MAPPING SOLAR ENERGY POTENTIAL THROUGH LIDAR FEATURE EXTRACTION

WOOLPERT WHITE PAPER

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Solar Energy Potential Is Largely Unrealized

Solar energy has been harnessed for man's use since the dawn of time; however, the need to maximize its potential has never been more important than it is today. In 2011, the International Energy Agency said: "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared."[1]

Many technology hurdles must be removed before solar power becomes a primary component of the U.S. energy portfolio, yet advances are happening on many fronts. One of the primary roadblocks standing in the way of solar adoption is the general lack of knowledge on the consumer level about where solar energy potential exists, especially when it comes to specific residential and business structures. While some state and local governments are more actively pursuing solar adoption by instituting programs that help consumers estimate solar potential and facilitate installation, most areas in the country suffer from the same knowledge gap that prevents consumers from realizing the potential of solar energy.

Aerial LiDAR Produces High-Precision, Multipurpose Data

For decades, aerial data collection techniques have been essential for mapping purposes. Traditional high-resolution orthophotography provides a powerful data layer for analysis, but alone its 2D dataset limits the amount of features that can be extracted. With the ability to create 3D digital surface models (DSM), light detection and ranging (LiDAR) offers much more precise datasets that enable exponentially more detailed feature extraction potential.

From an engineering standpoint, LiDAR datasets provide a variety of derived products, including solar mapping; impervious surface identification; building outlines; precise definition of land cover; and vegetation and wetland delineation, which supports specialized applications such as identifying insect nesting grounds. Almost all state and local agencies have invested in aerial mapping and most have invested in LiDAR data, but unfortunately they have not taken the next step to extract specific features and utilize the data for other beneficial purposes.

While the possibilities to use these datasets for civil improvements are virtually limitless, the process of using feature extraction techniques to create an interactive solar map that calculates solar energy potential and connects consumers to local installers will be the focus of this paper.

Determining Solar Energy Potential: LiDAR Data Collection, Processing and Feature Extraction

The objective of extracting solar mapping from LiDAR is to create the best possible estimate of usable rooftop area for receiving maximum incoming solar radiation. Data collection starts with an aerial LiDAR scan of the targeted region, scanning rooftops and obstructions that could potentially interfere with sunlight. Then, the process of rooftop

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[1] International Energy Agency (2011), Solar Energy Perspectives, OECD Publishing.

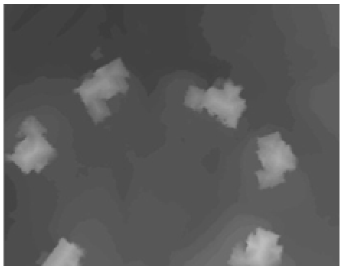

Figure 1. Building detection from LiDAR point cloud

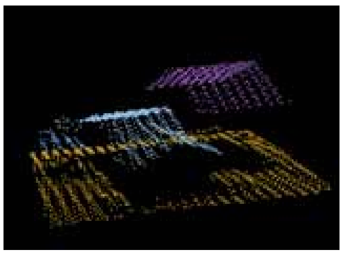

Figure 2. Unstructured point cloud segmentation, perspective view

Figure 3. Roof plane fitting model

feature extraction is performed through software that automates processing and interprets the data into useable datasets.

The semi-automated feature extraction process combines the LiDAR dataset, high-resolution four-band digital imagery (Red, Green, Blue, Near Infrared) and existing building footprints. The entire process takes place in multiple steps. First, the building footprint is detected from the unstructured 3D point cloud in the LiDAR dataset. From there, 3D point segmentation takes place to aggregate points with similar attributes, creating an abstraction layer of the building footprint. Then, the initial effort to identify the roof surface that holds the most potential for solar radiation takes place, considering each plane and its relative position to the sun. Figures 1-3 demonstrate the progression of LiDAR processing.

The last task in LiDAR processing is to define polygonal models that represent real-world building constructs. One method is to combine parametric and polyhedral models for automatic and semi-automatic building reconstructions (see figure 4).

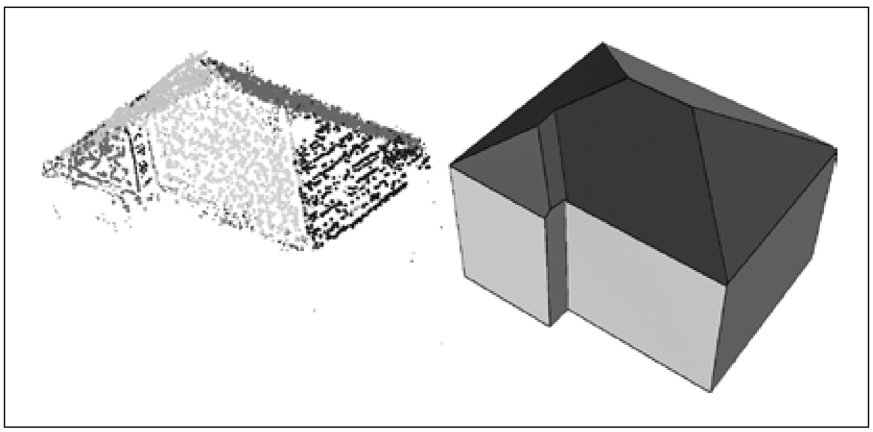

Figure 4. Segmentation of matched point clouds and building model

Next, technicians perform image processing of conventional 2D aerial photography and combine it with the LiDAR datasets to aid feature extraction. Objects and edge data are extracted from the photography and aggregated with the LiDAR dataset to closely approximate the true shape and position of a building, with the ultimate goal of identifying the 3D boundaries of the individual roof or surface planes (see figure 5).

