# *Automatic Valet Parking System Incorporating a Nomadic Device and Parking Servers*

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***Abstract*—Automatic Valet Parking System (AVP) is a system that supports autonomous maneuvering from a traffic lane to free parking slot. In this paper, we propose a hybrid framework using both in-vehicle and infrastructure based system for detecting environment and controlling the vehicle. Using the system, drivers can get off their car, and can monitor/control them in a safe and comfort way with their nomadic device.**

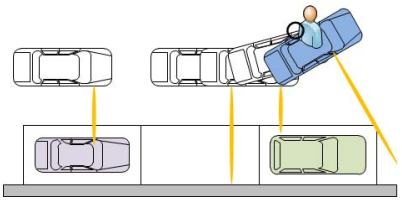
## I. INTRODUCTION

Parking task is recognized as the most difficult among the driving tasks since it includes finding free parking space and moving backward in large probabilities of collision [1]. To alleviate the aforementioned driver's burden, two different types of systems are studied and commercialized. The first is to provide a driver with vacant parking slot information and to guide the driver to the destination through VMS (Variable Message Sign) or network connected portable devices [2]. The second is to assist driver's parking maneuver by means of coordinated control of the steering wheel when performing parallel or perpendicular parking. Usually, the former is called smart parking system and the latter is called automatic parking assistance system [3].

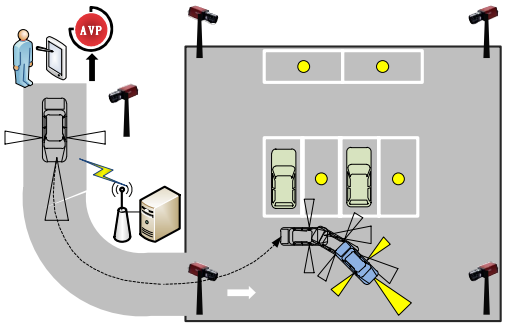
Although the previous two types of systems gives some degree of comfort and safety to the driver, they assume driver's presence in the car, and still need driver's much attention and constrained environment. In this paper, we suggest full autonomous valet parking system framework, called automatic valet parking system. The system framework incorporates a nomadic device (ex. smart phones, PDAs, etc.) and a parking server to guide a vehicle from road to the parking spot automatically in the parking zone.

## II. APPROACHES OF DRIVER ASSISTANCE SYSTEM IN PARKING

Several products of PAS (automatic Parking Assistance System) support automatic steering control when performing parallel and perpendicular parking [3]. As shown in Fig.1. (a), the driver should find free parking space by himself, and pass carefully by the region for the system to detect the free space by using in-vehicle sensors such as ultrasonic sensors and vision sensors. After the detection, the system controls the steering wheel, the driver controls the accelerator/brake pedals. However, this system has limitations since it does not help the driver to find free parking slot and often fails to recognize the geometry of the parking slot.



(a) Automatic Parking Assistance System




(b) Auto Valet Parking System

Fig. 1. Driver assistance in parking

To overcome the limitation of the PAS, the functionalities of finding available parking slot and aiding collision-free autonomous maneuvering is necessary. Automatic valet parking system can do the previous mentioned operations There were related studies like UGV (Unmanned Ground Vehicle) in DARPA Urban Challenge [4][5]. In those studies, a vehicle performs on-road navigation and zone-navigation including a parking operation without human intervention. However, it is impossible to apply those systems to real world application since high cost devices such as laser scanners, radars, DGPS/INS, computers, networking devices should be mounted on those vehicles. In this paper, we integrated infrastructure based sensor systems and in-vehicle sensor systems to lower the cost and incorporated nomadic device and parking servers to provide parking information and control vehicles as shown Fig.1.(b).

## III. PROPOSED SYSTEM

The proposed system framework consists of four major subsystems: a nomadic device, a vehicle controller, local spatial-aware servers and a global situation-aware server. Nomadic device is a portable device on which the AVP mobile application is installed. The vehicle controller is a

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device which is mounted on the car. The local spatial-aware server and the global situation-aware server are parking servers which reside in infrastructure for perception and control of the vehicles. The detailed modules and relationships are presented in Fig.2.

