RESEARCH LiDAR shows potential for increasing sensor coverage area in outdoor applications

By Cori Jackson

LiDAR has made the news in recent months as part of various high-profile archeological and geological projects. From discovering Mayan ruins to mapping our coastal seashores, LiDAR is the tool of choice. The technology also plays a critical role in autonomous vehicles, security systems and agriculture. LiDAR, shorthand for Light Detection and Ranging, may also prove useful in common lighting applications including potential use as a long-range occupancy detector to control outdoor lighting.

Today's outdoor lighting systems rely heavily on passive infrared (PIR) technology for occupancy-based control. PIR occupancy sensors detect motion by identifying a heat signature once it moves across its detection area. These sensors are usually mounted to a light pole or integrated into a luminaire. Generally, outdoor PIR occupancy sensors have a 180- to 360-deg coverage pattern and a maximum detection distance of approximately 40 to 50 ft when mounted at a height of 8 to 10 ft. For most PIR sensor designs, detection areas decrease at higher mounting heights and coverage gaps increase as you move away from the sensor.

For many outdoor lighting applications, occupancy sensors with larger detection areas are necessary to fully realize the energy and environmental benefits of occupancy-based control. This is where LiDAR technology may make sense. The technology shows promise in significantly increasing the coverage area achievable by a single sensor, and thus significantly increasing the ability of lighting systems to control lighting based on movement within their entire illuminated area.

In contrast to PIR, LiDAR is an active sensing technology. It sends out a pulse of infrared radiation and waits for that pulse to return, measuring the pulse's overall time-of-flight (ToF). A consecutively changing ToF is interpreted as an occupied condition. Using this approach, the LiDAR technology is capable of capturing size, speed and direction of objects moving within its detection area.

PUT TO THE TEST

To better understand the potential of commercial-grade, small-scale LiDAR technology for use as part of outdoor lighting control systems, the California Lighting Technology Center at UC Davis, with support from the Office of Naval Research, developed a standardized outdoor sensor test procedure for determining spatial sensitivity and then put LiDAR to the test.

CLTC evaluated a mechanically scanning, commercially-available LiDAR system marketed for security applications. The system essentially creates an invisible "wall," which generates a signal when it is disrupted by a moving object. The output signal can be used to control connected devices. The LiDAR system evaluated has a 180-deg field of view and a manufacturer-stated maximum detection distance of 100 ft. Other LiDAR systems can deliver detection areas many times this size.

Instead of using the technology to trigger video equipment or security alarms, as marketed by the manufacturer, the sensor was configured to control an outdoor luminaire. By wiring the LiDAR technology to a luminaire, CLTC was able to visually confirm occupancy triggers as well as evaluate a potential LiDAR-luminaire configuration appropriate for use as part of an outdoor lighting system.

CLTC evaluated the sensor's coverage area following its recently developed test procedure. To conduct the test, the LiDAR sensor was mounted to a scissor lift (**Figure 1A**), which allowed CLTC to complete three separate characterizations. Each characterization included the LiDAR sensor mounted at a different height and view direction (**Figure 1B**).

- **Setup A:** 5 ft high with viewing angle of 90 deg (parallel to grade)—allowed for quantification of total LiDAR detection area and maximum detectable distance.
- **Setup B:** 10 ft high with viewing angle of 84.25 deg—intended to maximize detection distance and include a mounting height less susceptible to vandalism.
- **Setup C:** 20 ft high with viewing angle of 45 deg—allowed for a steep downward detection angle while still allowing for detection of the direction of movement.

For all three setups, the sensor was set to its maximum sensitivity level. This allowed the sensor to detect objects as small as 6 in. and objects with movements as small as 1.6 ft in length.

The tested LiDAR system requires a two-step procedure for calibration and selection of the intended detection area. When mounted in a stationary application such as occupancy detection for outdoor lighting systems, the procedure is completed after the initial installation when the detection area is empty.

For the first step of the procedure, the LiDAR technology completes a full scan of its field of view. This scan determines the size of the coverage area, with the perimeter defined as the distance to nearby solid objects such as buildings, vehicles and trees. The second step of the process allows users to select specific zones within the detection area that will trigger a system response. In most cases, the trigger zones will include the entire detection area, but when used for occupancy detection, certain zones may be excluded to reduce false triggers from objects like moving tree branches or air conditioning fans. This step is similar to masking that is done for occupancy sensors used to control indoor lighting systems today.

Figure 1. A) LiDAR technology mounted to scissor lift for evaluation; B) Evaluated LiDAR technology.

Mounting Height (ft)	Max Detection Distance (ft)	Optimal Mounting Angle (°)	Coverage Distance from Base of Pole (ft)
10	95	84.0	94.5
20	95	77.8	92.9
30	95	71.6	90.1
40	95	65.1	86.2
50	95	58.2	80.8
60	95	50.8	73.7

Table 1. Potential mounting heights, angles and detection distances for LiDAR sensors.

