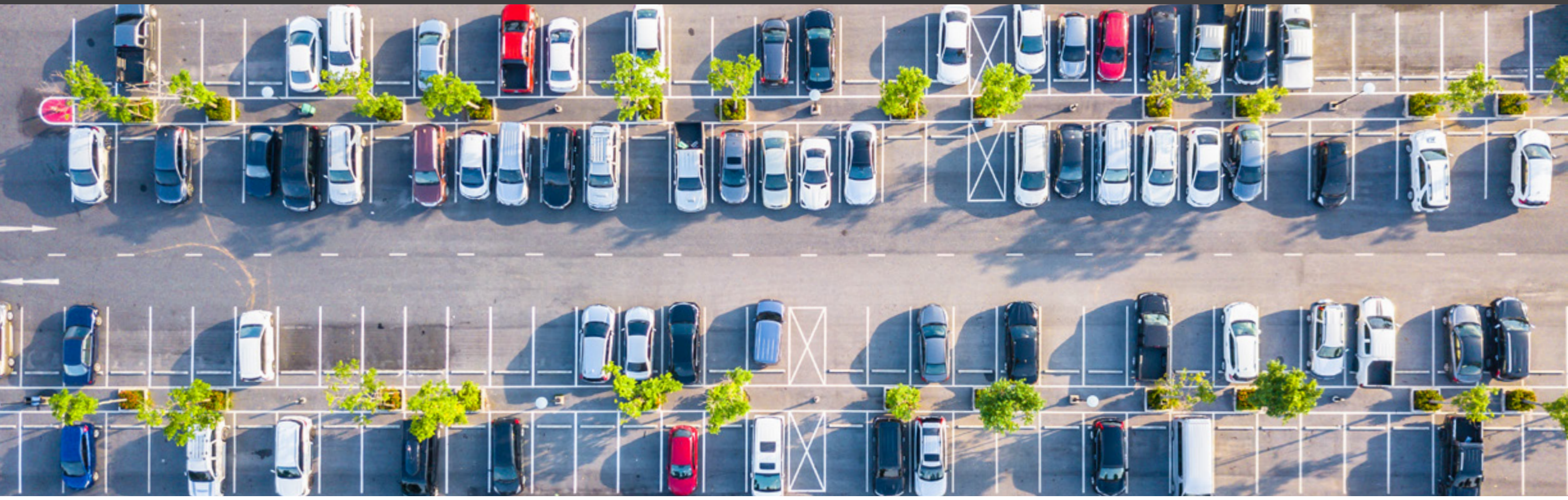


Intelligent Approach Expands Possibilities for Parking Automation

Parking assistance features like proximity warnings and driver-monitored hands-free parking have become common conveniences across most vehicle classes.

But as consumers increasingly demand more advanced parking features, it is becoming clear that autonomous parking systems must be designed as safety-critical technologies, not just as mere conveniences. A vehicle that is parking itself must be fully aware of nearby pedestrians, cognizant of all the available space around it and intelligent enough to use that information to execute the maneuver safely and efficiently.

That means that technologies used in advanced driver assistance systems (ADAS) for driving on local streets are critical to ensuring higher performance and safety when it comes to parking assistance. The same sensors and machine learning intelligence that power ADAS in complex urban driving scenarios and in difficult lighting and weather conditions will play key roles in automated parking as it evolves.

THE UNIVERSAL CHALLENGE

Parking is the expected conclusion of every vehicle trip, but the conditions under which this occurs can be as varied as an empty, well-lit parking garage, a driveway at night or a crowded parking lot in a rainstorm. Whether nosed in, backed in or parallel parked, every vehicle is expected to safely come to rest.

Automating that function across all conditions starts with robust sensing and perception capabilities. While many parking automation features rely primarily on ultrasonic sensors and cameras, state-of-the-art radar enhanced with artificial intelligence and machine learning (AI/ML) has significant advantages over other forms of sensing. Using radar to interpret a parking environment transforms the way in which a vehicle can plan and carry out parking tasks.

Enhanced radar data, fused with inputs from cameras and ultrasonic sensors, enables safe, reliable parking features with increasing levels of vehicle automation. For example, vehicles can use radar to identify an open parking space from a sufficient distance to pull into it directly, without going so slowly as to frustrate nearby drivers. Other sensing modalities often require the vehicle to first drive past the space when traveling at typical parking lot speeds. Intelligent systems can also map a parking area and be trained to navigate it later, and radar will let Level 4 autonomous cars safely drive away to park themselves in a garage and return on demand.

