AUTOMATIC TRAFFIC SIGN RECOGNITION IN DIGITAL IMAGES

by
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Abstract. The objective of this project is the development of an algorithm for the automatic recognition of traffic signs in digital images. The program An.Si. was created (from the Greek words ***An***agnorisi ***Si***maton which means Sign Recognition). Up to now, many algorithms for the traffic sign detection and classification have been introduced. Extensive research is being made by major car manufacturing companies in collaboration with Universities and other institutes on real-time and automatic recognition of traffic signs, so that it can be a part of the so called "Driver Support Systems" ([7]).

Two major problems exist in the whole detection process. Road signs are frequently occluded partially by other vehicles. Many objects are present in traffic scenes which make the sign detection hard (pedestrians, other vehicles, buildings and billboards may confuse the detection system by patterns similar to that of road signs). Colour information from traffic scene images is affected by varying illumination caused by weather conditions, time (day-night) and shadowing (buildings) ([7]).

The proposed method detects the location of the sign in the image, based on its geometrical characteristics and recognises it using colour information. Partial occlusion is dealt by the use of the Hough Transform and suggestions are made for future improvements so that the robustness of the algorithm in light condition changes can be increased.

1. Introduction

The whole process is part of a larger project concerning the Mobile Mapping. Mobile Mapping is the automated "mapping"-registration of features of interest from images acquired from a moving registration system, mounted either on an airplane or a vehicle. Research is being made, mostly in land-based Mobile Mapping Systems ([1], *Tsioumas 2003*).

Apart from traffic signs, other features of interest are traffic lights, road centerlines and edges and building facades. For building facades, the registration system doesn't necessarily have to be movable. For the rest of the features, effort is being made for real time recognition and mapping, so they can be a part of the so called "Driver Support Systems". The DSS is in a way the predecessor of the car autopilot.

Traffic sign recognition is part of the general case of Pattern Recognition. Major problem in pattern recognition is the difficulty of constructing characteristic patterns (templates). This is because of the large variety of the features being searched in the images, such as people faces, cars, etc.. On the contrary, traffic signs a) are made with vivid and specific colors so as to attract the driver's attention and to be distinguished from the environment b) are of specific geometrical shapes (triangle, rectangle, circle-ellipse) and c) for each sign there is a specific template. It is therefore rather easy to develop an algorithm in such a way that the computer has "a priori knowledge" of the objects being searched in the image.

The developed algorithm is divided in two basic phases each one composed of a certain number of steps. In the first phase the detection of the location of the sign center of gravity (which is used as a location reference point) in the image coordinate system is carried out, based on its geometric characteristics. The second phase is the sign recognition with the matching between the search image and the template images, already stored in a database.

The programming language used is IDL (Interactive Development Language), of Research Systems Inc., version 5.4. It was selected because of its simple syntax (similar to Visual Basic), but mainly because it is focused in graphic and image processing. Also, it is very effective in matrix manipulation, which is very important, considering the fact that images are processed in matrix form.

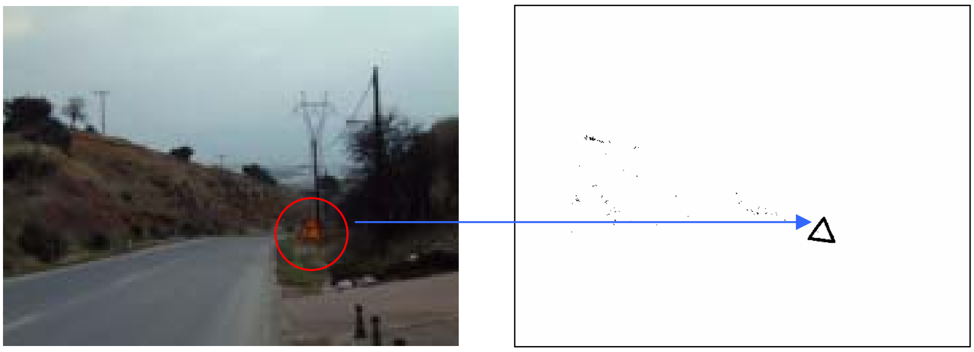
2. The algorithm

The basic steps of the algorithm in each phase are:

a. First phase: detection of the location of the sign in the image

1. ROI segmentation with image thresholding

   The first step of the algorithm is the region of interest segmentation, using sign color information. A "region of interest" is an area of the image that may contain a traffic sign. A new black and white image is constructed in which all the pixels that satisfy certain thresholds of the sign color are black and the background is white (binary image – an image with only two possible pixel values). The color thresholds are measured in test images.

