Navigating and Annotating 3D Geological Outcrops Through Multi-touch Interaction

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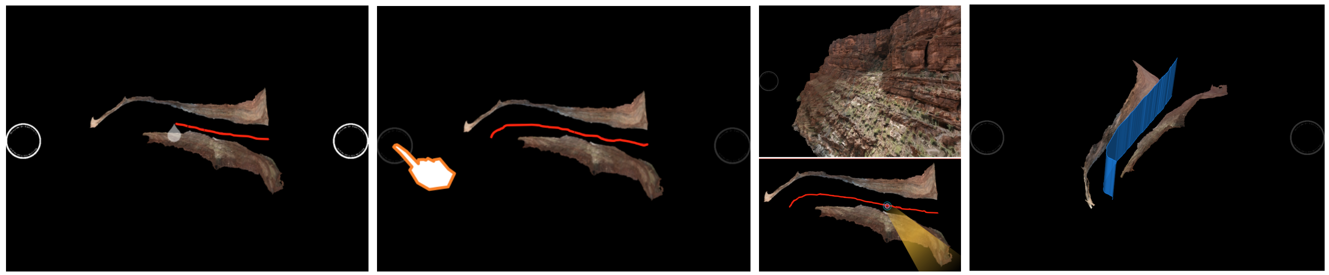
Abstract
The study of geological outcrops has seen recent improvements due to LiDAR technology, which allows for the creation of complex, high-resolution computational representations of geological terrains. It calls for suitable visualization strategies, that provide flexibility as well as timely intuitiveness. In this work we present our initial efforts to visually explore and annotate geological outcrops through multitouch, including a 3D navigation technique and horizon surface creation and edition.

Author Keywords
Geology; Interactive 3D Navigation; Outcrops; Multi-touch; LiDAR

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

Introduction
Geological outcrops are points of emergence of geological layers from the subsurface, and are fundamental elements of study of geological surveys. The study of outcrops is complex and requires solid spatial awareness skills, which can be facilitated by computer 3D visualization and interaction tools. LiDAR readings, on the other hand, are able to produce high-resolution computational models of



(a) (b) (c) (d)

Figure 1: The creation of a navigation surface. In (a) the user sketches a path from top view, (b) confirms the selection, and (c) enters navigation mode (bottom shows camera location and point-of-view). In (d) the navigation surface is displayed from an oblique angle.

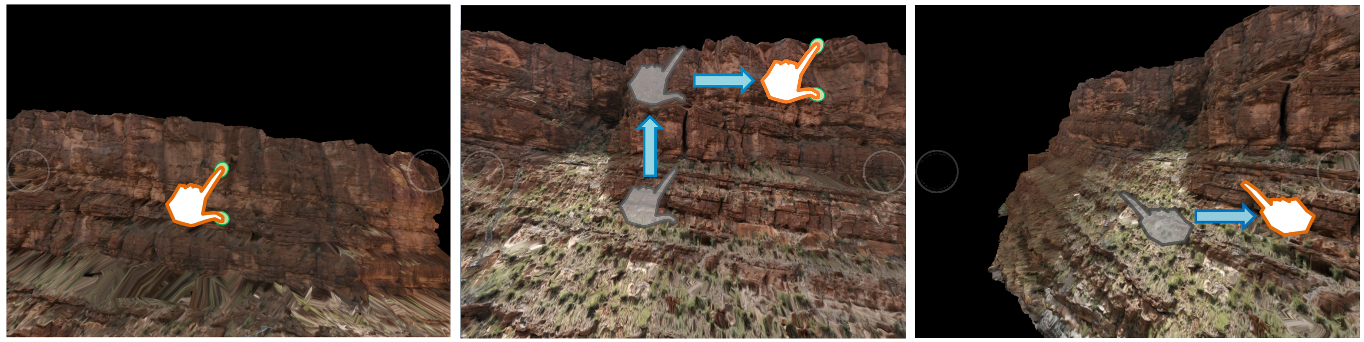
such structures, giving geologists the chance to analyze and visualize these formations with unprecedented precision and interactivity [5]. In parallel, we witness the emergence of multi-touch displays as platforms for geospatial tasks and visualization (*e.g.* [3, 7]). While 2D visualization and interaction (*e.g.* through maps) offer a direct mapping to 2D touch input, interacting with 3D visualizations presents many challenges [6]. In particular, we focus here on the problem of interactive 3D navigation, which has received some attention over the years for desktop environments (*e.g.* [4]), but has much to be explored for multi-touch interaction (*e.g.* [9]).

In this paper we present our ongoing efforts on interactive visualization for geologists [1], seeking to offer simple, intuitive, yet fine-grained and highly controllable navigation for outcrops as well as inspection and annotation through multi-touch interaction.

Multi-touch Outcrop Navigation

The outcrop datasets are represented by a collection of surfaces, each with an associated texture, representing the rock wall (Figure 1). Geologists should be able to perform finer inspection on such walls by identifying geological layers, detecting cracks, unusual features, and so on. They should also be able to quickly switch to a more general view, and move from one wall to another. Seamlessly moving back and forth between these perspectives was thus a priority for navigating the datasets, together with appropriate camera constraints to effectively translate 2D touch input to 3D navigation.

