University of Ulm
Department of Neural Information Processing

Diploma Thesis

Approximation of the Posterior Probability on the Basis of a Cascade Classifier for the Integration of Tracking into an Intelligent Pedestrian Searching Strategy

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1 Introduction

1.1 Motivation

Today's road traffic poses great challenges to all participants, especially to the drivers of vehicles. A great amount of information has to be processed quickly in order to enable an appropriate reaction to critical situations.

Several systems have been developed to increase safety on roads and to reduce the risk of traffic accidents. These systems can be divided into two categories: *passive systems* and *active systems*. Passive systems are designed to protect persons involved in an accident. Airbags and safety belts belong to this category. Active systems aim at preventing accidents. Examples of systems belonging to this category are the Antilock Brake System (ABS) and the Electronic Stability Programme (ESP). Unfortunately, there are only few systems that aim explicitly at the safety of outside traffic participants. Until recently, only one passive system could be found: Flexible bodies of vehicles help to reduce the severeness of injuries of pedestrians caused by a car accident. According to statistics of the Federal Statistical Office Germany in 2005[1], the second highest number of deaths on the road concerns pedestrians.

At night, pedestrians are even more put at risk on the roads due to their bad illumination. Addressing this problem, an active system has now been introduced to the market displaying images of a *near infrared* (NIR)-camera to vehicle drivers. The usage of NIR provides a great advantage: The reflected light of suited NIR-headlights provides the same range of sight for the driver as full beams without glaring the oncoming traffic.

The NIRWARN-project[2], supported by the Federal Ministry of Education and Research Germany, has been initiated in order to create a system that applies image processing methods to NIR-images. The goal is to automatically warn vehicle drivers on rural roads of pedestrians appearing in front of their cars at night. This thesis is part of the NIRWARN-project.

[1] http://www.destatis.de/basis/d/verk/verktab6.php
[2] http://www.bmbf.de/de/6107.php

1.2 Assignment of Tasks

This thesis refers to an existing pedestrian detection system which is based on video and has been developed in the context of the NIRWARN-project. The system is used in an experimental vehicle for the automatic detection of pedestrians on rural roads at night. This detection is done in real-time and on the basis of NIR-images captured by a NIR-camera. In case of the detection of a pedestrian, the driver of the vehicle is warned.

To accomplish this, the system includes a pedestrian searching strategy for the location of potential pedestrians and a *cascade implementation* for the verification of located potential pedestrians. In this work, an approach to an improved searching strategy is to be researched. Presently, the process illustrated in Figure 1.1 is performed in every time step, i.e. whenever a new image is captured by the camera. According to the searching strategy, a reasonably defined image area is simply scanned for pedestrians.

Figure 1.1: **Present detection system:** Information of previous time steps is lost.

In contrast to this, a new searching strategy is meant to utilise information from previous time steps, performing some kind of tracking. According to the conceptional formulation it is assumed here that this tracking is performed by a so called *particle filter*. The basic principle of a particle filter is to reduce a searching problem to a verification problem: Over time, search narrows down to image areas where the appearance of a pedestrian is more likely. This is achieved on the basis of verification results. The central issue of this thesis is how to use the output of a *cascade classifier* for this purpose. In this matter the approximation of the *posterior probability* is key. The potential new system is shown in Figure 1.2.

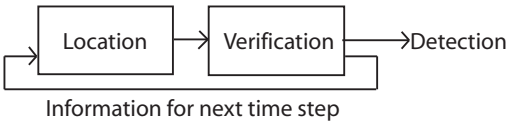

Figure 1.2: **Potential new detection system:** Information of one time step is used in the next time step.

In particular, a mathematical theory is required. As a starting point the recent publication [Tu05] was given. The transferability of the theory provided in this publication was also defined as an essential task of this work.

1.3 Related Work

This thesis is based on the existing pedestrian detection system mentioned in Section 1.2. It was created in the course of several theses in the NIRWARN-project at Daimler-Chrysler. The present pedestrian searching strategy was developed within the scope of [Kal05] and [Rot06]. The cascade implementation on the other hand is a product of [Wen03], [Ape05], [Kal05], [Rot06] and [Chr06]. This implementation is based on several theoretical concepts: First, *boosted classifiers* are used. Boosted classifiers and the related *AdaBoost algorithm* are explained in [FS95], [FS96], [FS99] and [Sch01]. Secondly, classifiers are combined. The idea of combining boosted classifiers in a cascade was first presented in [VJ01]. Additional information on this subject is available in [WL04]. Thirdly, filters similar to *Haar basis functions* are applied. Such filters were closely examined in [OPS$^+$97], [POP98] and [PP00].

Research on the tracking of objects was performed within the NIRWARN-project in [Idl05] where a multi-target particle filter for the tracking of cars was successfully developed. The implementation was later adapted for the tracking of pedestrians in [Arn06]. However, both theses base on heuristic models due to the missing posterior probability. A brief introduction to particle filters is provided in [AMGC02]. Further details can be found in [Dou98], [DDFG01], [TS] and [Den04]. Information on the special particle filter implementation called *condensation algorithm* is supplied in [Isa98] and [IB98].

Concerning the approximation of the posterior probability, the theoretical foundation was built in [SS98], [FHT98] and [Tu05]. The contribution of [SS98] is an upper bound on the misclassification error of a boosted classifier. In [FHT98] this upper bound is used to derive an equation for the approximation of the posterior probability, based only on the output of a single classifier trained with AdaBoost. In contrast to that, [Tu05] is concerned with the approximation considering not only one, but a combination of several such classifiers.

1.4 Thesis Outline

The thesis is structured as follows: Chapter 2 gives a very brief introduction to the pedestrian searching strategy used in the existing detection system. The classifier implementation of the system is presented in Chapter 3. Chapter 4 introduces the tracking of objects in general and basic particle filter theory. It also explains why a special particle filter implementation called condensation algorithm is especially appropriate for the development of an improved pedestrian searching strategy. In Chapter 5 it is discussed how the output of the cascade classifier can be used as input of a particle filter. However, one problematic characteristic of the cascade implementation regarding the presented theory is omitted in this Chapter and considered explicitly in Chapter 6. A number of experiments was conducted in order to verify all presented theory. These ex-

periments are described in Chapter 7 in detail. Finally, Chapter 8 provides a summary of the outcome of this thesis and outlines possible feature examinations.

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