Comparison Review on Autonomous vehicles vs Connected Vehicles

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Abstract – *The automotive industry is expanding its technical innovations, in which the autonomous cars and connected cars are two major trends in automotive industry. The development of autonomous cars and connected cars is a revolution which will change the perspective of driving comfort and safety of the passengers. This paper is presented in order to give a comparison review on autonomous cars vs connected cars.*

Key Words: Autonomous car, Connected car, Driverless vehicle, Connectivity, Self-driving car.

1. AUTONOMOUS VEHICLES

A self-driving car, also known as an autonomous car, driverless car, or robotic car, is a vehicle that is capable of sensing its environment and moving safely with little or no human input [1]. Self-driving cars combine a variety of sensors to perceive their surroundings, such as radar, lidar, sonar, GPS, odometry and inertial measurement units. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage [3][4]. Long distance trucks are seen as being in the forefront of adopting and implementing the technology.

1.1 HISTORY

Experiments have been conducted on automated driving systems (ADS) since at least the 1920s, trials began in the 1950s. The first semi-automated car was developed in 1977, by Japan's Tsukuba Mechanical Engineering Laboratory, which required specially marked streets that were interpreted by two cameras on the vehicle and an analog computer. The vehicle reached speeds up to 30 kilometres per hour (19 mph) with the support of an elevated rail.

The first truly autonomous cars appeared in the 1980s, with Carnegie Mellon University's Navlab and ALV [5][6] projects funded by DARPA starting in 1984 and Mercedes-Benz and Bundeswehr University Munich's EUREKA Prometheus Project in 1987.

By 1985, the ALV had demonstrated self-driving speeds on two lane roads of 31 kilometres per hour (19 mph) with obstacle avoidance added in 1986 and off-road driving in day and nighttime conditions by 1987. A major milestone was achieved in 1995, with CMU's NavLab 5 completing the first autonomous coast-to-coast drive of the United States. Of the 2,849 miles between Pittsburgh, PA and San Diego, CA, 2,797 miles were autonomous (98.2%), completed with an average speed of 63.8 miles per hour (102.3 km/h) [7].

From the 1960s through the second DARPA Grand Challenge in 2005, automated vehicle research in the U.S. was primarily funded by DARPA, the US Army, and the U.S. Navy, yielding incremental advances in speeds, driving competence in more complex conditions, controls, and sensor systems. Companies and research organizations have developed prototypes.

1.2 TECHNICAL CHALLENGES

There are different systems that help the self-driving car control the car. Systems that currently need improvement include the car navigation system, the location system, the electronic map, the map matching, the global path planning, the environment perception, the laser perception, the radar perception, the visual perception, the vehicle control, the perception of vehicle speed and direction, the vehicle control method.

The challenge for driverless car designers is to produce control systems capable of analyzing sensory data in order to provide accurate detection of other vehicles and the road ahead. Modern self-driving cars generally use Bayesian simultaneous localization and mapping (SLAM) algorithms, which fuse data from multiple sensors and an off-line map into current location estimates and map updates [8]. Waymo has developed a variant of SLAM with detection and tracking of other moving objects (DATMO), which also handles obstacles such as cars and pedestrians. Simpler systems may use roadside real-time locating system (RTLS) technologies to aid localization. Typical sensors include lidar, stereo vision, GPS and IMU. Control systems on automated cars may use Sensor Fusion, which is an approach that integrates information from a variety of sensors on the car to produce a more consistent, accurate, and useful view of the environment.

Researchers at their computer Science and Artificial Intelligence Laboratory (CSAIL) have developed a new system, called Map Lite, which allows self-driving cars to drive on roads that they have never been on before, without using 3D maps. The system combines the GPS position of the vehicle, a "sparse topological map" such as OpenStreetMap, and a series of sensors that observe the road conditions.

Heavy rainfall, hail, or snow could impede the car sensors.

1.3 TESTING

The testing of vehicles with varying degrees of automation can be carried out either physically, in a closed environment or, where permitted, on public roads (typically requiring a license or permit, or adhering to a specific set of operating principles), or in a virtual environment, i.e. using computer simulations. When driven on public roads, automated vehicles require a person to monitor their proper operation and "take over" when needed. For example, New York state has strict requirements for the test driver, such that the vehicle can be corrected at all times by a licensed operator; highlighted by Cardian Cube Company's application and discussions with New York State officials and the NYS DMV.

