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REAL TIME NUMBER PLATE LOCALIZATION ALGORITHMS

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Segmentation procedures are complicated and incorporate diverse problems, among which number plate localization, which is the subject of the current paper, constitutes a special case. Number plate identification comprises two well distinguishable fields: localization of number plates in the image and recognition of characters within the located areas. Neither is an easy task, *ie* both are time consuming procedures, but certain measurements indicate that localization and separation of the characters may last even 25 times longer than recognition. Number plate localization strategies that require remarkably smaller computational resources shall be introduced in the following. Algorithms based on fast and classical image processing methods such as filtering, edge finding and adaptive thresholding, which do not incorporate any learning procedure, shall be discussed. The first part of the current article introduces algorithms that are optimized for nearly horizontal number plates, while the second part focuses on differently located license plates. The section presenting the results reveals under what circumstances and conditions the individual procedures can be used effectively, considering also reliability and computational requirements.

K e y w o r d s: number plate localization, digital filtering, real-time signal processing, adaptive threshold

1 INTRODUCTION

Cars are used under various circumstances, as a result of which number plates get dirty, scrapped and eventually inflected. Further difficulties arise from the fact that the vehicles may drive at a high speed in the moment of being photographed, resulting in dim pictures with smeary edges and blurry contours. Images may also be tilted due to the position of the camera or the road, and are often noisy. Shadows can result in various grayscale spots in the number plate, which might lead to false identified areas. In this latter case, the extent of the localized regions is typically smaller than the actual size of the number plate. The photos depict the direct front or rear view in the case of ideal circumstances, but in most cases the pictures are taken from the sides or from a top view, considerably distorting the ratios.

The pictures are usually colour images, therefore they must be converted into black-and-white pictures prior to testing the algorithms. This may be done in two ways: either by generating the luminance and chrominance components (YUV description) and using only the luminance signal (*ie* the linear combination of the RGB components, see equation 1), or by relying on the brightness information obtained from hue, saturation and brightness (HSV) decomposition (equation 2). In the latter case the biggest one of the RGB colour components is chosen as an intensity value, resulting in an increment of the picture's energy content in most cases, *ie* the image becomes brighter. The relevant edges / transitions / tones may disappear in their environment this way, leading to faults in the case of number plate localization and so degrading the success of the search process. Another major issue is that original pictures are often not available; instead, a signal compressed by some lossy method (usually JPEG) must be processed. Ripples become visible in the value (V) component of the compressed images as a result of quantization, therefore algorithms that are resistant to this effect must be applied. The above mentioned facts provide a good reason for the application of YUV based description, since also the quantization effects are weaker in this case.

$$\begin{aligned} Y &= 0.299\,R + 0.587\,G + 0.114\,B \\ U &= B - Y, \quad V = R - Y \end{aligned} \tag{1}$$

$$\begin{aligned} MIN &= \min(R,G,B); \\ MAX &= \max(R,G,B) \\ V &= MAX; \\ \Delta &= MAX - MIN \\ S &= \begin{cases} \frac{\Delta}{MAX}, & MAX > 0 \\ 0, & MAX < 0 \end{cases} \\ H &= \begin{cases} 0, & \Delta < 0, \\ \frac{G-B}{\Delta}, & \Delta > 0, R = MAX, G! = MAX \\ \frac{2+(B-R)}{\Delta}, & \Delta > 0, G = MAX, B! = MAX \\ \frac{4+(R-G)}{\Delta}, & \Delta > 0, B = MAX, R! = MAX \end{cases} \\ H &= [0^\circ \dots 360^\circ], \quad S = [0 \dots 1], \quad V = [0 \dots 255] \end{aligned} \tag{2}$$

2 FAST ALGORITHMS FOR NUMBER PLATE LOCALIZATION

Most of the number plate localization algorithms merge several procedures, resulting in long computational (and accordingly considerable execution) time (this may be reduced by applying less and simpler algorithms). The results are highly dependent on the image quality, since

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Fig. 1a. Original picture.

Fig. 1b. Filtered image (FIR).

