POINT OF VIEW | AUTOMOTIVE

The Future of Autonomous Driving: Driver Sentiment Monitoring Analysis

MAY 2021

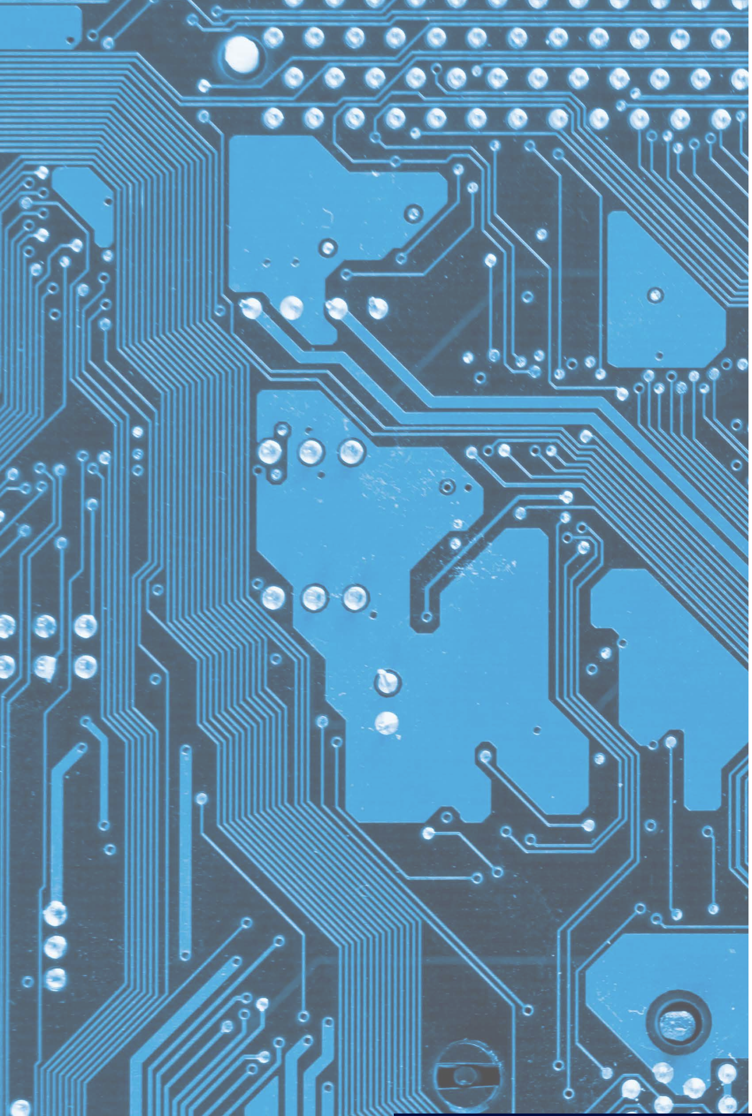


Table of contents

Executive summary

The automotive industry regularly sees major news articles published about emerging advanced driver assistance systems (ADAS) and autonomous driving (AD) technology. Whether it's a collaboration between automotive manufacturers or partnerships and alliances with suppliers/technology providers, the automotive industry is racing toward enhanced ADAS features. The goal: to implement automated driverless features for safety and electric mobility.

Recently, all major automotive manufacturers have made commitments to accelerate the inclusion of ADAS/AD features in new vehicles. Drivers, however, remain skeptical about these advanced features; it's a matter of trust in the technology and personal comfort while operating a vehicle. Both the automotive and the technology industries are investing heavily in developing more mature systems so drivers will become comfortable enough to embrace these features — sooner rather than later.