EFFICIENT, ROBUST PERCEPTION

Radar has significant advantages over both vision and ultrasonic sensors, creating more robust 360-degree sensing under a wider range of conditions. Because of these advantages, radar is increasingly becoming foundational for a wide range of ADAS features, but radar's advantages also enable OEMs to create parking features with greater capabilities over a broader operational design domain.

Compared with ultrasonic sensors — core components of many parking assistance systems — radar offers much longer range: potentially five to 10 times farther. This extended range significantly improves collision avoidance and enables new parking actions. For example, ultrasonic sensors can measure the size of a parking space only when directly in front of it, forcing the vehicle to drive past the space, back up, and return to enter it. Radar detects a suitable space between two parked vehicles from a farther distance, allowing the vehicle to directly maneuver into it.

In addition, recent advances in radar have expanded its field of view vertically so it can detect overhanging obstacles, such as tractor-trailer rigs or objects extending from the bed of a pickup truck.

Radar has key advantages over vision systems for accurately perceiving distance and distinguishing among objects. Radar detection inherently provides the distance to an object, while vision systems are limited by cameras' 2D perception. Vision systems have to rely on triangulation techniques while moving past objects to determine the distance to a given object in its field of view, such as a parked car, and the perception of distance with these systems declines at longer ranges. Radar is also better at distinguishing between one or two partially overlapping objects, such as pedestrians.

High availability

In addition, radar works in certain conditions, such as rain, fog and darkness, that make other sensors less reliable. Front-facing cameras rely on windshield wipers or headlights to keep their view clear, but cameras elsewhere around the vehicle lack those features. A buildup of salt, dust and grime, which may be a constant presence during severe weather, can degrade the performance of cameras and ultrasonic sensors, even triggering proximity alarms when ultrasonic signals bounce back from a heavy buildup of material on the surface of a sensor.

These conditions have much less effect on the transmission of radar waves, so radar units mounted around a vehicle can provide reliable 360-degree sensing in the widest possible range of driving scenarios.

INTELLIGENT PERCEPTION

Innovations in radar hardware and signal processing are building on the technology's inherent strengths, thus enabling new applications across the full range of vehicle automation, from parking to high-speed ADAS and autonomous driving.

Sensing gains precision

Emerging 3D air-waveguide technologies for radar antennas allow for the use of special radar beams tailored to specific applications. These technologies efficiently illuminate the environment with radar signals and receive the faint echoes that return with low loss, enabling higher precision while keeping costs down and sensor size the same. With 3D air waveguides, radar sensors receive more of the data needed to identify where objects are, how fast they are moving and even what they are, by feeding the data to machine learning systems to classify objects.

The latest generation of radar also adds a fourth dimension, sensing elevation. This allows the system to create a radar point cloud to model the surrounding environment in high definition, with important details such as low curbs, overhead signs and parking garage gates.

AI/ML: A force multiplier

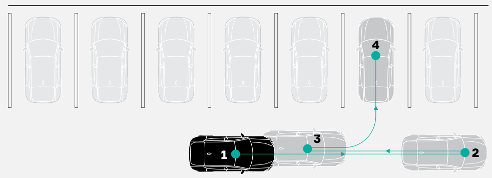
Artificial intelligence and machine learning are doing the most to transform the capabilities of radar. The growing power of flexible, centralized onboard computing platforms and the rapid development of pattern-recognition algorithms are helping to make this possible.

Radar has been used primarily to detect the location, direction and speed of vehicles and other highly reflective objects, especially for high-speed ADAS applications such as adaptive cruise control. Now, machine learning techniques like those used to train in-vehicle vision systems to distinguish among vehicles, pedestrians and roadside infrastructure are being applied to radar signals.

Better at Spotting Parking Spots

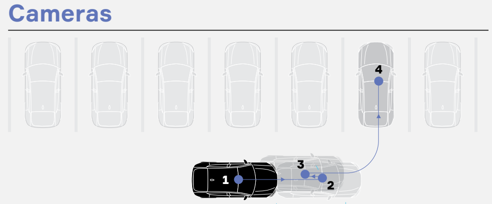
Several different sensing technologies can detect open parking spaces, but radar excels at detecting those spaces sooner at conventional parking-lot driving speeds.

