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ROBUST DRIVE-BY ROAD SIDE PARKING DETECTION ON MULTI-LANE STREETS USING AN OPTICAL DISTANCE SENSOR

Master's Thesis

to confer the academic degree of

Master of Science

in the Master's Program

Computer Science

Affidavit

I hereby declare that the following dissertation "Put your thesis title here" has been written only by the undersigned and without any assistance from third parties.

Furthermore, I confirm that no sources have been used in the preparation of this thesis other than those indicated in the thesis itself.

Linz, on November 4, 2017

Markus Hiesmair

Acknowledgment

Summary

Summary . . .

asdf

Abstract

Abstract . . .

Contents

To-Do: For now the TOC depth is 5 but will be reduced later

Abbreviations

GPS Global Positioning System

LIDAR Light detection and ranging

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Chapter 1

Introduction

To-Do: soll hier ein kurzer überblick über die Arbeit und das Kapitel gegeben werden? Also wo was beschrieben ist usw?

1.1 Importance of Research and Motivation

Traffic congestion in urban areas became a bigger problem every year in the past decades. Increasing traffic causes several issues, for example high monetary and environmental costs by using gasoline and by emitting CO_2 to the environment. There are several strategies to reduce urban traffic to mitigate these problems like for example new investments in public transport infrastructure. However, the usage of private cars in cities won't stop in the next decades, but increase. According to a study by Hao et al. [1] car sales will continue to grow in the upcoming decades and therefore also traffic will continue to become worse in big cities. Thus, it is important to find ways to reduce traffic in urban areas.

With more vehicles driving in urban areas, there also comes the need for a sufficient number of parking spaces. Finding parking spaces in urban areas can be a really difficult, frustrating and time consuming task for drivers. There often exists some information about the availability of parking spaces in parking garages, but in most cities the situation of road side parking is rather non-transparent. This not only leads to frustrated drivers, who are searching for parking spaces a long time, but again contributes to urban traffic congestion as many cars have to drive around close to their destination while searching for free parking spaces.

There are many studies, which show that the searching for parking spaces adds a lot of traffic. In 2013 a study by Nawaz et al. [4] showed that about 30% of traffic congestion is created by drivers looking for free parking spaces. Another study [2] found that

alone in 2007 searching for parking spaces caused costs of about 78 billion US dollars by using 2.9 billion gallons of wasted gasoline and 4.2 billion lost hours only in the United States. Furthermore, this obviously causes a lot of CO_2 emissions which is not only bad for the environment and contributes to climate change, but also lowers the quality of living in big cities through the significant amount of air pollution.

One of the most important contributors to high search times for parking spaces is not only the lack of vacant parking spaces, but also the lack of information, if and where free parking spaces are available. Therefore, one way to mitigate many of the above stated problems is to determine the current parking space situation in the city and make it accessible to the public (e.g. via web application), so that drivers can efficiently navigate to a vacant parking space, or even decide if they want to go by car or use public transportation, depending on the number of parking spaces available close to their destination.

However, detection of road side parking spaces and their states is a challenging task. Of course an obvious approach to the problem would be to put stationary sensors to every parking space in the city, which check, if the corresponding parking space is occupied or vacant. This, however, has the drawback to be very expensive as, for big cities, thousands of sensors would have to be bought, installed and maintained. Furthermore, because the state of parking parking spaces does not often change, the high frequency of sensing with such a system would be rather inefficient.

1.2 Drive-By Park Sensing

A promising novel approach to sense a city's parking situation is the use of mobile sensors instead of static ones. Crowd sensing has the advantage to be usually more cost effective and can provide sufficient accuracy for the purpose of providing parking space availability maps.

There are several approaches to mobile parking availability sensing, which will be discussed in chapter 2. This thesis will focus on "drive-by park sensing". The idea behind the drive-by sensing approach is that there are sensing vehicles which are driving through the city and collecting data of their environment through mounted sensors. Using the collected data parking cars and vacant parking spaces should be detected. There already exists a prototype implementation of such a system. In 2013, Mathur et al. [3] presented their system, called ParkNet, which continuously measured the distance to the nearest obstacle on the right side of the road, as well as the location of the sensing vehicle through a GPS sensor. Using these data, they used thresholding
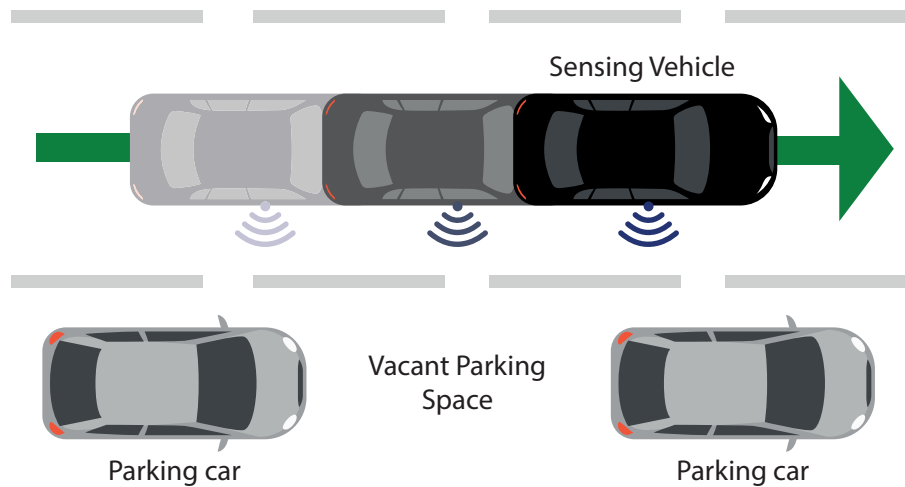
Figure 1.1: The sensing vehicle passes two parked cars and should identify a vacant spot in between using distance and location measurements. **To-Do:** Hier Referenz zu Parknet-Paper??? Ähnliche Grafik...

to detect parking cars and vacant parking spaces. A more detailed description of their work is being described in section 2.1.

