

Guided Fault Mapping Using Topographic Metrics

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This project tests the viability of offboard path generation from topographic metrics for UAV-based mapping systems. Topographic metrics are parameters computed from digital elevation models (DEMs) and are standard indicators of both landforms and geological processes. In the field of tectonic geomorphology, surface metrics such as slope and curvature can define the extent of earthquake surface ruptures, or fault scarps. High-resolution, aerial mapping of scarps enable quantitative, geomorphic analyses of fault zones which aid in our understanding of landscape evolution and earthquake hazards. Interest in autonomous aerial robots for such geological studies is expanding as these systems enable accurate mapping, rapid data collection, and real-time analyses of their surroundings.

Here, we utilize the OpenUAV test bed to simulate drone mapping of the Bishop fault scarp located in the Volcanic Tablelands of California. The Bishop scarp is of interest to geologists due to its rocky morphology, which has produced large rock particles—some of which are precariously balanced. This project addresses the scenario of geologists returning to the Bishop field site—mapped previously at lower resolutions—and using slope metrics computed from older data to plan drone paths for high-resolution mapping. The goal is to generate a series of waypoints along the scarp's extent for a drone to map the fault along its strike. Results from this project serve as a first step towards optimized, guided terrain mapping which may be useful in a variety of geological field investigations.

Our project workflow has three stages: 1) DEM generation and Pre-processing, 2) Waypoint extraction/Path generation, and 3) Implementation in OpenUAV testbed. For Stage 1, the Bishop scarp mesh (from the CPS Challenge 2020 workspace) was converted into a 1 meter-resolution digital elevation model (DEM) using Cloud Compare. We then computed the second derivative of elevation to produce a slope map of the fault scarp and applied a gaussian blur filter to remove noise. To segment out the scarp from the surrounding topography, we applied a K-means algorithm with two classes to the blurred slope map, and converted the output mega-pixels into georeferenced, polygon vector shapefiles.

For Stage 2, we select out just the polygon representing the fault scarp and compute its centerline using a Voroni diagram. We then extract the vertices—represented as latitude/longitude coordinates—of both the polygon's exterior boundary and of the polygon's centerline. Coordinates from the polygon corresponding to the upper edge of the scarp are extracted into a list of waypoints. These will be used to map the top of the scarp in Stage 3. Similarly, coordinates of the polygon centerline are used to map the lower portion of the scarp.

For Stage 3, the waypoints extracted from the scarp polygon's upper boundary and the centerline path are used in a rospy script to command the drone's position. The script is implemented in the OpenUAV testbed using ROS, Gazebo, and RTABmap. In simulation, the drone successfully maps both the upper edge of the scarp, and its lower slope along the strike of the fault. The drone is outfitted with a depth camera in 30m range and generates a point-cloud map using RTABmap.

Our code is implemented as two standalone Jupyter notebooks and two rospy scripts—one for mapping the upper portion of the fault, and the other for mapping the lower slope of the scarp. We have verified our workflow with an alternative DEM dataset to demonstrate reproducibility.