DETECTION AREA

During the detection area characterization, CLTC found that the LiDAR sensor was able to reliably detect objects up to 95 ft away when mounted parallel to the ground (Setup A). Based on the maximum detection distance of 95 ft and a range of standard mounting heights associated with outdoor lightings system, the LiDAR system may provide expanded occupancy detection areas for a wide range of outdoor lighting applications. A cross-section of potential mounting heights, mounting angles and resulting detection distances is provided in **Table 1**.

Sensor Type	False Triggers (%)
LiDAR	43%
PIR	43%
Microwave	35%

Table 2. False triggers caused by wind and tree movement.

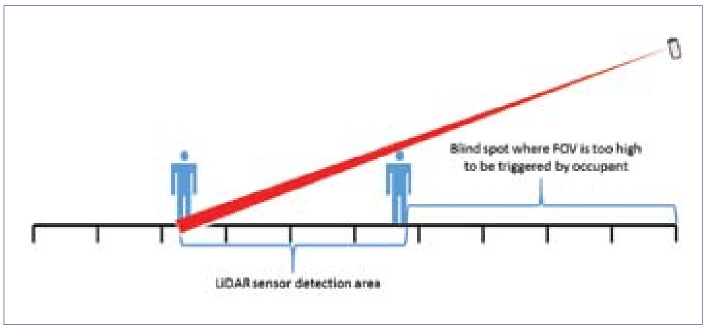

Figure 2. Theoretical LiDAR sensor detection areas and blind spots.

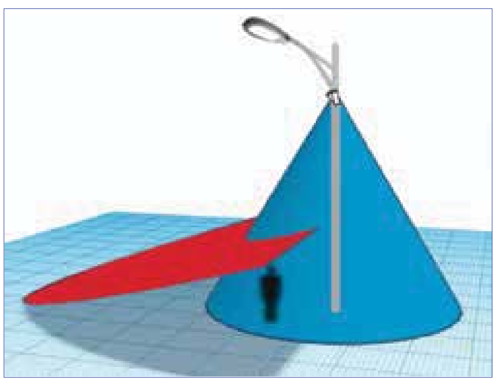

Figure 3. Theoretical dual-sensor detection range where blue is PIR and red is LiDAR.

ENVIRONMENTAL FACTORS

CLTC evaluated the LiDAR sensor for a number of environmental factors. One common situation evaluated is the impact of small-object movements on the sensor. For these tests, the system was mounted at 20 ft with a 45-deg mounting angle. CLTC utilized a toy remote controlled vehicle to simulate small-object movement through the detection area such as would be expected from animals. While the LiDAR was set to its maximum sensitivity, the toy vehicle did not induce a sensor response. Given the proposed application, this result may be desirable as small animals would not result in unnecessary light-level adjustments.

CLTC also considered environmental impacts of wind and moving tree branches on the LiDAR system. For comparison, CLTC tested a standard outdoor PIR sensor and a microwave sensor marketed for outdoor lighting systems. Researchers positioned the sensors in a test area that included various trees and shrubs. Fans were used to generate wind and 2 to 3 in. of displacement of tree limbs and branches. Displacement was generated under four different configurations of fan placement and wind speed. CLTC completed 10 tests of each configuration for each sensor.

For all tested sensors, nearly all configurations resulted in false triggers. As expected, higher wind speeds generated more false triggers. Air movement directed parallel to the sensor face resulted in more false triggers as compared to air movement generated perpendicular to the sensor face. However, unlike both the tested PIR and microwave sensors, the LiDAR system includes the ability to customize the perimeter of the detection area to exclude areas with foliage or other objects that could generate false triggers. This feature will prove useful should the technology be broadly considered for outdoor lighting applications. The total percent of false triggers for 40 tests is provided in **Table 2**. It is important to note that the LiDAR system was not customized to exclude foliage for these tests.

LOOKING AHEAD: A DUAL SENSOR APPROACH

Evaluation results show that today's LiDAR sensors and outdoor lighting systems are not a perfect match. There are limitations to the technology when considered for use with commercial lighting systems. For example, under standard, expected operating scenarios, the LiDAR detection area and mounting geometry leads to blind spots around the base of the pole (assuming the sensor is mounted to a light pole) due to reductions in the vertical field of view. The size of the blind spot is dictated by the LiDAR sensor's mounting height, mounting angle and height of the occupant, shown in **Figure 2**.

However, solutions also exist. To address this limitation, CLTC researchers are exploring the potential for a dual-technology sensor system that utilizes a LiDAR sensor and a traditional, outdoor PIR sensor. When used in combination, the PIR sensor is able to detect occupants in areas near the pole, effectively eliminating the blind spot in the LiDAR's detection area, shown in **Figure 3**.

The LiDAR and PIR dual-technology sensor concept demonstrates one enhancement to existing outdoor occupancy detection products that can yield improved detection reliability and energy savings benefits for the lighting industry. Further work is necessary to see LiDAR technology transition into common lighting applications; however, the initial exploratory evaluations conducted by CLTC show the technology is effective and reliable in limited field testing.

More information on this research may be found at *https://www.onr.navy.mil/en/Science-Technology/Departments/Code-33/All-Programs/333-sea-platforms-weapons/Neptune*. ☐

THE AUTHOR

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