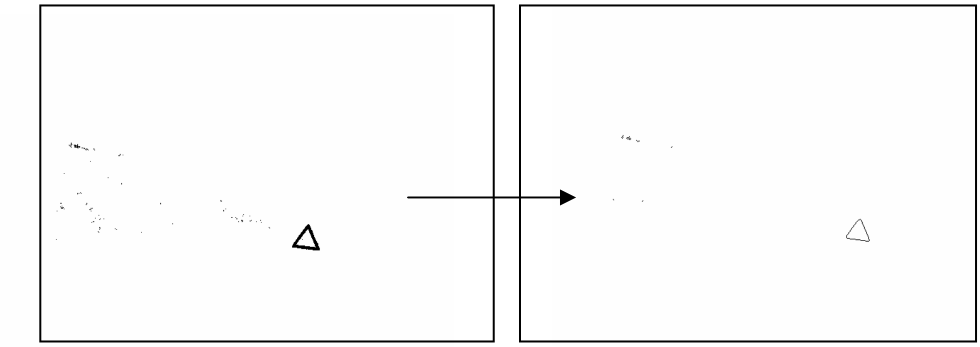


First image

Image after colour thresholding
(binary image)

2. <u>Thinning and Edge Detection</u>

   After image thresholding, a thinning algorithm is implemented. The goal of this process is the reduction of the edge thickness in the binary image. In result, the edges after the implementation have a thickness of one pixel. This process makes it easier for the algorithm to detect lines in a later step and also increases its speed (less pixels of interest). In the case of blue traffic sings which don't have a clear outline, an edge detection filter is implemented (Roberts filter) for the removal of their interior pixels.



3. <u>Region identifying and region clustering</u>

   Region identifying is the calculation of the down left and upper right apex coordinates of the rectangles which include the regions. This way the search is constrained only in the regions of interest. After that, the regions are clustered according to their total number of pixels and their center distances. Furthermore, regions with total number of pixels less than a certain value are eliminated and not examined in the later steps.

4. Line Detection

   In each roi, line detection is carried out so as to check the kind of shape in the roi (triangle, rectangle, circle – ellipse). In the case of the triangle and the rectangle, the line detection process also calculates the necessary data for the calculation of the sign's centre of gravity coordinates. The Hough Transform is used for the detection, a unique and effective way for the analysis of shapes and movement in images that include noise, missing or surplus data. It is a curve detection technique, that can be applied when the object location is unknown but its shape can be described as a parametric curve ([5], *Adamos, and Faig*).

5. Shape Check

   The angles between the lines can be now calculated, using the line direction coefficients deprived from the previous check. If there are three angles between [50,70] or [-70,50] degrees then the shape is accepted as a triangle. In the other case, the algorithm continues with the ellipse detection step.

6. Hough transform for ellipse detection.

   For the ellipse detection the algorithm uses a different approach of the Hough Transform, the RHT (Randomized Hough Transform) ([4], *Inverso, May 2002*). The general idea of the transform is the same. The term "Random" is used because the pixels of interest in the current roi are being tested in random groups of three. After the detection of an ellipse, the algorithm runs a check whether this ellipse is acceptable or not, based on its eccentricity and the number of points that belong to the ellipse. In the case of an accepted ellipse, detection of the location of the sign is complete because during the ellipse detection process, the center coordinates have been calculated. From this point on, the ellipse is considered a circle with a radius equal to the large half-axis. If there isn't an accepted ellipse, the algorithm loops back to the line detection step and examines the next roi.

7. Calculation of the apexes and the center of gravity (triangle and rectangle sign

From the line equations, the coordinates of the center of gravity and of the apexes are calculated. The coordinates of the apexes are needed in the later step of the template transformation. At this point the detection of the sign location is complete.