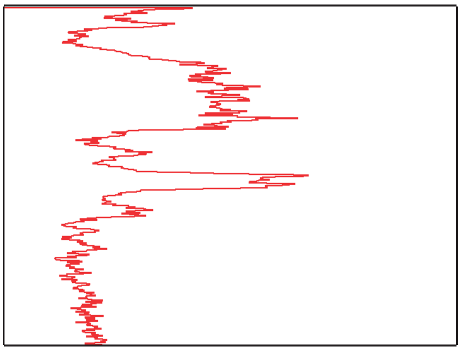

Fig. 2a. Sum of filtered rows (SFR).

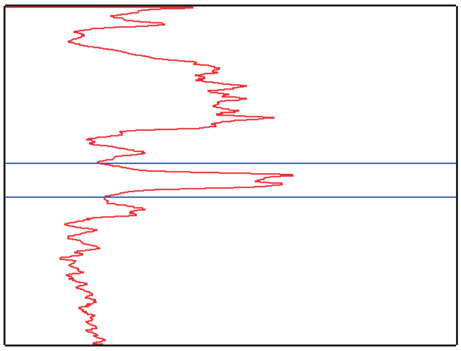

Fig. 2b. Smoothed sum of filtered rows.

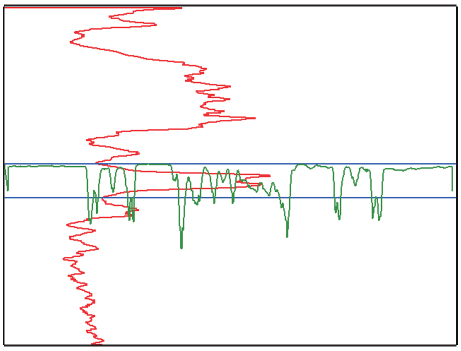

Fig. 3a. Sum of columns in the current band.

Fig. 3b. Possible parts of the plate.

the reliability of the procedures severely degrades in the case of complex, noisy pictures that contain a lot of details. Unfortunately the various procedures barely offer remedy for this problem, precise camera adjustment is the only solution. This means that the car must be photographed in a way that the environment is excluded as possible and the size of the number plate is as big as possible. Adjustment of the size is especially difficult in the case of fast cars, since the optimum moment of exposure can hardly be guaranteed.

Procedures elaborated and tested by our team [4, 6] shall be introduced in the following, where the major objective was to provide fast and reliable operation.

2.1 Number Plate Localization on the Basis of Edge Finding

These algorithms rely on the observation that number plates usually appear as high contrast areas in the image (black-and-white or black-and-yellow). The letters and numbers are placed in the same row (i.e. at identical vertical levels), resulting in frequent changes in the horizontal intensity. This provides the reason for detecting the horizontal changes of the intensity, since the rows that contain the number plate are expected to exhibit many sharp variations. Accordingly, the algorithm first determines the extent of intensity variation for each row, while in the second step it selects the adjacent rows which exhibit the biggest changes. Number plates are highly probable to be in these rows. The horizontal position of the number plate must also be determined, which is done by using the previously determined values that characterize the changes. The variations are the highest at the letters (black letters on white background); therefore this is where the rate of change within a row is expected to be the highest [9].

A simple, effective and fast edge finding algorithm must be applied in the first step, which sufficiently highlights the characters of the number plate in contrast to

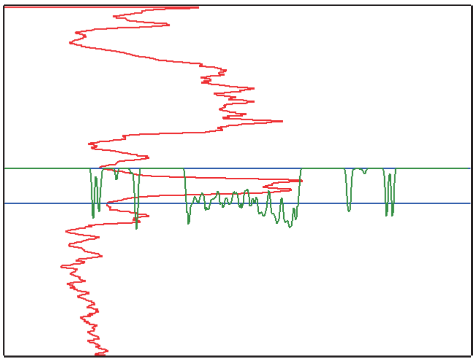

Fig. 4a. Sum of columns after horizontal and vertical filtering.

