AVALANCHE MONITORING USING PORTABLE LOW-COST INFRASOUND SYSTEMS

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The detection and triangulation of both avalanches and controlled explosions by means of infrasound technology has been demonstrated over the past two decades [e.g. Bedard et. al, 1988; Havens et. al, 2014; Ulivieri et. al, 2012; Johnson et. al, 2018] — at present, two highway avalanche forecasting programs in the United States use this technology on a daily basis. However, the commercial system utilized by these services is no longer in production, and was prohibitively expensive for most avalanche monitoring services. To fill the need for a low-cost and easily-deployed avalanche detection system, we are developing and testing such a device. The aim of this project is to develop a general-purpose, mobile infrasound detector known as a goniometer [Pook, 2015]. This device can be used to detect seismic phenomena and the discharge of ballistic weaponry. The current implementation is a portable, compact, self-contained unit that is easily installed in virtually any environment. It utilizes four sensors arranged in a two-meter tetrahedron pattern to calculate the Direction of Arrival (DOA) of infrasound events. The design focuses on the use of off-the-shelf components for optimal cost efficiency.

KEYWORDS: Infrasound, avalanche detection, sensor

1. INTRODUCTION

During the winter of 2017-2018, a device prototype was deployed in Little Cottonwood Canyon, Central Wasatch Mountains of Utah, Salt Lake County, Utah, USA. Figure 1 shows the Utah Department of Transportation data map with the device location and detected events. The goniometer is located at LC2.

This system recorded infrasound events and stored the raw data to an SD memory card for post-processing.

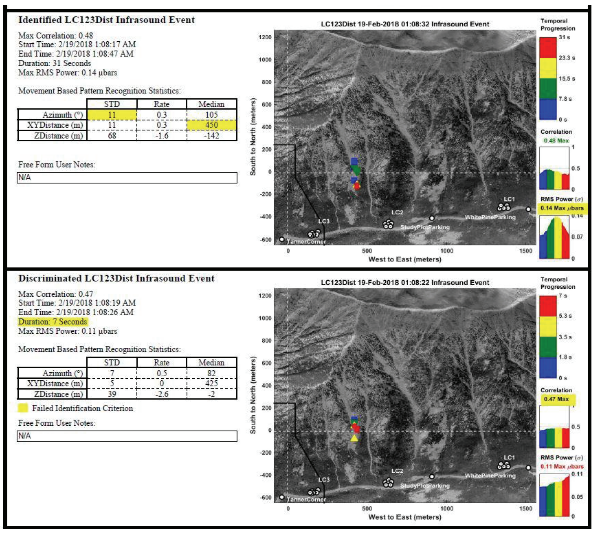

Figure 1: UDOT Infrasound Data 2/19/2018 1:08:19 AM. Prepared by Inter-mountain Labs (IML).

2. RESULTS

Figure 2 shows the raw infrasound data collected by the goniometer during the events depicted in Figure 1. Seven seconds of high-intensity infrasound waves were independently recorded by the four microphone sensors. Early analysis of the recorded data shows these systems capable of detecting both artificial and natural avalanches, as well as detecting artillery detonations used to trigger controlled events.

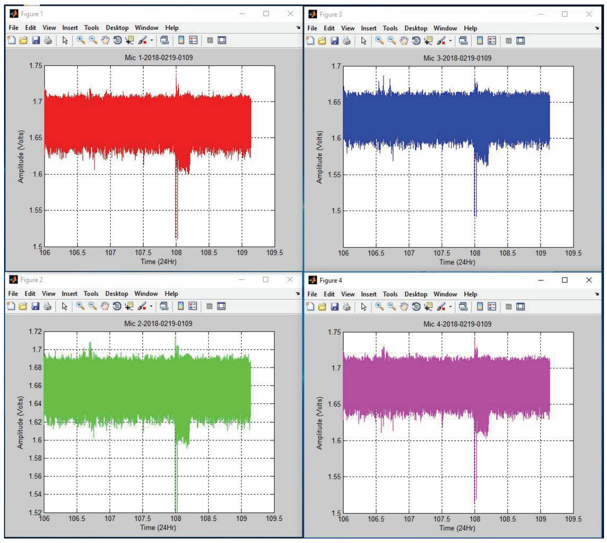

Figure 2: Goniometer Raw Data 2/19/2018 from 1:06 to 1:09 AM, Mid Canyon

Figure 3 is illustrations prepared by Inter-mountain Labs (IML) showing the location of the goniometer relative to potential avalanche paths in the Little Cottonwood Mid-Canyon, White Pine Path. The goniometer was located at the south terminus of a ridge, with the orientation of its azimuth data indicated by the yellow lines. The azimuth is measured counterclockwise from the east side of the device, such that 0° is east, 90° is north and 180° is west. The Lone Pine chute area lies within 0° to 90° azimuth, while the White Pine path is between 90° and 180° azimuth.

