DETECTION AND RECOGNITION OF END-OF-SPEED-LIMIT AND SUPPLEMENTARY SIGNS FOR IMPROVED EUROPEAN SPEED LIMIT SUPPORT

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Abstract. We present two new features for our prototype of European Speed Limit Support system: detection and recognition of end-of-speed-limit signs, as well as a framework for detection and recognition of supplementary signs located below main signs and modifying their scope (particular lane, class of vehicle, etc…). The end-of-speed-limit signs are globally-recognized by a Multi-Layer Perceptron (MLP) neural network. The supplementary signs are detected by applying a rectangle-detection in a region below recognized speed-limit signs, followed by a MLP neural network recognition. A common French+German end-of-speed-limit signs recognition has been designed and successfully tested, yielding 82% detection+recognition. Results for detection and recognition of a first kind of supplementary sign (French exit-lane) are already satisfactory (78% correct detection rate), and our framework can easily be extended to handle other types of supplementary signs. To our knowledge, we are the first team presenting results on detection and recognition of supplementary signs below speed signs, which is a crucial feature for a reliable Speed Limit Support.

Keywords: Advanced Driving Assistance System (ADAS), Traffic Sign Recognition, Speed Limit

INTRODUCTION AND RELATED WORKS

An assistant constantly informing the driver of the current speed limit, or a smart Adaptive Cruise Control (ACC) ensuring the respect of this speed limit, are some of the currently emerging important driving assistance functions. Most current GPS navigators now include a function to inform the driver of the supposed current speed-limit. However speed-limit information extracted from GPS cartographic data is neither always complete nor systematically up-to-date. Moreover, temporary speed limits for road works, and variable speed limits, are by definition not included in pre-defined digital cartographic data. And when a roadwork temporary speed-limit is visually detected, it is then essential to also correctly detect the end-of-speed-limit sign generally posted at the roadwork end. Also some traffic signs along roads provide specific speed limits that are applicable, for instance, only to a particular lane or only to certain vehicle categories, those specificities being mentioned on "supplementary signs" (sometimes also called "complementary" or "supplemental" signs) located below the main sign. For all these reasons, a *visual* real-time speed-limit sign detection and recognition system is a mandatory complement to GPS systems for designing high-level advanced driving assistance systems such as Speed Limit Support (SLS) and smart ACC. And this visual sign recognition should take into account end-of-speed-limit signs and supplementary signs as well.

Traffic Signs detection and Recognition (TSR) usually involves two main steps: 1/ detection of potential traffic signs in the image, based on the common shape/color design of sought traffic signs; 2/ classification of the selected regions of interest (ROI) for identifying the exact type of sign, or rejecting the ROI. Many TSR systems (e.g. [1], [2]) use color information to make detection step easier. But as noted and advocated in [3] and [4], using only shape information in grayscale improves robustness for operation in dark or night condition. This is what we do in our Speed Limit Support (SLS) prototype, already presented in [5] and [7], which relies on digit extraction and identification for recognition step (contrary to most TSR

systems which use global recognition as in [1] [2] [3] [4] [6]). Our current SLS system is quite robust and fast for detecting and recognizing signs for *beginning* of speed-limit [5][7]. It should be noted that, thanks to our digit-recognition-based approach as well as to our efficient (patented) rectangle detection, we were probably, to our knowledge, the first research team reporting satisfying results on U.S. speed sign recognition (see [5], a year before more recent work by [9] which still have unacceptably high false alarm rate). We also have recently significantly improved our European speed sign recognition by using a global number segmentation before applying digit recognition [8].
However, in order to design a complete Speed Limit Support system, we need to include proper recognition of end of speed limits as well, and also detection and recognition of potential complementary signs under speed-limit signs, as presented in this paper.

END OF SPEED LIMIT SIGNS DETECTION AND RECOGNITION

The potential end-of-speed-limit signs are detected by the same Hough-based circle detection as the one we use for speed-limit signs. The main challenge is the recognition step, because there are many subtypes of end-of-speed-limit signs in each country, and their designs can be quite different in various E.U. countries. Another potential difficulty arises from the need to avoid confusion with similar signs such as end-of-no-passing. Finally it is difficult (and nearly impossible) to collect a large number of examples properly covering, for each sign class, the potential variability in size, orientation, etc… We therefore created a database of *synthetic* examples. Positive examples were generated from each end-of-speed-limit sign prototype by randomized controlled transformations covering as much as possible the various expected appearances, and negative examples were either synthetically generated (for potentially confusing signs) or extracted from videos. The example were all histogram-equalized and normalized to a standard 16x16 size, as illustrated in figure 1.

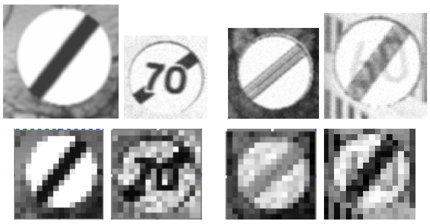

Fig. 1. Some synthetic examples (top line), and their normalized to 16x16 version (bottom line)

Signs detected and validated with correct type	**Validated False alarms**
18/22 = **82 %**	**1**

Table 1. First evaluation of European end-of-speed-limit sign detection and recognition on French+German roads.