Fig. 4b. Possible parts of the plate.

the intensity of the other areas in the image. Band-pass filtering has proven to be the most optimal solution for this case, the impulse response of which may either be finite (FIR) or infinite (IIR), adapted to the problem to be solved. FIR filters of short response time require less computational time, yielding faster filtering process; therefore these were selected as experimental tools. Execution can be further accelerated by simple filter characteristics. A filter featuring an impulse response of 5 to 7 (depending on the expected size of the number plate) has proven to be the most adequate during our experiments. The original and the filtered images can be seen in the Figs. 1a and b respectively.

The vertical position of the number plate must be found in the second step by using a picture obtained by bandpass filtering. Having summed up the results of filtering for each row (sum of filtered rows, SFR curve, Fig. 2a), the vertical position of the number plate is determined on the basis of the statistical properties of the individual rows. To provide a fast algorithm, simply the row featuring the highest amplitude is selected (the number plate is most likely to be located there). Following this, the upper and lower boundaries of the number plate are approached by searching both upwards and downwards. To this end, the following procedure is applied: first the rows featuring one half of the maximal value are searched in both directions, and then the evaluation is continued until the first local minima are found. The two minimum values (i.e. the ones corresponding to the upper and lower boundaries) may severely differ; therefore the position of the number plate is aligned to the row featuring the bigger minimum value. To increase the accuracy of the procedure, the SFR curve is smoothed by a lowpass filter (Fig. 2.b), eliminating several small local minima in this way.

The horizontal position of the number plate is found in the third step of the algorithm by applying a procedure similar to the one described above. The results obtained by bandpass filtering are summed up for each column only in the area identified in the previous step. The maximum value is not used in this case since the curve always reaches a minimum value in the empty regions between the characters; instead, the boundaries are found by analyzing the averages (Figs. 3a and b). Prior to summing up the values, the results can be further improved by applying bandpass limiting in the area concerned in both horizontal and vertical directions (Figs. 4a and b).

Fig. 5. Number plate identified by simple edge search.

In certain cases the number plate may be split up into several independent regions and also false results may occur. Therefore, the probable position must be selected from these in the last step. Figure 3 shows that many areas appear close to each other at the place of the number plate, while the false results are located further. The areas close to each other are merged. This requires the definition of a maximum distance which is estimated on the basis of the expected size of the number plate.

The real number plate is selected from the remaining areas by post processing methods. Two simple procedures are applied: analysis of the boundary ratios and the extent of the areas. Investigation of the boundary ratios relies on the fact that the ratio of the horizontal and vertical sizes of a number plate falls in a predefined interval. If the found number plate does not fulfil this criterion, the search process must be continued in another place. In the case of area evaluation, those regions are eliminated that are too small to process or are too big, even if they fulfil the boundary ratio requirement. If still more possible areas remain, the one featuring the highest specific brightness is selected because number plates usually contain a lot of sharp changes. The number plate identified by edge finding was cut from the original image. Fig. 5 shows the result.

2.2 Number Plate Localization on the Basis of Window Filtering

The drawback of the above solution is that after the filtering also additional areas of high intensity appear besides the number plate (Fig. 7) if the image contains a lot of details and edges (*eg* complex background, Fig. 6) the further areas. As a result, the SFR curve exhibits a smaller increment at the number plate and the edges in the surrounding areas may sometimes be more dominant

Fig. 6. Image with complex background.

Fig. 7. Filtered complex image.

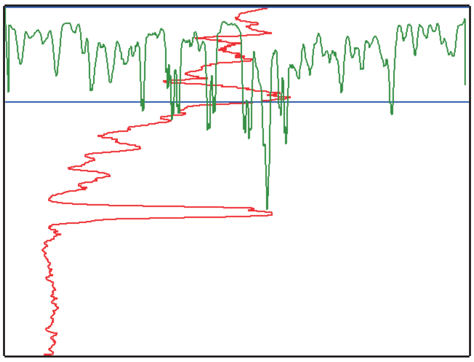

Fig. 8. Sum of filtered rows and columns.

