

## A proposal of automated valet parking system using automatic pallet

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### Abstract

Recently, various issues in self-propelled multi-storey car parks are becoming social concerns: accidents thefts, difficulty in finding a parking space, limited space for getting in/out of cars, and less friendly environment for novice/elderly users. These issues can be solved by introducing a valet parking system where car parking staff receives a car key from a user and drive the car to the parking space. However, the operator of the parking system needs to employ these staff, which impacts negatively financially. This paper aims to solve these conflicting demands by proposing an automated valet parking system by incorporating automatic pallets, which are mobile parking spaces. An automatic pallet is an equipment dedicated specifically for transferring a car: it enables automatic entrance and exit procedures. The proposed system requires no human intervention and enables complete automated parking procedures.

### Key words

automatic valet parking, automatic pallet, hybrid multi-storey car park, automatic driving, wheel stopper

### 1. Introduction

Currently, there are many reported problems with automobiles: these include erroneous operation and traffic accidents by the elderly, drowsy driving due to overwork, traffic violations due to lack of normative awareness, malicious tilting driving, driver shortage due to poor working conditions, and traffic congestions caused by an increase in private cars. As a solution to these problems, autonomous driving is currently receiving extremely high expectations. An initiative set by the Government of Japan specify the year in which the goals will be achieved under detailed conditions in the three fields: mobile services, private cars, and logistics services. The factors being considered in determining automatic driving levels include road type (highway, general road etc.), weather, speed, as well as driver's intervention in emergencies. Based on these factors, the three fields have their own completion target year for each level. For example, in mobile service filed, unmanned autonomous driving limited to highway will be implemented nationwide by 2025 (Strategic Conference for the Advancement of Utilizing Public and Private Sector Data, Strategic Headquarters for the Advanced Information and Telecommunications Network Society, 2019).

While the cars performing people's movements continue to evolve, are parking lots, which are temporary or long-term storage locations for the cars, keeping up with these continuous evolutions of the cars?

Existing researches on the current state of autonomous driving and the future of parking lots have shown autonomous driving technology for vehicles has almost completed

the experimental stage and is gradually being introduced to commercial vehicles (especially those in the high price range) (Tanikawa, 2019; Yamazaki et al., 2019; Kitagawa Corporation, n.d.; Japan Automobile Research Institute, n.d.). Examples are (1) automatic assist functions on the highway (steering and acceleration/deceleration) and (2) automatic parking function (entrance and exit) by voice command or simple operation in the home garage. With the evolution of such automated driving technology, there is a high possibility that automatic valet parking will be required in the near future, which would allow cars to automatically enter and leave parking lots in urban area. However, a wide variety in types, specifications and performances of commercial vehicles raises problems for accurate and safe automatic-parking. These problems have not been solved and fully automate unmanned parking has not been materialized. In its place, there are many types of semi-automatic valet parking that people use with them (Saito, 2018; Autonomous Driving Lab, 2020).

If realized in full, automatic valet parking has different merits for parking lot users and owners:

Benefits for users:

- Be able to park without driving
- No need to find a parking place
- Less concern about accidents and thefts in the parking lot.
- Be able to get on and off in a spacious boarding area
- Be able to shorten the boarding/deboarding time
- Friendly to novice and the elderly drivers

Benefits for owners:

- Increased turnover rate and improved income
- Less concern about accidents and thefts in the parking lot.
- Reduced personnel costs (no need for staff to guide)

The revenue of the owner can be improved by full operation of the facility, increase in the number of users, and reduction of labor and maintenance costs. The number of users and accompanying income will increase thanks to the 24/7 operation of the facility and the increase in the number of parking spaces per floor area. On the other hand, in terms of costs, compared to the conventional manned type, labor costs are no longer required, which results in significant reductions in overall cost. In terms of maintenance, it is possible to perform the necessary maintenance while keeping a high operating rate by partially and systematically repairing the automatic pallets based on certain criteria such as frequency of use and the presence or absence of breakdowns. For large-scale remodeling and maintenance of buildings, it is possible to maintain a high degree of operation and minimize the negative impact on the revenue by renovating only a part of the area. Therefore, the proposed parking lot system will improve the revenue of the owner.

Given these potential benefits, demand for automated valet parking is expected to increase in the future. This paper aims to compensate for the lack of accuracy and safety of automatic parking due to the variety of vehicle types, specifications, and performance and proposes automatic valet parking with an electric pallet on which the car can be placed. This electric pallet can be considered as an autonomous car for its automatic operation from entrance to exit. In this paper, only one type of pallet is used to limit the usage environment. This limitation allows an automatic valet parking with practical value.

