RELIABILITY OF DISCONTINUITY DATA COLLECTION BY AN UNMANNED AERIAL VEHICLE (UAV)

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Abstract

Current methods of discontinuity data collection for slope stability analysis include Brunton compass and ground-based LiDAR. This study compares discontinuity data acquisition via an unmanned aerial vehicle (UAV) to these established methods in order to determine if UAV technology can be used reliably to collect structural data. Ground-based LiDAR is limited by "shadow zones" where gaps in data are produced by a small scan angle, slope features blocking the outcrop, and position of the surveying equipment relative to the slope face. Unmanned aerial vehicles have the benefit of easily accessing portions of an outcrop that may be otherwise physically impossible to access. Two field sites in Virginia were scanned for this study, a shale pit and a cut slope in Deerfield along highway 629. The Deerfield slope consists of shale, fine-grained metasediments, and minor sandstone of the Brallier Formation (Devonian) folded around the axes of paired anticline-syncline. Roughly 300 Brunton measurements of discontinuities were taken at each site. In addition, ground-based LiDAR scans and UAV photogrammetric data were collected at each location. Once data collection was completed, scans from the LiDAR unit and the UAV were converted into point clouds for use in stability analysis. Cyclone was used for LiDAR data and VisualSFM/Pix4DMapper Pro was used for UAV data. These point clouds were then imported into Split FX for analysis of discontinuity patches and to export data to DIPS for determining principal joint sets and kinematic analysis. Results indicate that UAV is a reliable means of collecting discontinuity data.

Background

The method of remote sensing used in this study is photogrammetry. Photogrammetry works on the basis that 3D point locations can be determined by making measurements of features through analysis of overlapping photographs. Current software algorithms such as VisualSFM and Pix4Dmapper Pro can automatically process collections of overlapping photographs to rapidly extract the 3D coordinates of millions of surface points to create a cloud model. Structure from motion (SFM) is a photogrammetric technique in which camera positions and orientation are solved automatically, in comparison to traditional photogrammetry, which requires previous knowledge of these parameters. The limitations of ground based surveys can potentially be avoided by using an unmanned aerial vehicle (UAV) in place of physical measurements or ground based survey equipment. Unmanned aerial vehicles have the benefit of easily accessing portions of an outcrop that may be otherwise physically impossible. UAVs are now a widely available technology, can have programmed flight patterns, and can be outfitted with a camera to record photogrammetric data. Once the 3D cloud model created from UAV data is completed and colorized, it can be used to identify discontinuities present in the rock face of interest. Detection of discontinuities such as joints, bedding, and faults can be done manually or through programmed algorithms. These discontinuities can then be used to evaluate possible modes of failure for that region of the slope. In order to use UAV-based photogrammetry for collecting discontinuity data needed for evaluating stability of slopes, there is a need to compare the UAV derived data with the ground based LiDAR data and manual measurements of discontinuities using Brunton compass. This research project was designed to fulfill this need.

Acknowledgments

Dr. Shakoor, Dr. Skip Watts, Matthew Reihl, Brian Bruckno, George Stephenson, Robert Huber, Tyson Le Roy, VDOT.