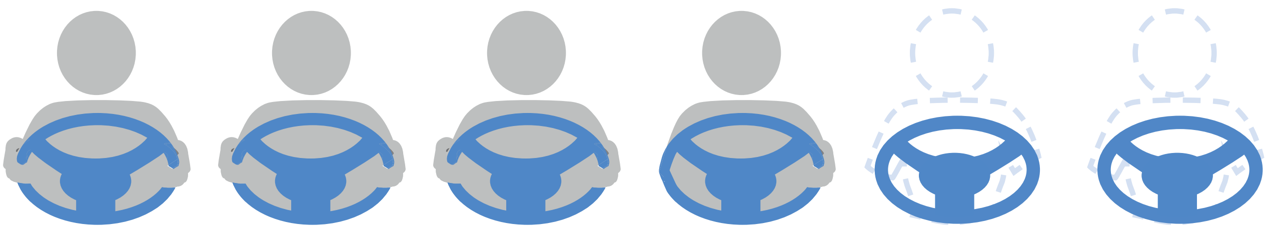
Technology maturity will play a big role in gaining drivers' trust, but the key is the ability to understand individual driving preferences and drivers' feelings or emotions. This will provide insight into how to further fine-tune the characteristics of ADAS/AD features to make these systems more widely accepted. But how do we read and analyze real-time driver sentiment — during the act of driving — and use that information in a meaningful way?

This paper explores the rise of ADAS/AD technology and presents a developing concept of driver sentiment monitoring analysis for specific driving events to bridge drivers' trust in and comfort with active safety features.

The journey to autonomous driving

The journey from driver assistance systems to AD started more than 40 years ago. It started with the introduction of features, such as anti-lock braking and cruise control, continued with recently introduced features like the Tesla Autopilot and now sees automotive manufacturers and component suppliers focusing on ADAS-related features that will lead to fully automated driverless vehicles. To better understand the progression from ADAS to AD, standards organization SAE International defines six levels of driving automation. Levels 0–2 cover driver support features, while Levels 3–5 include automated driving features. (Figure 1).[1]

In Levels 0–2, automation capabilities include lane departure and blind spot warnings, features defined primarily as driver support aides. These features provide passive safety to the driver, who always has full control of the vehicle, and have been in the market for some time now. They've almost reached full maturity, and drivers are comfortable using them. Active safety features such as automatic emergency braking and lane keep assist are among the capabilities leading us toward fully automated driverless vehicles.



0	1	2	3	4	5
No automation	**Driver assistance**	**Partial automation**	**Conditional automation**	**High automation**	**Full automation**
Manual control. The driver has total control of all driving tasks.	The driver maintains control, but there's a low level of driver assistance such as cruise control.	Advanced driver assistance. The vehicle can perform automated functions like acceleration and steering, but the driver must remain engaged at all times.	Environment detection. The vehicle can mostly drive on its own, but the driver must be ready to take control at any time.	The vehicle can perform all driving functions under specific circumstances. Driver override is available.	Zero driver attention or interaction required. The vehicle can perform all driving functions under any circumstance.

Figure 1: The levels of driving automation[1]

Levels 3–5 include automated driving features like traffic jam assist. The market for these more advanced options is expected to grow significantly by 2030.[2] Automotive manufacturers, component suppliers, and semiconductor and technology companies are investing heavily in cutting-edge technologies to further mass adaptation of automated driving features more quickly than was previously anticipated.

Consumer sentiment: What's driving concern and how is the industry responding?

While automotive manufacturers are moving toward offering more features related to ADAS and AD, the question remains: How are drivers accepting and adapting to these new features? Many studies and surveys have been done to better understand just that. One U.S. survey by Consumer Reports indicates that drivers readily accept passive safety features that provide visual and audible warnings.[3]

> Younger drivers tend to be more willing to trust technology than older drivers when it comes to active safety features.

When it comes to active safety features, drivers are starting to embrace them more. Approximately 84% of consumers are very satisfied with blind sport warning features and 69% are comfortable with automatic emergency braking.[2] A generational divide also plays a role in adapting to ADAS/AD features. Younger drivers tend to be more willing to trust technology than older drivers when it comes to active safety features. Yet drivers remain mostly skeptical about automated driving.

Technology maturity and safety are drivers' biggest concerns at this point. They're hesitant to fully trust that a system could adapt and maneuver a vehicle in unique, real-time driving scenarios better than a human driver can. It even leads some drivers to deactivate active safety ADAS features currently present in their vehicles.