## 2. Composition of proposed parking system

### 2.1 Automated pallet

The automatic pallet is electrically driven and large enough to carry a car from boarding area to the open parking space (entrance procedure) and vice versa (exit procedure) (Figure 1). The sets of automatic pallets are the core components in realizing an automated valet parking system, which is a fully automatic version of existing manned valet parking system. The proposed system performs following two tasks done tra-

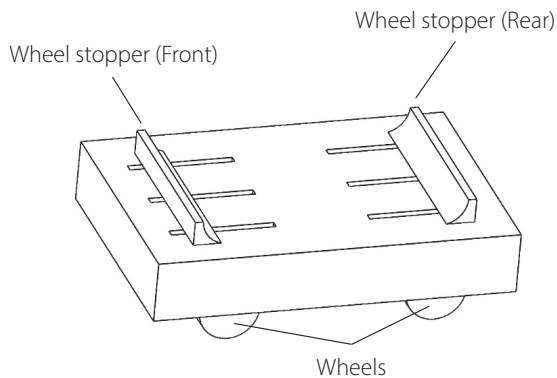


Figure 1: Structure of automatic pallet

ditionally by parking staff.

- Staff searches for a parking place and stores the car.
- Staff drives the car to the boarding area.

The automatic pallet has wheel stoppers on the front and rear to stably fix the car on it. The stoppers are retracted when not being used and deployed when in use. When they are deployed, the front and rear stoppers are gradually moved to shorten the distance between them to securely fix the wheel.

### 2.2 Entrance procedure

The car arriving at the parking entrance is parked at a designated place on the turntable where a cell pallet is embedded (Figure 2). When the car is not parked within the pallet, an alarm beeps to ask the driver to park in the designated area. If parked correctly according to the instructions of the parking system, the driver (and other passengers) gets off and lock the car. The driver shows his/her face to a camera for identification to register. The front and rear wheel stoppers are deployed and move in opposing direction to cramp the wheels securely. After securing the car, the cell pallet goes down to underground level where a pallet passage leads to the multi-story car park. After the pallet with the car vacates the turntable, a new cell pallet is placed for a new vehicle to accommodate (Figure 3). These operations are automatically conducted.

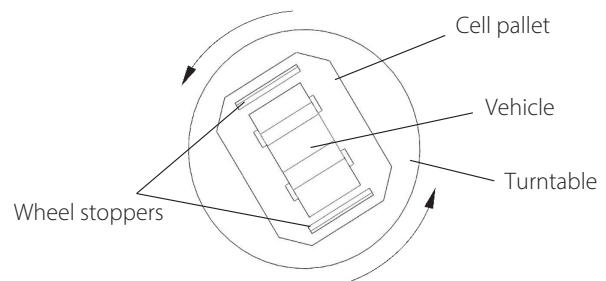


Figure 2: Turntable with automatic pallet used for entrance and exit procedure

### 2.3 Multi-storey car park used in the system

The multi-storey car park used is an existing self-propelled multi-storey car park. In addition, the existing traffic regulations in the parking lot will be used. The difference between the normal multi-storey parking lot and the proposed parking lot is that the automatic driving is used to search for a parking place and to get the car out of the boarding area. In other words, it is automatic valet parking. In a conventional self-propelled multi-storey car park, the driver often parks in a vacant place at random. Therefore, in this study as well, random numbers are used to determine the position of the parking

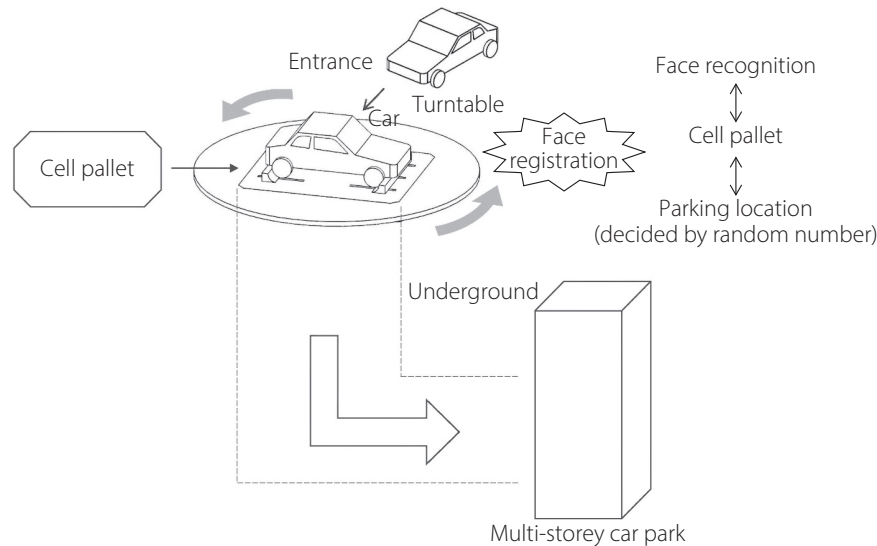


Figure 3: Entrance procedure

place.

