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SELF-DRIVING VEHICLES IN LOGISTICS

A DHL PERSPECTIVE ON IMPLICATIONS AND USE CASES FOR THE LOGISTICS INDUSTRY

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PREFACE

Next time you are stuck in slow-moving traffic, you'll possibly want to trade your conventional vehicle for an autonomous model. Maybe you would like to read a newspaper, look out at the scenery, or even take a refreshing nap. A switch like this may be possible one day, freeing each driver to do something more productive and enjoyable with their time.

Unlike human drivers who sometimes cannot react fast enough to a sudden road hazard ahead, driving assistants or self-driving vehicles are programmed for constant vigilance and safety. In addition, these systems can find the swiftest route to avoid traffic congestion, reduce motoring costs, and minimize environmental impact, achieving an overall experience that's safer and greener for everyone.

We invite you to join us on a journey to discover the incredible potential of autonomous vehicles.

This trend report examines the distance that needs to be covered before self-driving technology reaches full maturity, and addresses the challenges of regulations, public acceptance, and issues of liability. It also shines the headlights on various best-practice applications across several industries today, and takes a detailed look into the existing technology that's successfully used today as well as some future applications for self-driving vehicles in the logistics industry.

You will learn that logistics provide some of the most ideal working environments for self-driving vehicles. Examples include warehouses and other private and secure indoor locations where goods (not people) are loaded and transported, and relatively isolated and remote outdoor locations where harsh conditions and long hours can put human drivers at risk.

It's no surprise then that the logistics industry has been deploying self-driving vehicles for several years, and is adopting advances in self-driving technology more rapidly than many other industries.

The road to the future is going to be extremely interesting. Sit back, buckle up, and we hope you enjoy this trend report!

Sincerely yours,

Matthias Heutger

Dr. Markus Kückelhaus

1 UNDERSTANDING SELF-DRIVING VEHICLES

This introductory chapter sets the scene by providing some common ground for understanding the topic of self-driving vehicles. It offers a technical definition, describes the current developmental status, and reviews the benefits and technological requirements of autonomous driving. This chapter also highlights some key challenges and concerns about driverless vehicles, exploring how society will regulate these vehicles, whether the general public will accept these vehicles, and what changes will be required to insure these vehicles.

1.1 Definition and context

Self-driving vehicles have been defined as “vehicles in which operation occurs without direct driver input to control the steering, acceleration, and braking”,[1] according to the National Highway Traffic Safety Administration. In this type of vehicle, the driver is “not expected to constantly monitor the roadway while operating in self-driving mode”.

This definition assumes that the vehicle will always have a driver. However, this isn’t essential – autonomous technologies are already able to perform all of the required functions for a vehicle to move safely from A to B without anyone on board at all.

The widespread adoption of driverless vehicles may seem a distant vision – something we would expect to see in a futuristic movie perhaps. However, the reality is that some of the world’s leading automotive and technology companies are already showcasing first prototypes and discussing the advent of “the next automotive revolution”. First trials of fully driverless vehicles are already underway. And if you look closely at the vehicles on our roads today, you’ll find that many adopt a number of the key technologies required for autonomous driving.

The race to bring self-driving vehicles to our roads has begun, and it is not just the automotive manufacturers that are leading the charge – as early as 2011, the US tech giant Google famously debuted its version of a driverless car which has since been spotted doing many test rounds on the streets of the US.

Figure 1: An advertisement for America’s Electric Light and Power Companies, 1950s; **Source:** Computer History Museum

Beyond testing, how long will it take before we see the first autonomous vehicles on public roads? Some industry analysts predict this could happen within the next three years.

1.2 Key benefits

The hype surrounding autonomous driving clearly suggests that there must be advantages to be gained from investing in driverless vehicles. And these benefits will increase exponentially as more and more people adopt this method of transportation.