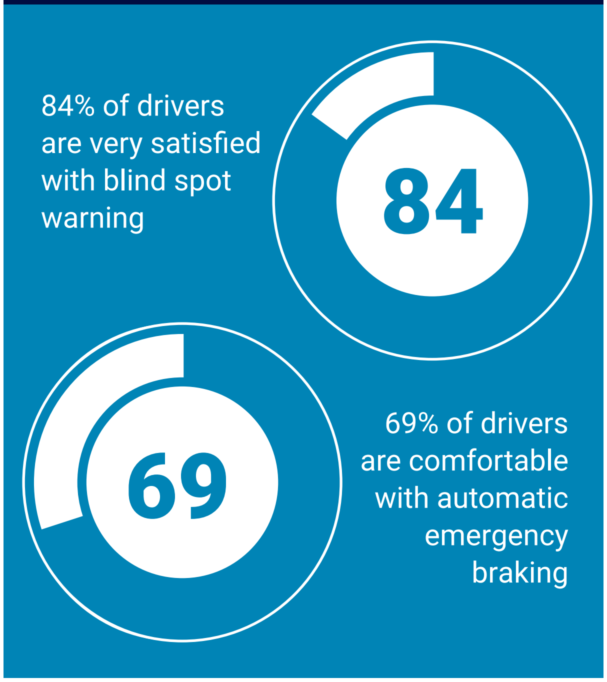
The automotive industry faces significant challenges in reaching mass adoption of autonomous vehicles. To overcome this, they're investing heavily in three major areas:

- Sensing technology like LiDAR, radar, camera and ultrasonic
- Semiconductors for computing power
- Software like artificial intelligence (AI), deep learning and machine learning

According to a recent McKinsey & Company report, the ADAS/AD sensor market will grow to approximately US$43 billion between 2020 and 2030 while the software market is expected to reach approximately US$28 billion by 2030.[3] A significant amount of work is also being done in system integration and validation through simulation, which creates unique driving conditions to improve the performance of ADAS/AD features.

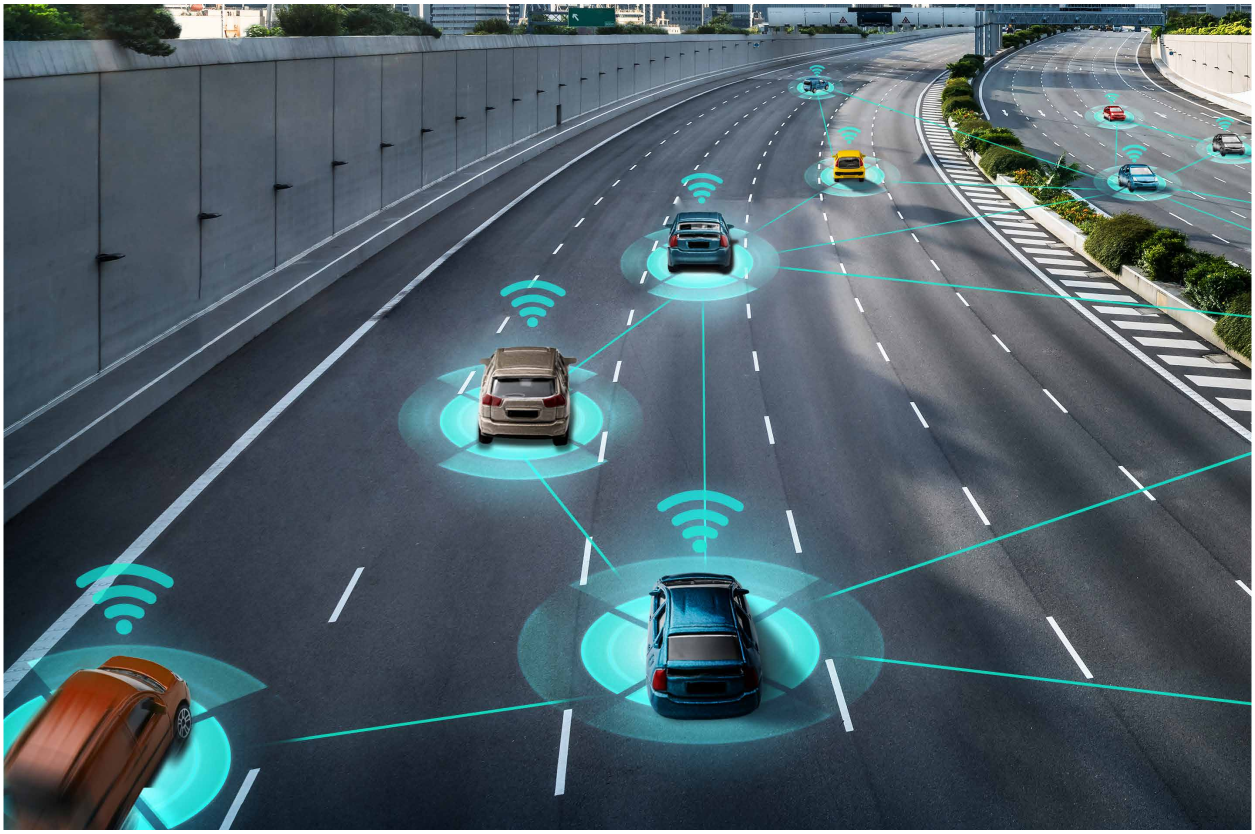
While the industry is focusing primarily on technological improvements, system integration and validation to improve performance and maturity, there's also a growing need to understand consumer feelings and experiences in real time — as these features are used during the act of driving. Understanding driver sentiment while operating a vehicle can unlock the potential to adjust ADAS features to such an extent that all drivers will start to feel comfortable with the systems and, hopefully, use them more frequently. Recognizing the benefits of such a capability, several automotive manufacturers are working to develop analytical methods or systems to understand real-time driver sentiment as it relates to specific driving events.