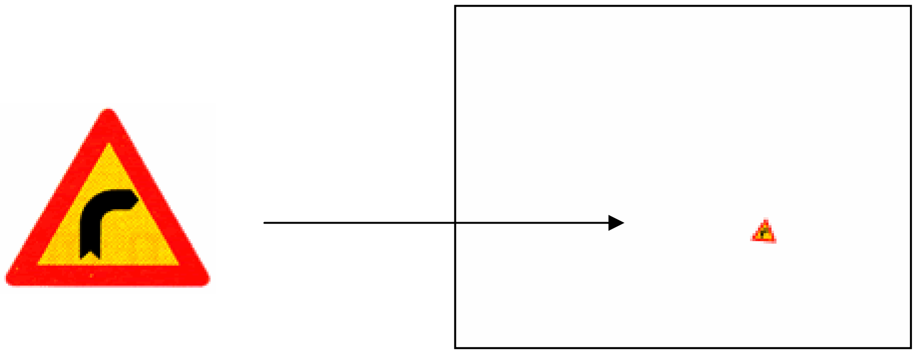
b. Second phase: recognition of the sign.

The sign recognition is carried out with the use of the cross-correlation matching between the region of interest extracted from the previous steps and specific template images.

For the matching process, the two images must have the same coordinate system; therefore the templates are transformed to the search image coordinate system.

1. Affine transformation (triangle, rectangle).

   The two coordinate systems are different by two different components of parallel translation in each axis, in two rotation angles and in two scale coefficients. The common points used for the calculation of the transformation parameters are the apexes of the detected shape. Their coordinates in the template system are already known and their respective ones in the search system have been calculated in the location detection phase. All the template images are transformed and the new images constructed have the same dimensions with the search image. The template is located in the same place as the detected sign.

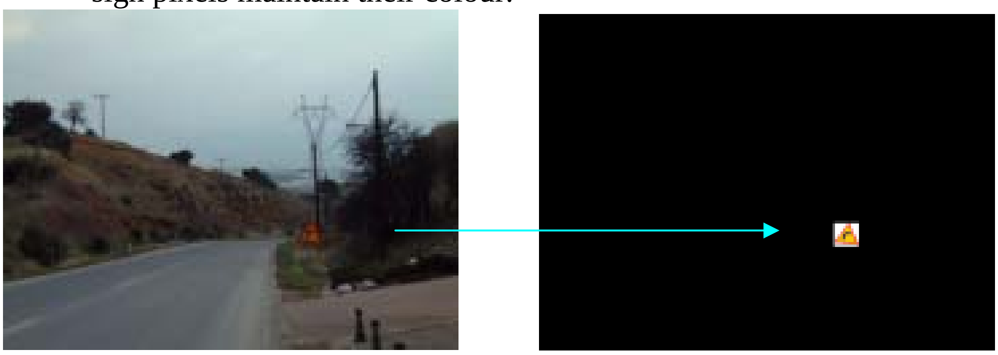


2. Similarity transformation (circle)

   In the case of a circle sign, there is only one common point, the center, therefore the affine transformation cannot be used. A similarity transformation is used instead. It is considered that the two systems are different by one scale coefficient (same by x and y) and by two different components of parallel translation in each axis. The scale parameter is calculated from the ratio of the sign radius in the two images. In the same way as in the affine transformation process, new images are constructed for each template.

3. Search area definition (bounding box)

   The cross correlation coefficient is calculated for the entire roi. The search image pixels which are included in the roi but do not belong to the sign, affect the correlation process and may lead in wrong results. Their colour is changed to that of the background, so their influence is eliminated. In the case of the circle sign, it is easy to determine whether a pixel belongs to the sign or not. All the pixels with a distance to the circle center greater than the radius are whitened (set to the background colour). In the case of triangles and rectangles those pixels are found using a "Point Inclusion In Polygon Test" ([6], *WR Franklin*). In the new image, all the pixels with a distance to the circle center greater than the radius are whitened (set to the background color). The pixels outside the region are not of any interest because the calculations are only made for the pixels inside the region, so they are left black. The sign pixels maintain their colour.



4. Cross correlation matching

   For every roi pixel, the cross correlation coefficient ([3]) between the template and the search image is calculated, for each colour channel (red, green and blue). The final coefficient is the mean of the three RGB coefficients. The template with the largest coefficient corresponds to the sign searched.