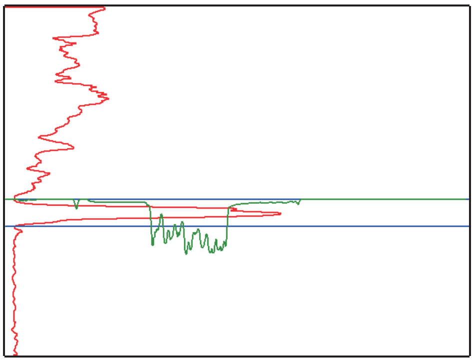

Fig. 9. Windowed sum of filtered rows and sum of filtered columns.

Fig. 10. Number plate localized by the window method.

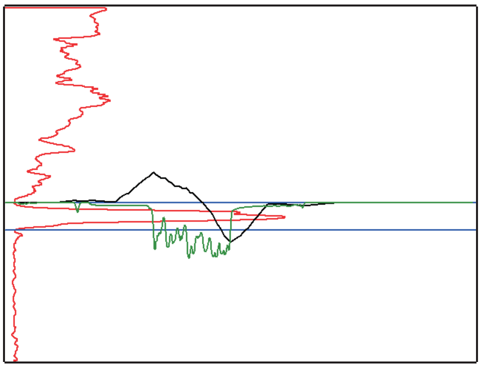

Fig. 11. Weighted and windowed sum of filtered image.

Fig. 12. Number plate localized by the window method and using S curve (formula 3).

(Fig. 8). To avoid this phenomenon, the application of a window that matches the size of the number plate proves to be useful when the SFR curve is generated. In this case only the values within the window are added. By shifting the window, the position at which the sum has a maximum is searched in each row. The SFR curve is assigned this maximum value for every row, therefore, the rows that contain scattered intensity values can be eliminated (Fig. 9). The window size is estimated on the basis of the expected size of the number plate. If the window is chosen to be as wide as the image, then the previously introduced algorithm is obtained, while too small window size leads to incorrect results. This latter algorithm reveals the number plate more effectively from its surroundings. The number plate found using the window method can be seen in Fig. 10.

The boundaries of the number plate can be localized by other methods too. To find the horizontal position, a weighted and windowed summation must be performed, during which the SFR curve values that fall into the first part of the window are multiplied by -1, while those in the second part are assigned a positive sign (see formula 3). The sum value varies with the window position. The final result is the tilted S curve depicted in Fig. 11, which clearly shows that a maximum and a minimum are obtained at the beginning and the end of the number plate, respectively. The best result is obtained if the window size equals the width of the number plate, but smaller window dimensions provide fairly good values too.

The vertical position is determined in two steps: first, the most probable vertical position is searched for, then, moving both upwards and downwards, the top and the bottom are found. The search window described by formula 4 (with a size of L) is used to determine the position. The boundary search is started from a position that is slightly above and below the found optimum position, using a properly selected window size with a method applied for the determination of the horizontal position.

Low pass filtering (smoothing) of the SFR curve can be omitted because the search window already performs bandpass filtering in itself, *ie* it suppresses the high frequency components. This search window yields the result depicted in Fig. 12.

$$H(x) = \begin{cases} -1, & \text{if } x \le 0.5\,L \\ +1, & \text{if } 0.5\,L < x \end{cases} \tag{3}$$

$$V(y) = \begin{cases} -1, & \text{if } y \le 0.25\,L \\ +1, & \text{if } 0.25\,L < y < 0.75.,L \\ -1, & \text{if } 0.75\,L \le y \end{cases} \tag{4}$$

3 NUMBER PLATE LOCALIZATION USING ADAPTIVE THRESHOLDS

It was shown in the previous section that the number plate localization methods relying on edge search and area analysis and using properly selected bandpass filters provide good results in a short process time. The accuracy, however, can be further improved at only a minimal increment of the computational time. In most cases the number plates are surrounded by some frame (*eg* number plate support). This feature can be exploited to further improve the accuracy of the localization of the characters in a number plate.

