2017-05TS
Published March 2017

DEPARTMENT OF TRANSPORTATION

RESEARCH SERVICES & LIBRARY

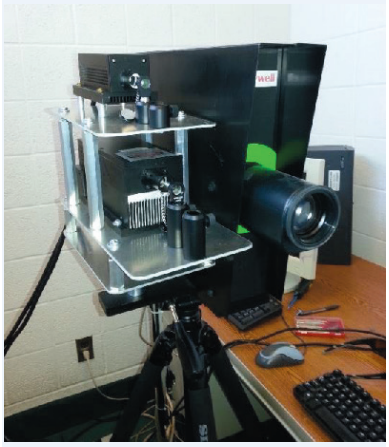
TECHNICAL SUMMARY

Technical Liaison:
Brian Kary, MnDOT
Brian.Kary@state.mn.us

Project Coordinator:
Deb Fick, MnDOT
Deb.Fick@state.mn.us

Principal Investigator:
Nikos Papanikolopoulos,
University of Minnesota

PROJECT COST:
$97,200



Infrared lasers helped the TBI sensor detect people through glass, but they also pose a danger to eye safety.

Infrared Sensing Not Yet Suitable for HOV/HOT Lane Enforcement

Tests of the Honeywell Tri-Band Infrared sensor showed that it is not currently suitable for use in high-occupancy vehicle/high-occupancy toll lane enforcement. To consistently detect passengers through windshield glass, the system requires high-power supplemental illumination that would pose a safety hazard to drivers.

What Was the Need?

High-occupancy vehicle/high-occupancy toll (HOV/HOT) lanes have gained popularity in recent years as a way to address highway congestion in urban areas. However, enforcing the provisions that either prohibit or charge a toll to single-occupant vehicles in HOV/HOT lanes can be challenging. Currently, enforcement is handled by law enforcement officers, but this is a labor-intensive process that can't catch every violator and can create a traffic safety hazard.

Obtaining technology to assist officers with enforcement is a goal for MnDOT and many other agencies that operate HOV/HOT lanes, and several manufacturers are working to develop enforcement cameras. But this has proven to be a difficult task. Window tinting and glare from sunlight can thwart common sensing technologies like video cameras and microwave radar (commonly used in speed limit enforcement). Previous research using near-infrared (NIR) sensors has shown promise, but none has produced completely successful results.

Honeywell's Tri-Band Infrared (TBI) sensor was originally used to automatically detect intrusions at high-security entrance gates. In addition to a black-and-white camera and an illuminator, the TBI has two co-registered NIR cameras. The system takes advantage of the fact that human skin reflects infrared light much more effectively at wavelengths below 1400 nanometers. The TBI's infrared cameras are sensitive to different wavelengths, one below and one above that threshold, and fusing the images from these two cameras makes silhouettes of faces more prominent.

What Was Our Goal?

The goal of this project was to evaluate whether the TBI sensor is suitable for HOV/HOT lane enforcement applications.

What Did We Do?

Investigators first tested the sensor outdoors on oncoming vehicles with known positions that ranged from 25 to 140 feet from the sensor. These tests demonstrated that the sensor had limited ability to penetrate modern vehicle glass, possibly because the system's illuminator component was ineffective.

Investigators purchased two infrared lasers providing illumination at wavelengths of 1064 nanometers and 1550 nanometers to increase the TBI sensor's ability to detect people through windshield glass. Then they conducted indoor tests to compare the impact of these illuminators with that of the original illuminator: With a test subject holding front passenger windows from several manufacturers in front of his face, the lasers were aimed at the subject while the TBI attempted to detect him.

