Expert Systems With Applications 48 (2016) 67–75

Contents lists available at ScienceDirect

Expert Systems With Applications

journal homepage: www.elsevier.com/locate/eswa

On circular traffic sign detection and recognition

Selcan Kaplan Berkaya*, Huseyin Gunduz, Ozgur Ozsen, Cuneyt Akinlar, Serkan Gunal

Department of Computer Engineering, Anadolu University, Eskisehir, Turkiye

ARTICLE INFO

Keywords:
Circular traffic sign detection
EDCircles
Traffic sign recognition
HOG
Gabor filter
LBP

ABSTRACT

Automatic traffic sign detection and recognition play crucial roles in several expert systems such as driver assistance and autonomous driving systems. In this work, novel approaches for circular traffic sign detection and recognition on color images are proposed. In traffic sign detection, a new approach, which utilizes a recently developed circle detection algorithm and an RGB-based color thresholding technique, is proposed. In traffic sign recognition, an ensemble of features including histogram of oriented gradients, local binary patterns and Gabor features are employed within a support vector machine classification framework. Performances of the proposed detection and recognition approaches are evaluated on German Traffic Sign Detection and Recognition Benchmark datasets, respectively. The results of the experimental work reveal that both approaches offer comparable or even better performances with respect to the best ones reported in the literature and are compatible to real-time operation as well.

1. Introduction

Detection and recognition of traffic signs in digital images have been an important problem for researchers over the last decade. Application areas include advanced driver assistance systems (Timofte, Prisacariu, Van Gool, & Reid, 2011), autonomous driving (Levinson et al., 2011), building and maintaining maps of signs, etc. The problem consists of two successive steps: Traffic Sign Detection (TSD) and Traffic Sign Recognition (TSR). TSD deals with identifying the regions of interest (ROI) and the boundaries of the traffic signs in a given image. A good TSD algorithm must find all relevant traffic signs in an image while producing as few false detections as possible. TSR deals with the classification of a given image patch. A good TSR correctly classifies a given image patch within a pre-formed set of traffic sign classes while making as few false recognitions as possible.

In this paper, we propose methods for circular traffic sign detection and recognition on color images. For detection, we employ the high-speed, parameter-free circle detection algorithm, EDCircles (Akinlar & Topal, 2013), and propose color thresholding algorithms to eliminate false detections. We then quantitatively evaluate the performance of the proposed detection algorithm on the widely-used German Traffic Sign Detection Benchmark (GTSDB) (Houben, Stallkamp, Salmen, Schlipsing, & Igel, 2013). We conclude that the proposed algorithm detects most of the circular traffic signs in the test images. For traffic sign recognition, we try different feature extraction methods ranging from Histogram of Oriented Gradients (HOG), Local Binary Patterns (LBP), Gabor Filter, and a combination of these, and use the Support Vector Machine (SVM) for classification. Finally, we quantitatively evaluate the performance of the proposed recognition methods using the German Traffic Sign Recognition Benchmark (GTSRB) (Stallkamp, Schlipsing, Salmen, & Igel, 2011).

The rest of this paper is organized as follows: Section 2 introduces the dataset used for quantitative evaluation of the algorithms. In Section 3, we review the related work on traffic sign detection algorithms, present our TSD algorithm, and perform a quantitative evaluation of the proposed method within the GTSDB testbed. In Section 4, we review the literature on TSR, present techniques for TSR of our own, and quantitatively evaluate the proposed methods within the GTSRB testbed. Finally, we conclude the paper in Section 5.

2. Traffic sign dataset

To quantitatively evaluate the performance of TSD and TSR algorithms and to compare and contrast their performance with those of the algorithms presented in the literature, we make use of the widely-used German Traffic Sign Benchmark datasets. Fig. 1 shows the 43 classes of traffic signs in those datasets organized in different subsets. GTSDB is used to evaluate the performance of traffic sign detection algorithms whereas GTSRB is used to evaluate the performance of traffic sign recognition algorithms.