The basic principle is to find the frame of the number plate, then, having done so, to omit the areas out of this frame. The inner field therefore contains only the characters and the background of the number plate. The characters are printed in black on a white or yellow background (light background with dark letters), and the frame of the number plate is also black, therefore these colours must be distinguished from each other. This simplifies the procedure to the task that a proper thresholding method must be found for grayscale pictures. This method is expected to result in equally dark characters (and frame) and light background, while the rest of the objects shall become either light or dark, depending on the colour of the car and illumination. As a consequence, the boundaries of the number plate's background must only be found, providing the accurate position of the identified number plate.

3.1. Adaptive Threshold (ATH) Procedures

Having tested several threshold procedures [1–3, 8] the modifications of the Adaptive Threshold [4] procedures have proven to provide the best results. Their advantage is that they are able to adjust to the energy content (*ie* to the brightness, Y component) of the image.

The original adaptive threshold [5] algorithm divides the picture into several blocks, then, prior to processing the first block, determines the initial levels on the basis of the number of levels to be distinguished (*ie* the number of colour tones). Two typical methods are available for this: either the complete range [0 to 255] of the luminance signal is divided into equal sections, or, according to a further improved method, the initial levels may be determined by dividing only the range between the smallest and strongest levels in a certain block. (The algorithms we implemented apply the latter procedure.) In the next step every pixel of the first block is processed (in undefined order). Every pixel is checked for the closest level, and the average value of the level concerned is modified, *ie* the thresholds vary. Thus not only the threshold values are stored for every level, but also the number of the corresponding pixels. The levels obtained for the first block as a result of the procedure are transferred to the second block, *ie* the initial thresholds of the second block will be identical to those of the preceding one. The algorithm is continued until all of the blocks are processed. Having completed the processing of the blocks, they are thresholded with the corresponding levels obtained, or, the complete picture is thresholded with the final values.

The above description of the normal adaptive threshold procedure clearly shows that this method implies several arbitrary options, can be executed in many different ways, therefore the results provided by the different versions may deviate from each other.

The steps introduced above [4] also reveal the weak points of the ATH algorithm:

- The result of the thresholding procedure depends on the initial reference level, because different initial values may lead to different final levels. Procedures SA ATH, EATH, EATH+ATH [4] are intended to reduce the differences between these results.
- The variation of the reference levels is mainly influenced by the processing order of the image. For example, calculating upwards down and the other way round are not identical, since the results may be different in the two cases.
- If the complete image is divided into blocks instead of processing it as a whole, the identical or nearly identical pixels in the adjacent blocks may be assigned to different reference levels as a result of the different thresholds, which may lead to blocking effect. This can degrade the actual object boundaries, and the determination of the proper block size is also difficult.

Fig. 13. Refining the area of the number plate by thresholding.

Due to the facts mentioned above, execution of the ATH algorithm on the complete image may often lead to bad results, because the number plate provides only a small part of the picture, and so the points of the number plate barely influence the variations of the reference levels. The contents of the picture may distort the reference levels to an extent that the characters of the number plate melt into the background. On the other hand, the rest of the picture is out of interest, therefore the execution of ATH algorithms is recommended only in the localized area, requiring less computation. The whole picture is handled as one unit during the final thresholding procedure instead of dividing it into blocks. For safety reasons, it is recommended to slightly increase the size of the analyzed area (*eg* in case the number plate tilts), which ensures that all the four corners of the number plate is found.

The following procedures have been investigated to overcome the above mentioned issues and to execute the ATH algorithm more accurately.

3.1.1 Successive Approximation Adaptive Threshold Algorithm (SA ATH)

Different results are obtained if the points are collected in different order. It is hard to find the optimal method for the collection of the points, but there is a solution which is less sensitive for the processing order and yields more optimal results than the original ATH procedure. One reason of the problems is that the reference levels do not vary properly during processing. The probability of incorrect changes can be reduced by setting the initial reference levels to an optimal level. Such improved approach is if the initial reference values are provided by a previously executed ATH algorithm. By cyclically repeating this, the reference levels will tend to certain values that can be considered as optimal. On the basis of this it can be proven that the algorithm must be repeated until the variation of the individual thresholds becomes negligible. The experiments indicate that the final values are obtained after 2 to 8 cycles.

