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Abstract: Light detection and ranging (LiDAR) data demonstrate how derived horizontal and vertical coordinates of the ground and objects above the ground can be used to provide detailed information for improved emergency management and disaster response.

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1. Introduction and Study Area

The Naval Postgraduate School (NPS) is exploring improved approaches to utilizing remote sensing (the capture of information without contact with the subject), and geographic information system (GIS) data to assist emergency first responders and managers in disaster response situations.

The primary study area, Monterey County, California, lies in a seismically active area prone to disasters such as earthquakes, tsunamis, landslides, and flooding of the low-lying areas. Emergency and disaster situations could potentially be mitigated with improved technology to prepare for, respond to, and recover from these events. Remote sensing has proven to be an effective response technique during recent events such as the 2010 Haiti earthquake; the 2011 Joplin, MO tornados; and 2011 Hurricane Irene disasters.

This paper describes several analysis products derived from Light detection and ranging (LiDAR) data that could assist with future disaster response efforts. The use of LiDAR data to accurately map surface and terrain elevation of a large area provides significant advantages over satellite or stereo imagery methods. LiDAR have significantly higher spatial resolution than most remote sensing datasets. They also provide another dimension of information (vertical information about buildings, trees, and other surface objects) not available from other sources. LiDAR data were collected in September 2010 for the coast and inland valleys of Monterey County. This collection was contracted by the Association of Monterey Bay Area Government (AMBAG) and sponsored by U.S. Geological Survey (USGS). The vendor reported vertical accuracy of 0.232 sf and horizontal accuracy better than 2 sf. The collection resolution was 2.5 points/m².

2. Applications and Products

2.1. 3D Modeling and Damage Assessment

Many buildings and houses are damaged during earthquakes by the lateral forces of ground shaking. The first step in any coordinated response begins with the assessment of the damage. In previous earthquakes; however, the assessment of wide areas and difficulty maneuvering on the ground have challenged stakeholders in disaster response. Overhead imagery has now been used after many events as an alternative tool to assessment on the ground [1]. The limited spatial resolution of imagery, however, often prevents emergency managers from relying on this capability alone. LiDAR provides an additional capability to understand the height of structures. After the Haiti earthquake, the fusion of LiDAR and imagery products assisted researchers with extracting the damaged buildings [2]. They concluded that “elevation derived from LiDAR provides important aid in determining damaged buildings by introducing the missing dimension in the remote sensing imagery”.

For this research, the AMBAG LiDAR point cloud data of a portion of Monterey County, California, were used to generate digital 3D surface models that included buildings, trees, and all other above ground features. First, the LiDAR point cloud file was transformed into a gridded surface model. Then, a National Agricultural Program
(NAIP) orthoimage acquired in 2010 was transformed into the same projection as the LiDAR data. The NAIP surface texture generated from the orthorectified imagery was then draped over the model (Fig. 1). The downtown Monterey model assisted with visualization of buildings and their relationship to other surface materials. At the cantonment area of Camp Roberts in Southern Monterey County, damaged buildings were used to validate the idea of using draped 3D LiDAR models (Fig. 1). There was strong agreement with the damaged barracks found in the data and ground-observed damage. Because the data were captured and validated at different times, however, an exact metric was not calculated. The addition of contour lines made this damage even more apparent. This research will help determine the need for additional data collection after an earthquake. It proved that fused imagery and LiDAR data can provide the emergency managers with an alternative to damage assessment for a large area.

![Fig. 1: LiDAR data fused with NAIP orthoimagery for downtown Monterey. The 3D surface model textured with imagery provides a realistic representation of the urban area. Top-Right: LiDAR data fused with imagery for a destroyed barracks in Camp Roberts clearly demonstrates the capability of damage assessment. Damaged (collapsed roof) barracks marked with red arrow.](image)

2.2. Communications Equipment Line of Sight Analysis

Analysis of high resolution LiDAR derived digital elevation models (DEMs) for placement of emergency communications equipment was performed in coordination with the Hastily Formed Networks (HFN) group at NPS. The LiDAR ground point data were interpolated to create a “bare earth” model. This model was analyzed to determine where WiMAX terminals which provide Wi-Fi connectivity via the NPS VSAT satellite link should be placed. With correct placement, the WiMAX signal can travel some 25-30 miles.

![Fig. 2: LiDAR derived digital elevation model (DEM) with line of site analysis from point A (Point Lobos) to point B (NPS). Top-Right: An obstructed communications link from point A to B demonstrated by the blue dot. The green areas are those visible from the origin while a red area and the red dot suggest those areas that are obstructed. Bottom-Right: Using a hop from the Lobos peninsula through the valley would provide an un-obstructed link to the VSAT communications link at the Naval Postgraduate School.](image)

The challenges of a disaster response are exacerbated when cellular or internet connections aren’t available. These communications back-ups provide required connectivity to much of Monterey County. With this WiMAX
emergency communications equipment in the delivery stage to the Monterey County Office of Emergency Services, the LiDAR topographic analysis was necessary to meet coverage requirements for emergency response.

2.3. Tsunami Inundation Analysis

The recent tsunami in Japan demonstrated that domestic preparedness for these events is critical. While much of the Western Coast of California has been mapped using lower resolution digital elevation models (DEMs), the high resolution LiDAR-derived DEM provides an opportunity to understand on a street by street or building by building basis which assets are at the greatest risk. In particular, an understanding of the risk a tsunami poses to critical infrastructure and key resources (CIKR) will benefit the emergency manager before, during, and after an event.

Fig. 3: This LiDAR-derived tsunami inundation warning map takes advantage of the high vertical accuracy of the data to show which areas and critical infrastructure are at the greatest risk. The data were classified using the height attribute. With improvements in tsunami modeling and forecasting, this type of derived analysis will prove indispensable for coastal communities.

4. Conclusions and Future Research

While imagery derived products have long been used in emergency management and disaster response, new data acquired through Light Detection and Ranging (LiDAR) provide additional capabilities to overcome many of the remaining challenges. This paper described several of the opportunities to apply this data to overcome damage assessment, communications, and tsunami dangers. Additional investigations of the relationship between slope and landslides, safe helicopter landing areas, and secure placement of recovery shelters are still underway. The discrete return number of laser pulse and relative height above the ground is also being investigated to derive tree height maps that could benefit both fire response and mitigation of power line damage. The LiDAR data make new analysis products possible that will help mitigate, prepare, respond, and recover from future disaster events.

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5. References
