Driverless Cars

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ABSTRACT

This paper has as its goal the providing of a concise, high-level overview of the current state of driverless cars. Driverless technology is still very much in the midst of being developed, with several companies competing to be leaders in its innovation [5], so readily available hard-and-fast rules have yet to really be established. However, useful information and explanatory frameworks can still be found [7], [4]. The technical features involved in how driverless cars work will be outlined [7], [4], [1], followed by technical challenges [1], [4], [3] as well as potential philosophical and political barriers [2], [5], [6], [8]. While the focus of this analysis will generally be on the future individual consumer sphere of driverless technology, "driverless cars" and "autonomous vehicles" are used interchangeably.

Author Keywords

Driverless; Autonomous; Cars; Vehicles; Computer Vision; Sensor Fusion; Localization; Path Planning; Object Recognition; Object Tracking; Obstacle Avoidance; LiDAR; Robot Operating System (ROS); Deep Learning; GNSS

INTRODUCTION

Driverless car technology is an emerging and incredibly complex field. Different researchers in turn have different ways of conceptualizing and imposing frameworks on this technology [7], [4]. Silver's framework is not only easy to understand but also comes from the perspective of an educator in this field [7], so his conceptualization will be used as a starting point with further elaboration provided by Liu et al's architecture [4].

As with any emerging technology, autonomous vehicles face their fair share of technical challenges. These challenges include but are not limited to sensor and computational challenges [1], reliability [4], performance [4], and security [4] challenges. Even priming drivers before handover in the case of an emergency is an issue to be addressed [3].

Of course there are countless potential benefits of the implantation of driverless vehicles, fewer overall accidents and higher productivity just to name a few [5]. However, there are issues that must be worked out before we can begin to reap these benefits. Such barriers to the implementation of driverless cars include loss of transportation jobs, public stigma, and perceived loss of personal autonomy [5], [6], [8], [2].

HOW DRIVERLESS CARS WORK

General Framework

An effective general framework for understanding driverless cars is provided by educator David Silver, who teaches courses on driverless technology [7]. In his framework, he breaks driverless technology down into 5 broad chunks: computer vision, sensor fusion, localization, path planning, and control [7]. This framework can be seen in Figure 1 [7].

Figure 1. How a Self-Driving Car Works

As explained by Silver, computer vision refers to the data collected using cameras placed around the vehicle whereas sensor fusion denotes how data can be garnered from other devices, like radar and lasers [7]. It is important to note that the software in a driverless car uses deep neural networks or 'deep learning' in order to identify what it sees (cars, pedestrians, lanes, etc.) using computer vision [7]. Sensor fusion usually relies heavily upon LiDAR (light detection and ranging), a series of lasers fired rapidly and continuously in 360 degrees [1] to augment the car's 'picture' of its surroundings.

Following Silver's flowchart and moving on to localization, this step refers to a driverless car's ability to determine its position in the world [7]. While this step employs some kind of GNSS (global navigation satellite system) [1], its accuracy error of up to two meters can be reduced using triangulation to nearby landmarks in addition to data gathered from computer vision and sensor fusion [7].

Moving onto path planning, this step simply denotes plotting a route for the driverless car to take [7]. To do this, the car's software will create and travel through a series of waypoints it places in response to predictions for what other vehicles will do, while also taking into account the markings/rules of the road and other potentially encountered objects like pedestrians [7].

Finally, a driverless car needs to actually execute the physical motions required to fulfill its objective of getting through its self-imposed waypoints [7]. Driverless cars utilize all of the control mechanisms one would see in any car (i.e. steering, acceleration, braking) in order to follow its waypoints as closely as it possibly can [7].

Elaborated Architecture

A useful expansion on Silver's framework is the architecture posited by Liu et al in their recent book on autonomous vehicles, which can be seen in Figure 2 [4].