Ultrasonic



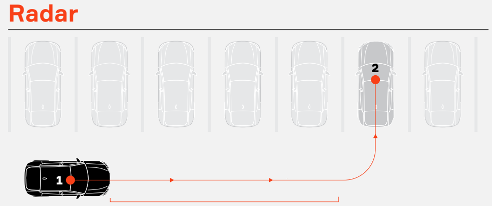
Detection only possible after passing the open spot

Cameras



A few meters away

Radar



15 meters away

Enhanced resolution, trained neural networks and more powerful radar reception algorithms give these intelligent systems greater ability to correctly identify stationary and less-reflective objects. In parking applications, the combination allows vehicles to analyze all potential obstacles in the environment, including partially occluded objects such as pedestrians walking behind cars.

Sensor fusion adds value

Vision remains essential to many parking applications for uses such as reading signs and identifying lane markings, and such data can be merged with radar inputs through sensor fusion. Readings from ultrasonic sensors, which provide low-cost short-range sensing, can also be merged with this data. Sensor fusion helps to build the best possible picture of the surrounding environment.

Radar is especially well suited to AI/ML processing compared with other sensing technologies. Unlike ultrasonic sensors, radar captures enough detail to be used for object classification. But it generates less overall data than vision systems, which take in unnecessary details such as vehicle color, so identifying hazards requires less computing power in the vehicle's core computing platform. In-vehicle preprocessing of data from radar sensors can further reduce computing requirements.

ADVANCED PARKING BREAKTHROUGHS

Next-generation parking assistance features benefit from advances in sensing and perception including AI/ML signal processing, for increased automation, availability and safety. Aptiv has developed several such applications.

Automated Park Assist

Automated Park Assist allows a vehicle to automatically find, enter and exit a parking spot. It controls the steering, speed, brakes and gearbox while the driver monitors the process from inside or outside the vehicle. Radar sensors scan a parking lot and identify a suitable space. The vehicle can then go directly to it and maneuver into it — and later leave the space — with no driver input. A neural network processes radar data using AI/ML to detect, track and identify all types of hazards while integrating vision to read signs and road markings.

As an SAE Level 2 automation feature, Automated Park Assist can operate only when the driver is paying attention and ready to take control, either in the vehicle or at a distance with a key fob or smartphone app that can stop the vehicle. This allows owners to park in spaces that are exposed to weather or too tight for the doors to open.

Memory Park Assist

This feature, first demonstrated by Aptiv at CES 2023, allows a vehicle to record the process of parking in a given location and later repeat it automatically with the driver present.

The first time a driver parks in a given location and instructs the system to record, Memory Park Assist detects and classifies all stationary objects in the environment, exclusively with radar enhanced with AI/ML. It uses this data to build a virtual map that remains in the vehicle, and the data recorded on subsequent trips is aggregated to keep the map current. If there is a major, permanent change in the area, Memory Park Assist will instruct the driver to retrain it.

Memory Park Assist models the scene using an occupancy grid, in which a radar reception algorithm classifies any stationary object in a given quadrant, such as a garage pillar, to a high degree of certainty. The virtual map, along with real-time sensor inputs, enables the vehicle to situate itself within the learned environment through simultaneous location and mapping.

Memory Park Assist self-maps the area without referring to any existing map, but it can also be aligned to a commercial map of the surrounding area when one is available. This feature — also known as home zone parking — is designed for navigating to a space or garage on private property, such as a home driveway. A Level 2 “summon” feature is possible using the same technologies without any further training.

Though designed initially as an SAE Level 2+ feature that requires driver monitoring from either inside or outside the vehicle, Memory Park Assist could be implemented as Level 4 — allowing vehicle autonomy within a limited domain — with enough redundant sensing and computing systems to ensure safety.

Reverse Assist

Reverse Assist is a driver-assistance system that helps with reversing maneuvers by automatically steering the vehicle along a memorized path. The driver retains control of acceleration and braking throughout the reversing maneuver. Reverse Assist memorizes the last 200 meters driven at a maximum speed of 36 km/hr, including steering wheel movements.

Smart Summon

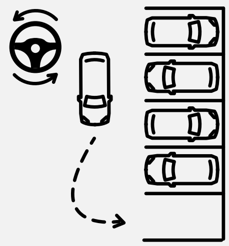
Smart Summon allows drivers to remotely call upon their vehicle to navigate out of a parking spot where it was previously parked. Smart Summon functions effectively when the user is within 65 meters of the parked vehicle. During the Smart Summon process, the user is in complete control. It’s crucial to maintain a clear line of sight to the car. The user can stop the vehicle at any moment by simply releasing a button, ensuring a secure and controlled experience.

Remote Park Assist

Remote Park Assist is similar to Automated Park Assist when the driver is outside the vehicle. When an appropriate parking space is found, the driver leaves the vehicle and activates the automated parking function through a mobile phone. After parking, the vehicle sends a parking completion message to the mobile phone.