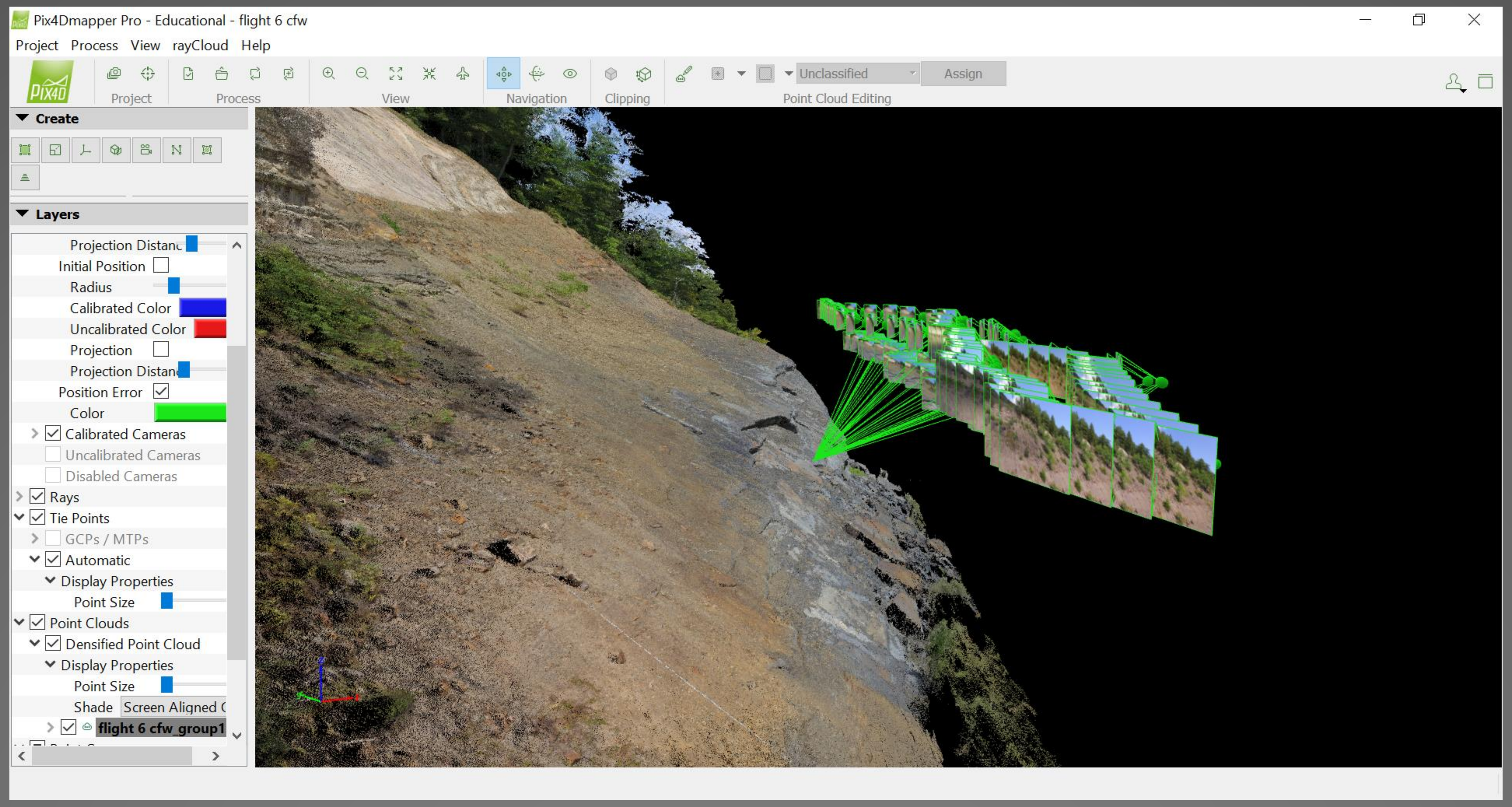

Fig. 1: Screen capture of Pix4DMapper Pro software. Flight path of the UAV is displayed through floating images, and green lines are visually representing the tie points that were determined from the images shown.