GTSDB consists of 600 training and 300 test images each of size 1360×800 pixels. Each image contains zero or more traffic signs of different colors and shape (Houben et al., 2013). GTSRB, on the other hand, consists of over 50,000 annotations from all of 43 classes of traffic signs (Stallkamp et al., 2011).

* Corresponding author. Tel.: +902223213550; fax: +902223239501.
E-mail addresses: selcankaplan1@gmail.com, selcankaplan@anadolu.edu.tr (S. Kaplan Berkaya), huseyingunduz@anadolu.edu.tr (H. Gunduz), oozsen@anadolu.edu.tr (O. Ozsen), cakinlar@anadolu.edu.tr (C. Akinlar), serkangunal@anadolu.edu.tr (S. Gunal).

http://dx.doi.org/10.1016/j.eswa.2015.11.018
0957-4174/

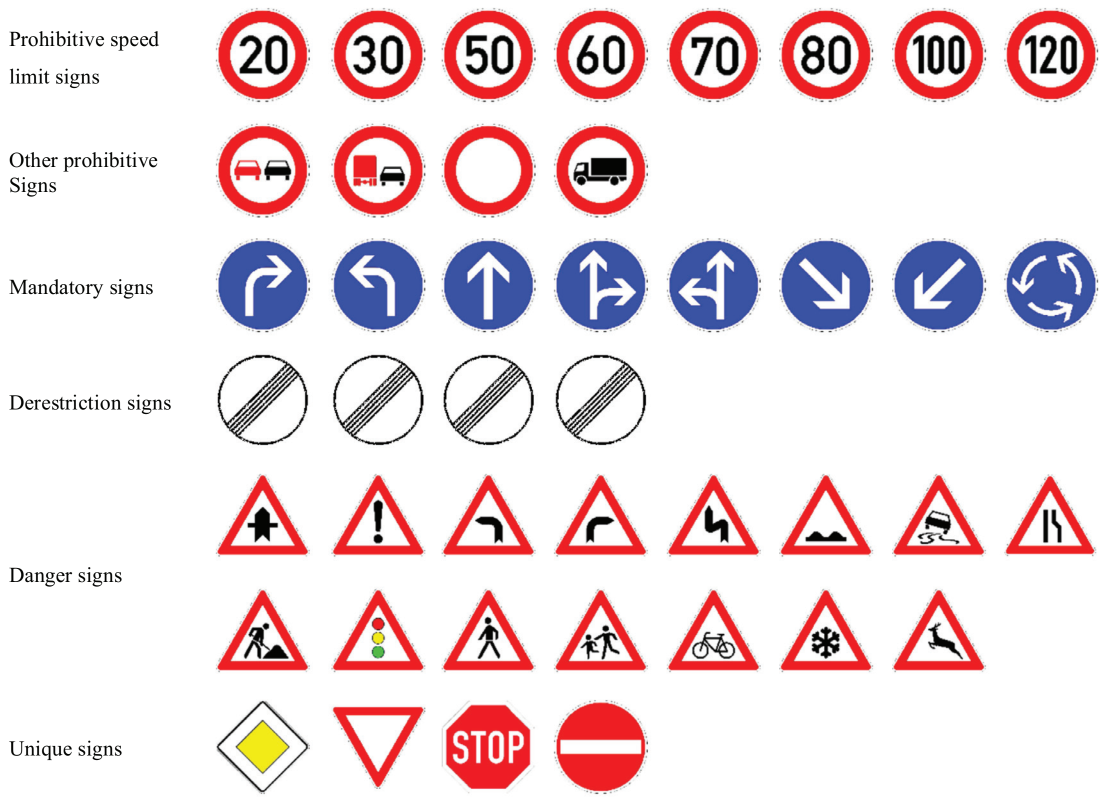

Fig. 1. 43 classes of German traffic sign benchmark datasets. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