Imagine a world where our streets and highways are full of driverless trucks and cars moving in perfect sync with each other. Road traffic accidents caused by human error will become a thing of the past. Our daily commute to work will be stress-free and safe – we’ll get into our cars, enjoy a cup of coffee, read the latest news, interact with other passengers, and even catch up on some sleep! The American public had this dream already some 70 years ago (see Figure 1). We’ll arrive relaxed and refreshed at our destination and step out of our vehicles and directly in through our office door. We’ll leave the car to find an available parking space autonomously.

[1] http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development

Improved safety: Research indicates that up to 90 % of road traffic accidents are caused by the driver. Advocates for driverless vehicles use statistics like this to argue that autonomous systems make better and faster decisions than humans. They also claim that self-driving vehicles will always monitor and adapt to varying traffic and weather conditions, and will avoid obstacles in the road, doing all this with more diligence, speed, and safety than human drivers.[2]

Figure 2; **Source:** Construction Skills Training

Higher efficiency: Traffic can flow faster and congestion can be reduced with autonomous driving. Using vehicle-to-vehicle communication, autonomous systems can set high speeds and intelligently avoid busy routes. With fuel efficiency achieved by optimized driving and by convoying, owners of driverless vehicles can reduce their carbon footprint and motoring costs by approximately 15 %.

In addition, the all-too-familiar time limitations placed on freight trucks will be removed; they will be able to travel 24/7 without requiring driver rest time and – compared with today's driving – could achieve overall cost reductions in the region of 40 % per kilometer.[3]

Figure 3; **Source:** Thinkstock

Lower environmental impact: With fewer cars and more efficient fuel consumption, autonomous systems are programmed to minimize environmental impact. Self-driving vehicles can achieve lower emissions. This of course benefits the environment and puts less stress on the road network.[4]

Figure 4; **Source:** Hutchinson

[2] http://www.bosch-presse.de/presseforum/download/de/7966ks-d_Anlage_Befragung_Fahrerassistenz.pdf

[3] http://irandanesh.febpco.com/FileEssay/barnamerizi-1386-12-8-bgh%28353%29.PDF

[4] http://www.daimler.com/dccom/0-5-876574-49-1691209-1-0-0-1727129-0-0-135-0-0-0-0-0-0-0-0.html

Greater comfort: In an autonomous vehicle, the driver becomes a passenger. He or she doesn't have to watch the road ahead but can rest and enjoy other activities. This also makes self-driving vehicles a very attractive form of transportation for the elderly, underage, people with physical disabilities, and even the intoxicated. Parking a car used to be stressful and time consuming … but now the self-driving vehicle can find a parking space and, later, return to a specified pickup point all on its own!

Figure 5; **Source:** MotorTrend Magazine

After evaluating the initial key benefits of self-driving vehicles, the following section provides an overview of existing technology.

1.3 Technology overview

Autonomous technologies have been used productively in a number of different applications for many years. One of the most obvious uses is in aviation – it is considered normal for airlines to deploy auto pilot technology as standard equipment. Other examples include the fully automated metro and shuttle trains that operate in multiple cities and airports around the world.

As with many technological developments, the military sector was an early adopter of self-driving vehicles. A significant example is the military use of autonomous technologies for mine sweeping. This has saved countless lives by keeping soldiers and civilians out of danger until mines have been detected and safely detonated or disabled.

As seen in Figure 1, people have been thinking about self-driving vehicles for several decades already. Autonomous vehicles were on display as part of the GM Futurama Exhibit at the 1940 New York World's Fair and, by the 1950s, both GM and Ford had running prototypes.[5]

Several simple autonomous features such as an **anti-lock braking system** and **cruise control** can be found in most current vehicles. Beyond these supporting functions, already there are many advanced features that can take over an element of primary control. An example is **adaptive cruise control** which has been included over the past couple of years in selected vehicles. This technology maintains a specified distance between the conventional or driverless vehicle in front (see Figure 6).

