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Reducing the Impact of Stroboscopic Effect on the Results of Vehicles' Plate Recognition Using Super-Resolution Techniques by Non-Coherent Camera Triggering

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ABSTRACT

The use of super-resolution algorithms can increase the resolution of image subject to further analysis in relation to the physical resolution of the camera recording the video sequence. A typical recording of such sequence is done with a fixed time interval (pre-determined number of frames per second). This can cause the shift of the plate image for subsequent frames by the total number of pixels, resulting in inability to take advantage of super-resolution algorithms that require shifts or rotations by a fractional part of pixels both vertically and horizontally. A possibility of reducing the impact of this effect by non-coherent triggering cameras is suggested in the paper.

KEYWORDS: register license plate number recognition, super-resolution, camera triggering

1. Introduction

Register License plate recognition is one of the most typical tasks performed by the machine vision systems used in the transport domain [1]. Such systems may be used for various purposes, not only for the identification of the vehicles that violated traffic regulations. Some other applications are the automatic control of parking gates and barriers, automatic accounting and fleet monitoring in the storehouses etc. Presently, such recognition is often used ad thee are many various applications of different methods based on the digital image processing and machine vision.

The recognition task is usually implemented as consisting of several stages performing a decomposition of the problem into smaller and simpler parts. The first task is related to the selection of the vehicle's shape from the image. For this purpose the background estimation techniques may be used, which are based on the analysis of the differences between the consecutive video frames. In order to eliminate the influence of noise, only the pixels with colors differing from their equivalents in the previous frames more than by a specified threshold are assigned as representing the vehicle.

This part of the process can be implemented without any additional complicated algorithms, since the knowledge of the exact shape of the vehicle is not necessary.

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The second task is to find the recognition plate on the image with eliminated background. This stage is quite complex and usually belongs to the most difficult ones. Since the recognition tablesplates can be placed in various positions, not necessarily in the central part between the light, wrong results may be obtained. Problem may occur due to changes of the lighting conditions, presence of a dirt on the tableplate etc. Nevertheless, in many algorithms the central position of the tableplate is assumed in order to speed up the process of its detection.

The proper detection of the register license plate is necessary for its extraction from the image, so the further processing can be performed using only a fragment of the image representing the plate.

In many countries there are some regulations related to the main types of the register license plates allowed for use as well as some additional types. They can be characterized as containing one or two rows of symbols, usually alphanumerical, with various density. Before the recognition of each symbol it is necessary to determine the type of the plate. Since the symbols are located in the specified places for each type of the plate and they are well separated, the image analysis procedure allowing proper detection and division of the image into the fragments representing each symbol is not complicated. For this purpose, even the binary image analysis and morphological operations can be successfully applied.

After the detection of each symbol the smaller images representing each of them are analyzed separately using the pattern recognition algorithms. For this purpose a number of various methods can be used, such as the comparisons with patterns, shape analysis based on graphs, statistical algorithms and soft computing techniques (neural networks, evolutionary algorithms, fuzzy logic).

Since the symbols are standardized by some norms, the most of such algorithms can lead to good accuracy in practical applications, also for contaminated images (bright and dark spots, presence of noise, blur).

The symbols recognized by one of the algorithms mentioned above are then combined into the string representing the recognized plate number which can be further verified in some of the systems e.g. using the connection with a database.

2. The influence of resolution and super-resolution approach

The recognition task is relatively simple if the high resolution images of register license plates are available. Assuming the camera is located far from the road, even for the high resolution cameras the number of pixels representing the register table is low. In such situations neither the typical recognition algorithms nor a human cannot recognize the number properly.

One of possible solutions is the use of the narrow-angle lens but it is worth noticing that such approach leads to the limitation of the working area of the system. The application of higher resolution cameras may be financially inefficient, especially of some cameras are already mounted. Besides, in such case the requirements of the system's operator usually increase, so there is always a need of a better quality and better accuracy.

The increase of the amount of data which can be used for the plate number recognition corresponds to the increase of the physical resolution of the analyzed image. One of the possible solutions is the increase of the number of cameras (preferably identical ones) but the cost of such system is relatively high and the final result depends on many factors such as e.g. relative locations of the cameras [2]. Another idea is the use of partially unstable single camera in order to obtain random shifts of consecutive frames but this approach is troublesome and increases the computational cost of background estimation.

Instead of the use of a single image for the plate number recognition (or several cameras) a sequence of images can be used, even acquired with lower resolution (many cameras offer such functionality). Using such video sequence with the same element (register license plate) visible on each frame, the application of the super-resolution algorithms is possible, similarly as for the other configurations described above [3-7]. As the result a single high resolution frame is obtained. An essential advantage of such approach is the fact that the resulting image is achieved with increased physical resolution in contrast to standard interpolation methods which artificially increase the number of pixels, which do not contain additional information.

Fig. 1. Example of a high resolution image containing a fragment of a register plate and resized low resolution one
Source: [own work]

The video sequence used by the super-resolution methods should meet several conditions. The first requirement is related to the relative positions of the camera and the object, which should differ for each frame. Assuming the motionless camera, the object should move, so stopping the vehicles is unnecessary. The best results can be obtained for random disturbances of relative locations with uniform distribution. The consecutive frames should also have similar brightness and colors and the number of them is also very important: much better results can be obtained using e.g. 10 frames instead of 3.

