Semantic segmentation of road images based on cascade classifiers

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Abstract

In this work a novel algorithm for lane marking and road-covering defects detection on rectified images of road covering is proposed. Proposed method is based on image over-segmentation and classification of resulting segments. We use cascaded classifiers for lane marking and road defects detection. Each cascade layer involves binary classification and the last layer involves multi-class classification of image segments.

Introduction

Roadway video passport systems are widely-used for roadway quality monitoring and repair planning. These systems like [1] include a complex of video cameras and other sensors mounted on a car as shown on Fig. 1. These cars move along the road and gather information from the sensors.

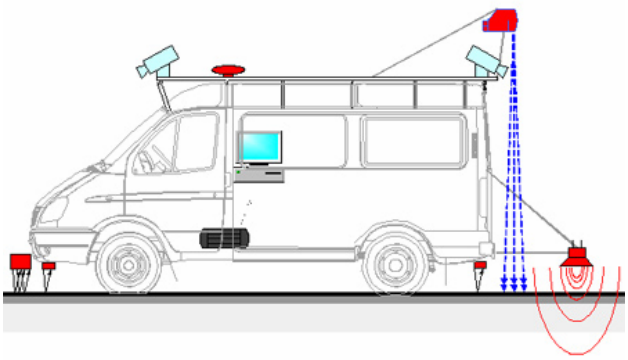


Figure 1 Road laboratory. Video cameras are mounted on the front side and on the back side of the car.

At the moment video gained by these mobile laboratories is usually processed manually. Operator manually marks objects like traffic signs, road edges, roadway defects (holes and cracks) and patches on each video frame. This procedure is laborious and takes plenty of time; therefore the task of automation of objects detection comes into focus.

In this paper an automatic algorithm for lane marking and road-covering defects detection is considered. This method is integrated into roadway video passport system. In contrast to [5] where interactive algorithm for road-covering defects detection is proposed, our method provides full automatic detection of road-covering defects.

As long as the usage of video for marking and defects detection has severe drawbacks [5], we use so-called rectified images of the road covering. These images are obtained from video frames with the aid of perspective plane transformation.

Rectified images can substantially differ from each other depending of roadway material, time of survey and weather conditions. Therefore we can consider each rectified image is unique. For this reason using of machine learning methods that allow learning on-line is appropriate for this task. This allows accounting for specific characteristics of every section of the road.

The outline of processing of rectified image for a user if as follows: first automatic detection is applied to an image, after which the user checks results of automatic method, corrects some typical errors, then detection algorithm is re-trained in order to take new examples into account. During this process the error rate of automatic detection decreases; thus minimal user input is required.

Lane marking and defects detection algorithm

In this work the task of lane marking and road covering defects detection is formulated as a problem of classification of the image superpixels, or segments. Features used for classification of segments include color statistics, area, sizes of a segment projected on coordinate axes, elongation, orientation and other cues that capture shape, color and location.

Proposed approach is based on the use of cascade classifiers. The idea of cascades is taken from [2]. General operational scheme of cascades is the following. There is ordered set of classifiers, there every subsequent classifier is more "complex" than the preceding one ("complexity" of the classifiers is defined depending on specificity of data or application). Input data array is passed through these classifiers in turn; each classifier eliminates the data that confidently does not belong to the target class, the remained data is transmitted to the following, more "complex" classifier, for more detailed consideration, etc.

The general idea of cascades involves detection of one target class that implies binary classification. In our task the cascade is applied to a problem of separating objects of two different classes from a background; that means three-class classification. It is important to notice, that the background class in our task dominates significantly over classes of a marking and patches as well as in [5]. This finding suggests modifying the scheme of cascades used in [5] in order to allow detection of several classes of objects.

Cascade operational scheme

Input of the cascade is the rectified image of a road covering. The image is divided iteratively into homogeneous areas which scale decreases on each iteration of algorithm. Segmentation on each following level is subdivision of segmentation on the previous level, therefore forming a sequence of the enclosed segments (hierarchy). Each layer of the cascade involves a certain level of hierarchy of segmentation and a corresponding binary classifier. Those segments that have not been rejected at the preceding layers of cascade are classified into two classes: objects of interest (including lane marking and road covering defects) and background. The goal of classification is to reject the segments that do not contain pixels of interest objects. For this purpose the threshold on the classifier output is set up so that the detection rate is close to 100 %.