Advanced Parking Breakthroughs

Advances in sensing and perception enable several parking applications.



Automated Park Assist

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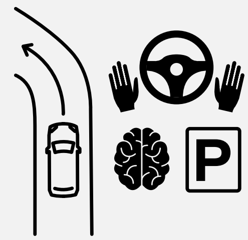

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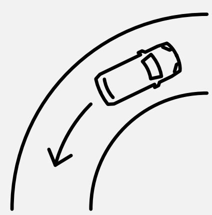

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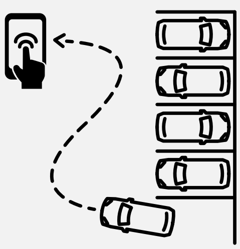

Smart Summon

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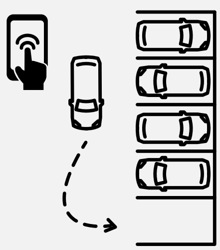
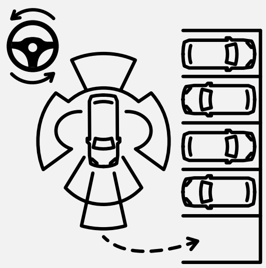


Remote Park Assist

allows a vehicle to automatically park when the driver is outside the vehicle.



Surround View

uses sensor fusion to combine data from various sensors in a view of the vehicle’s surroundings on the in-cabin display.

Surround View

This feature uses sensor fusion to combine data from radar, vision and ultrasonic sensors in a view of the vehicle's surroundings shown on the in-cabin display. It stitches together images from multiple surround-view cameras and can provide multiple viewing angles. Other information, such as the current steering path and distance warnings, can be overlayed onto the video image.

A SYSTEM APPROACH

Parking assistance is increasingly not just a convenience feature but a part of the continuum of vehicle automation, subject to all the real-world safety demands imposed on this technology. As parking assistance features evolve from Level 2 to Level 4 and beyond, unlocking increasing degrees of autonomy, the most capable and cost-efficient parking automation solutions will be those that combine ADAS cruising innovations with the power of AI-enabled radar.

An end-to-end ADAS platform provides a complete safety package, including features such as forward collision warning and automatic emergency braking, that can be extended into parking automation features with proven effectiveness and reliability. In addition, comprehensive ADAS development and testing generates a wealth of knowledge on nearly all types of driving scenarios, adding to the robustness of parking capabilities.

Parking assistance is a critical component of Aptiv's Gen 6 ADAS platform. The next-generation parking features described above, which were introduced with the platform, build on Aptiv's deep experience developing and manufacturing industry-leading automotive radar systems. Together with our Satellite Architecture, this platform allows OEMs to implement scalable, integrated ADAS capabilities in a modular, flexible and cost-effective way for increasingly intelligent real-time sensing and decision-making.

Aptiv's system approach to vehicle automation, which spans parking, ADAS cruising and ultimately autonomous driving, brings together a full safety package, a comprehensive sensor fusion platform, and access to extensive driving data. With a detailed road map and proven solutions on the market, we are able to partner with OEMs for parking automation and beyond.

Parking assistance is increasingly not just a convenience feature but a part of the continuum of vehicle automation, subject to all the real-world safety demands imposed on this technology.

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Walt Kosiak has spent his career at Aptiv innovating in the fields of integrated circuit design, passive safety systems, active safety and driver assistance, and automated vehicles. His areas of expertise include ADAS/AD feature/function algorithms, threat assessment and warning algorithms, radar and radar-vision fusion, adaptive cruise control systems, vehicle-to-everything communication, map-based electronic horizon technology, and rapid prototyping systems for automotive systems development. Walt is an inventor on 24 U.S. Patents and was a member of the team that completed the first U.S. coast-to-coast automated drive in 2015.

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Gürhan Gümüssu is responsible for leading and coordinating systems activities of Aptiv's parking feature development in the Global Product Organization. He has been with Aptiv for four years, contributing to system teams on various projects and supporting business pursuits. Before joining Aptiv, he worked at a global automotive manufacturer as systems engineer.

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Dr. Kamil Ostrowski leads the software development activities for parking at Aptiv. In his seven years at the company, he has helped successfully launch products related to radar, vision and features for multiple customers. Previously, he worked for a U.K. OEM and in the railway industry. Kamil holds a doctoral degree from the University of Liverpool, U.K., with a research focus on advanced control algorithms for the powertrain domain. He is currently pursuing an executive MBA at Poznan University of Economics and Business.

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