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Computer Vision in Automated Parking Systems: Design, Implementation and Challenges

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Abstract

Automated driving is an active area of research in both industry and academia. Automated Parking, which is automated driving in a restricted scenario of parking with low speed manoeuvring, is a key enabling product for fully autonomous driving systems. It is also an important milestone from the perspective of a higher end system built from the previous generation driver assistance systems comprising of collision warning, pedestrian detection, etc. In this paper, we discuss the design and implementation of an automated parking system from the perspective of computer vision algorithms. Designing a low-cost system with functional safety is challenging and leads to a large gap between the prototype and the end product, in order to handle all the corner cases. We demonstrate how camera systems are crucial for addressing a range of automated parking use cases and also, to add robustness to systems based on active distance measuring sensors, such as ultrasonics and radar. The key vision modules which realize the parking use cases are 3D reconstruction, parking slot marking recognition, freespace and vehicle/pedestrian detection. We detail the important parking use cases and demonstrate how to combine the vision modules to form a robust parking system. To the best of the authors knowledge, this is the first detailed discussion of a systemic view of a commercial automated parking system.

Keywords: Automated Parking, Automotive Vision, Autonomous Driving, ADAS, Machine Learning, Computer Vision, Embedded Vision, Safety critical systems

1. Introduction

Cameras have become ubiquitous in high-end cars, with a rear-view camera being the minimum and full surround view camera systems at the top-end. Automotive camera usage began with single viewing camera systems for the driver. However, both the number of cameras and the number of ADAS applications made possible with automotive cameras have increase rapidly in the last five years, mainly due to the fact that the processing power has increased during this time period to enable the high levels of real-time processing for computer vision functions. Some examples include applications such as back-over protection, lane departure warning, front-collision warning, or stereo cameras for more complete depth estimation of the environment ahead of the vehicle. The next level of advanced systems requires driving automation in certain scenarios like highway or parking situations. In this paper, we focus on the latter, namely automated parking systems. There are many levels of autonomous [1] driving as defined by Society of Automotive Engineers [1]. Fully autonomous driving (Level 5) is an ambitious goal. The current systems are, at best, Level 3 and are designed to work mainly for highway driving.

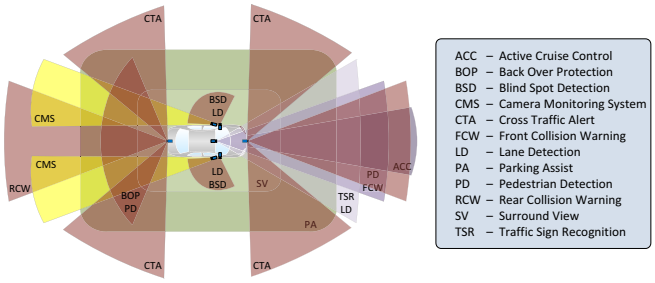

Figure 1: ADAS application of cameras and the respective field of view

Certainly there are risks involved as no algorithm is perfect, and the sensors utilized can have limitations in certain scenarios. Automated parking is a good commercial starting point to deploy automated driving in a more restricted environment. Firstly, it involves low speed manoeuvring with a low risk of high impact accidents. Secondly, it is a more controlled environment with fewer scene variations and corner cases. Stable deployment of automated parking in the real world and analysis of performance statistics is an important step towards going to higher levels of autonomy.

The first generation semi-automated parking systems were based on ULS or radar, with cameras recently and gradually adding more value. In this paper, we consider cameras as an important component of a parking system, extending the capabilities of or providing inexpensive alternatives to other sensors. Figure 1 shows the various field of views of the important appli-

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[1]The words autonomous and automated are used interchangeably by researchers in both industry and academia. In this paper, we use the term automated instead of autonomous implying that the system is not completely independent and there is a driver trigger.