Figure 2: Drivers are starting to accept active safety features



Driver sentiment monitoring analysis solutions in the market today

While no true automotive-grade solution for driver sentiment monitoring analysis exists in the market today, every major ADAS/AD component supplier has some form of camera-based driver monitoring system to detect driver distraction and/or drowsiness. Beyond the component suppliers, some startup companies are using AI-based approaches to further enhance these systems to detect human expressions. Solutions from companies like Cipia[4] and Affectiva[5] are gaining attention in the market. Both companies combine camera-based systems with AI software to expand features to in-cabin occupant monitoring. However, none of these systems can predict a driver's more complex emotions or state of mind in relation to a specific driving event. To uncover these sentiments, NTT DATA has developed a proof of concept that connects a driver's emotional and cognitive responses with an actual driving event, and then uses that information to predict the occurrence of a similar critical event about 500 milliseconds to 1 second before it happens.



Connecting driver emotion with driving events: A proof of concept

NTT DATA wants to take driver monitoring systems to the next level. Our concept correlates real-time driving events with a driver's sentiment (emotional and cognitive) leading up to and during that event, simultaneously processing three dimensions of data — human, vehicular and environmental — using the vehicle's existing hardware in conjunction with complex AI models:

1. Human emotions achieved through the real-time recognition of:

- Facial expressions during critical situations or different driving maneuvers
- Estimated level of distraction and focus on the road during the drive
- Drowsiness detection and estimated level of tiredness