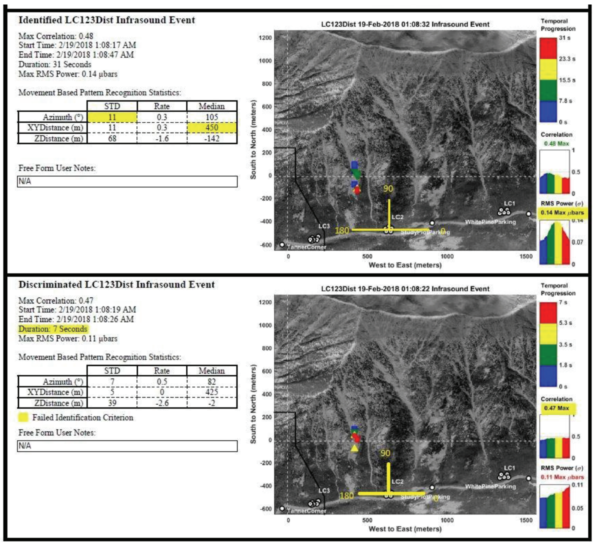

Figure 3: UDOT Image Showing Goniometer Location and Azimuth Orientation. Prepared by Intermountain Labs (IML).

Northwest of the device are events recorded by the Utah Department of Transportation's avalanche detection system on January 19, 2018 at approximately 1:09 AM. The UDOT system determined the events lasted for seven seconds. The goniometer readings were consistent with the time, duration and general azimuth of those recorded by the UDOT system.

Figure 4 shows the azimuths of the detected events found during post-processing of the infrasound data shown in Figure 2. The signal threshold was set to less than 1.62V. The algorithm creates a window around this trigger event and produces a delay matrix used to calculate the DOA. The system is capable of determining both azimuth (xy-plane direction) and elevation (angle between xy-plane and z-axis).

Azimuths of approximately 130° and 90° account for 70% of the recorded values. The azimuths of 130° accurately correlate with the avalanche of the west wall of the White Pine path. The azimuths of 90° may be the result of echoes on the east wall of the White Pine path. Values less than 90° are believed to be errors created by internal system noise and are being investigated.

Goniometer Azimuth Data (MATLAB)

Azimuth values are estimates (on-site survey required).

Values of approximately 90° or 30° may be echoes or system artifacts.

Values of approximately 130° are associated with events.

Azimuth:	130.89°	Azimuth:	130.95°
Azimuth:	130.89°	Azimuth:	30.00°
Azimuth:	131.14°	Azimuth:	130.95°
Azimuth:	130.95°	Azimuth:	92.39°
Azimuth:	35.35°	Azimuth:	30.24°
Azimuth:	71.82°	Azimuth:	87.95°
Azimuth:	130.89°	Azimuth:	30.00°
Azimuth:	89.41°	Azimuth:	31.45°
Azimuth:	84.57°	Azimuth:	130.95°
Azimuth:	130.89°	Azimuth:	89.47°
Azimuth:	130.89°	Azimuth:	30.00°
Azimuth:	89.91°		

Figure 4: Goniometer Azimuth Calculations via MATLAB

3. GONIOMETER SYSTEM

The goniometer uses four microphone sensors arranged in a tetrahedron pattern with a two-meter gap between each microphone. Figure 5 shows the configuration used in the Little Cottonwood Canyon during the 2017-2018 testing. Since sound travels at a fixed rate, each microphone records the arrival of an infrasound wave at a slightly different time. If the amplitude of the wave exceeds a specific threshold, this interval is used to calculate and record the wave's direction of arrival. The cylindrical objects at the end of the arms are the microphone enclosures. This design used small ports resembling pitot tubes as a path from the outside environment to the microphones, with the intent of providing protection from the elements. These enclosures introduced an inherent directionality to the system that may have contributed to azimuth error. New microphone enclosures which avoid this issue have been designed and 3D-printed for the next iteration of testing.

Figure 5: Goniometer Mounted on Mid Canyon Tower

Early implementations of the device relied on frames assembled together using standard PVC pipe. The current iteration employs a custom-designed, collapsible aluminum tripod with adjustable arms. The microphone cylinders were fabricated on a 3D printer using weather-resistant plastics. Fully deployed it occupies the volume of a typical Christmas tree, and folds into a bundle small and light enough to be carried by a single person. A standard lead-acid battery powers the device for extended periods.

4. CONCLUDING REMARKS

Boise State's goniometer systems will be deployed in the Little Cottonwood Canyon again during the winter of 2018-2019. Development of real-time avalanche detection algorithms and wireless data transmission is underway. This will allow avalanche forecasters to be notified of events the moment they occur.

Firmware and hardware have been improved in summer of 2018 with WiFi added for reporting real-time snow avalanche. The objectives in the winter of 2018-2019 deployments are to test new firmware, enclosure design, system reliability and performance, and real-time avalanche reporting.

ACKNOWLEDGEMENTS

This work was funded by the U.S. the Transportation Avalanche Research Pool (TARP) program. The authors thank the UDOT avalanche forecasting program for facilitating the installation and providing validation data for the avalanche detections.

The initial infrasound system was designed and prototyped by M. Pook. Most recently, the infrasound system was funded by the Idaho State Board of Education Incubation Fund.

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