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Traffic sign recognition using group sparse coding

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ABSTRACT

Recognizing traffic signs is a challenging problem; and it has captured the attention of the computer vision community for several decades. Essentially, traffic sign recognition is a multi-class classification problem that has become a real challenge for computer vision and machine learning techniques. Although many machine learning approaches are used for traffic sign recognition, they are primarily used for classification, not feature design. Identifying rich features using modern machine learning methods has recently attracted attention and has achieved success in many benchmarks. However these approaches have not been fully implemented in the traffic sign recognition problem. In this paper, we propose a new approach to tackle the traffic sign recognition problem. First, we introduce a new feature learning approach using group sparse coding. The primary goal is to exploit the intrinsic structure of the pre-learned visual codebook. This new coding strategy preserves locality and encourages similar descriptors to share similar sparse representation patterns. Second, we use a non-uniform quantization approach based on log-polar mapping. Using the log-polar mapping of the traffic sign image, rotated and scaled patterns are converted into shifted patterns in the new space. We extract the local descriptors from these patterns to learn the features. Finally, by evaluating the proposed approach using the German Traffic Sign Recognition Benchmark dataset, we show that the proposed coding strategy outperforms existing coding methods and the obtained results are comparable to the state-of-the-art.

1. Introduction

Improving traffic safety is an important goal of intelligent transportation systems [36]. A popular method for traffic safety is deploying an on-board camera-based driver alert system to identify traffic signs such as stop signs and speed limit signs. The role of traffic signs is to inform drivers about the current state of the road and provide them other important information for navigation. Traffic signs are planar rigid objects with different shapes and colors. The information provided by the road signs is encoded in their visual traits: shape, color, and pictogram. Several car manufacturers adopted the Advanced Driver Assistance System which included traffic sign recognition. For instance, in 2008, Mobileye partnered with Continental AG to launch three features in the BMW 7 series, namely, a lane departure warning, speed limit information based on traffic sign detection and intelligent headlight control (http://mobileye.com/technology/applications/traffic-sign-detection/). However, traffic sign recognition in an uncontrolled environment is still an open problem.

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Traffic sign recognition includes three steps: detection, rectification, and recognition. A tracking method can also be used to speed up recognition as a smaller area of the detected object can be targeted for recognition. Because we are focusing on traffic sign recognition in this paper, no further discussion is provided on detection, rectification, or tracking. Research on traffic sign recognition began in the last century. An old survey, which was lastly updated in May 1999, can be found in [22]. Because a wide variety of traffic sign recognition techniques have been proposed in the literature during the past decade, we do not try to give a comprehensive literature survey, and instead concentrate on several background work most relevant to the present research. Please refer to Refs. [24,18,11] and the references therein for recent advances in this area.

In practical scenarios, the challenges of vision-based traffic sign recognition include, but are not limited to the following:

1. Multi-class classification: One primary challenge is the large number of classes and the similar appearance of signs. In addition, the size of the traffic signs varies across very different scales (see the first column in Fig. 1 for some examples).
2. Poor image quality due to low resolution: See the second column in Fig. 1 for some examples.
3. Motion blur: Capturing a traffic sign from a mobile platform often introduces motion blur, which presents a substantial challenge to many existing recognition approaches. The third column in Fig. 1 shows some examples.
4. Varied lighting conditions: See the fourth column in Fig. 1 for some examples.
5. Weather: Rain, snow, dust, and mist make recognizing traffic signs very difficult. Some examples are shown in the fifth column in Fig. 1.
6. Background (e.g., the presence of buildings, static/moving vehicles, roads, signboards, and trees). See the sixth column in Fig. 1 for some examples.
7. In-plane and out-of-plane rotations: Although the perfect position for a road sign is perpendicular to the trajectory of the vehicle, in many cases, the sign is not positioned that way. Images of signs may be diverted from the fronto-parallel view due to the inherent tilt and rotation, and the projective transformation of the camera system. See the seventh column in Fig. 1 for some examples.
8. Occlusion: Occlusion of traffic signs due to the presence of objects such as trees, buildings, vehicles, pedestrians, or other signs is also an important factor that should be considered. The eighth column in Fig. 1 gives some examples.

Fig. 1. Some representative difficult traffic signs. All sample images are borrowed from the GTSRB dataset.