Finally, investigators conducted outdoor tests using the TBI to detect people in three test vehicles from the front and the side under both sunny and cloudy conditions. These

continued

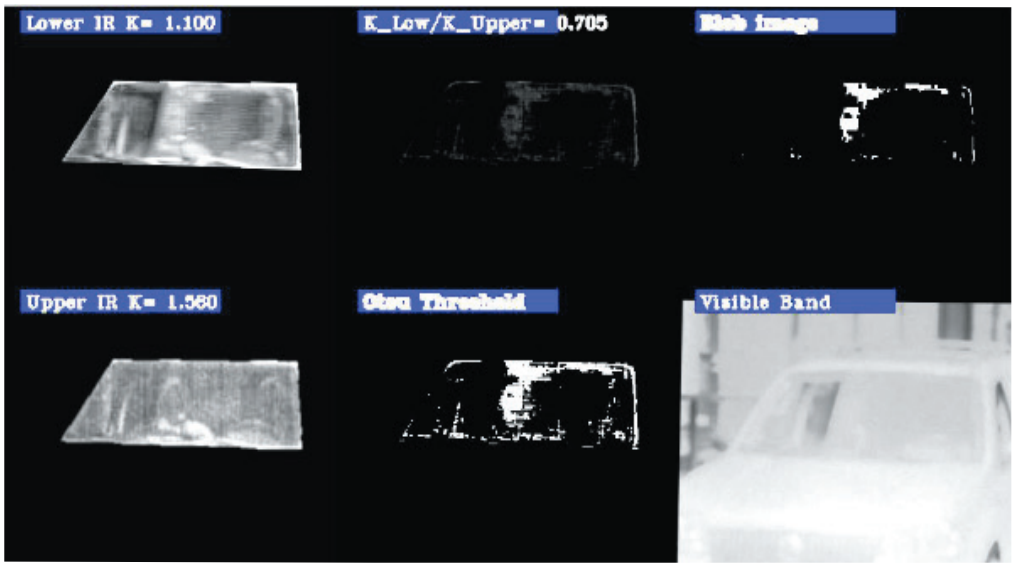
"Some vendors have proposed significant investments in sensing technology for HOV/HOT lane enforcement. This research demonstrated that it's not safe, so the tests saved a lot of money and protected the well-being of drivers."

—Nikos Papanikolopoulos,
Professor, University of Minnesota Department of Computer Science and Engineering

"Development is still continuing in the industry, so we will cautiously evaluate sensing technologies as they come along. This research gave us a solid base of knowledge about what we'll be looking for and what we need to avoid."

—Brian Kary,
MnDOT Freeway Operations Engineer

Produced by CTC & Associates for:
Minnesota Department
of Transportation
Research Services & Library
MS 330, First Floor
395 John Ireland Blvd.
St. Paul, MN 55155-1899
651-366-3780
www.mndot.gov/research



In outdoor tests without supplementary illumination, the sensor was able to detect a passenger through vehicle glass in only one case out of 24 attempts. With illumination, the sensor generally did not successfully detect a person through windshield glass.

tests were conducted both without illumination and with the aid of high-power incandescent spotlights modified to output infrared light, and with the sensor at several different distances from the vehicles.

What Did We Learn?

The indoor tests demonstrated that when aided by supplementary illuminating lasers, the TBI sensor was capable of detecting humans through commonly manufactured vehicle window glass.

However, to achieve successful results, these lasers must operate with high power in a narrow range of wavelengths. Despite operating outside the visible spectrum, they can damage human eyes when operating at the necessary power level to enable effective detection through glass. While investigators conducted this project's indoor tests with adequate protection, there is currently no way to ensure safe usage of the lasers in real-world applications.

In the second outdoor tests, the unilluminated sensor successfully detected a passenger only once out of 24 attempts. With illumination, the sensor successfully detected people in some cases, particularly when there was no direct sunlight or reflective glare. One surprising discovery was that high-band (above 1400 nanometers) infrared light penetrated window glass more consistently, even though the low band had more spectral energy.

What's Next?

Due to safety concerns about using the illuminating laser at a high enough power to penetrate all windshield glass, the system is not suitable for HOV/HOT lane enforcement. There is some indication that sensor technology has improved since the release of the TBI, and MnDOT will continue to monitor industry developments, but it has no current plans to pursue using infrared cameras for this application.

The technology may be suitable for other sensing applications that do not require high-power illumination. For example, the sensors might be useful in systems that provide information to drivers in real time, such as applications that identify available truck parking spaces in rest areas or that alert drivers to the presence of workers in work zones.

This Technical Summary pertains to Report 2017-05, "Sensing for HOV/HOT Lanes Enforcement," published February 2017. The full report can be accessed at mndot.gov/research/TS/2017/201705TS.pdf.