Given these characteristics, we envisioned a first-person perspective as an intuitive way to visualize the outcrops, and designed a fly-by navigation strategy for multi-touch interaction. Navigation is constrained to a 2D surface, similar to Hanson *et al.* [4]; the main distinction from this work is that we constrain only the camera position, giving the user freedom to control other camera parameters through multi-touch interaction. Another difference is



(a) (b) (c)

Figure 2: Multi-touch navigation on the user-defined surface. 2+-touch panning makes the camera translate on the surface, as shown in (a) and (b); 1-touch translation changes the view vector direction, as shown in (c).

that the navigation surface is defined by the user herself, sketched top-view and extruded down to the bottom as a parametric general cylinder. In our implementation, the sketch is performed through a tangible device in the shape of a pointer (Figure 1(a)); the same functionality could be achieved with a stylus, or even direct touch, depending on the precision required. When the user is satisfied with the selection, she can tap the faint circular areas on opposite ends of the screen, to switch to the navigation mode (Figure 1(b)). The camera is then placed directly on the navigation surface, as shown in Figure 1(c).

The camera position is defined as a (u, v) pair of normalized parametric coordinates in the space $[0, 1]^2$ (as illustrated in Figure 1(d)). Using a parametric surface to guide the 3D navigation allows us to seize the natural mapping between the 2D input space and the (u,v) coordinates. There are 4 basic gestures to control the navigation: pan, rotation, zoom, and tilt. These gestures are recognized by the number of fingers and kind of displacement. To change the camera location (panning gesture) on the navigation surface the user scrolls on any screen direction using 2+-fingers (Figures 2(a) and 2(b)), which changes the (u, v) camera center coordinates proportional to the input displacement (mimicking 2D panning behavior). With a 1-touch translation, the user adjusts the gaze direction (Figure 2(c)); a 2+-finger scaling gesture maps the camera zoom; and finally, a 2+-finger rotation tilts the view around the view vector, i.e., the camera up vector is rotate on the view plane.

Multi-touch Outcrop Horizon Annotation

Outcrop horizons delineate the distinct inner geological layers found in outcrops, and are often used to help reconstruct underground geology. We provide mechanisms to sketch and define horizons directly on the outcrop models, through the tangible pointer. Another tangible device – a transparency "knob" – is provided to control the transparency of the outcrops and make the inner horizons visible. Users can also control the extrusion and deletion of a horizon; edition controls are activated by placing the tangible pointer inside one of the faded circles. Hereafter, a 1-touch tap selects the underlying horizon for edition , a 2+-touch scale gesture controls the extrusion depth of the selected horizon, a 2+-touch panning gesture changes the extrusion direction, and a 1-touch tap inside the edge circles deletes the selected horizon.

Future Investigations

This work is still ongoing, with several directions to explore next. Firstly, we deployed our system on a completely horizontal tabletop platform; we believe the ideal environment would be a tilted tabletop instead, due to the natural *Up* orientation of the models [7]; another setup could employ a tabletop and a vertical display, with the earlier focused on top view perspectives [2, 3]. Secondly, we would like to enable more complex navigation [4], such as enabling closed surfaces and self-intersecting surfaces (crossroads), as well as automatic or semi-automatic generation (the latter through user-defined heuristics). Improvements on the outcrop and horizon rendering should also be incorporated, such as stylized rendering for depicting depth, texture or geological features [8], as well as smart transparency control on outcrops for better management of horizon occlusion. Finally, we must validate and refine our work through user studies with domain experts, and possibly explore other types of 3D geological datasets as well.

References

[1] Agar, S., Geiger-Boschung, S., Matthai, S., Alway, R., Tomás, S., Immenhauser, A., Shekhar, R., et al. The impact of hierarchical fracture networks on flow partitioning in carbonate reservoirs: Examples based on a jurassic carbonate ramp analog from the high atlas. In *SPE ATCE* (2010).

[2] Coffey, D., Malbraaten, N., Le, T. B., Borazjani, I., Sotiropoulos, F., Erdman, A., and Keefe, D. F. Interactive slice wim: Navigating and interrogating volume data sets using a multisurface, multitouch VR interface. *IEEE Trans. on Visualization and Computer Graphics 18*, 10 (2012), 1614–1626.

[3] Forlines, C., Esenther, A., Shen, C., Wigdor, D., and Ryall, K. Multi-user, multi-display interaction with a single-user, single-display geospatial application. In *Proc. of the 19th annual ACM symposium on User interface software and technology*, UIST '06, ACM (New York, NY, USA, 2006), 273–276.

[4] Hanson, A. J., and Wernert, E. A. Constrained 3d navigation with 2d controllers. In *Proc. of VIS'97*, IEEE Computer Society Press (Los Alamitos, CA, USA, 1997), 175–ff.

[5] Hodgetts, D. *LiDAR in the Environmental Sciences: Geological Applications*. Wiley-Blackwell, 2009, 165–179.

[6] Isenberg, P., Isenberg, T., Hesselmann, T., Lee, B., von Zadow, U., and Tang, A. Data visualization on interactive surfaces: A research agenda. *Computer Graphics and Applications, IEEE 33*, 2 (2013), 16–24.

[7] Klein, T., Guéniat, F., Pastur, L., Vernier, F., and Isenberg, T. A design study of direct-touch interaction for exploratory 3d scientific visualization. *Comp. Graph. Forum 31*, 3pt3 (June 2012), 1225–1234.

[8] Patel, D., Giertsen, C., Thurmond, J., and Gröller, M. E. Illustrative rendering of seismic data. In *Proc. of VMV'07* (Nov. 2007), 13–22.

[9] Schöning, J., Steinicke, F., Krüger, A., Hinrichs, K., and Valkov, D. Bimanual interaction with interscopic multi-touch surfaces. In *Proc. of INTERACT '09*, Springer-Verlag (Berlin, Heidelberg, 2009), 40–53.