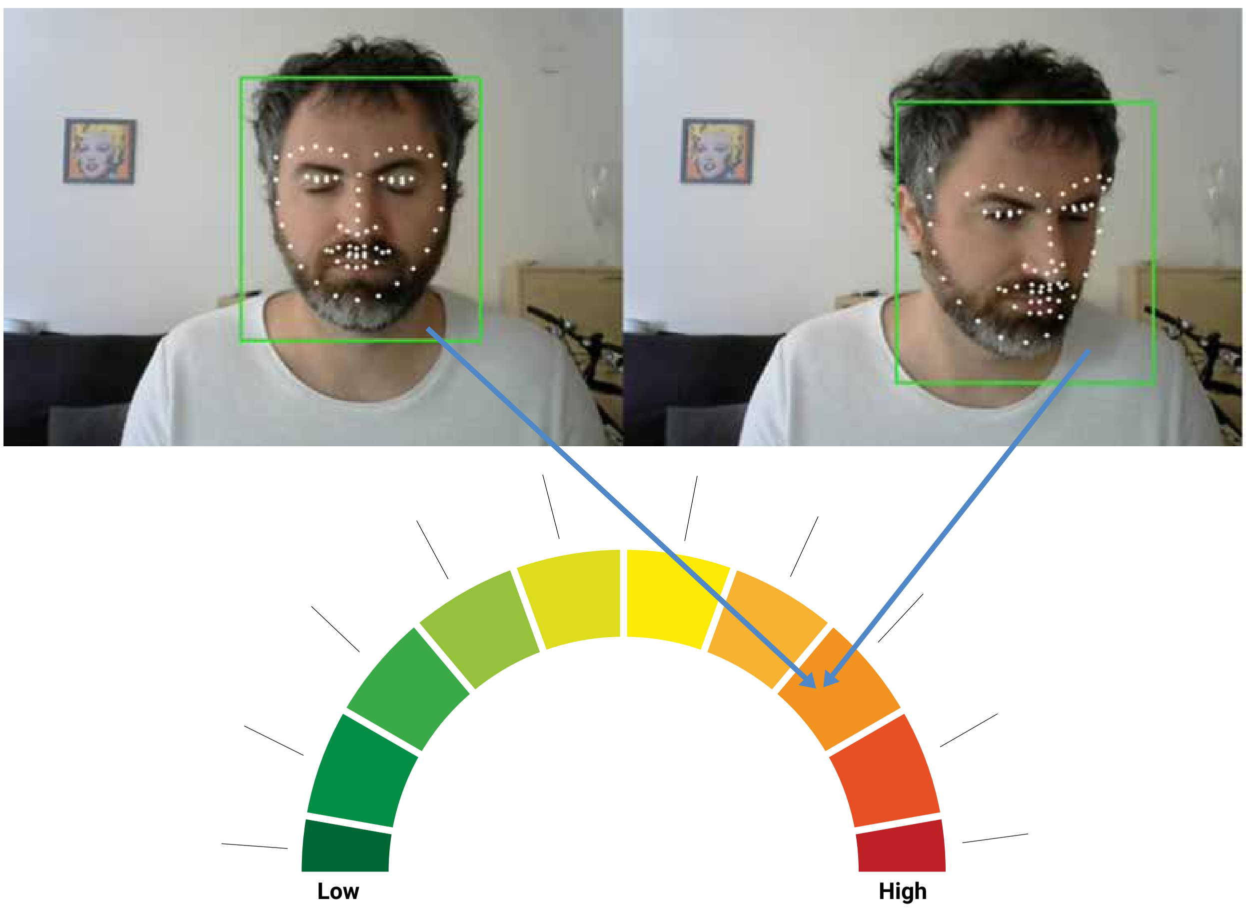


Figure 3: Measuring distraction levels

2. Vehicle dynamic achieved through vehicle controller area network (CAN) data processing by:

- Analyzing historical and real-time CAN signals
- Enabling the system to project a critical event (like cutting into another lane or suddenly braking) approximately 500 milliseconds to 1 second before it occurs

3. Environmental characteristics (road conditions) achieved through real-time:

- **Navigation services** — necessary to determine if the current vehicle position is on an urban road, off road or on a highway, and where there is traffic congestion
- **Front camera video processing** — necessary to recognize objects/obstacles in front of the vehicle and classify them in different groups (such as car, truck, pedestrian, bike, traffic light or stop sign); it's equally important to understand the critical driving event an obstacle causes and/or the current driving rules by analyzing vehicle CAN signals (for example, sudden braking because of a traffic light)
- **Weather forecast service** — necessary to determine weather conditions (such as, icy road, low temperatures, heavy rain and fog), which significantly change driving perception

Powerful edge-computing platforms combined with cutting-edge radar technology and an audio feed can significantly improve the robustness of the system. Radar is capable of detecting a driver's vital signs, such as heart or respiratory rate, for any stress or irregularities while the driver's audio feed, as well as that from any other vehicle occupants, provides additional information about the driver's state of attentiveness during vehicle operation. Figure 4 shows the driver sentiment monitoring system within the concept's system-level architecture.

