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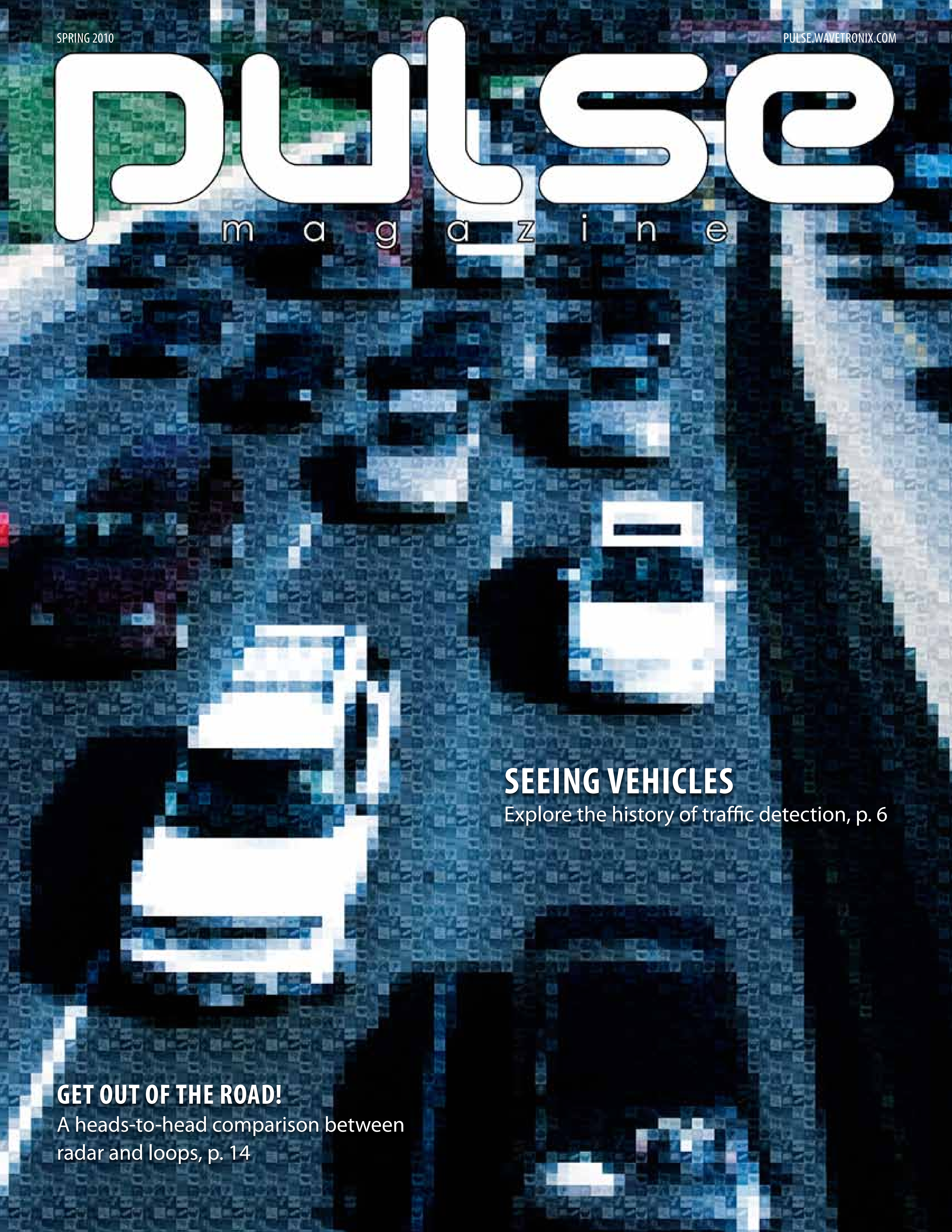

SEEING VEHICLES

Explore the history of traffic detection, p. 6

GET OUT OF THE ROAD!

A heads-to-head comparison between radar and loops, p. 14

The Odyssey of Detection

by Peter Goldin

Nearly a century of innovation has made traffic detection an integral part of modern ITS, and experts say the future is bright for this ever-evolving industry.

Traffic detection technology is critical to the effective operation of today's roads and highways. Today, departments of transportation have a wider range of vehicle detection devices to choose from than ever before — from inductive loops and magnetometers to video- and radar-based detectors. Many of the sensors currently available have been made possible by the latest technology advancements, but it is also important to remember that they are built on almost a century of innovation in traffic detection.

