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Augmenting Geological Field Mapping and Interpretation with Real-Time 3D Digital Outcrop Modeling

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Summary

Geological field mapping has traditionally been conducted by highly trained geologists using a series of tools that aid in making field observations and measurements such as a hand lens, compass, pace counter, rock hammer and notebook. With the advancement of information technology, pacing as a means to navigate has given way to Global Positioning Systems, sketching as a means to record important visual outcrop information has given way to photographs/video, and notebooks have given way to field tablets for immediate digitizing of measurements and notes. These technologies do not necessarily add new types of critical information but instead aid geologists by streamlining and optimizing the process by which they can record critical and specialized observations while in the field. Increased retention of information can be further achieved by integrating these existing advancements with automated, real-time 3D digital outcrop modeling technology.

Methodology

A limitation with the conventional method of outcrop mapping is that the information gathered is subject to the decisions, filters, biases and lenses of the geologist making the observations. Often, this recorded data is a much smaller subset of the total information observed. While in the field, making observations for the first time, it is often challenging to identify which observations will be critical for decisions and interpretations in the future. If a critical piece of information is omitted and an outcrop needs to be revisited to confirm or build from an existing observation, this can come at a great cost (time, effort, financial, lost productivity elsewhere). This limitation still occurs with the help of streamlining technologies as the geologist decides what information should be recorded. One way to increase the retention rate of raw unfiltered outcrop information and decrease the likelihood that a critical piece of information is omitted, is to deploy an augmentation technology alongside the geologist that can compute real-time 3D digital outcrop models (Xu et al., 2000). The goal with this augmentation technology is that the 3D spatial information and measurements are stored at a retention rate orders of magnitude higher than before. This technology allows for an accurate and georeferenced digital outcrop model to be captured in real-time and at minimal additional cost to a field campaign. 3D digital outcrop modeling can be computationally demanding requiring advanced post-processing to acquire meaningful results. Examples of terrestrial laser scanning for geological mapping can be found in Buckley et al., 2008 and Mills and Fotopoulos, 2013.

Recently, technological advancements in both hardware and software have given rise to real-time, handheld, 3D modeling technologies. These technologies are also compatible with field tablets, allowing them to be compact, lightweight and mobile. Typically, the range of capture for these handheld devices varies between 0.5 m and 2 m; a practical distance compatible with the collection of field observations and measurements on an outcrop scale. Additionally, these devices can capture spatial information from multiple focal points during a scan, allowing for the continuous movement of the sensors without compromising the digital model. This is typically not the case for terrestrial laser scanners which require precise leveling and low movement tolerances (Silvia and Olsen 2012). These real-time, handheld devices, such as the PrimeSense, Carmine 1.08 and 1.09 and Intel, RealSense make use of infrared sensor triangulation, CMOS (complementary metal-oxide semiconductor) depth sensors, LiDAR (light detection and ranging) and high-resolution RGB cameras to create 3D, colored point clouds. The spatial x/y resolution (2σ values) of these scanners are 0.9 mm and 3.4 mm at a scanning distance of 0.5 m and 2 m, respectively. The depth resolution (2σ values) of these scanners are 0.1 cm and 1.2 cm at a scanning distance of 0.5 m and 2 m, respectively (see PrimeSense, 2019 for more details). Software applications such as Dot3D by DotProduct, allow for the real-time computation on field tablets given these specialized spatial inputs. Overall, this technology shows potential for real-time, 3D, digital outcrop modeling applied to geological applications and field mapping. The aim of this study is to demonstrate the applicability of collecting real-time 3D digital outcrop models at a 1 – 10 m^2 scale and at a 1 cm point resolution, as well as identify specific geological applications that would benefit from both real-time models and three-dimensional data (as opposed to typical photographs). The interactive software coupled with the real-time capture of the 3D digital outcrop models, allows the geologist to make in-situ annotations, interpretations and measurements in the modelling space on-site. Higher resolution terrestrial laser scanning (Telling et al., 2017), photogrammetric models (Ouédraogo et al., 2014), and close-range hyperspectral imagery (Kurz et al., 2013) are generated and interpreted after returning from the field.

