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Generalizing Projected LiDAR Data with Support Vector Machines for Solar Energy Applications

Ádám Bognár*, Roel C.G.M. Loonen, Jan L.M. Hensen
Building Physics and Services, Eindhoven University of Technology

* a.bognar@tue.nl

Aim
This project aims to facilitate the application of Light Detection and Ranging (LiDAR) point-clouds for taking into account shading of photovoltaic (PV) systems in the urban environment. In the Netherlands, LiDAR data is available nationwide, with a 0.5 m resolution (see Figure 1). We use machine learning to turn this raw point-cloud data into a valuable asset for shading calculations. Applications include PV and building design support, and providing input for making digital twins for fault detection of PV systems.

Approach
Calculating the effect of shading on PV performance generally requires the geometry of the shading surfaces. LiDAR measurements provide a point-cloud sample of a surface with x-y-z coordinates instead of a surface. This point-cloud needs to be generalized into a surface. Such process is demonstrated in Figure 2 and 3. As a pre-processing step, the LiDAR point cloud and solar positions are projected to the sky hemisphere. Every point on the hemisphere can be described with its azimuth and zenith (see Figure 3a). The training data for the SVM are the LiDAR-points (labeled as obstructed sky) and a uniform sky point-grid (labeled as unobstructed sky) with the features azimuth and zenith. For the predictions we introduce a grid of test points and perform a non-linear soft-margin classification. The cover factor of a sky-segment can be calculated from the ratio of (+) and (-1) predictions in them (see figure 3b) and the actual solar positions can be tested as well individually, using the features solar azimuth and zenith. The former is used for diffuse, the latter for direct solar irradiance simulations (not discussed here).

Results of a proof of concept case study
Figure 4 shows the result of simulations conducted with state of the art irradiance simulation software DAYSIM/Radiance with the geometry shown in Figure 2. The two cases compare the outcome with a conventional shading geometry input method using SketchUp 3D modeling software, and with the proposed method from an artificially generated LiDAR point-cloud.

Figure 1. Visualization of LiDAR point-cloud in Eindhoven city center.

Figure 2. Projection of LiDAR point-cloud of a vertical wall and solar positions on the sky-hemisphere.

Figure 3. (a) LiDAR point-cloud on the solar azimuth-zenith feature space. (b) Azimuth-zenith segmentation with added sky point-grid, solar positions and predicted obstructed and unobstructed sky area.

Figure 4. Simulated Irradiance on a cloudy and sunny day with the conventional and the proposed shading geometry input.