Real-Time Regular Polygonal Sign Detection

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Summary. In this paper, we present a new adaptation of the regular polygon detection algorithm for real-time road sign detection for autonomous vehicles. The method is robust to partial occlusion and fading, and insensitive to lighting conditions. We experimentally demonstrate its application to the detection of various signs, particularly evaluating it on a sequence of roundabout signs taken from the ANU/NICTA vehicle. The algorithm runs faster than 20 frames per second on a standard PC, detecting signs of the size that appears in road scenes, as observed from a camera mounted on the rear-vision mirror. The algorithm uses the symmetric nature of regular polygonal shapes, we also use the constrained appearance of such shapes in the road scene to the car in order to facilitate their fast, robust detection.

1 Introduction

Improving safety is a key goal of road vehicle technology. Driver support systems aim to improve safety by helping drivers react to changing road conditions. Although full automation of road vehicles may be achievable in the future, our research focuses on systems that can assist drivers immediately. Rather than replacing the driver, we aim to keep the driver in the loop, while supporting them in controlling the car.

Road signs present information to alert drivers to changes in driving conditions. Critical information signs, such as speed, give-way, roundabout, and stop give information that a driver must react to, as opposed to informational and directional signs. These signs appear clearly in the road scene, and are well distinguished. However, drivers may sometimes miss such signs due to distractions or a lack of concentration. This makes detecting critical information signs and making the driver aware of any they may have missed a key target for improving driver safety. The lack of driver awareness of a sign may be detected through a lack of response.

We have previously demonstrated the application of the radial symmetry operator [1] to detecting speed signs, demonstrating real-time performance [2].
Here detection took advantage of the circle that must appear on Australian speed signs. The radial symmetry algorithm is a shape detector, based on image gradient, and so is robust to varying lighting conditions and occlusions, or the incomplete appearance of edges due to sign degradation under weather conditions. This detection algorithm was coupled with recognition to allow a full system that reported the current speed limit to the driver in real-time.

The regular polygon detector is a more general algorithm than radial symmetry that is able to detect all regular polygons including triangular, square, and octagonal shapes [3]. General regular polygons may be detected in an image up to a similarity transform. All the properties of the radial symmetry algorithm are maintained in terms of robustness to illumination changes, occlusion, and poor edges. In this paper, we adapt this algorithm specifically to real-time road sign detection. By only examining gradients that could be part of the road sign being sought, we are both able to simplify the detection process without significantly impacting robustness. This allows the detection to run at less than 50 ms per image on a standard PC installed in the vehicle. We demonstrate this performance on a real road sequence, showing robust and effective detection.

This class of regular polygon detectors has complexity $O(Nkl)$, where $l$ is the maximum width of the segments of the shape, $k$ is the number of scales that are being considered, and $N$ is the number of image pixels. Note that for small shapes $k$ and $l$ are small numbers. The generalised Hough transform [4] is a general algorithm that can perform the same function, however, even modern hardware-based implementations take multiple seconds to recognise a single shape [5]. This improved computational performance is the benefit of specialised algorithms for detection of known features.

Other work in perceptual grouping [6] takes a similar approach in terms of finding local support for shapes. However, this work does not use pixel-based gradient information, and works at the level of edge segments for gradient. A complexity of $k^2$ was reported where $k$ is the number of edge segments, however for a cluttered image, if the segment size is one pixel, $k$ may be of order of the size of the image.

The regular polygon shape detector class of algorithms is specialised for real-time performance by exploiting the nature of regular polygon-like shapes that have a defined centre point, using it as the voting centre. This makes the algorithm robust to pixels that are missed due to occlusion, poor gradient direction estimates or broken edges, as the vote at the centre point will still be high. The regular polygon detectors are parametric in the formulation, and can be easily and efficiently applied in situations where constraints are available from the embodiment of the vision system within, such as the appearance of a road sign to a car. In this paper, we focus specifically on the aspect of adapting the detector for road sign detection.

This detector improves on previous sign detection results by facilitating fast, robust detection that can reduce the region of interest for sign recognition to only a few pixels, returning the position, centroid, scale and shape