Central Hardwood Abstract

Title: Comparative efficacy of multimodal handheld hyperspectral/ultrasonic

/LiDAR recreation trail assessment versus analog methods.

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Extended Abstract:

Outdoor recreation causes diverse impacts (positive and/or negative changes) to associated forest ecosystems (Bhuju and Osawa 1998, Yoda and Watanabe 2000). For example, hiking, equestrian trail riding, mountain biking, and all-terrain vehicle trail riding each have associated rates of trail erosion (e.g., Ziegler et al. 2000, ). Recreation ecology seeks to quantify these impacts in order to assist land management agencies and resource managers tasked with balancing fundamentally competing goals. The first goal involves protecting physical resources’ integrity and function according to policy mandates and sound principles of ecology. The second goal involves maximizing high quality recreation opportunities inseparable from those physical resources. Forest recreation trails exemplify one solution for balancing these goals: localizing negative impacts to a small and controlled spatial proportion while improving recreation access beyond developed areas and transportation networks. However, trail systems are nontrivial to measure for impacts. GIS modeling has been used to predict trail erosion, however, regulatory monitoring requirements mandate assessment, not modeling (Bridgland et al. 2002, Ferris 1995). Satellite-based remote sensing is prevented by atmospheric physics from measuring trail micro-topography and aerial LiDAR remains too expensive for widespread use. Consequently, trails are commonly assessed on foot (Marion 1994, Godwin 2000, Burde and Renfro 1986, Fish et al. 1981).

Current methods for assessing actual extent and severity of trail and proximal resource degradation require labor-intensive onsite expert assessment. The methods are analog—*e.g.*, tape measure (though gathered data may be recorded digitally, e.g., by handheld GPS) using 1) spatially sparse discontinuous point sampling relying on spatial autocorrelation of microtopography or 2) continuous segment assignment to region-specific (*i.e.*, difficult to generalize) condition classes sometimes built upon non-mutually-exclusive classes (Leung et al. 1997). With the advent of open source microcontrollers, task-specific electronics and robotics can be developed inexpensively and efficiently to improve upon previous film-based methods (Warner and Kvaerner 1998).

This study evaluated *de novo* multimodalcontinuous digital electronic measurement of multiple simultaneous trail data streams paired with sub-meter GPS positioning then compared the accuracy and efficiency (as mean time/meter of trail assessed) against point sampling & problem assessment equivalent methods applied to the same segments of trail. Trail surface data were collected from a stratified sample of the Shawnee National Forest in southern Illinois. Each 100m trail segment was digitally scanned while moving using near-infrared LiDAR, ultrasonic rangefinding, 1080p video at 30 frames per second. Confounding motion at the sensor head was corrected using accelerometer-guided active leveling and post-hoc signal processing. The trail surface was continuously assessed, and point sampled for erosion, muddiness, and rugosity (lateral/transverse). Multivariate regression modeling indicates that temporal sampling resolution and high frequency motion correction drive digital assessment accuracy. In addition, parallel sensing modalities were found to extend each other’s practical detection limits and provide needed error-correction.

This study begins to explore a capability to reduce large-scale trail network management cost and field staffing through uptake of digital surveying and assessment techniques. Current limitations include channelized erosion rills with depth higher than the sensor’s vertical offset above the trail centerline as well as accuracy degradation under rapidly dynamic lighting conditions (e.g., full sun through partial canopy. Next steps for research include shifting data stream processing from server-based to *in situ,* as well as mounting the sensor system onto ground-based autonomous navigation platforms to reduce onsite staff cost. Benefits to management may include a more standardized procedure and detailed metadata on data quality.