The progress of automated vehicles can be assessed by computing the average distance driven between "disengagements", when the automated system is switched off, typically by the intervention of a human driver. In 2017, Waymo reported 63 disengagements over 352,545 miles (567,366 km) of testing, an average distance of 5,596 miles (9,006 km) between disengagements, the highest among companies reporting such figures. Waymo also traveled a greater total distance than any of the other companies. Their 2017 rate of 0.18 disengagements per 1,000 miles (1,600 km) was an improvement over the 0.2 disengagements per 1,000 miles (1,600 km) in 2016, and 0.8 in 2015. In March 2017, Uber reported an average of just 0.67 miles (1.08 km) per disengagement. In the final three months of 2017, Cruise (now owned by GM) averaged 5,224 miles (8,407 km) per disengagement over a total distance of 62,689 miles (100,888 km) [15]. In July 2018, the first electric driverless racing car, "Robocar", completed a 1.8-kilometer track, using its navigation system and artificial intelligence.

1.4 FIELDS OF APPLICATION

1.4.1 AUTONOMOUS TRUCKS AND VANS

Many companies (i.e. Otto, Starsky Robotics,) have focused on autonomous trucks. Automation of trucks is important, not only due to the improved safety aspects of these very heavy vehicles, but also due to the ability of fuel savings (through platooning).

Autonomous vans are being used by online grocers such as Ocado.

1.4.2 TRANSPORT SYSTEMS

In Europe, cities in Belgium, France, Italy and the UK are planning to operate transport systems for automated cars, and Germany, the Netherlands, and Spain have allowed public testing in traffic. In 2015, the UK launched public trials of the LUTZ Pathfinder automated pod in Milton Keynes. Beginning in summer 2015, the French government allowed PSA Peugeot Citroen to make trials in real conditions in the Paris area. The experiments were planned to be extended to other cities such as Bordeaux and Strasbourg by 2016. The alliance between French companies THALES and Valeo (provider of the first self-parking car system that equips Audi and Mercedes premi) is testing its own system. New Zealand is planning to use automated vehicles for public transport in Tauranga and Christchurch.

In China, Baidu and King Long produce automated minibus, a vehicle with 14 seats, but without driving seat. With 100 vehicles produced, 2018 will be the first year with commercial automated service in China. Those minibuses should be at level 4, that is driverless in closed roads.

1.5 LEVELS OF DRIVING AUTOMATION

In SAE's automation level definitions, "driving mode" means "a type of driving scenario with characteristic dynamic driving task requirements [10] (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.)

- Level 0: Automated system issues warnings and may momentarily intervene but has no sustained vehicle control.
- Level 1 ("hands on"): The driver and the automated system share control of the vehicle. Examples are systems where the driver controls steering and the automated system controls engine power to maintain a set speed (Cruise Control) or engine and brake power to maintain and vary speed (Adaptive Cruise Control or ACC); and Parking Assistance, where steering is automated while speed is under manual control. The driver must be ready to retake full control at any time. Lane Keeping Assistance (LKA) Type II is a further example of level 1 self-driving.
- Level 2 ("hands off"): The automated system takes full control of the vehicle (accelerating, braking, and steering). The driver must monitor the driving and be prepared to intervene immediately at any time if the automated system fails to respond properly. The shorthand "hands off" is not meant to be taken literally. In fact, contact between hand and wheel is often mandatory during SAE 2 driving, to confirm that the driver is ready to intervene.
- Level 3 ("eyes off"): The driver can safely turn their attention away from the driving tasks, e.g. the driver can text or watch a movie. The vehicle will handle situations that call for an immediate response, like emergency braking. The driver must still be prepared to intervene within some limited time, specified by the manufacturer, when called upon by the vehicle to do so.
- Level 4 ("mind off"): As level 3, but no driver attention is ever required for safety, e.g. the driver may safely go to sleep or leave the driver's seat. Self-driving is supported only in limited spatial areas (geofenced) or under special circumstances, like traffic jams. Outside of these areas or circumstances, the vehicle must be able to safely abort the trip, e.g. park the car, if the driver does not retake control.

- Level 5 ("steering wheel optional"): No human intervention is required at all. An example would be a robotic taxi. In the formal SAE definition below, note in particular what happens in the shift from SAE 2 to SAE 3: the human driver no longer has to monitor the environment. This is the final aspect of the "dynamic driving task" that is now passed over from the human to the automated system.

2. CONNECTED VEHICLES

A connected car is a car that is equipped with Internet access, and usually also with a wireless local area network (LAN) [11]. This allows the car to share internet access, and hence data, with other devices both inside and outside the vehicle. For safety-critical applications, it is anticipated that cars will also be connected using dedicated short-range communications (DSRC) radios, operating in the FCC granted 5.9 GHz band with very low latency.

2.1 HISTORY

General Motors was the first automaker to bring the first connected car features to market with OnStar in 1996 in Cadillac De Ville, Seville and Eldorado. OnStar was created by GM working with Motorola Automotive (that was later bought by Continental). The primary purpose was safety and to get emergency help to a vehicle when there was an accident. The sooner medical helps arrives the more likely the drivers and passengers would survive. A cellular telephone call would be routed to a call center where the agent sent help.

