Infrared Technology and Applications to Autonomous/Self Vehicles, a Global Session in Infrared Technology and Application Conference

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Last year over 37,000 people were killed in automotive collisions in the USA by human driven vehicles, and only one by a self-driving vehicle (SDV), and infrared imagery may have prevented that fatality. SDVs have the potential to transform modern society and immeasurably increase the human condition (Table 1). It is inevitable that this will happen and, likely, children born this year will never learn how to drive, just like most of us reading this, can't command a buggy-whip. Human driven cars will be soon relegated to a sport and hobby.

TABLE 1: Benefits of Autonomous Driving Vehicles:

- Increased Safety
- Increased Productivity
- Lower Product Costs
- Increased Comfort
- Mobility and Independence for the Aged and Disabled
- Reduce Pollution and Carbon Emissions
- Reduced Traffic Congestion

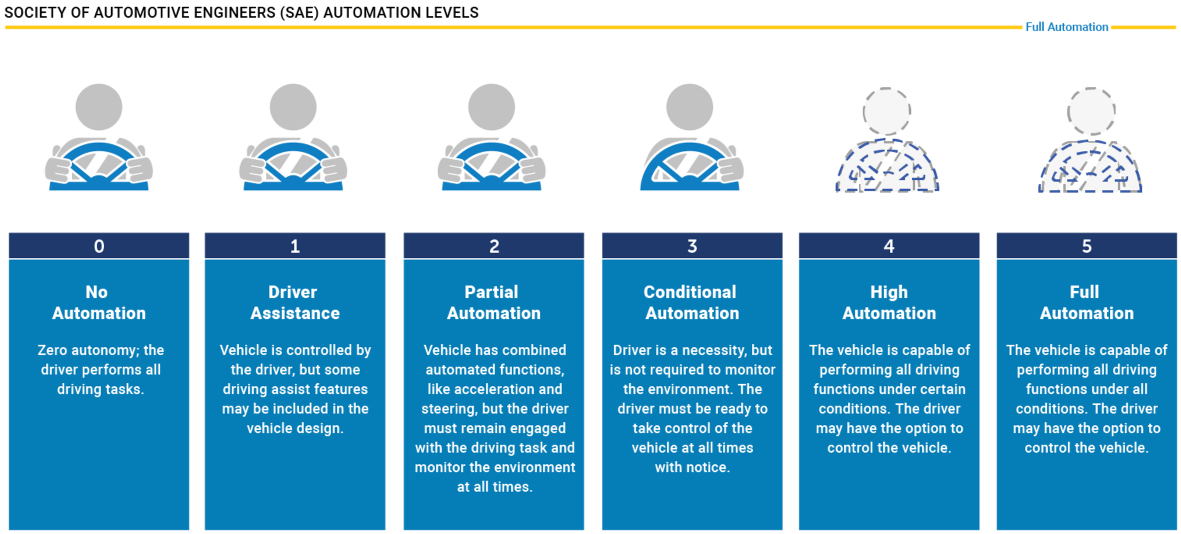
Infrared technology holds the promise to enable these safe autonomous/ Self Driving Vehicles (Table 2). The road to fully autonomous vehicles will likely employ infrared imagers, lasers and LIDARS. The chairs plan to initiate an annual global key and pivotal session of speakers on the application of infrared to self-driving vehicles (from commercial cars, industrial trucks, home delivery systems and military vehicles).

TABLE 2: Features and Benefits of Infrared Technology

- Unassisted Night Vision
- Long range situational awareness
- Excellent Human and Animal Detection
- Enhanced Vision thru Fog and Smoke
- High Resolution Imagery
- Eyesafe Lasers and LIDARs

Papers in our conference on any technique (including thermal imagers, LIDAR etc.) are encouraged. Participating will allow you to describe and promote your technologies to other attendees from laboratories, governments, auto companies and companies. You can expose your technology and techniques and reach potential collaborators, funding sources and customers. The conference is Infrared Technology and Applications, XLV, in Baltimore from April 14 to 18, 2019.