3.1.2 Equal Area Threshold Algorithm (EATH)

During successive approximation every reference value has "migrated" from an initial level to an optimal one. Besides the contents of the image, also the initial values significantly influence the optimal positions. The initial levels have so far been uniformly distributed over the entire interval. Better results may be obtained if the content of the image is already taken into consideration during the selection of the initial values, i.e. the results of a threshold procedure are used for the setting of the initial reference levels.

Thus, the initial values are not spread uniformly over the interval like in the case of the original ATH; instead, they are determined on the basis of histograms. It is assumed that every level contains the same number of points, and the reference levels are calculated accordingly. It can simply be proven that this condition cannot always be fulfilled [4], therefore the procedure calculating the initial values was modified in a way to minimize the standard deviation of the number of pixels corresponding to the individual reference levels (formula 5). Under ideal circumstances, every reference level is assigned the same number of pixels (Height*Width/M number of pixels, where M is the count of reference levels).

$$P_{iopt} = P_i \mid \arg\min \sqrt{\frac{\sum_{i=0}^{M-1}\left(\frac{Height*Width}{M} - P_i\right)^2}{M}}. \quad (5)$$

3.1.3 Combination of Equal Area Threshold Calculating and ATH Algorithms (EATH + ATH)

The comparison of the results of the ATH, SA ATH and EATH algorithms shows that the ATH and SA ATH algorithms provide less noisy pictures but do not sufficiently separate the individual sections [4]. The important areas can be well distinguished in pictures yielded by EATH, but the images are noisy. The advantages of the two algorithms can be exploited while their shortcomings suppressed by their consecutive application.

3.2 Number Plate Localization on the Basis of Thresholds

The threshold procedures introduced so far do not explain directly how the number plate boundaries are found. A simple, fast and considerably accurate solution is that the area around the number plate that has been localized in the previous steps is thresholded on 2 or more levels (not exceeding 3 or 4). The number of levels required to obtain optimal results depends on the luminance signals in the area of the number plate and around it. Most of the cases 2 thresholds are sufficient. After thresholding the original image (Fig. 13a), the brightest level is considered to be the background in the resultant picture (Fig. 13b), while the rest of the levels constitute the environment, characters and the frame of the number plate. That is, only this area has to be localized accurately. Advancing along the centre line of the image, the area with uniform background is searched for, which is expected to be the number plate itself (in certain cases this may consist of separate parts; if this is the case, all parts must be localized).

Though the area of the number plate has been identified, the four corners must still be found. Starting from every corner along a 45° line, the first points whose colour is identical to that of the background are searched for (Fig. 13c). These may be the corner points if they fulfil the condition that most of their adjacent points constitute the background of the number plate.

Due to the principle of the algorithms the result is not influenced by rotation and distortions, because the threshold procedures separate the background of the number plate, independent of the angle of the number

Fig. 14. Localized number plate.

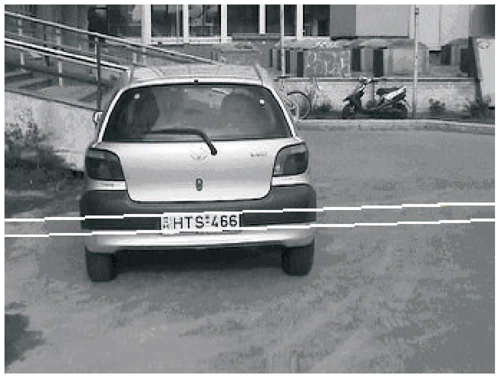

Fig. 15. Result of direction sensitive window filtering ($\alpha = 2°$).

plate. The area of the localized number plate is shown in Fig. 14, while Fig. 13d depicts the separated and restored number plate.

