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Traffic-Sign Recognition Systems

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Chapter 1
Introduction

Abstract In recent years, the car industry has pushed forward large-scale research and industrial projects in Japan, the US and Europe related to the development of assisted driving technologies, thus allowing a real technology transfer from research to market. Several of these technologies are related to the problem of automatic traffic sign recognition, which has reached a certain level of maturity from a scientific point of view. Nevertheless, in spite of the fact that the most advanced cars have been equipped with these systems, at present, human drivers are still the main actors for ensuring safety in the traffic environment. Limitations for detecting and recognizing traffic signs can be grouped into four topics: Lighting conditions, environment clutter, sign variability, and data acquisition. In the following chapters, we will describe a full generic approach to the detection and recognition of traffic signs that cover state-of-the-art methodologies and deals with the aforementioned recognition problems.

Keywords Traffic sign detection · Traffic sign recognition · Color-based description · Shape-based description · Uncontrolled environments · Multi-class classification

Human beings have always needed to mark routes along their common pathways. Road signs are as old as roads themselves; the earliest ones were milestones, which indicated the distance or direction to important places. From the times of the tribune Gaius Gracchus, elected in 123 B.C., the Romans built tall marble columns all over the Empire showing the distance from Rome. To exploit the resources of the Empire, Gracchus made new roads throughout the country, repaired old ones, and erected the milestones which were arranged in a network with its center in a corner of the Forum in Rome. Within 200 km of this point, milestones showed the distance to Rome, and further afield milestones showed the distance from the nearest large town.

In the Middle Ages, multidirectional signs at intersections became common, giving directions to cities and towns. Traffic signs took on huge importance with the development of automobiles. One of the first modern-day road sign systems was devised by the Italian Touring Club in 1895. The basic patterns of most traffic

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signs were set by the International Road Congress held in Rome in 1908. In 1909, nine European governments agreed on the use of four pictorial symbols, indicating "bump", "curve", "intersection", and "level railroad crossing". The intensive work on international road signs carried out between 1926 and 1949 eventually led to the development of the European road sign system. By 1949 Europe had adopted a common system although the US government rejected it and designed a system of its own. In the 1960s, US signage began adopting international symbols into its system.

With the advances in computing and electronics, the idea of computer-based assistive technologies for drivers rapidly gained momentum. Technologies for anti-skid braking (ABS) and cruise control systems were quickly adopted by manufacturers, but more advanced systems, in spite of their potential benefits, have not been commercialized until recently. Examples of these systems are detection of driver fatigue or inattention, pedestrian spotting and blind spot checking and driver feedback for lane keeping, which all merge assistance and road context monitoring. One of the common features of these systems is that they rely on rich sensor data which is inherently imprecise, complex, and difficult to analyze. So the key to their success has been the development of robust methods to perceive the car environment.

Automatic traffic sign detection and recognition has now been successfully transferred from research to the market. Originally, this field of applied computer vision research was concerned with the automatic detection and classification of traffic signs in scene images acquired from a moving car. It is not difficult to see that a system of this kind can significantly increase driving safety and comfort, but this is not its only application: for instance, it can be used in a highway maintenance system to verify the presence and conditions of traffic signs. Recognition of road signs is a challenging problem that has engaged the Computer Vision community for more than 40 years. Significant breakthroughs were made in the 1980 and 1990s, when the problem of computer vision-based driver assistance began to be taken seriously for the first time. In recent years the car industry has pushed forward large-scale research and industrial projects in Japan, the US and Europe. Although with the latest technology cars carry automatic traffic sign detectors, at present it is still human drivers who have to recognize traffic signs and ensure safety in the traffic environment. The following applications are examples of automatic traffic sign recognition (the list is not exhaustive) [1]:

- *Assisted-driving application*. Automatic traffic signs recognition can help drivers in basic tasks warning them of situations of particular danger, assisting in controlling speed, "reading the text" on road signs [2], etc.
- *Constructing autonomous*, *intelligent vehicles*. In the near future, intelligent vehicles are expected to take advantage of automatic TS recognition systems and other functions such as detection of road lines, pedestrians, and other road obstacles. Autonomous intelligent vehicles should contain facilities for traffic detection and recognition. An example is the "Intelligent Stop & Go" system developed in the European Prometheus project [3] which constructs an intelligent vehicle that "keeps a constant distance from the vehicle in front (as a radar-based system would do), is able to follow the car in front, stop at red traffic lights and stop signs, give

way to other vehicles if necessary, and try to avoid unpredictable hazards, such as children running across the street".
- *Sign maintenance application*. Many road maintenance and other road inventory companies still inspect roads manually. Manual detection and recognition of traffic signs is a slow, expensive and tedious process because of the size of today's road networks (comprising millions of kilometers) and the high number of traffic signs per kilometer. Automating this process allows the replacement of human operators by automatic image processing and computer vision systems able to achieve faster and efficient results and drastically/significantly bring down their production cost.

Drivers, cyclists and pedestrians are the main users of traffic signs. For these reason, traffic signs were designed for optimal human detection and reading. Visibility design requirements ensure that the sign is visible by people of all age groups from an appropriate distance. Visibility also means that the sign has enough contrast with the background to be conspicuous and that the contents on the sign have sufficient contrast with the background of the sign. These characteristics make the problem less difficult than the general object recognition problem in computer vision, but there are nonetheless at least four sources of problems when detecting and recognizing traffic signs:

- *Lighting conditions*. Lighting differs according to the time of the day and season, weather conditions, and local variations such as the direction of light.
- *Environment clutter*. The presence of other objects—trees, pedestrians, other vehicles, billboards, and buildings—can cause partial occlusion and shadows.
- *Sign variability*. The sign installation and surface material can physically change over time, influenced by accidents and weather. Moreover, traffic signs exist in hundreds of variants that often do not comply with legally defined standards.
- *Data acquisition*. Images taken from the camera of a moving car often suffer from motion blur and car vibration.

In the following chapters, we will describe a full generic approach to the detection and recognition of traffic signs. The approach is based on the latest computer vision methods for object detection and on powerful methods for multiclass classification. It was originally developed for a mobile mapping application. The main aims were to robustly detect a set of different sign classes in real time and to classify each sign detected into a large, extensible set of classes. To address these problems, we developed several state of the art methods which can be used for different recognition problems. These methods are described in detail in the following pages. This book is divided into five chapters. Chapter 2 introduces the traffic sign detection and categorization problem. Chapter 3 focuses on the detection problem and presents some recent developments in this field. Chapter 4 surveys a specific methodology for the problem of traffic sign categorization, Error-Correcting Output Codes, and presents several algorithms. Chapter 5 shows experimental results for a mobile mapping application. Finally, Chap. 6 draws some conclusions about future lines of research and challenges for traffic sign recognition.

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Chapter 2
Background on Traffic Sign Detection and Recognition

Abstract The automatic sign detection and recognition has been converted to a real challenge for high performance of computer vision and machine learning techniques. Traffic sign analysis can be divided in three main problems: automatic location, detection and categorization of traffic signs. Basically, most of the approaches in locating and detecting of traffic signs are based on color information extraction. A natural question arises: which is the most proper color space to assure robust color analysis without influence of the exterior environment. Given the strong dependence on weather conditions, shadows and time of the day, some autors focus on the shape-based sign detection (e.g. Hough transform, ad-hoc models based on Canny edges or convex hulls). Recognition of traffic signs has been addressed by a large amount of classification techniques: from simple template matching (e.g. cross-correlation similarity), to sophisticated Machine learning techniques (e.g. suport vector machines, boosting, random forest, etc), are among strong candidates to assure straightforward outcome necessary for a real end-user system. Moreover, extending the traffic sign analysis from isolated frames to videos can allow to significantly reduce the number of false alarm ratio as well as to increase the precision and the accuracy of the detection and recognition process.

Keywords Traffic sign detection · Traffic sign recognition · Color-based description · Shape-based description · Uncontrolled · Environments · Multi-class classification

Recognition of road signs is a challenging problem that has engagedthe attention of the Computer Vision community for more than 30 years. According to Paclik [1], the first study of automatedroad sign recognition was reported in Japan in 1984. Since then, anumber of methods have been developed for road sign detection andidentification. For years, researchers have been addressingthe difficulties of detecting and recognizing traffic signs.

The most common automatic systems for traffic signs detection and recognitioncomprise one or two video cameras mounted on the front of the vehicle

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