Observations and Results

A DotProduct DPI-10 handheld 3-D scanner (Figure 1) was deployed to capture three simulated geological outcrops for preliminary testing. The first was a 360° scan of a 1.1 m x 1.2 m x 1.5 m boulder and the second was a 1.1 m x 0.8 m x 0.2 m slab of sandstone with 4.3 cm wave ripples. The third was a scan of a 6.5 m x 2.5 m simulated vertical outcrop face and adjacent staircase. Each scan took approximately 5 minutes to complete, a length of time that would typically be spent taking measurements while at a hypothetical outcrop in the field. These scans resulted in a 3D point cloud, as shown in Figure 2. Processing of the gathered data and point clouds with the Dot3D software was conducted on-site and took less then 10 seconds, resulting in the 3D digital outcrop models presented in Figures 3, 4 and 5. The 3D digital outcrop models are interactive within the software allowing for the addition of measurements, fractures, planes and geological findings directly into the 3D model while on site and still observing the natural outcrop. This is demonstrated in Figure 4, where planes and dimensions of the sandstone slab have been fitted and in Figure 5, where the dimensions of the simulated vertical outcrop face are calculated. This annotation process within the modeling space occurs in real-time and while still physically observing the natural outcrop adding in the accuracy of the information gathering and annotation process.

Figure 1: (Left) Back and (Right) Front of the DotProduct DPI-10 handheld 3D scanner.

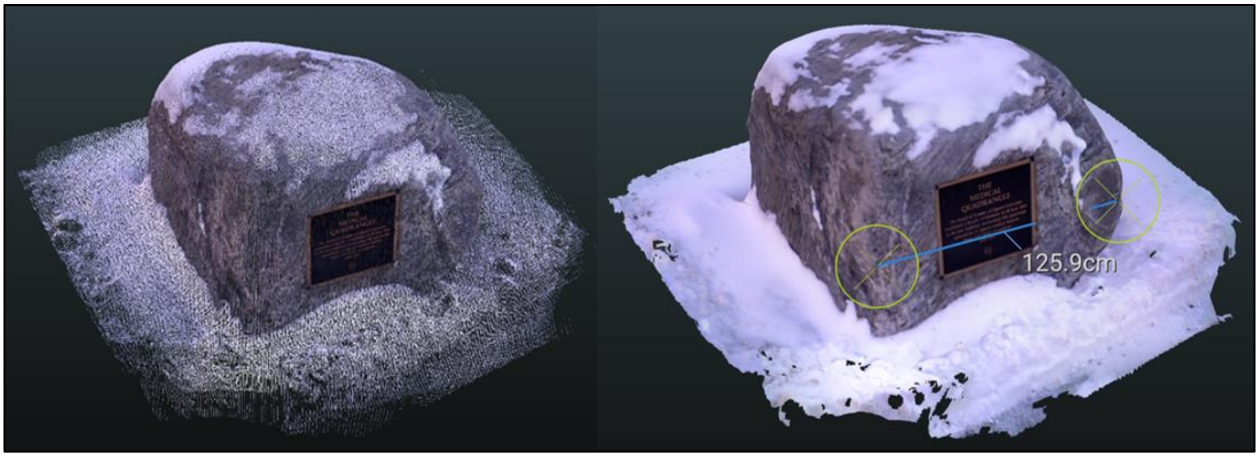

Figure 2: (Left) 3D point cloud positions used to create the 3D digital outcrop model of the 1.1 m x 1.2 m x 1.5 m boulder (right).

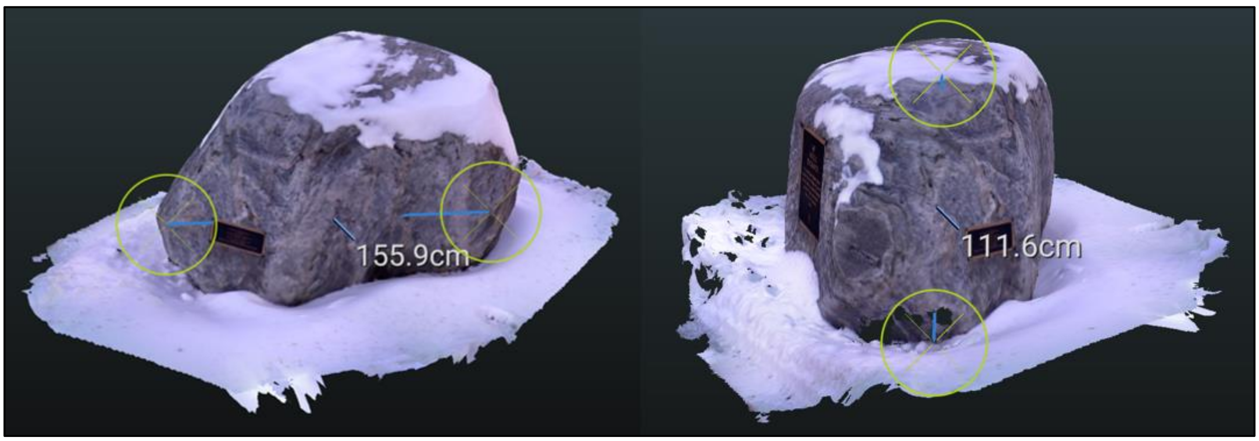

Figure 3: 3D digital outcrop model of a 1.1 m x 1.2 m x 1.5 m boulder.

