), as well as a lower mean response time (PSSM = 14.6s, hillshade = 15.9s), both t(105) > 2.94, p < 0.004, *d* = 0.25).

Taken together, these results provide very strong evidence in favor of the efficacy of the PSSM for the visualization of high resolution DSMs of human-modified terrain.

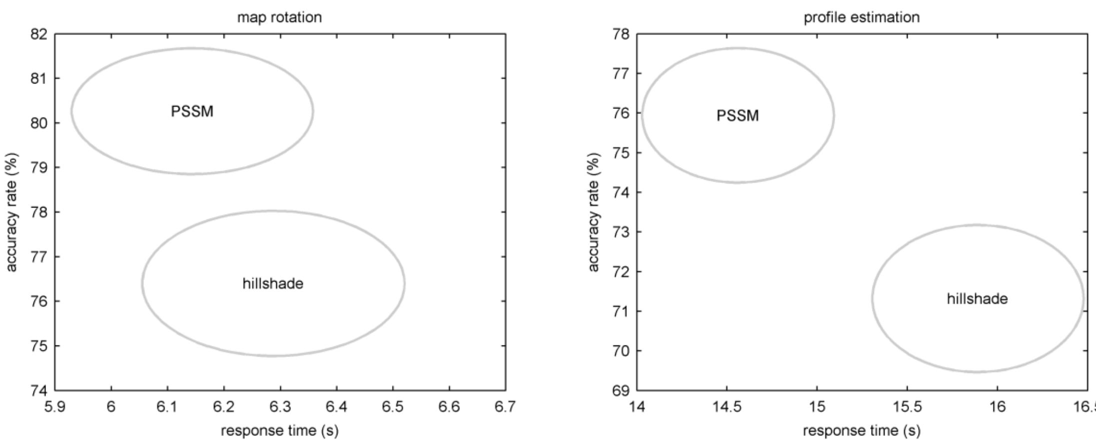

Figure 4. Standard error ellipses for accuracy rate and response time for both tasks. Differences in accuracy rates were statistically significant for both tasks, while difference in response time was statistically significant for profile estimation only.

Conclusions and Future Work
We report here the results of the PSSM-specific testing, which clearly demonstrated the viability of the PSSM visualization. Both mean response time and accuracy rates were superior for PSSMs than for shaded relief images in our rests. Future work will focus on assessing the impact of sex, experience, and environmental spatial ability on PSSM uptake. We are currently preparing a manuscript based on this work for publication in Cartography and Geographic Information Science.

Works Cited

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