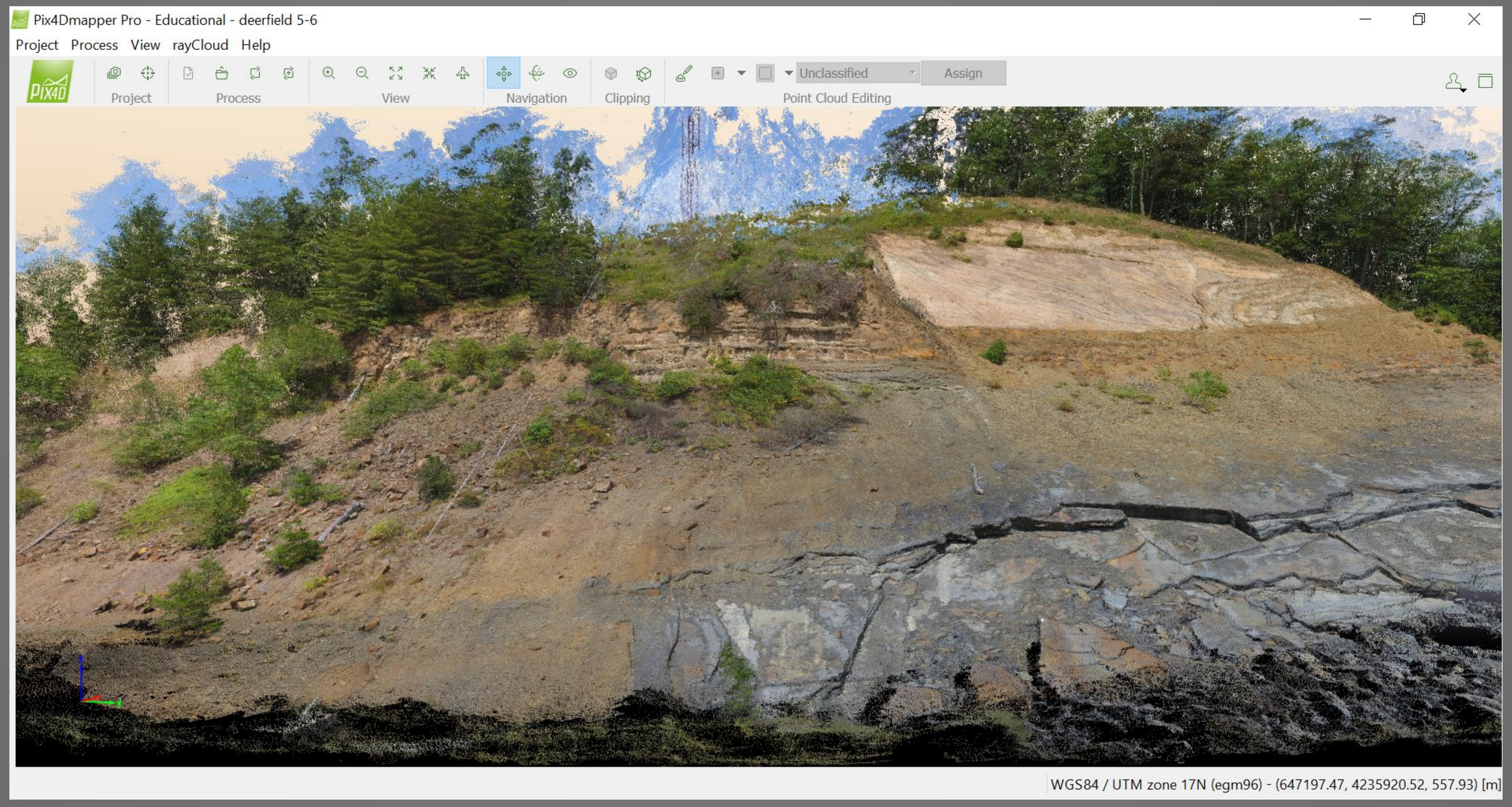

Fig. 2: Completed 3D point cloud of the Deerfield site, front view. Sky and vegetation have not yet been discarded as false data.