The evolution of traffic detection has been driven by the fact that the growth of traffic volume has consistently outpaced the development of new roads. Detection is one of the vital tools in intelligent transportation systems, providing an alternative to expensive new highway construction by allowing more efficient utilization of the current infrastructure. The continued increase in traffic and the need to manage it, and the advancement of technologies inside and outside the ITS industry, are all factors that have shaped the long history of traffic detection technology.

The Dawn of Detection

In the 1920s, manually-operated traffic signals were replaced with automated signals. Although fixed time controllers changed traffic signals based on typical traffic patterns, transportation officials wanted to base signals on real-time traffic needs, and this appears to be the original motivation behind the innovation of traffic detection technology.

Experts agree that the first known vehicle detector was a sensor invented by Charles Adler, a railway signal engineer. The device included a small microphone that actuated a traffic signal when the driver honked his car horn. The device was first installed at a Baltimore intersection in

1928 and remained in regular service for several years, despite its understandable unpopularity with local residents.

Just weeks after Adler's semi-actuated signal detector installation, a pressure-sensitive detector developed by a Yale University professor was installed in New Haven, Connecticut. The first detector to be embedded in pavement, the pressure detector, also called a treadle, consisted of a rubber pad set into a metal frame that was flush with the road surface. Two metal strips sealed in the rubber pad were brought together by the pressure of a vehicle's wheels, sending an electrical signal to the controller. The treadle remained in use for 40 years.

The second important traffic sensor was the magnetic detector, developed in the 1930s. Also embedded in the roadway, the magnetic detector sensed vehicle motion, which causes a distortion of the Earth's magnetic field.

"Intersection control drove the first traffic detector," explains Brian Taylor, P.Eng., Vice President of Business Development at Pavement Scientific International Inc. "However, it was not long after that pneumatic hose traffic counters were conceptualized and deployed to count cars in a general traffic sense, in the early 1930s."

As the search for improved traffic detection capabilities continued, the 1950s and 1960s saw the launch of several new sensor options, including microwave radars, infrared detectors, magnetometers and most importantly, inductive loop detectors.

In the Loop

The popularity of the inductive loop detector grew quickly, and today it has become the most widely utilized sensor in traffic management systems. One of the major advantages that helped the inductive loop take over the traffic detection market is the ability to detect vehicles that are stopped as well as in motion.

The inductive loop's simple design consists of one or more turns of insulated wire embedded in a shallow slot cut into the roadway surface. A vehicle passing over the loop or stopped within the area enclosed by the loop will absorb some of the radio frequency energy, reducing inductance and causing the oscillator frequency to increase, actuating the detector's output relay. The inductive loop's supremacy in the traffic detection arena remained unchallenged for about 40 years, until less intrusive detection options such as video and radar became advanced enough to offer feasible alternatives that solved some of the inherent challenges of inductive loops.

"The main problem with loops is maintenance," says Gene Hawkins, Associate Professor of Civil Engineering at Texas A&M University. "As the pavement shifts it can break the wires, and the loop no longer functions."

"The roadway environment is very hard on equipment, between temperature variations, chemical spills, and snow removal operations," agrees Barbara Katherine Ostrom, Principal Engineer, MACTEC Engineering and Consulting, Inc. "One agency estimated that in any given month half their loop counters were producing no or bad data."

Transportation authorities try to avoid cutting into pavement to repair loops because it increases the likelihood that the pavement will be damaged. In addition, congested roads limit the ability to get into the roadway for long enough periods to do installation and maintenance. All of these factors have pushed the industry to find new sensor alternatives in recent years.

Above and Beyond

"Societal changes have had a great impact on the evolution of traffic detection," explains Brian Taylor. "Society has always demanded mobility. In the early 1990s, a key element to traffic sensor advancement was the US Intermodal Surface Transportation Efficiency Act (ISTEA), which provided stimulus worldwide for improved mobility, delay reduction and efficiency gains in our transportation network."

Taylor says the attention this initiative garnered included a focus by road operators and agencies on improving efficiency and led to an explosion of sensor technologies, including many non-intrusive sensors. "This program dropped significant stimulus money into the traffic detection business and built immediate demand, which spurred along development efforts," he adds.

Video image processors, microwave and laser radar, passive infrared, and ultrasonic and acoustic sensors are the major new non-intrusive detection devices that have been deployed as alternatives to inductive-loop detectors in traffic management applications during the last decade. These options are considered non-intrusive because they are mounted above or alongside the roadway, making installation and maintenance relatively easy, and alleviating the need to cut into pavement.