A number of today's new motor vehicles have technology that helps drivers avoid drifting into adjacent lanes or making unsafe lane changes, that warns drivers of other vehicles behind them when they are backing up, that brakes automatically if a vehicle ahead of them stops or slows suddenly, among other things. These and other safety technologies use a combination of hardware (sensors, cameras, and radar) and software to help vehicles identify certain safety risks so they can warn the driver to act to avoid a crash. When all systems are operating properly, self-driving vehicles do not get tired, distracted, inebriated, panic or overdrive their capability. The artificial intelligence required by self-driving cars, needs sensory input from multiple phenomenologies. It will progress in defined steps as proposed by the Society of automobile Engineers (Figure 1).



SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Figure 1: 6 step levels of automation defined by the SAE. Figure Courtesy of the US Government (National Transportation Safety Agency), found at: www.nhtsa.gov/technology-innovation/automated-vehicles-safety

According to the US National Transportation Safety Agency: "A number of today's new motor vehicles have technology that helps drivers avoid drifting into adjacent lanes or making unsafe lane changes, or that warns drivers of other vehicles behind them when they are backing up, or that brakes automatically if a vehicle ahead of them stops or slows suddenly, among other things. These and other safety technologies use a combination of hardware (sensors, cameras, and radar) and software to help vehicles identify certain safety risks so they can warn the driver to act to avoid a crash. The continuing evolution of automotive technology aims to deliver even greater safety benefits and – one day – deliver Automated Driving Systems (ADS) that can handle the whole task of driving when we don't want to or can't do it ourselves."[1]

Traffic in cities will become more congested and commute times increase due to the increased volume and/or people moving further away from their workplaces and airports. Eventually, self-driving vehicles will allow all passengers to talk on the phone, answer e-mails and otherwise work; all increasing productivity. As human productivity increases, so does personal wealth, corporate profits and global gross domestic product.

When freight is transported between ports and warehouses and stores via automated vehicles the consumer product price of an item will decrease, allowing for personal higher purchasing power. Additionally the price home deliveries of food, and other products will be reduced, while accuracy and reliability increased. This will displace some jobs, but it is expected that it will create many high paying engineering and technical jobs to enable and maintain this capability, just like computers did in the past.

Even at lower levels of Automation, passenger comfort is increased, and is especially so at the high levels. One can sleep, practice hobbies and play games while being safely transported by an automated vehicle. See the future cabin of a car as envisaged by Guardian Optical Technologies (Figure 2).

Figure 2: A Future car interior, figure courtesy Guardian Technologies.

Another large social benefit is the increased independence and mobility these will afford the aged and physically challenged. Humans that currently cannot drive, will be able to go anywhere they want at any time. The old adage of being a “Shut-in”, will disappear!

Operation of artificial intelligence vehicles will be more efficient, due to optimal control of acceleration and gears for the existing and near future condition (e.g., sensing the upcoming curve or hilltop). Additionally, they will eventually communicate with each other and all start instantly when a light turns green (like a train), this significantly speeds up the process of a line going through a light, saving energy and reducing congestion. These efficiencies reduce the pollution and carbon footprint from a vehicle.

Several issues remain, as explained in the following from Wiki: “In spite of the various potential benefits to increased vehicle automation, there are unresolved problems, such as safety, technology issues, disputes concerning liability, resistance by individuals to forfeiting control of their cars, customer concern about the safety of driverless cars, implementation of a legal framework and establishment of government regulations; risk of loss of privacy and security concerns, such as hackers or terrorism; concern about the resulting loss of driving-related jobs in the road transport industry; and risk of increased suburbanization as travel becomes less costly and time-consuming. Many of these issues arise because autonomous objects, for the first time, would allow computer-controlled ground vehicles to roam freely, with many related safety and security concerns.” [2]

Current autonomous/self-driving cars use LIDAR, radar and visible sensors. The LIDAR provides high range and velocity resolution 3d points and grid of the dynamic surroundings, but has limited range due to its light source. Any LIDAR employed will likely be in the SWIR for eye-safety issues.