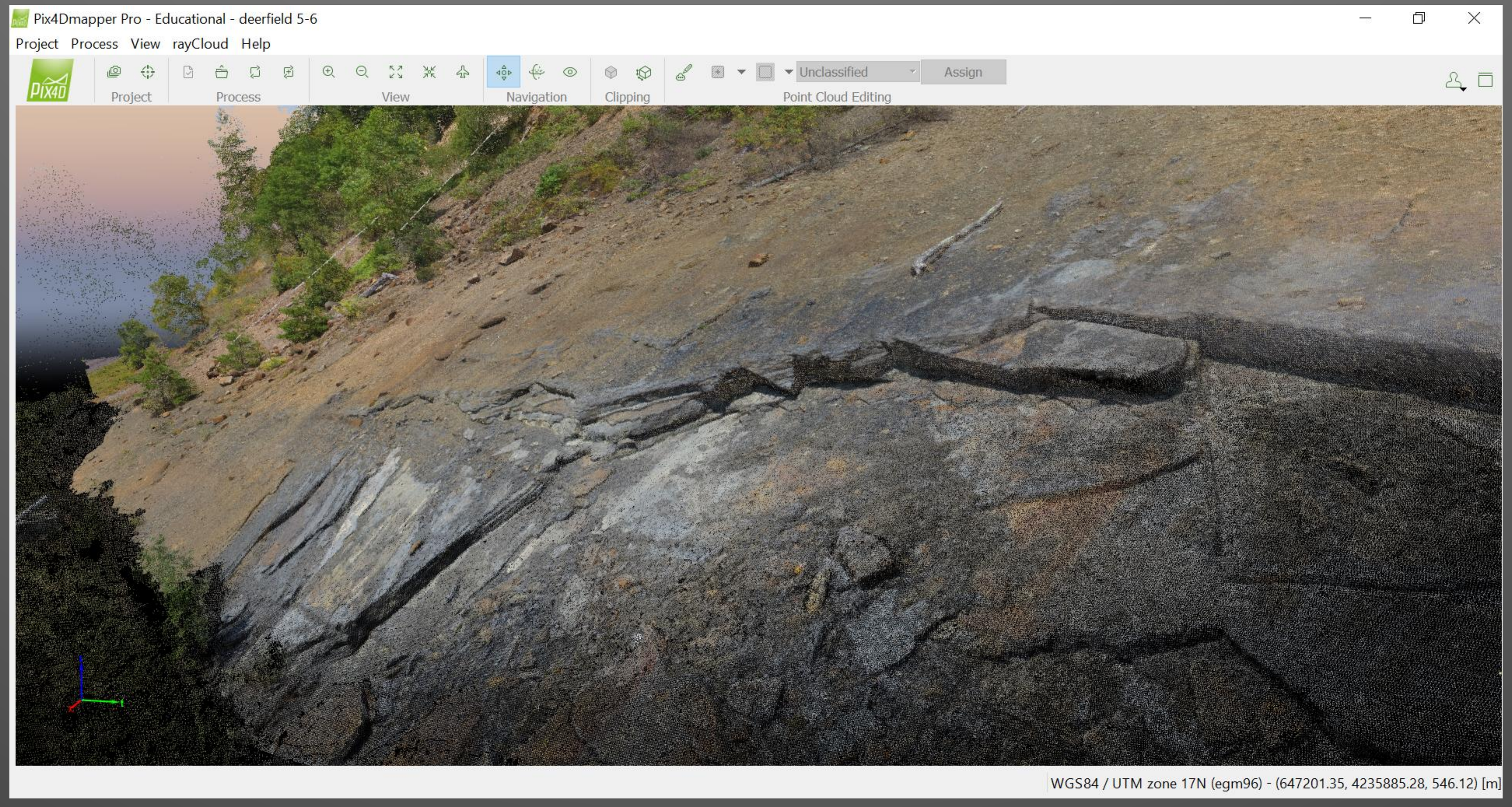

Fig. 3: Completed 3D point cloud of the Deerfield site, side view displaying prominent joint sets. Vegetation has not yet been discarded as false data.

Site Selection

The second site is a cut slope in Deerfield along highway 629, in Augusta County, and experienced a rockfall in 2009. This event involved 10,000 cubic yards of rock material, which forced road closure for a period of three months . Deerfield lies entirely within the Valley and Range physiographic province on an anticline with the bedrock consisting of generally siltstones and shales of Devonian age, specifically the Brallier Formation. This formation is approximately 2400 feet in thickness, and is comprised of micaceous sub-fissile shales, siltstones, and sandstones, with dimpled bedding surfaces. Bedding is several feet thick in the upper section, and gradually become thinner downward . The slope is formed by shale, fine-grained metasediments and minor sandstone of the Brallier Formation (Devonian), folded around the axes of a paired anticline-syncline. The intense folding of these strata has resulted in jointing of the rock that promotes release of blocks downslope. This rock slope has LiDAR data available from previous investigations by VDOT, but does not have manual compass measurements. VDOT has shared information about this site, and is willing to provide access to the site.

Unmanned Aerial Vehicle

The model of UAV used in this study is the DJI Phantom 3 Professional.

This UAV model includes a 12 Megapixel Photo Camera on a 3-axis stabilization gimbal, and was flown by a professional pilot along with a certified spotter in order to maintain required 50' clearance from all power lines and cables. (Image courtesy of dji.com)

Data Analysis

Data analysis will consist of generating point clouds from UAV imagery and creating patches, or images illustrating the definition of a surface, for determining orientation of discontinuities and comparing the results with those obtained from LiDAR and manually obtained data . The UAV imagery will be processed using Pix4DMapper software, and VisualSFM software, which is a freely available program. This program ties digital photos together using reference points common to overlapping areas. Photo-textured meshes can be created from point cloud data using Meshlab. The digital images are compared to each other and correlated features are automatically detected. Then, these matching points between images are used to calculate the spatial relationship between them, which indirectly derives the positions of the camera during data collection. The eventual result of this calculation is a color 3D model of matching points and their camera positions, and is known as the point cloud. Split FX software will be used to extract discontinuity data from LiDAR. Split FX software will automatically determine dip, dip direction, and patch surface data for each scan.