4 NUMBER PLATE LOCALIZATION ON THE BASIS OF DIRECTION SENSITIVE WINDOW FILTERING

Certain parts (corners) are inaccurate in Fig. 12 due to the tilt of the number plate, which makes the consecutive character recognition process harder. This problem may be overcome by searching in more directions, *ie* during the generation of SFR curve the intensity values are calculated not only horizontally but also along lines of various slope. The case that provides the highest weighted sum by the $V(y)$ window (formula 4) is selected from the results obtained at different slopes. This procedure also provides the vertical position and the tilt angle of the number plate (Fig. 15).

The wider the range in which the angle is swept and the finer the step width is, the better results can be obtained, *ie* the tilt angle of the number plate can be determined at higher accuracy. However, this requires considerably higher computational power; therefore it is recommended to execute this procedure only in a certain domain of the image, primarily in the vicinity of the previously found number plate.

The experimental results have shown that the number plates can be localized by this algorithm in most of the cases, and, more to the point, the top and bottom of the number plate characters can accurately be determined (Fig. 15). Making use of this feature, an effective and fast algorithm that differs from the previous ones can be applied to find the horizontal position of the number plate. The algorithm consists of the following steps:

- The found range is transformed to horizontal.
- The lightest pixel is searched for in every column (Fig. 16. Maximum Values).
- Vertical bandpass filtering is performed in every column of the horizontal range (Fig. 16. Filtered Region).
- A sum of filtered columns (SFC) is generated using the results of filtering (Fig. 16. SFC).
- Aligned to the vertical size of the number plate (its height is known), the maximal value curve is filtered

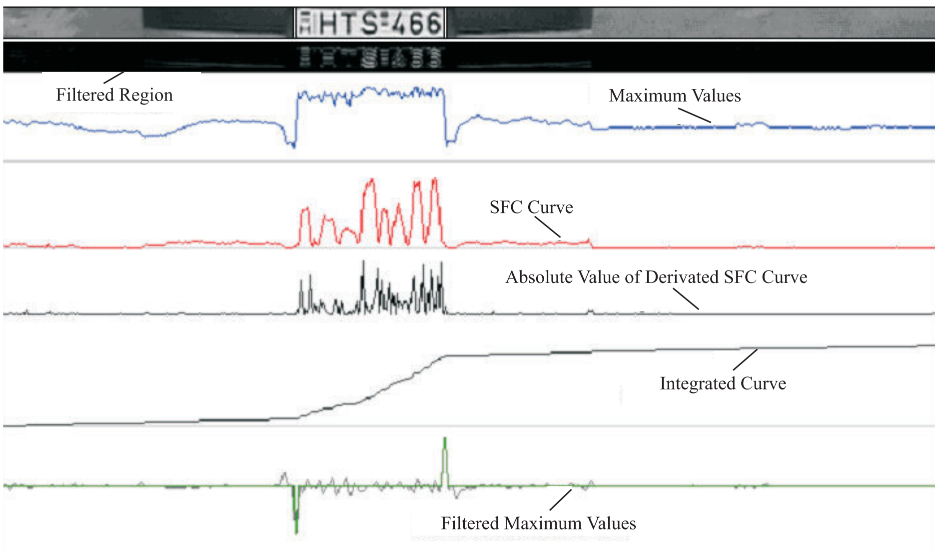

Fig. 16. Determination of the horizontal position of the number plate in the case of direction sensitive window filtering.

Fig. 17. Localized number plate distorted back to horizontal position.

Fig. 18a. Window method + ATH.

Fig. 18b. Direction sensitive method.

Table 1.

Algorithm	Resolution	Time (s)
Window edge search	640×480	0.18
Window edge search	320×240	0.08
ATH versions + search (fine localization)	640×480	0.06
ATH versions + search (fine localization)	320	0.04
Direction sensitive edge search	640×480	2.37
Direction sensitive edge search	320×240	0.80
Direction sensitive edge search (only for number plate)	130	0.05

on the basis of formula 5 (Fig. 16. Filtered Maximal Values; $L = 2 \ldots 5$). As a result of this, the rising and falling edges appear. The values smaller than half of both the negative and positive peaks are set to zero, due to which only the relevant peaks remain.