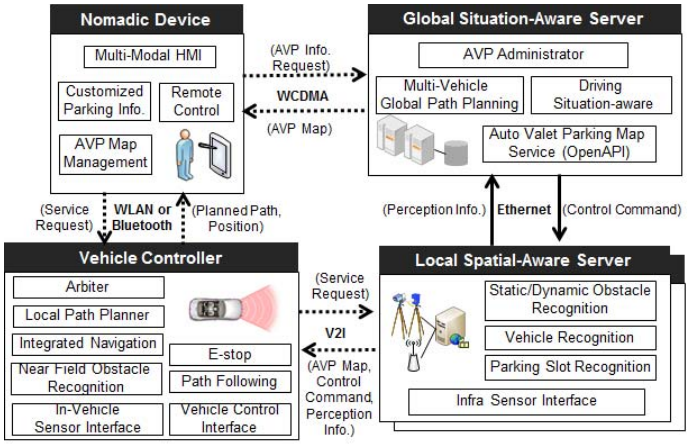


Fig. 2. Architecture of Automatic Valet Parking System

### A. Nomadic Device

A driver can request valet parking map service to the GS (global situation-aware server) using nomadic device through wireless communication (WCDMA) and then receives customized parking information such as map of the parking zone and available candidate parking slot information. If the driver wants to control the car automatically, the driver connects and registers the device to the VC (Vehicle Controller). After that step, the driver may get off the vehicle and can request AVP service to the VC. The VC gives planned path and the vehicle status (position and in-vehicle sensor information) to the nomadic device. After acquisition of the grant from the user, the VC controls the vehicle to reach to the target destination.

### B. Vehicle Controller

Vehicle controller receives AVP map, control commands, perception information from LS (Local Spatial-Aware Server). The VC integrates and fuses the perception information with in-vehicle sensor information, producing reliable position of the vehicle and obstacles. The sensors are chosen according to the trend of in-vehicle sensors which is used also for other purposes like ACC (Adaptive Cruise Control), LDWS (Lane Departure Warning System), PAS, and etc.. Integrated navigation (GPS/UWB/DR/Map) for positioning is necessary since parking zone can be indoor environment. Using the computed perception information, a local path, which guarantees collision-free, is generated. The path follower controls actuators through vehicle control interfaces according to the path.

### C. Local Spatial-Aware Server

The LS is responsible for detecting the positions of static/dynamic obstacles and the controlled vehicle. Also, it should detect occupancies of parking slots, and the attitudes of parked vehicles to determine the geometries of the free space. Multiple LSs which are connected with infra-based sensors are used since the coverage of sensors is limited. We used laser scanners and cameras to measure the positions. V2I (Vehicle to Infrastructure) communications (ex. IEEE 802.11p) are used between the VC and the LS to satisfy data transmission requirements.

### D. Global Situation-Aware Server

The GS (Global Situation-Aware Server) is responsible for high level multi-vehicle path planning and decision making according to the driving-situation. When vehicles or obstacles have possibilities of collision, it schedules the movement or sends emergency commands to the VC through LS. Also it provides Auto Valet Parking Map Service for nomadic device. Unlike the binary based application protocol for AVP control among VC-LS-GS, it provides open API based on web service and XML for nomadic device and mash up services. Operators can monitor overall systems and parking zones by received perception information from the LS and can sends E-stop commands for abnormal situation. The GS communicates with the LS through wired network (Ethernet) and coordinates control handover when the vehicle passes through the coverage of the current servicing LS.

## IV. CONCLUSION

This paper suggested auto valet parking system framework including a nomadic device, a vehicle controller, local spatial-aware servers, and a global situation-aware server. The proposed system hybrids both in-vehicle sensors and infra-based sensors, reducing device cost of individual vehicle and provides reliable sensor information. Also drivers can get information and control remotely their vehicle to perform parking maneuvering in a safe and comfort way.

By using this system, air pollution and energy consumption can be reduced by shortening travel time to the parking slot. Also social problems such as theft of valuables in the car or robbery in the parking lot can be prevented by unmanned automatic parking. In the future, electronic vehicle charging service can also be implemented by using this technology.

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