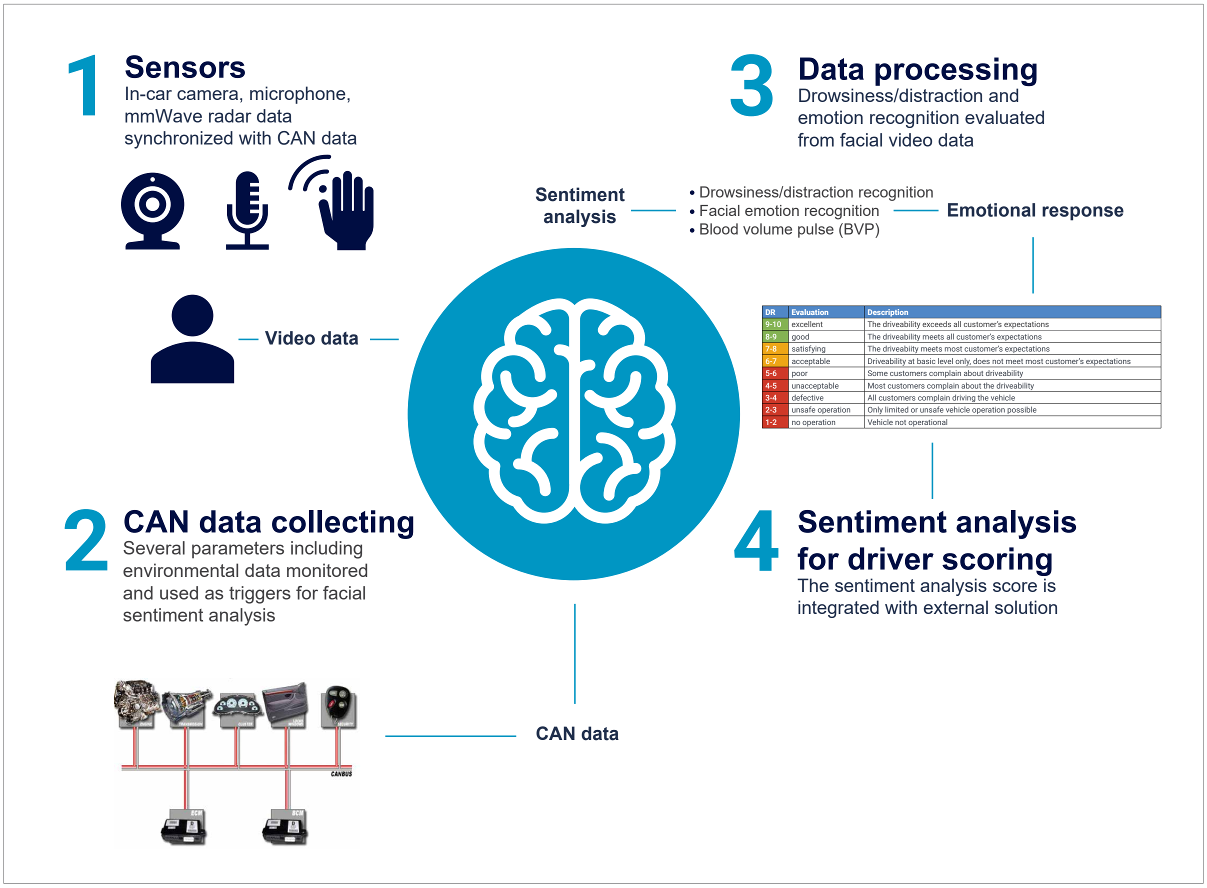


Figure 4: Driver sentiment architecture

AI-based software models deliver accuracy and performance

The software architecture, along with the design approach, is a critical aspect of the system. Software is designed with AI-based models for various components in a modular manner; these models are fused together to achieve the predicted outcomes. The combination of machine learning, deep learning and statistical methods is used to simultaneously analyze real-time sensor inputs, vehicle data and environmental data to calculate and predict the output of various modules of the software architecture.