- The absolute value of the differentiated SFC curve is calculated (Fig. 16. Absolute Values of Differentiated SFC Curve).
- The above curve is integrated from the beginning of the range concerned (Fig. 16. Integrated Curve).
- Negative (left side) and positive (right side) adjacent peak pairs are searched for whose distance nearly equals the expected width of the number plate and between which the SFC curve exhibits frequent changes (this is indicated by the Integrated Curve). If several possibilities are obtained, the range exhibiting the highest relative changes is selected.

Figure 17 shows the result of the algorithm. In certain cases (for example, when the number plate is darker than its environment) the maximal value curve has a shape just opposite than the one depicted in Fig. 16. This results that the peaks indicating the boundaries of the number plate on the filtered maximal value curve have opposite directions. Considering these facts, the peaks are searched in an opposite order (positive left side and negative right side adjacent peaks) in case the process is not successful.

If the search process still remains unsuccessful, a new strategy may be tried, because the number plate can often be found on the basis of the absolute value of the number plate's differentiated SFC curve.

$$H(x) = \begin{cases} +1, & \text{if } L < x < 0 \\ 0, & \text{if } x = 0 \\ -1 & \text{if } 0 < x < L\,. \end{cases} \tag{6}$$

5 SUMMARY

After the completion of the algorithms introduced in this paper, when the area of the number plate is precisely localized, a transformation that restores the horizontal position of tilted number plates is recommended to be performed on all tilted number plates. This facilitates character recognition, since a character recognition module can easier separate and identify the characters after this operation. In addition, the transform always yields the same character picture size, the various number plate dimensions therefore do not influence recognition.

Each algorithm was also tested with images of different noise levels (Fig. 18). The results indicated that below a certain noise level the procedures operate perfectly, but severely degrade beyond this limit. The reason of this lies in the fact that the curves obtained as the sum of filtered rows and columns are distorted beyond this limit to an extent that the implemented filter procedures are no longer able to find the number plate. If it is known in advance that the system is to be operated in a noisy environment, then the filters, the search parameters and the thresholds must be set accordingly. The reliability of the system can be maintained this way. The performance can be further improved by various noise filtering methods, if required. As a result, number plate localization remains reliable even under such noisy circumstances when the character recognition module is no longer able to identify the characters.

The algorithms were not optimized for speed and were implemented on i386 architecture (P4 2.4 GHz processor and Windows XP operating system). The obtained results are in Tab. 1.

The reliability of the algorithm does not improve at higher resolution, but the computational time increases remarkably and the filter parameters, window size, *etc* must be realigned to the expected size of the number plate. In the case of low resolution images, the number plate is small and cannot be found securely, and also character recognition becomes more difficult. The optimal size has proven to be around 320×240 pixels.

The table indicates that the computational time required for improving the results of a window edge search by some adaptive threshold algorithm is identical to the one required by direction sensitive edge search, provided the latter one is executed in a found area. On the basis of the results, direction sensitive edge search is recommended as a fine search procedure, because usually it yields better results than thresholding at nearly identical run time. A further great advantage of the introduced procedures is that they are less sensitive for the improper illumination and contamination of the number plates [7]. In addition, the implemented ATH algorithms perfectly fit to the binarization procedures which are widely applied for registration number recognition, and may provide considerably better results than a thresholding algorithm that is based on average calculation.

Finally, the following conclusions may be drawn upon summarizing the introduced algorithms. The procedures are not sensitive for contaminations on the number plates as well as for adverse illumination, and feature excellent noise resistance. Precise learning process is not required at all. To achieve better results, windowing is always recommended in the case of procedures based on "basic" and direction sensitive edge finding (see chapters 2 and 4, respectively). The solution using "basic" edge finding is considerably faster than the direction sensitive method in the case of large images. However, the former procedure is less accurate, therefore correction is needed (ATH). The final goal is to obtain the possible fastest and most accurate procedure, which can be accomplished by unifying the two methods: the position of the number plate in the image is approximately determined by windowed edge finding, and, following this, direction sensitive windowing is applied as "fine localization" in this reduced area. This is the most accurate procedure to determine the location of the number plate.

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