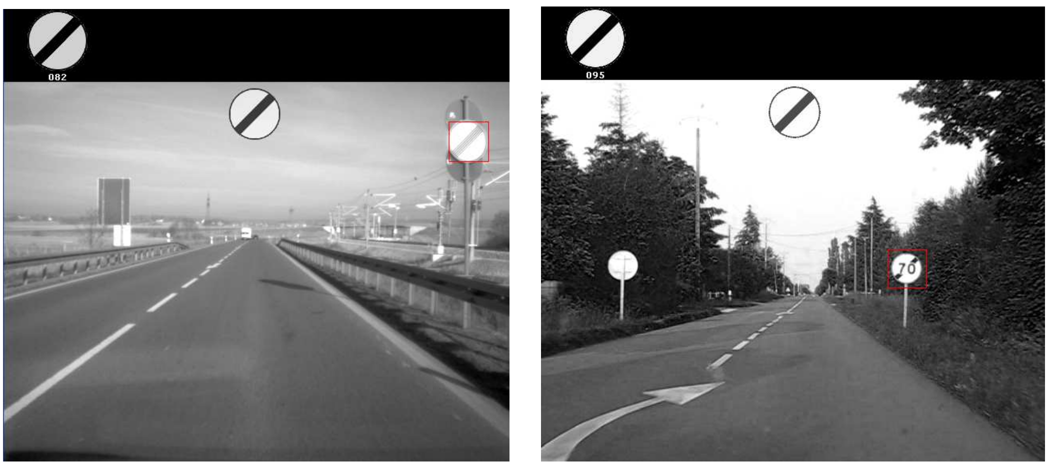

Fig. 2 Illustration of correct recognition of end-of-speed-limit signs in Germany (left) and in France (right)

A first systematic evaluation was done on a small set of recorded French and German videos (see figure 2) containing 22 end-of-speed-limit signs. The quantitative results obtained, given in table 1, are not perfect (82% global recognition rate) but already quite satisfactory.

SUPPLEMENTARY SIGNS DETECTION AND RECOGNITION

One of the main difficulties is that the supplementary signs may have various positions, width/height ratios, and even relative size. We therefore decided to define a relatively wide “search region” below each recognized speed-limit sign. These searched regions are histogram-equalized before we apply inside them our original (and Valeo-patented) rectangle-detection developed for American speed-limit rectangular signs detection (see [5] or [7]). Rectangle detection results are illustrated on figure 3. There are indeed some spurious detected rectangles, but they shall be efficiently filtered by the posterior classification step.

As a first test, we focused on French exit-lane supplementary signs, which exist in various “flavours”, some of them square, and others with rectangular shape. We decided that the most convenient way to deal with that was to systematically resize the potential supplementary sign to a common (experimentally chosen) 12x12 square size. The classifier itself is a MLP neural network with 12x12=144 inputs, and only 1 output neurons designed to output +1 for all positive examples of exit-lane supplementary signs and -1 for any other image. The hidden layer size was set to 10 neurons, by comparing, on validation set, correct classification rates for several hidden layer sizes. A first evaluation was done on a set of recorded French videos containing 50 speed-limit signs, among which 18 with an exit-lane supplementary sign below. The results obtained are illustrated on figure 4, and quantified in table 2. The correct detection rate of 78% is already quite satisfactory for a first implementation, and further improvement to increase precision by collecting more negative examples is underway.

Fig. 3. Illustration of research zone below recognized speed-limit signs, and of rectangle-detection inside: on the left, a supplementary sign is detected, on the right spurious rectangles are detected but shall be eliminated by recognition step

Speed-limit sign with exit-lane supplementary sign below correctly detected and recognized	False alarms on other speed-limit signs
14/18 = **78 %**	3/32 = 9 %

Table 2. First evaluation of French exit-lane supplementary sign detection and recognition

Fig. 4. Illustration of correct detection and recognition of square and big (left) as well as rectangular and small (right) French exit-lane supplementary signs

CONCLUSIONS AND PERPECTIVES

We have presented the successful introduction in our prototype Speed Limit Support system of 2 new important features: recognition of end-of-speed-limit signs, and detection and recognition of a first type of supplementary sign modifying the scope of its above speed-limit sign. The performance of our first version of detection and recognition of end-of-speed-limit signs is already good (82%), but can certainly be improved, which we are currently working on. Also, the current version of this feature has been developed and tested only on French and German signs. Evaluation of pan-European generalization of this feature is currently under way, with promising results in Italy. Regarding supplementary sign, our prototype currently handles (with 78% correct detection rate) only the French “exit-lane” sub-sign. However, our framework and methodology presented here for detection and recognition of supplementary sign could easily be extended to handle more kinds of supplementary signs. To our knowledge, we are the first team presenting results on detection and recognition of supplementary signs below speed signs, which is a crucial feature for a reliable Speed Limit Support. The final correct handling of detected speed signs taking supplementary signs into account will most probably require to know if the vehicle does or not drive on the outgoing exit-lane, which should be easy to do by fusion of vision information with GPS information, a technique for which we have already promising results [10].

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