3. Traffic sign detection

TSD in digital images is traditionally divided into two categories: color-based methods and shape-based methods (Mogelmose, Trivedi, & Moeslund, 2012). Color based detection methods aim to segment a given color image in order to provide a ROI for further processing. The biggest problem of such methods is the difficulty to correctly access the color information in an image due to light intensity variations and illumination changes due to day-night variations and weather conditions (rain, fog, snow, etc.). With color based methods, researchers choose different color spaces and thresholds, and eliminate what they consider to be non-traffic signs. HSI color space, which is less affected from illumination changes and different weather conditions, is very commonly used for segmentation (Maldonado-Bascon, Lafuente-Arroyo, Gil-Jimenez, Gomez-Moreno, & Lopez-Ferreras, 2007; Xu, 2009; Zhu, Zhang, & Lu, 2005). delaEscalera, Moreno, Salichs and Armingol (1997) uses the normalized RGB color space with fixed thresholds in which the red component was chosen as a reference. Authors in (Yalic & Can, 2011) also use RGB color space. Researchers in (Ruta, Li, & Liu, 2010a; Zaklouta & Stanciulescu, 2014) use color enhancement in RGB space. CIELab and Gabor filters are used by Khan, Bhuiyan and Adhami (2011) to represent a color image because this space can independently control color and intensity information. CIECAM97 color model is used in (Gao, Podladchikova, Shaposhnikov, Hong, & Shevtsova, 2006).

In shape-based TSD methods, the usage of Hough Transform (HT) is quite common (Garcia-Garrido, Sotelo, & Martin-Gorostiza, 2006; Loy & Barnes, 2004). Although the methods using HT may offer satisfactory performance, their main disadvantages are high computational complexity and large storage requirements. Some shape-based methods make use of the corners in the image. Distance Transform (DT) is one of these methods. In this method, the corners are found first. DT feature vector image is then obtained by computing the distance of each pixel to the nearest corner (Maldonado-Bascon et al., 2007; Moomivand & Abolfazli, 2011). Although this method is helpful in detecting certain shapes, it takes a long time to create the feature vector, and therefore, it is not suitable for real-time applications (Gavrila, 1999). In (Overett & Petersson, 2011; Xie, Liu, Li, & Qu, 2009), HOG features are also used for the detection of the shapes of traffic signs.

As mentioned above, the main cues for traffic sign detection are color and shape (Salti, Petrelli, Tombari, Fioraio, & Di Stefano, 2015). In order to achieve better results, recent researches combine the color based method with the shape based method (Li, Sun, Liu, & Wang, 2015). Recently, authors in (Li et al., 2015; Lillo-Castellano, Mora-Jimenez, Figuera-Pozuelo, & Rojo-Alvarez, 2015) take both into consideration. In (Lillo-Castellano et al., 2015), color segmentation is based on $L*a*b*$ and HSI spaces, after that machine learning techniques are applied to the traffic sign shape detection.

Some recent works (Greenhalgh & Mirmehdi, 2012; Salti et al., 2015; Yuan, Hao, Chen, & Wei, 2014) have focused on the local stability of traffic sign regions. They use a novel application of maximally stable extremal regions (MSERs) for traffic sign detection, which is reported to be robust to variations in contrast and lighting conditions. The algorithm detects candidates based on the background color instead of border colors of the sign. Then, HOG is adopted to represent the shape features of ROIs and SVM is used to identify traffic signs (Li et al., 2015; Salti et al., 2015).

In (Liu, Chang, & Chen, 2014; Yuan, Guo, Hao, & Chen, 2015), approaches are proposed to handle the difficulties of color and shape based methods. In (Yuan et al., 2015), the authors propose graph based ranking and segmentation algorithms. In (Liu et al., 2014), the authors detect traffic signs without any color and shape information. However, computational complexity and the number of false alarms increase due to the usage of local features.

3.1. Circular traffic sign detection by EDCircles and color thresholding

In this paper, we propose detecting circular traffic signs by the recently-proposed high-speed, parameter-free circle detection