Figure 6: Audi's Adaptive Cruise Control helps to keep a safe distance from the vehicle in front; **Source:** Hearst Communications

Advanced technologies such as this are extremely helpful to drivers, but they fall short of enabling a fully autonomous experience.[6]

To achieve a vehicle capable of driving itself, four basic interdependent functions are required. These are **navigation**, **situational analysis**, **motion planning**, and **trajectory control**[7], described in further detail in the following section.

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[5] http://www.wisburg.com/wp-content/uploads/2014/09/%EF%BC%88109-pages-2014%EF%BC%89MORGAN-STANLEY-BLUE-PAPER-AUTONOMOUS-CARS%EF%BC%9A-SELF-DRIVING-THE-NEW-AUTO-INDUSTRY-PARADIGM.pdf

[6] http://www.mrt.kit.edu/z/publ/download/2014/ZieglerAl2013ITSMag.pdf

[7] http://www.mrt.kit.edu/z/publ/download/2014/ZieglerAl2013ITSMag.pdf

Navigation

Navigation is essentially route planning. More specifically, it creates and recalculates a digital map that includes information on locations, road types and settings, terrain, and weather forecasts.

Figure 7: Safety-related information is instantly communicated with V2V communication; **Source:** MotorTrend Magazine

Nowadays, vehicles complete route planning using **global positioning system (GPS)**. In the fully autonomous vehicle, however, navigation is enhanced by integrating **vehicle-to-vehicle (V2V)** communication (see Figure 7). This describes the ongoing exchange of data between vehicles via communication systems such as wireless local area networks (WLANs). With V2V communication,the autonomous system can recognize critical and dangerous situations at an early stage, and receive the required safety-related information within a fraction of a second.[8]

Situational analysis

Situational analysis monitors the environment through which the vehicle is moving to ensure the autonomous system is aware of all relevant objects and their movements.

Visual image recognition techniques, broadly defined as **video cameras**, identify relevant objects in the environment such as other vehicles, pedestrians, traffic signs, and traffic lights (see Figure 8).[9] Additionally, precise positioning data can be obtained using **markers** embedded in the infrastructure. This solution is often deployed in warehouse applications (described in more detail in Chapter 3) – with markers it is possible to successfully track the position of all moving vehicles in a defined area, and detect any obstacles in their way.