Various weighting factors are used to determine the criticality of an event and synchronize it with the driver's emotion prior to/leading up to the critical driving event. The basic driver emotion for a given critical event can be categorized as neutral, startled or afraid. However, our model and algorithm can predict a broader spectrum of a driver's emotional state or cognitive sentiment — from anger, disgust and fear to happiness, sadness, surprise and neutral.

NTT DATA and AVL North America jointly presented this concept at the CES 2020 tech event.[6] It was well received and generated positive interest. NTT DATA and AVL North America also demonstrated basic driver sentiment analysis using only a single off-the-shelf camera to monitor a driver's expression, and the model was able to predict driver sentiment leading up to a critical driving event like aggressive braking. (See Figure 5 for a dashboard view of the demonstration.)

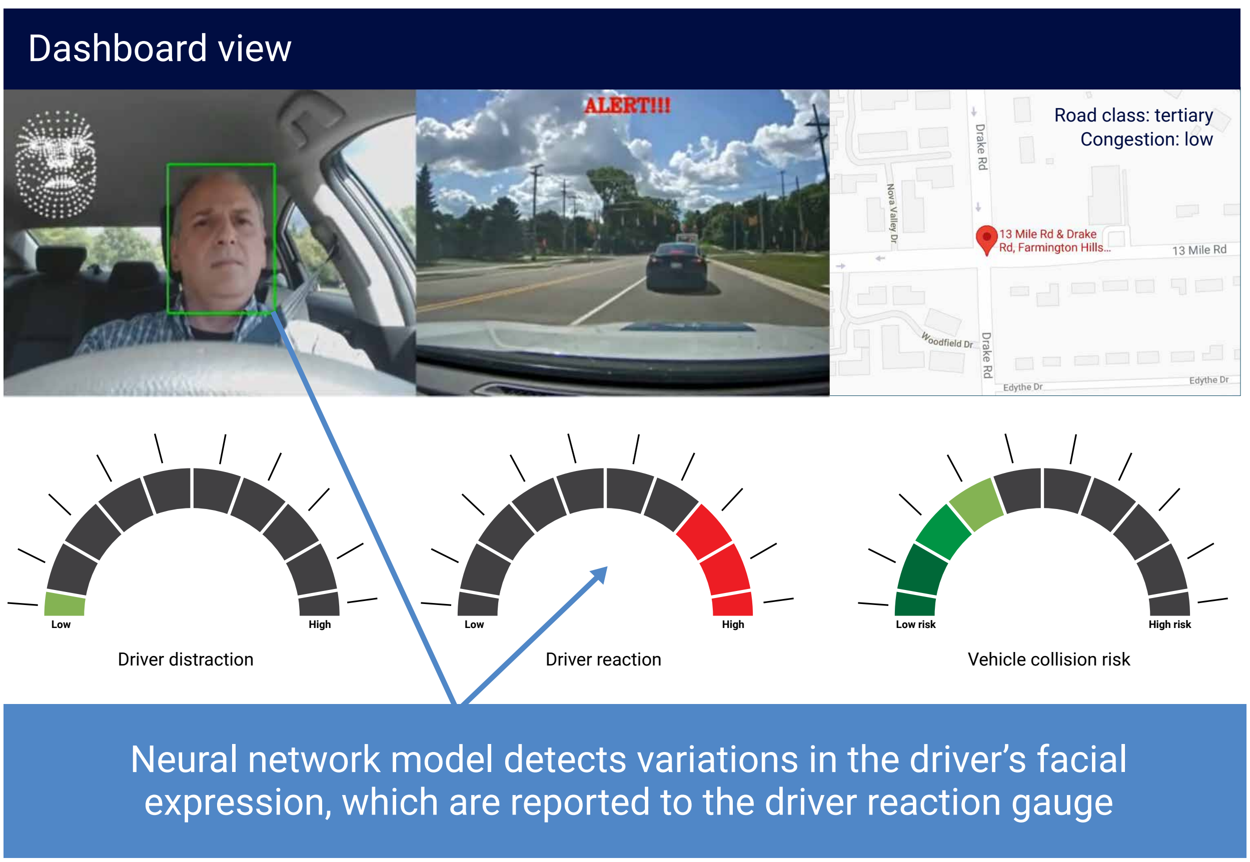


Figure 5: Dashboard view of a driver's response to a critical driving event

Conclusion

The automotive industry is investing heavily in the race toward autonomous vehicles. Drivers, however, remain hesitant to embrace ADAS/AD features for several reasons — primarily the safety and maturity of the technology to address all unique use cases that can emerge at any given time while driving. Drivers' emotions and preconceived perceptions, and the real-time monitoring and analysis of these sentiments, will play a key role in the adaptation of new technologies within autonomous vehicles.

Understanding real-time driver sentiments or emotions during the operation of a vehicle with ADAS/AD features can vastly improve the performance of these features. Sentiment monitoring analysis offers an opportunity to further customize key performance parameters based on an individual driver's personal preference or comfort level. It can also provide a wealth of information to ADAS/AD system suppliers or original equipment manufacturers, during development and post-production to help developers adjust and fine-tune key feature characteristics. This will help drivers feel more comfortable using these features, and further the quicker adoption of automated driving capabilities.

With more vehicles being connected to the cloud every day, the opportunity to gather real-time data in conjunction with driver sentiment data can lead to deeper analysis using AI-based models, features fine-tuned to an individual driver's preferences and vehicle software updated over the air for faster and safer proliferation of ADAS/AD features. All this is possible in the very near future.