C. SEPARATE RECTANGLE CASE

Rectangle signs are detected with a slight altered and separate process because of two basic differences:

a) During the Hough Transform, only (approximately) vertical and horizontal lines are searched

b) The correspondence of the common points in the affine transformation step is more complicated to program than that of the triangle shape.

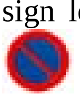
3. Results

Below are some digital images, which the algorithm was tested:

The algorithm successfully detected and identified the sign.

The algorithm successfully detected and identified the sign.

The algorithm successfully detected and identified both of the signs. However, it accepted the region at the left edge of the image as a sign, because of its similar blue colour and its rectangle shape.

The algorithm successfully detected the sign location, but the greater cross-correlation coefficient was that of the sign  . That's due to the shadowing of the sign in the search image, which made it's interior colour more similar to light blue than the white of the correct sign:

4. Conclusions – future directions

Implementation of the algorithm in test images showed that it is very effective in the sign location phase. There is a slight weakness in the second phase, in cases of color similarity between signs and other areas of the image. It is sensitive in light condition changes during the image acquisition, because of the effect they have in the color thresholds used in the regions of interest segmentation step. The use of proper thresholds is very important as it affects in a great deal the success of the sign location detection and it's final recognition.

Based in the experience acquired from the tests, the aspects which should be further researched and be improved in the future are:

- Recognition of signs of more complex shape (eg. Stop sign-octagon, right of way-diamond). The shape of such signs could be detected using another variation of the Hough Transform, the *Generalized Hough Transform*. The GHT can detect shapes in an image, which doesn't necessarily have to be described by an analytical mathematical equation such as the triangle or the circle.

- Recognition of two (or more) signs in the same region of interest.

It is possible in some cases that there two or more signs in the same region of interest.

Such a problem can be dealt with changes in the algorithm's structure

- Increase of the speed of the algorithm by improving the source code and again, by possible changes in its structure.

- Increase of the robustness of the algorithm in light condition changes.

The RGB representation is far from the human concept of colour. Furthermore, image processing of the RGB model has several disadvantages:

1. all three components (R, G, and B) depend on intensity,
2. colours, which for a human might be perceptually close, do nat have to be close to each other (Euclidean distance) in RGB space.
3. smoothly shaded surfaces might correspond to several clusters in a colour space.

These factors indicate that colour thresholding, a step very essential to the whole process, is greatly affected by light condition changes. One possible solution to the problem is the contiguous replacement of the threshold values during the acquiring of the images, by photographing a metal plate constructed with the same colour as the signs in the current light conditions and measurement of the new threshold. Alternatively, the HSI colour system could be used instead of the RGB. The HSI system (**H**ue, **S**aturation, **I**ntensity) is much less sensitive in light condition changes than the RGB ([2], *Gadzamowicz, April 1999*.)

- Merging of the rectangle and triangle-ellipse detection process
- Use of “Neural Networks”.

“Neural Networks” is a method for pattern recognition which has recently started being researched and is associated with the Artificial Intelligence. It simulates the human nervous system and it uses its ability to “learn” in order to find “recognisable” shapes and objects in images. Programming of “Neural Networks” is much more difficult, but also a more effective and faster recognition process.

References:

[1] Introduction to Mobile Mapping Systems, *Tsioumas Michael, Post Graduate Thesis, May 2003*

[2] Automated Processing of Georeferenced Color Stereo Images for Road Inventory, *Krzysztof Gajdamowicz Dissertation, April 1999.*

[3] Detection and sub-pixel location of photogrammetric targets in digital images, *Photogrammetria, Elsevier Science Publishers B.V., Amsterdam*.

[4] Ellipse Detection Using Randomized Hough Transform, *Samuel Inverso, May 2002.*

[5] Hough Transform in Digital Photogrammetry, *C. Adamos and W. Faig. Department of Surveying Engineering, Univ. of New Brunswick, Canada Comission III.*

[6] PN-POLY, Point inclusion in polygon test, *WR Franklin (WRF), www.ecse.rpi.edu/Homepages/wrf/*

[7] Road Sign Recognition Survey, *http://euler.fd.cvut.cz/research/rs2/*

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