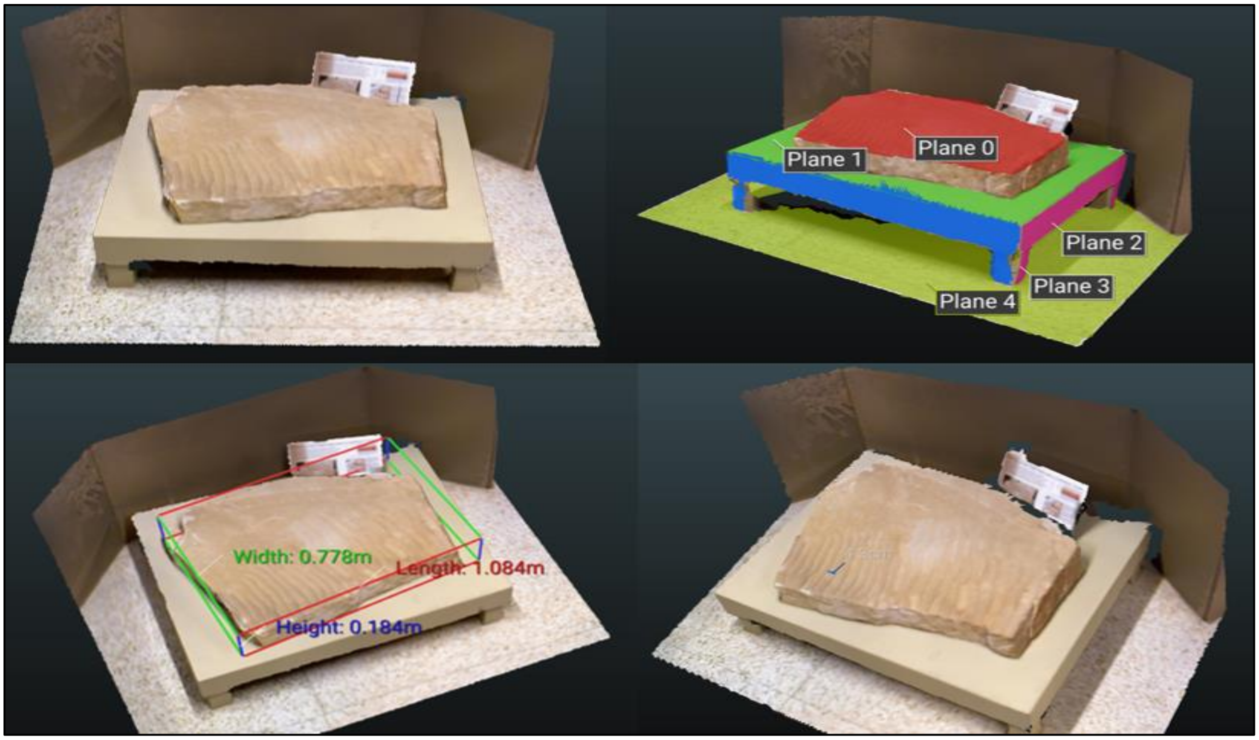

Figure 4: 3D digital outcrop model of a 1.1 m x 0.8 m x 0.2 m slab of sandstone.

Figure 5: 3D digital outcrop model of a vertical stone wall and staircase.

Conclusions and Future Work

Two 3D digital outcrop models were generated in real-time and on-site using the DotProduct DPI-10 handheld scanner and DotProduct Dot3D software with minimal time commitment and computational resources. This technology and workflow will be further tested and developed on a variety of natural rock outcrop sizes and shapes to determine practical conditions and limitations of the technology for real-time 3D digital outcrop modeling. In addition, the accuracy and precision will be assessed to determine the optimal surveying and mapping parameters for geological field work. The primary focus of future work will be on incorporating this technology into the already established workflow of making, recording and organizing geological field observations and measurements (Enge et al., 2007). Furthermore, this type of technology can be used to scan and model outcrops that can be compiled into a virtual field trip and used as an augmented learning tool.

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