Automatic pallets need a size to carry a car. However, the size of the automatic pallet used in this proposal is designed to be smaller than the space for one car in a normal parking lot. In addition, since the automatic pallet is automatically operated, getting on and off at the parking place does not occur, and the distance between parked vehicles can be narrowed.

It is inevitable that the adoption of the automatic pallet will impose some restrictions on the types of vehicles that can be parked. However, in the future, as the technology for autonomous driving advances, consideration for the autonomous-control aspect is expected to become more important factor in designing the car. Additionally, as a measure against global warming, demands from the society for further reduction in the environmental load derived from automobiles will increase. Based on these considerations and requests, the types and sizes of passenger cars for the general public to be released in the future will be expected to become even more restricted. That is, there is a high possibility that the restrictions on the types of vehicles used due to the adoption of automatic pallets will not be a major drawback in the future. Rather, the proposed system is highly likely to be socially implemented as a system that suits future needs.

#### 2.4 Exit procedure

The procedure is conducted in the opposite flow of the entrance procedure. The driver goes to the boarding area and have his/her face identified with the face recognition camera. The automatic pallet picks up the car owned by the identified driver. If the parking lot is charged, paying the fee for the hours parked will release the front and rear wheel stoppers; if it is a free parking lot, the wheel stoppers will come off as

soon as the automatic pallet arrives at the boarding area. The retraction of the stoppers allows the driver to drive and leave. Additionally, parking history information is recorded for each authenticated face image. Figure 4 shows the exit procedure.

### 3. Conclusion

The automatic valet parking in this paper is equipped with an entrance facility for putting a car on an automatic pallet and a boarding area facility for getting a car out of the automatic pallet. This system is installed in an existing self-propelled multi-storey parking lot. Parking places are determined by random numbers. Instead of ticketing, facial recognition is used to associate the user with the car on a specific pallet. Entire operations of the pallets are automatically controlled. The use of single-type pallet leads to a more focused environment where practical implementation is easy to be realized.

The future research will address the following three issues:

- Parking in the designated area: in entrance procedure, a driver with insufficient driving skills may not be able to park smoothly within the designated area in the turntable where the automatic pallet is embedded. To address this issue, an automatic adjusting mechanism is worth considering.
- Facial recognition fraud: Criminals may try to steal a car by fraudulent authentication. As a countermeasure against such vehicle theft, it is worth considering adding a function to photograph and record a legitimate driver while he/she is in the driver seat, the entire vehicle, and a license plate.
- Parking place decision rule: In the proposed automatic valet parking, the parking place is decided using random numbers. However, some users may want to park the car near the boarding area to shorten the time required for exit

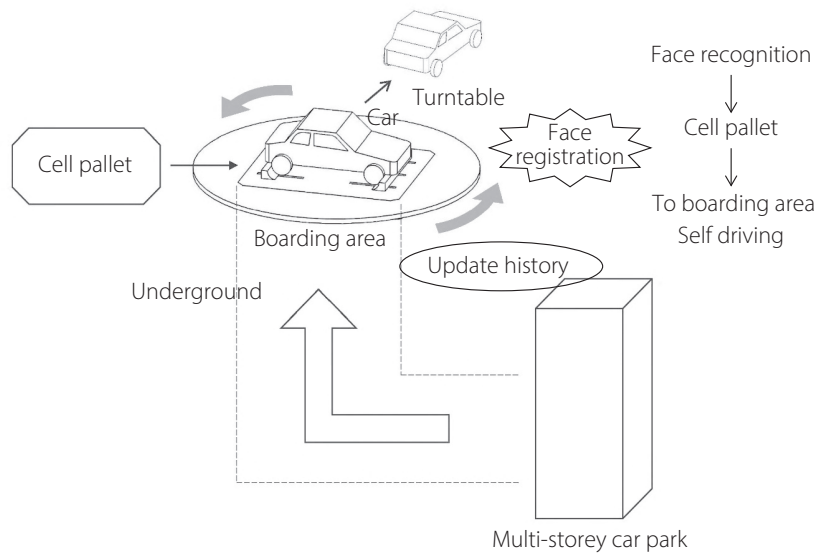


Figure 4: Exit procedure

procedure. A system to accommodate this demand with dynamic pricing function needs to be considered.

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