Using lidar to create shade maps

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In the near-term, climate change is expected to make heat waves more intense and frequent. These impacts will be severely felt in cities, where temperature extremes are amplified by the presence of large amounts of heat-trapping impervious surfaces. Consequently, urban extreme heat has been recognized as a looming public health crisis. Trees are among the most effective tools for mitigating urban heat for two reasons: they provide shade, which reduces direct solar exposure; and they cool the air by exchanging heat when they release water vapor through evaporation and transpiration. Artificial shade structures, including buildings, also mitigate heat through shade, but this is partially counteracted by the fact that their hard surfaces also absorb and re-radiate heat. Studies have found that shade can significantly reduce ambient temperature and human thermal comfort. This effect is even more pronounced in arid and semi-arid locations like Denver, where low humidity results in a noticeable improvement in thermal comfort when people move from sun to shade.

Understanding which locations have adequate or inadequate shade and tree cover, then, is an important planning issue, one that requires spatial data and technologies to operationalize. While we have accurate depictions of where buildings and trees are, precisely mapping shady locations is far more difficult. This is because shade cast at a particular location depends on the physical dimensions of the objects casting the shade, the position of the object relative to the sun at any given time of day, and the change in the diurnal shade pattern over the course of the year as the solar angle changes.

Thankfully, the data and technology exist to do just this. Light detection and ranging data, just collected in 2020 for DRCOG's entire service region, is the basis for this analysis. Lidar is created by sensors mounted on aerial platforms that take laser altimetry readings of the terrain below. Taking the form of millions of points, each with geographic coordinates and a height value, Lidar data can be used to generate three-dimensional models of both the bare ground and of the objects over the ground, including buildings and trees. Trees can be easily distinguished from other "above-ground" objects because, unlike buildings, laser beams can penetrate trees and so a tree will register height values or "returns" at multiple vertical locations throughout a tree.

Once 3D representations are built of aboveground objects, geographic information system software can be used to model the shade these objects would cast at any given time of day and year. That shade is represented as pixels on the two-dimensional ground surface (it can also be modeled on the vertical surface of three-dimensional objects, such as the façade of a house, but doing so is much more complicated). Those shade pixels can be overlaid with thematic features, such as sidewalks or building footprints. In this way, we can measure how shade strikes individual features with great precision.

Modeling shade in an urban park.

Our team of researchers at the University of Colorado Denver, College of Architecture and Planning, succeeded in using an earlier generation of the Denver regional lidar data set to map out shade, categorized by whether it was generated by trees or buildings, for all of Denver. We also created a similar map for the city of Baltimore. For each pixel in the resulting maps, one meter in resolution, we generated an aggregate measure that summarizes the average number of shade hours across the hottest seven hours of the statistically hottest day of the year in mid-July. We were then able to overlay the shade maps with building footprints, allowing us to calculate which homes receive shade and for how long during the day. Such information could be extremely valuable in targeting where to plant more trees or where energy efficiency or cooling assistance measures might be needed. It could also be useful in determining suitability for rooftop solar, among many other applications.

Currently, as we prepare to process DRCOG's newly released lidar data set, follow-up analyses are about to begin that illustrate the wide range of applications of lidar-based shade analysis. This includes a plan to study which Regional Transportation District transit stops are shaded or not and at what times of day, a significant issue for thousands of people who rely on transit and often have to face exposure to high temperatures in the summer months. Understanding where the high-exposure transit stops are could help strategically prioritize investments in more trees and shade structures. Beyond that, many more potential applications will be explored, from looking at the shading of pedestrian routes and sidewalks to parks and public gathering spaces.