"If you can put sensors on poles by the roadway, it is a lot less intrusive on the roadway itself, and becomes more reliable," says Rod MacKenzie, Vice President of Programs and CTO of ITS America. "There are a number of operational reasons for wanting to move technology out of the road surface and onto a pole next to the roadway."

One of the most promising non-intrusive options has been video detection. Originally, video cameras were introduced to traffic management because they could transmit images to a human operator for interpretation. Now image processing software can automatically analyze and interpret images for traffic surveillance and management. A video image processor can replace several inductive loops and provide detection across multiple lanes.

"I have experienced an improvement in non-intrusive detectors in terms of accuracy, cost, and ease of use," says Dan Middleton, Ph.D., P.E., a research engineer and program manager for the Texas Transportation Institute. "For example, video detection has improved to reduce some of the early detection discrepancies dealing with shadows, changing light conditions, nighttime detection, and some weather conditions."

According to Middleton, there was initially a high level of interest in video imaging and other technologies for replacement of inductive loops at intersections and on freeways to reduce traffic delays, reduce damage to pavements due to saw-cutting for loops, and reduce the danger of agency and contractor workers being in or near the traffic stream. "Video was not as accurate as inductive loops, but its non-intrusive nature made it attractive even given the reduction in accuracy," he says. "Many operating agencies have a long-term goal of removing in-pavement sensors due to the noted factors."

A more recent trend is replacement of some video detectors with other non-intrusive technologies that show even more promise. Says Middleton, "One example of the newer detectors is for dilemma zone detection where video tends to miss inter-vehicle gaps and extend the main street green phase unnecessarily. There are also ongoing issues with video in certain lighting conditions at the stop line, so I expect the use of technologies that are not as affected by weather and light conditions to replace video in coming years."

Brian Taylor points out that digital electronics has been another essential factor in the evolution of modern traffic detectors. "The ability to build low power, low cost devices changed the way users, and hence manufacturers, looked at these devices," Taylor says. "The introduction of digital technology made other technologies, such as radar, affordable. I am impressed with the non-intrusive sensors and advancements made in this area of sensing over the past few years. The radar-based sensors are definitely improving and becoming the standard sensor for freeway traffic management applications."

Radar, which transmits electromagnetic signals and receives echoes to detect vehicles, was first used in the 1950s but recent advancements in the technology have made it a top traffic detection option in the last decade. The radar sensor may be mounted over the middle of a lane to measure traffic flow in a single lane, or at the side of a roadway to measure traffic across multiple lanes, and it can be used to measure traffic volume, speed and vehicle length.

Embedded vs. Non-Intrusive Detection

The last decade or more of traffic detection history has been marked by the debate over the proven accomplishments of embedded loop detectors versus the notable advantages of non-intrusive technologies such as video and radar. While inductive loops remain the most widely deployed traffic detection devices, the industry seems to be shifting attention to non-intrusive technologies. Many industry experts see the move toward non-intrusive alternatives as a direct reflection on the limitations of inductive loops.

"In my opinion, the main driver that has created this move from intrusive to non-intrusive sensors is the perceived failure rate of loop detectors, and the expense and cost of repairing and maintenance," notes Taylor. "Non-intrusive technologies have a significant number of advantages by not being in pavement. Advancements in freeway traffic management systems require a great number of detection points, making a side or overhead non-intrusive technology very practical and affordable. Multi-lane sensors also improve the overall cost-effectiveness of deployment."

Gene Hawkins agrees. "The technology continues to advance and the cost continues to decrease," Hawkins says. "I could see a scenario where non-intrusive detection technologies become the de facto mechanism, but in some cases that would mean installing them in places where they are not installed right now."

Middleton believes more and more non-intrusive detection will be used but the inductive loops that are still working today will continue to function for several years.

"If newer detectors are as accurate as inductive loops for traffic operations applications, then the new detectors will likely replace the failing loops," Middleton predicts. "To the contrary, planning agencies will continue to have a need for in-pavement detection for vehicle classification and weigh-in-motion."

Taylor also believes that non-intrusive will never completely replace intrusive, or in-pavement, technologies. "I approach this from a systems perspective, where certain sensors have an advantage over other sensors. Therefore, I believe that the optimum system is made up of technologies that can overlap, and fill the weaknesses of the others," he says. ■

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Peter Goldin is a freelance journalist specializing in transportation and technology. He has written for magazines such as ITS International, World Highways, and the ITS Daily News at the ITS World Congress. Mr. Goldin can be reached at pgoldin@ix.netcom.com.

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