Figure 5. 3D roof boundaries are clearly identified

Figure 6. Aerial image

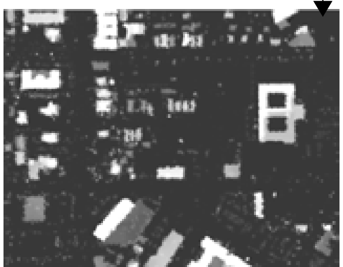

Figure 7. Normalized digital surface

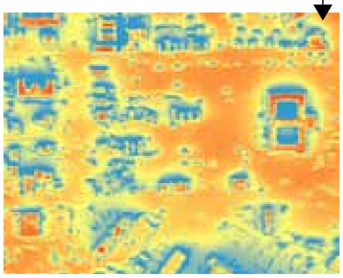

Figure 8. Solar radiation map

Creating Solar Radiation Models

With rooftop polygonal delineation and obstructions identified, a normalized DSM is created to analyze the effects of the sun over a one-year period. The data gathered throughout the year tracks the angle or slope of the roof in conjunction with the azimuth of the sun, calculates the insolation across the entire landscape and considers the obstructions that may occlude the roof plane throughout the year. Figures 6-8 demonstrate the progression of feature extraction from an aerial image to a solar radiation map.

The final step of the data collection process is to calculate the solar energy potential of individual roof surface areas. Figure 9 demonstrates how solar energy potential is ranked: high, medium and low.

Figure 9. Solar energy potential map (red points represent the highest potential; pink, medium; and blue, lowest)

Making the Data Accessible to the Consumer

To some, the LiDAR data collection and feature extraction process may seem like an abstraction, but the end goal is quite tangible: provide hands-on tools to enable the average consumer to determine the solar energy potential for their home and business, and more importantly, understand the area and specific location for solar panels.

For maximum accessibility and ease of use, there's no better way to present solar energy potential than in an interactive Web-based portal. State and local governments have effectively used Web-based portals for targeted regions, relying on this interactive tool to tell residents and business owners the critical information needed to base solar panel installation decisions, such as:

- Determination of optimal surface area on individual roof slopes advises consumers on proper surface installation
- Effectiveness scale rates the solar energy potential and helps consumers gauge their return on investment (ROI)

The level of detail available to consumers provides them with a true understanding of what's needed to achieve their individual solar energy potential, in turn raising the confidence of the home and business owner while reducing unnecessary solar panel expense from uninformed installations.

Recommended Interactive Features

An effective Web-based portal provides a quick, easy way for individuals to learn about their building's specific solar potential. To be effective, it should present consumers with a familiar map interface—such as Google Maps—where multiple search and navigation methods are available. Visitors should have the option to search by property or address or use traditional click, drag and zoom techniques to locate their structure.
Once a visitor has selected a structure, the following data should be made available to them:

- Solar potential points on a map, with effectiveness classifications
- The total and available area of each rooftop plane
- Estimated potential annual solar energy output
- Contact information of a recommended solar panel installer

Figure 10 is an example of a live solar map portal that's currently being used in the Denver region.

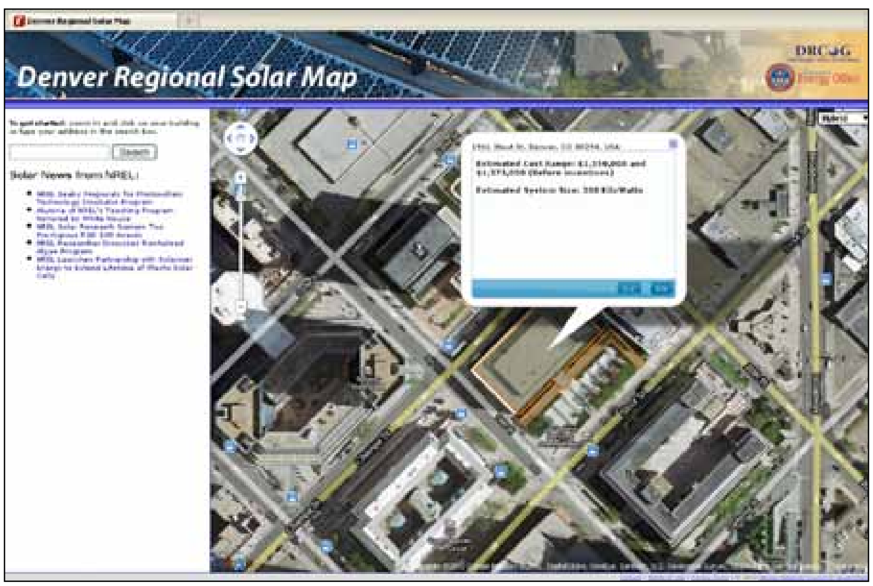

Figure 10. Solar map portal currently used in the Denver region

LiDAR Precision Offers Unlimited Mapping Potential

In recent years, the refinement of mapping technologies used to calculate solar energy potential has increased dramatically. We now have the ability to accurately identify the best roof slopes on which to install solar panels and achieve maximum ROI. As a result, home and business owners have the confidence of knowing what their solar energy opportunities are. LiDAR advancements in the past several years have resulted in improved precision from two-meter point spacing to 0.7 meters, all while the costs of acquisition have actually decreased.

Solar mapping is just one example of the many potential uses for LiDAR feature extraction. And while widespread adoption of this technology is still relatively low, it's important to realize that LiDAR's accuracy and precision represent the best available technology for mapping and feature extraction purposes. The many benefits it could provide to state and local governments throughout the U.S. are only limited by their imaginations.