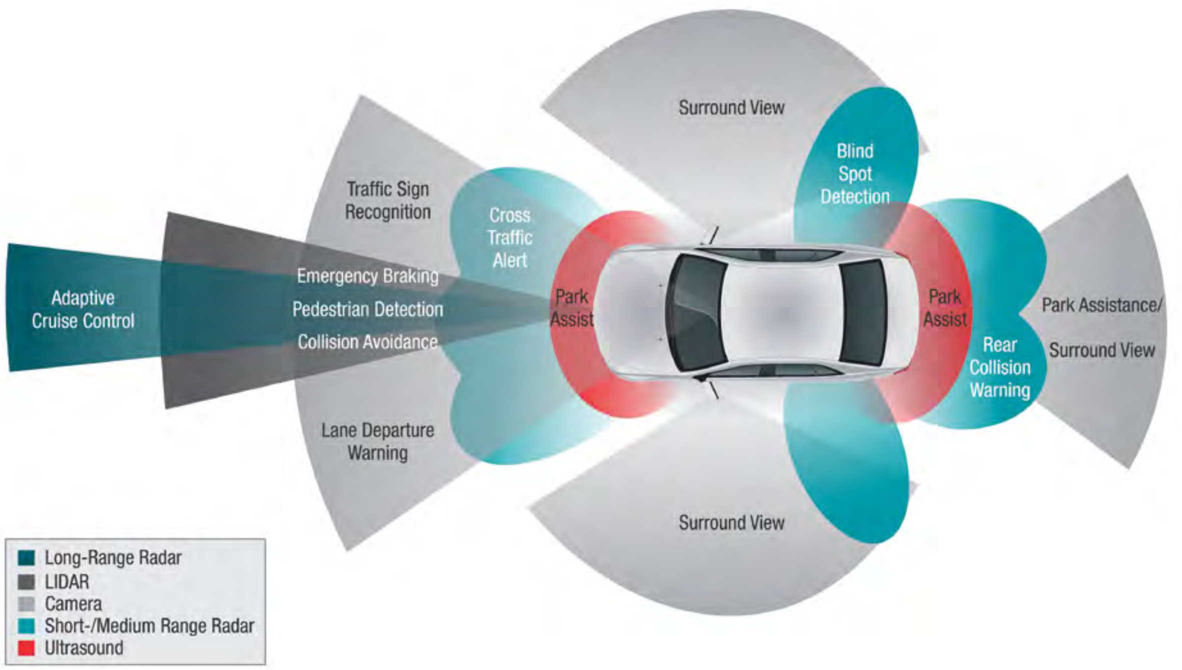

Figure 8: Situational analysis using various different sensors; **Source:** Texas Instruments

[8] http://www.heise.de/ix/artikel/Sichtweite-erhoehen-820516.html

[9] http://www.mrt.kit.edu/z/publ/download/2014/ZieglerAl2013ITSMag.pdf

A downside is that this solution requires considerable investment. Other key techniques are to use **radar** and **ultrasonic sensors**. These solutions create images with electromagnetic waves and ultrasonic waves, respectively. While visual image recognition depends on good weather, radar and ultrasonic technology can work reliably in difficult weather conditions such as fog or heavy rain.[10]

One further technique is to use a remote sensing technology known as **LIDAR** (light detection and ranging). The principle is comparable to radar systems but this technology works with laser pulses (optical detection) instead of electromagnetic waves. The LIDAR system creates a rapid series of 360° profiles; it matches each of these to each other to detect any deviation such as movement (see Figure 9). Although LIDAR is a state-of-the-art system, it is just one of several recognition technologies that make autonomous driving possible.[11]

Figure 9: Using LIDAR to scan the environment; **Source:** DriverlessCar.com

Motion planning

Motion planning monitors the vehicle's movements. It does this by using sensors that determine a precise course of motion within a defined period of time. This course must ensure that the moving vehicle remains in its lane and continues in the correct direction as defined by the navigation system, so that the vehicle avoids collision with the static and dynamic objects that are identified by situational analysis.

Direction is determined by the current position of the vehicle and the route of the road, avoiding any detected static objects. Decisions have to be made about adapting speed and direction, and these are based on a myriad of variables. The appropriate speed, for example, depends on the width of the driving lane, the preferences and schedule of the passengers, the speed limit on a particular stretch of road, and much more. And one of the main challenges is to avoid not just static objects but also dynamic objects, as this requires prediction of their future movements (see Figure 10).

Obviously, the more dynamic an object is, the more difficult it is to predict its future movements. For example, it is not always easy to know which way a bicyclist or pedestrian is likely to turn next. To improve predictive ability, this technology would have to analyze indicators such as the bicyclist's hand signals or the pedestrian's facial expressions. This level of capability is not yet available in today's video recognition systems or even through rapid vehicle-to-human interaction.[12]

Figure 10: A vehicle with motion planning can predict what will happen next; **Source:** Thinkstock

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[10] http://faculty.nps.edu/jenn/Seminars/RadarFundamentals.pdf

[11] http://www.wisburg.com/wp-content/uploads/2014/09/%EF%BC%88109-pages-2014%EF%BC%89MORGAN-STANLEY-BLUE-PAPER-AUTONOMOUS-CARS%EF%BC%9A-SELF-DRIVING-THE-NEW-AUTO-INDUSTRY-PARADIGM.pdf

[12] http://www.mrt.kit.edu/z/publ/download/2014/ZieglerAl2013ITSMag.pdf

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