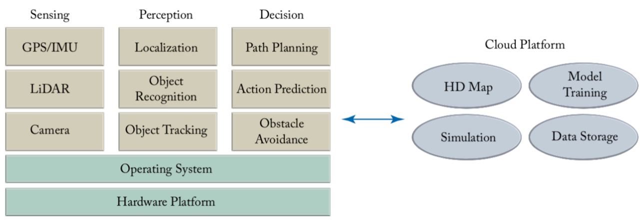

Figure 2. Autonomous Driving System Architecture Overview

While this architecture is obviously laid out differently than the framework proposed by Silver, with some of the same-named constructions grouped in more of a hierarchical format, there is still continuity to be found. Computer vision and sensor fusion can both found in the Sensing hierarchy as Camera and LiDAR, grouped with GPS/IMU (a form of GNSS) [4], [1]. Localization is now subordinate to the Perception hierarchy, along with Object Recognition and Object Tracking, which were both lumped into Path Planning in Silver's framework [4], [7]. Path Planning is now subordinate to the Decision hierarchy, along with Action Prediction and Obstacle Avoidance, so this hierarchy is comparable to the Control stage of Silver's framework [4], [7].

Every construction within Silver's framework fits into the tan-coloured boxes of Liu et al's architecture [4]. According to Liu et al, the tan boxes together comprise the 'Algorithms' sub-system of autonomous driving, whereas the green-coloured boxes and grey-coloured circles comprise the 'Client Systems' and 'Cloud Platform' sub-systems, respectively [4]. According to Liu et al, the Algorithms sub-system is what collects raw data from the car's environment, the Client Systems sub-system is what interprets the data that the algorithms collect, and the Cloud Platform sub-system "provides offline computing and storage capabilities" [4].

TECHNICAL CHALLENGES

Hardware Platform

Due to the computational requirements of driverless cars, they must be equipped with powerful CPUs and several powerful GPUs [4]. Liu et al note that a CPU and several GPUs can be fit in a box installed in the driverless car [4]. However, they also note that if the box becomes damaged or goes down for whatever reason, the rest of the hardware in the driverless car runs into serious problems [4]. This can be addressed by installing a secondary box as a backup [4].

Operating System

Driverless car technology faces a series of challenges. Several of these are due to the operating system itself, which is the Robot Operating System (ROS) often used in robotics [4]. It suffers from reliability issues due to system crashing, but researchers have found a way to deal with it by incorporating a back-up master node [4]. It suffers from performance issues due to inefficient transmission of information, but researchers have dealt with this by modifying the way information is transmitted [4]. Finally, the ROS operating system suffers from security issues [4]. This issue is more complicated, but researchers have attempted to deal with it by essentially utilizing encapsulation and encryption methods [4].

Localization

Based on the constructions just laid out, accurate localization is evidently important in order to avoid accidents. GNSS is blocked to a problematic extent in built-up urban centers, but researchers rely more heavily on LiDAR in those environments due to the density of surfaces to for the lasers to reflect off of and generate a detailed 'picture' of the car's environment [1]. In rural areas, while LiDAR is lacking the density of structures of reflect its lasers off of, GNSS is much more responsive [1]. Thus researchers have found ways to allow these different inputs to complement each other effectively [1].

Driver Handover

Practical challenges exist in terms of how a human attendant in a driverless vehicle would take over in the case of an emergency [3]. Researchers have proposed and tested auditory alerts prior to when handover is prompted, which is effective in giving the person time to assess the situation before assuming control of the vehicle [3].

BENEFITS AND OBSTACLES

In light of deaths caused by the implementation of driverless car technology [6], [8], society is certainly experiencing growing pains in accepting this emergent change. While driverless cars reasonably promise a safer future overall [5], there is still the negative emotional response characteristic of societal change. This is fueled further by the prospect of the loss of transportation jobs [5], as well as the loss of perceived individual autonomy [2].

That being said, driverless technology promises to eliminate much of the human error which can be attributed to the vast majority of automotive accidents, create new jobs, and give people more time for their own productive pursuits [5]. While perceived autonomy may seem threatened, driverless cars can give autonomy to many people who would not otherwise have it without driverless cars, including elderly people and those with disabilities [5], [2].

Shifts in insurance and liability issues will also need to be explored, but these issues themselves should not act as a barrier so much as a necessary check before moving on [5].

CONCLUSION

Using Silver's framework as a starting point and expanding upon it with the architecture laid out by Liu et al provides a broad yet concise over of driverless car technology [7], [4]. While there are countless more nuances involved that are beyond the scope of this paper, the analysis provided here lays down a good starting point for this vast and constantly developing topic.

Researchers have thus far been mostly able to equip themselves to deal with issues that arise with this technology [4], [1], [3], but more issues – both technical and societal – are bound to emerge. Despite the obstacles facing society [6], [8], [5], [2], we will have to find a way to address the downsides while maximizing the benefits [5], [2].

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