At first, OnStar only worked with voice but when cellular systems added data the system was able to send the GPS location to the call center. After the success of OnStar, many automakers followed with similar safety programs that usually come with a free trial for a new car and then a paid subscription after the trial is over.

Remote diagnostics were introduced in 2001. By 2003 connected car services included vehicle health reports, turn-by turn directions and a network access device. Data-only telematics were first offered in 2007.

In the summer of 2014, Audi was the first automaker to offer 4G LTE Wi-Fi Hotspots access and the first mass deployment of 4G LTE was by General Motors. By 2015, OnStar had processed 1 billion requests from customers.

In the UK, the breakdown association 'The AA' introduced the first piece of connected car technology, in Car Genie that connects directly to a breakdown service, not only warning of issues with car health, but intervening directly with a phone call to customers to help them prevent a breakdown.

In 2017, European technology start-up Stratio Automotive provides over 10,000 vehicles predictive intelligence enabling fleet operators to better manage and maintain their vehicles.

2.2 TYPES OF CONNECTIVITY

There are 5 ways a vehicle can be connected to its surroundings and communicate with them [14]:

1. V2I "Vehicle to Infrastructure": The technology captures data generated by the vehicle and provides information about the infrastructure to the driver. The V2I technology communicates information about safety, mobility or environment related conditions.

2. V2V "Vehicle to Vehicle": The technology communicates information about speed and position of surrounding vehicles through a wireless exchange of information. The goal is to avoid accidents, ease traffic congestions and have a positive impact on the environment.

3. V2C "Vehicle to Cloud": The technology exchanges information about and for applications of the vehicle with a cloud system. This allows the vehicle to use information from other, though the cloud connected industries like energy, transportation and smart homes and make use of IoT.

4. V2P "Vehicle to Pedestrian": The technology senses information about its environment and communicates it to other vehicles, infrastructure and personal mobile devices. This enables the vehicle to communicate with pedestrians and is intended to improve safety and mobility on the road.

5. V2X "Vehicle to Everything": The technology interconnects all types of vehicles and infrastructure systems with another. This connectivity includes cars, highways, ships, trains and airplanes.

2.3 HARDWARE

The necessary hardware can be divided into built-in or brought-in connection systems. The built-in telematics boxes most commonly have a proprietary internet connection via a GSM module and are integrated in the car IT system. Although most connected cars in the United States use the GSM operator AT&T with a GSM SIM such as the case with Volvo [9], some cars such as the Hyundai Blue Link system utilizes Verizon Wireless Enterprise, a non-GSM CDMA operator.

Most brought-in devices are plugged in the OBD (on-board diagnostics) port for electrification and access to vehicle data and can further be divided into two types of connection:

1. Hardware relies on customers smartphone for the internet connection.
2. Hardware establishes proprietary internet connection via GSM module.

All forms of hardware have typical use cases as drivers. The built-in solutions were mostly driven by safety regulations in Europe for an automated Emergency Call. The brought-in devices usually focus on one customer segment and one specific use case.

2.4 CATEGORIES OF APPLICATIONS

Applications can be separated into two categories:

1. Single vehicle applications: In-car content and service applications implemented by a single vehicle in connection with a cloud or back office.
2. Cooperative safety and efficiency applications: they provide connectivity between vehicles directly have to work cross-brand and cross-borders and require standards and regulation.

The connected car segment can be further classified into 8 categories [13].

- Mobility management: functions that allow the driver to reach a destination quickly, safely, and in a cost-efficient manner (e.g.: Current traffic information, Parking lot or garage assistance, Optimized fuel consumption)
- Commerce: functions enabling users to purchase good or services while on-the-go (e.g., fuel, food & beverage, parking, tolls)
- Vehicle management: functions that aid the driver in reducing operating costs and improving ease of use (e.g., vehicle condition and service reminders, remote operation, transfer of usage data)
- Breakdown prevention: connected to a breakdown service, with a back end algorithm predicting breakdowns and an outbound service intervening via phone, SMS or push notification.
- Safety: functions that warn the driver of external hazards and internal responses of the vehicle to hazards (e.g., vehicle condition and service reminders, remote operation, transfer of usage data).
- Entertainment: functions in the entertainment of the driver and passengers (e.g., smartphone interface, WLAN hotspot, music, video, Internet, social media, mobile office).

3. CONCLUSIONS

Autonomous vehicles do not need connected vehicle technology to function since they must be able to independently navigate the road network. However, connected vehicle technologies provide valuable information about the road ahead—allowing rerouting based on new information such as a lane closures or obstacles on the road. By incorporating connected vehicle technology, Autonomous vehicles will be safer, faster, and more efficient.

Furthermore, virtually all autonomous vehicles will require some form of connectivity to ensure software and data sets are current. As autonomous vehicles rely on knowing the roadway they are traveling on, changes to the roadside such as new development or construction will require the type of real-time exchange of information that connected vehicle technology provides.

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