MAPPING WILDLAND-URBAN INTERFACE STRUCTURES USING LIDAR AND HIGH-RESOLUTION DIGITAL ORTHOPHOTOS

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Large-scale maps of wildland-urban interface (WUI) areas are useful for fire risk mapping, emergency planning, fuels reduction, and public education efforts. Given the increasing availability of high-resolution data, remote sensing techniques can be used for WUI mapping. Airborne topographic lidar data is particularly applicable to building footprint extraction. Rapid development of new software for lidar visualization and analysis is simplifying the mapping process.

This project tested various techniques for lidar and high-resolution imagery to map structures within forested areas in the WUI. The project was initiated and funded by the USDA Forest Service San Dimas Technology and Development Center, Inventory and Monitoring Technology & Development.

1. AIRBORNE TOPOGRAPHIC LIDAR

Lidar (also written as LIDAR) is an acronym for LIght Detection And Ranging. Lidar systems measure distances using the same principle as a laser rangefinder. The travel time of each laser pulse to an object and back is divided by two and multiplied by the speed of light to calculate the precise distance.

An airborne topographic lidar system scans, receives and georeferences multiple pulse returns from the ground, treetops, rooftops and other objects tens of thousands of times per second. The system employs an inertial measurement unit (IMU) and a global positioning system (GPS) unit to record the geolocation of each lidar return in three dimensions, automatically adjusting for the "look angle" which is typically 20 degrees to either side of vertical. Airborne topographic lidar systems typically use a near-infrared laser to minimize noise from background solar radiation. The optimum wavelength varies depending on the backscattering properties of the target area and the type of detectors used, and can range from 800 to more than 1500 nm (Wehr and Lohr, 1999).

Some lidar systems also measure the return energy or intensity. Lidar intensity data has the potential to help distinguish between different surfaces. For example, a highly reflective metal roof will show a higher intensity than an asphalt roadway (Fowler, 2001).

Commercial lidar systems often have a ground sample distance of 0.25 to 2 meters. Normal horizontal accuracy is within 0.5 to 0.75 meters, depending on the steepness of the terrain, flight height above ground and the scan angle. Vertical accuracy ranges from 0.15 meters to 0.5 meters. Airborne topographic lidar is often acquired from between 100 and 1,000 meters above ground level.

Lidar systems generate millions of recorded data points. The "point cloud" of raw data must be converted to ASCII or binary format containing x, y and z values (multiple z values in the case of more than one return) and intensity values (for some datasets).

Sometimes a processed lidar dataset will consist only of last returns. The last return indicates the elevation of the ground level, except where buildings or dense tree canopy exist. If an observer at ground level cannot see the sky, as a rule of thumb the lidar system won't be able to measure the ground elevation at that point.



Figure 1. The basic elements of an airborne topographic lidar system are a laser scanner, an inertial measurement unit (IMU) and a global positioning system (GPS). First and last return lidar data are symbolized here by blue and red dots. Single returns are recorded as a last return. In forested areas, many of the laser pulses will not reach the ground.

2. HIGH-RESOLUTION DIGITAL ORTHOPHOTOS

High-resolution digital orthophotos, with a ground sample distance of 1 meter or less, can be produced from traditional aerial photography or acquired using digital cameras.

The best way to classify these images is through image segmentation, which takes the place of a pixel-by-pixel approach. Features can be represented as image objects, using software such as Feature Analyst (Visual Learning Systems) or eCognition (Definiens Imaging).

Image segmentation algorithms work well on digital orthophotos, however panchromatic or natural-color images cannot be classified as well as multispectral images that include a near-infrared band.

Aerial imagery, particularly of the WUI, often includes tree canopy and shadows that obscure rooftops. The addition of airborne topographic lidar leads to more accurate results. Elevation data helps distinguish between objects of similar shape and different height (for example, a building and a parking lot).

In conjunction with lidar datasets, digital orthophotos can be a useful ancillary reference for identifying ground features, provided the photography is up to date.

Source photography for digital orthophotos is usually not truly orthographic. As a result, the tops of trees, buildings and other tall features may exhibit relief displacement in the image even though they may be correctly georeferenced at ground level. This effect can cause mis-registration when digital orthophotos are draped over lidar data.

3. ANALYSIS TECHNIQUES

Lidar contour analysis was tested using Surfer (Golden Software). Surfer gives the user complete control over grid creation from point data. Grids were produced using the same posting as the lidar ground sample distance. Contours and shaded relief based on the grid revealed building footprints. Surfer does not have an automated feature extraction tool; manual editing is necessary to extract building footprints from contours.

An edge detection and classification technique suggested by Arefi and others (2003) was tested with both 2-meter and 1-meter lidar datasets using ERDAS Imagine (Leica Geosystems). Gridded data was used to build a three-band image for classification. The first band is the output from a 3x3 Laplacian edge detection filter. The second band was the original dataset, with contrast enhancement and/or noise reduction. The third band was a slope/gradient image. A supervised classification was used to detect buildings with good results.

Data fusion using Feature Analyst (Visual Learning Systems) and co-registered imagery and lidar elevation data was tested. Feature Analyst employs "hierarchical learning." This is a sequence of operations to refine the process by identifying correct and incorrect classifications and missed features in the initial results. Acceptable results were obtained.

The last technique tested was automated feature extraction using Lidar Analyst (Visual Learning Systems) and ArcGIS (ESRI). RSAC obtained a beta version of the Lidar Analyst, which was released commercially in April 2005.

Lidar Analyst runs a bare earth extraction process, which produces a digital terrain model (DTM) by removing trees, buildings and other above-ground objects. If first and last return data are available, both can be used for best results. The bare earth layer can be "cleaned up" and modified using a collection of automated and manual tools.

Building extraction is the next step. The inputs are the last return data and the bare earth layer. The building extraction process can be fine-tuned using a variety of options. Results are shown in Figure 2.

As a final step, Lidar Analyst can perform tree extraction, which produces tree points or forest polygons. First and last return and bare earth images are needed as inputs. A building shapefile can be added to mask out previously identified buildings (Visual Learning Systems, 2004).

4. CONCLUSIONS

High-resolution airborne topographic lidar analysis is a good method for mapping structures, and can be automated with newlyavailable software. Lidar elevation datasets can yield more accurate results than imagery without elevation data.

While lidar cannot always penetrate forest canopy with sufficient resolution to identify structures, this problem can be mitigated by acquiring "leaf-off" data.

Automated feature extraction is the most efficient lidar analysis technique, with the use of Feature Analyst or a lidar toolkit. Contour analysis and edge detection classification are more labor-intensive but can produce accurate results. Data fusion methods can work well, but close spatial and temporal correspondence between imagery and lidar is required.

Lidar toolkit programs, for example Lidar Analyst from Visual Learning Systems, offer efficient and cost-effective techniques for feature extraction. Development of these toolkits is continuing, and new functions are being added. Accuracy and ease of use are improving as well.



Figure 2. Automated building footprint extraction using Lidar Analyst (Visual Learning Systems). Background image is a shaded relief of last-return lidar elevation data.

References

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About the author

Richard Warnick is a remote sensing analyst employed by RedCastle Resources, Inc., a contractor with the USDA Forest Service <u>Remote Sensing Applications Center</u> (RSAC) in Salt Lake City, Utah. He has previously worked with a wide variety of satellite and aerial imagery projects, including active fire monitoring using MODIS data. In the last year, RSAC has begun to take on some lidar analysis pilot projects. RSAC is hosting a Forest Service lidar workshop May 17-19, 2005.