Figure 1.1 shows a standard drive-by scenario of a sensing vehicle which passes two parallel parked cars and a vacant parking space in between them. The distance measurements while passing the parked cars will be much shorter than the measurements taken while passing the vacant parking space. This should allow a basic algorithm to recognize parking cars and vacant parking spaces.

However, the situation which is shown in figure 1.1 is an idealistic one. In real life traffic, there will be much more complex situations to face, which are not as easily detectable and which might influence the success of the detection. For instance, the sensing vehicle might not drive in the right-most lane, therefore the measured distances will be much longer. Another possible issue are other driving cars, motorcycles or bicycles which the sensing car overtakes. There are many of such distractions which have to be filtered out to ensure that there are as few false detections as possible. The existing ParkNet prototype does not take any of such situations into account, because it was only evaluated on parallel parking cars on single lane roads.

The high complexity of urban traffic and the many distractions during sensing make it nearly impossible to create a rule set based on the sensor measurements which would

be able to detect parking situations at a sufficient accuracy. Therefore, simple thresholding as applied in the ParkNet prototype will not work in real life traffic scenarios. Furthermore, such rule sets would have to be created for each city individually because of the different nature of the roads and the parking spaces. For instance, the distance between roads and parking spaces can vary highly in two different cities. Thus, to be able to detect parking situations, new methods have to be found, which should be more flexible to distractions and changes in the environment.

1.3 Research Goals and Methodology

The overall goal of this thesis is to determine which accuracy can be achieved for detecting the parking space situation in urban real world traffic scenarios using drive-by park sensing. Furthermore, distracting situations should be identified and strategies to cope with them should be found to be able to keep the detection accuracy high. In contrast to existing approaches in this thesis machine learning will be applied to classify different road traffic and parking scenarios to be able to better cope with the high variety of situations possible. To achieve these goals, the following steps will be executed:

Building a test bed As a first step a test bed has to be built, which is able to access the required sensors to record all the necessary data. A Raspberry PI will be used as processing device because of its popularity and the many compatible sensors which work with this platform. It is connected to a LIDAR-Lite v3 sensor which continuously measures the distance to the nearest obstacle on the right side of the road. A GPS receiver will track the location of the sensing vehicle and a camera will be used to record images of the ground truth for evaluation purposes only. **To-Do:** evtl. referenz zur section wo die hardware genauer beschrieben wird...

Acquiring a dataset As soon as the test bed is ready, the sensors should be mounted on the prototype car to be able to start recording the dataset. Test drives should be done in some selected streets in Linz, Austria with the focus of variety of the recorded situations. The test scenes should include single lane as well as multi lane streets and measurements in all streets should be done several times. Furthermore, the car should be driving as it would in regular traffic (not only in the right most lane, etc...) and the scenes should also include high and low traffic scenarios to have a high amount of diverse data. All measured distances, GPS locations and ground truth images should be saved to files with the according timestamps to be able to evaluate the results of different approaches later on.

Ground truth tagging All captured pictures with the camera have to be manually labelled in different class (Parked car, free space, overtaken car, ...) to be able to evaluate the performance of detection algorithms later on.

Preprocessing and filtering the sensor data As next step the measured sensor values have to be preprocessed and filtered in order for the following algorithms to work. Sensing and overflow errors as well as outliers in the measurements should be identified and removed before further processing.

Segmentation As parking cars and other cases which should be classified consist of several sensor measurements, the corresponding sensor measurements should be grouped together and merged to segments which will be later classified.

Classification Features on the created segments are calculated (for instance length, average distance and variation of the distances) and are being used to train and evaluate several machine learning algorithms which will be compared on their performance. Furthermore, some deep learning models will also be evaluated on the raw sensor data of the segments and will be compared to common machine learning results.

Post processing To-Do: todo

Chapter 2

Related Work

2.1 ParkNet

parknet...

Chapter 3

Prototype Implementation

blabblabla

3.1 System Design

- System description (type of sensors, requirements); overall envisioned system of cars detecting free spaces and communicating the information - Testbed description (concrete HW and technical capabilities)

3.1.1 Test Bed Description

3.2 Experiment description and data collection

- Description of experiments (scenarios we are interested in: parking car, etc.) - Data set derived (raw data, size, etc.) - Map data and camera ground truth data

3.3 Data processing

- Preprocessing, feature definition ... - Traditional ML Algorithms (incl. a short description of each algorithm and configuration options) - Deep Learning

3.4 Experimental results

- Results of the different ML approaches, important features, difficult cases, etc. - Comparison of traditional ML and Deep Learning (cf. our demo)

Chapter 4

Results and Discussion

Chapter 5

Conclusions and Future Work

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