The NTT DATA proof of concept presented in this paper could lead to more dedicated research and development into technologies that can accelerate the adaptation and proliferation of ADAS/AD features and, eventually, autonomous vehicles throughout the world.

About the author

Hasib Hassan, Business Development Strategic Advisor, NTT DATA

Hasib focuses on in-vehicle embedded software and how it connects with NTT DATA's rapidly growing connected car, mobility and autonomous driving capabilities. As a key contributor and spokesperson for NTT DATA, he's often called on to engage in thoughtful discussions with clients and analysts on topics such as connectivity, automotive cybersecurity, ADAS/AD and electrification. Hasib has more than 26 years of experience in automotive electronics product development, management and technical sales. Prior to joining NTT DATA, he held various global leadership and key engineering positions with L&T Technology Services, Magna Electronics, Cummins, Ford Motor Company and Chrysler Corporation. He holds a bachelor's degree in Electrical Engineering from State University of New York at Stony Brook and authored seven patents.

Sources

1. SAE International. “SAE Standards News: J3016 automated-driving graphic update.” January 2019. https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic

2. Ondrej Burkacky, Johannes Deichmann and Jan Paul Stein. “Automotive software and electronics 2030.” McKinsey & Company. July 2019. https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/mapping%20the%20automotive%20software%20and%20electronics%20landscape%20through%202030/automotive-software-and-electronics-2030-final.pdf

3. Consumer Reports. “Auto Safety Report.” November 2017. https://data.consumerreports.org/wp-content/uploads/2020/05/auto-safety-report.pdf

4. Cipia Solutions. https://cipia.com/

5. Affectiva Solutions. https://www.affectiva.com/

6. AVL North America. https://www.avl.com/?avlregion=NA&groupId=1981533&lang=en_US

Visit **nttdataservices.com** to learn more.

NTT DATA Services, a global digital business and IT services leader, is the largest business unit outside Japan of NTT DATA Corporation and part of NTT Group. With our consultative approach, we leverage deep industry expertise and leading-edge technologies powered by AI, automation and cloud to create practical and scalable solutions that contribute to society and help clients worldwide accelerate their digital journeys.

NTT DATA
Trusted Global Innovator