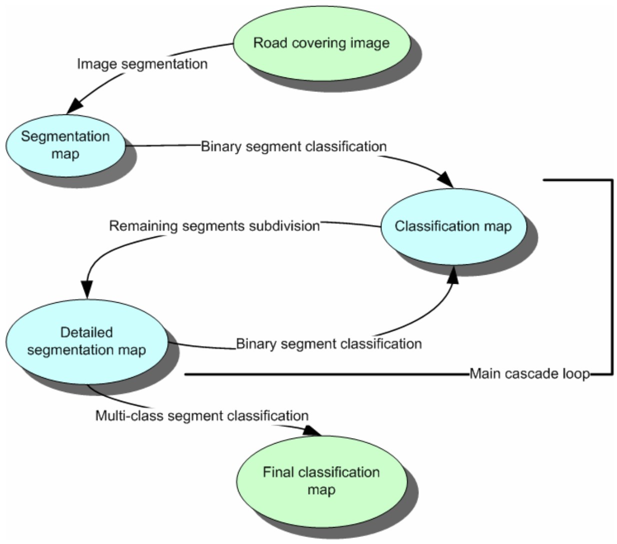
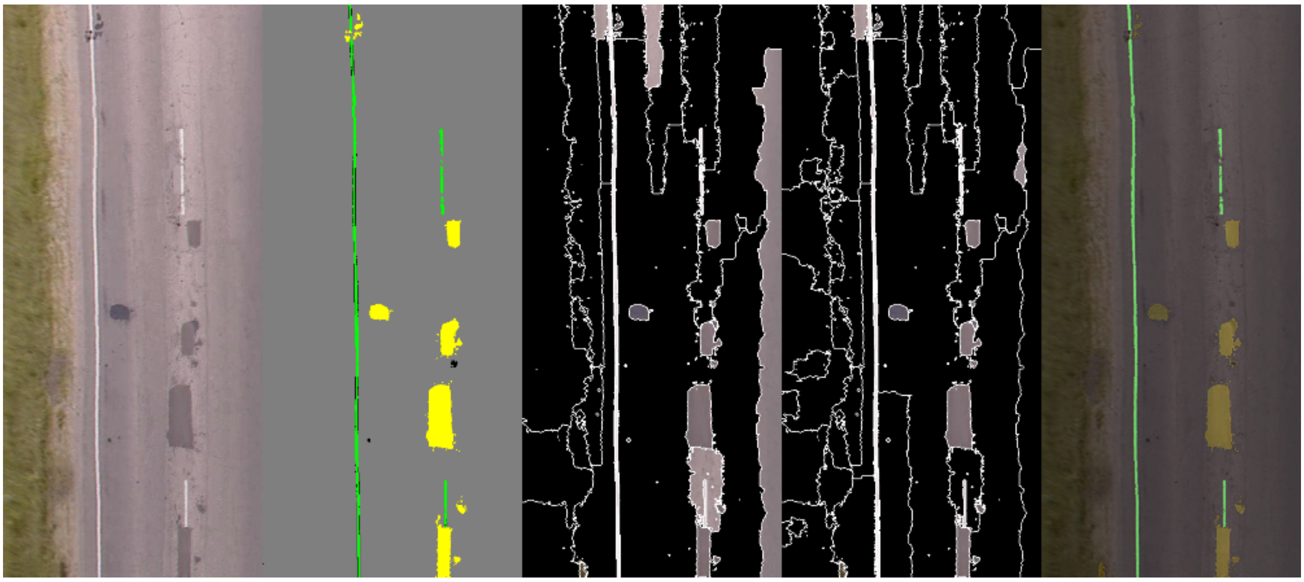


Figure 2. Outline of proposed algorithm for lane marking and road-covering defects detection on rectified image of a road. Classification map contains coordinates of pixels that are confidently neither defects nor marking; Final classification map shows areas corresponding to a marking, defects and background

This procedure is repeated up to the last cascade layer and then multi-class classification is applied. Segmentation corresponding to the last layer of the cascade is detailed enough to capture precise bounds of interest objects. Moreover, the majority of background segments are rejected at the preceding layers, so the number of background segments passed to the



(a) (b) (c) (d) (e)

Figure 3 Cascade classification stages. (a) – Input image, (b) – manually marked image, (c) – 1st cascade layer result, (d) – 2nd cascade layer result, (e) – overall algorithm result.

last layer approximately equals to the number of lane marking segments and segments of road covering defects. Therefore cascade classifiers also solve a problem of imbalanced classes thus helping to achieve better classification performance.

In this work we use «one vs all» algorithm for multi-class classification on the last cascade layer. Gentle AdaBoost [4] with a tree of depth 4 is used as binary classifiers at each cascade layer including the last one. We use a method proposed in [5] for the cascade training

Hierarchical segmentation

The segment hierarchy is a powerful tool to analyze data in many application tasks. There are some basic approaches to construct such multi-level structure.

The first approach consists of recursive segmentation. An image is segmented in a large scale, and then segments are divided independently. Next approach is a successive segmentation of an image with several scales. But in this case large segments are not necessarily unions of smaller ones, that makes such segmentation inapplicable for some tasks.

Other method consists of a determination of strength of the boundaries between segments by means of the analysis of saddle points between density modes and merging segments that weakly separated. By means of this approach it is possible to access any level of hierarchy. For segmentation of the image in our work the hierarchical version of algorithm of mean shift, offered in [3] is used. This algorithm provides fast hierarchical segmentation on the basis of idea of the saddle point analysis that is especially important for effective implementation of cascade algorithm.

Experiments

Set of 90 rectified images of a road covering (Fig. 3(a)) was used as evaluation set. Dimensions of each image are about 450x1000 pixels. We manually marked objects of interest on these images and used this dataset for algorithm training and performance evaluation (Fig. 3(b)). This image set was divided into three equal parts: the first one was used for cascade training, the second one was used as validation set for tuning classifiers thresholds and the last one was used for evaluation of cascade performance.

	Cascade		1vsAll	
	Detection rate	False positive rate	Detection rate	False positive rate
Marking	96%	5%	94%	4%
Defects	90%	20%	90%	27%

Table 1. Comparison of the proposed method with the simpler "one vs all" scheme

We used cascade training method described in [5]. The minimum acceptable detection rate was set up as 0.95 and the target overall false positive rate was set up as 0.05. The trained cascade consisted of 3 layers. Estimates of an amount of true and false positives have been achieved by calculation of correctly and incorrectly classified pixels of images from test set.

Simpler multi-class classification algorithm has been implemented for comparison. It involves single segmentation and classification of the resulting segments by "one vs all" algorithm. This algorithm uses the same segmentation method [3] as the proposed method. In order to compare road covering defects detection performance for these two algorithms we chose classifier thresholds in order to achieve fixed detection rate. Final results of comparison are shown in Table 1.

Apparently, lane marking detection rate is high enough for both algorithms. Road marking defects detection results are quite different. The cascade algorithm has shown essentially lower level of false positives than conventional algorithm of multi-class classification.

References

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