One key spectrum is the infrared; although providing complete night vision, it also has smoke, haze, and fog penetration capabilities superior to the visible. Although MMW (millimeter wave) and Radar outperform Infrared in the latter, they are resolution challenged. Moreover, eyesafe lasers for LIDARs (imaging or not), also operate in the infrared spectrum, as eye safety becomes much easier to obtain at wavelengths beyond 1.5 microns.

“A car traveling at 70 miles per hour would have just four seconds to respond to an obstacle. The angular resolution is also too low to make out an object that’s far away, because the laser beams will be too spread out to return a viable image. As a result, many autonomous cars use data from other sensors to help recognize obstacles, even if they have LIDAR sensors on board. [3]

Infrared LIDAR is a key to SDVs, but the cost must be reduced to consumer affordable levels. “But existing systems “remain very, very niche,” said Arunprasad Nandakumar, market analyst at Frost & Sullivan. And expensive. The price of a LIDAR system needs to plummet to a few hundred dollars for any chance at mass deployment. He believes that will happen. He forecasts sales of 6 million LIDAR units in 2025 — half of them complex lidars needed for driverless cars, for a $2-billion market. (The rest are simpler, single-beam lidars used to detect pedestrians and other obstructions.)” [4]

In addition to other modalities, Radar provides lower resolution 3d data in all weather conditions and the visible sensors provide high resolution conventional 2d imaging.

Another application of infrared in SDV is passenger awareness in the car. This is to determine if the back-up human driver is conscience, how many people are in the car for safety system activation and balance and performance issues.

Infrared sensors may find their way into self-driving public transportation such as buses and shuttles. “The coming age of driverless cars has typically centered on Silicon Valley highfliers like Tesla, Uber and Google, which have showcased their autonomous driving technology in luxury sedans and sport utility vehicles costing $100,000 or more. But across

Europe, fledgling driverless projects like those by Deutsche Bahn are instead focused on utilitarian self-driving vehicles for mass transit that barely exceed walking pace.”[5]
Also in the future, boats, taxing aircraft and low flying UAVs.

SWaP-CR (Size, and Weight, Power and Cost and Reliability) considerations are paramount for large acceptance of IR technology into this application. Especially cost, with imagers and lidars desired to be under $500 in production. Producibility is another concern as the volumes are of a scale not presently achieved by any infrared sensor of this nature (some SWIR telecom applications are the exception). Depending on where the sensors are mounted, environmental and reliability may also be unproven issues.

Some believe the roots of SDVs were started with power steering, automatic transmissions and cruise control in the 1960’s, although it was considered as early as the 1920’s. In the late seventies, Tsukuba (in Japan) developed a vehicle that could go 30 Km/hr using coded paint and an elevated rail on roads. However; DARPA was fundamentally instrumental in true autonomous development. Staring in 1984 with their award to Martin Marietta for an Autonomous Land Vehicle (ALV) contract (one of the authors –Miller, had a small IR sensor role on this project). The University of Maryland, Hughes, University of Southern California and ERIM were key subcontractors. This vehicle was the size of a small van jammed with processors, and have imagers and laser rangers, but was able to autonomously roam the Martin Denver facility. DARPA followed almost two decades later with the Grand Challenge series of autonomous vehicle challenges. The first was in 2004, no vehicle completed it; Carnegie-Mellon’s, went the furthest. There were other more difficult challenges in 2005. 2007, 2012 and 2013, with much better results from several competition teams.

As the world’s largest infrared technology conference, we invite papers on any sensor technology used in self-driving vehicles that is in the infrared spectrum (beyond the visible and shorter in wavelength than millimeter wave).

We have an open invitation to present papers by:

- Driverless vehicle developers
- Users of infrared imaging detector and system developers
- Developers of military and commercial systems with applicable sensor technologies
- Developers of infrared components for self-driving vehicles.
- Application of Infrared technology to self-driving military vehicles
- “In- car” passenger awareness sensors
- SWaP-C boundaries and concepts for meeting requirements for SDVs.

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