The changes of the scale for the input images are allowed, but the super-resolution algorithm has to perform an additional scale matching in that case. Some limited affine deformations of the image is also allowed, but it increases the total amount of computations [8].

Acquisition of the video sequence containing the register license plate in motion is usually done by the industrial cameras. Some more advanced cameras are equipped additionally in the mechanism of synchronic triggering. Assuming the moving vehicle and a relatively short video sequence (several frames) a constant shift of the plate in consecutive frames may be possible for some vehicle's velocities depending on the geometrical configuration of the camera and the vehicle's motion path. Such an phenomenon is similar to the stroboscopic effect and causes poor matching within the super-resolution algorithm, especially in the vertical direction. In such case the final effect of the super-resolution procedures may be unsatisfactory.

For the reduction of the impact of the stroboscopic effect described above, the random sampling in the time domain should be used. Assuming that the time when the register license plate is visible is long enough for the acquisition of several frames needed by the super-resolution algorithm, a slight decrease of their number can be made without significant influence on the final results. In such situation the triggering for each frame should be delayed by a random period leading to the non-coherent (asynchronic) triggering. The only limitation is the possibility of automatic camera's external triggering, but such additional input is common in most presently used models.

3. Experiments and results

In order to verify the correctness of the proposed approach some tests have been performed using some synthetic images containing random combinations of two letters and five digits, what is typical for most register license plates in Poland. A number of images have been rendered and four exemplary ones are presented in Fig. 2. The physical resolution of the images is 600×200 pixels.

In order to simulate the camera located far from the road the images have been down sampled to 30×10 pixels and blurred as well as contaminated by Gaussian noise. Zoomed resulting images are shown in Figs. 3 and 4.

For each of the test images four types of sampling, simulating the movements of the register plate in the video sequence, have been used:

- uniform – the random translations by one or more pixels without any fractional parts (synchronized camera triggering),
- partially random – 10% random vertical random shifts are allowed (simulation of the movement towards the bottom part of the image),
- partially random in two directions - 10% random vertical and horizontal random shifts are allowed (almost synchronized triggering),
- random – any shifts in two directions are allowed (asynchronic triggering of the cameras).

The assumed model of contaminations contains the Gaussian noise simulating the distortions on the plate e.g. related to the presence of dirt, snow etc. The blurring convolution filter is used for the simulation of further decrease of the resolution (4 pixels moving average filter is applied), which may be related e.g. to air trembling, blur on the CCD or the decrease of the optical density. The additional Gaussian noise is also used in order to simulate the acquisition (measurement) noise.

Apart from these distortions another pseudo-random number generator of uniform distribution is used in order to simulate the random changes of the sampling period.

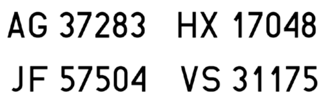

Fig. 2. Example synthetic high resolution images used in our experiments
Source: [own work]

Fig. 3. Example low resolution images used in our experiments
Source: [own work]

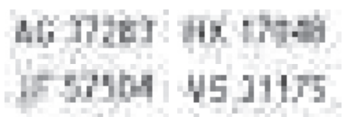

Fig. 4. Example low resolution images with additional noise
Source: [own work]

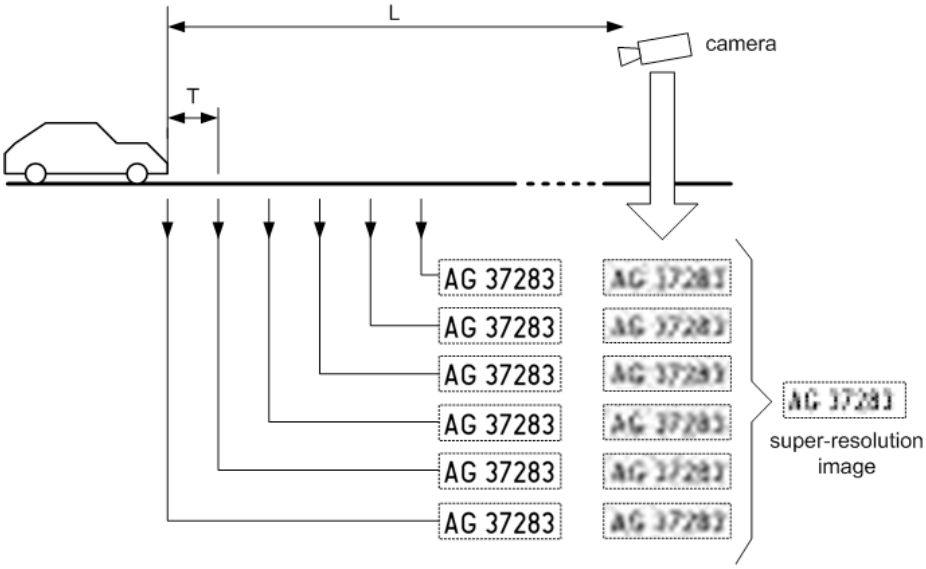

Fig. 5. The illustration of the idea of coherent sampling (synchronic triggering)
Source: [own work]

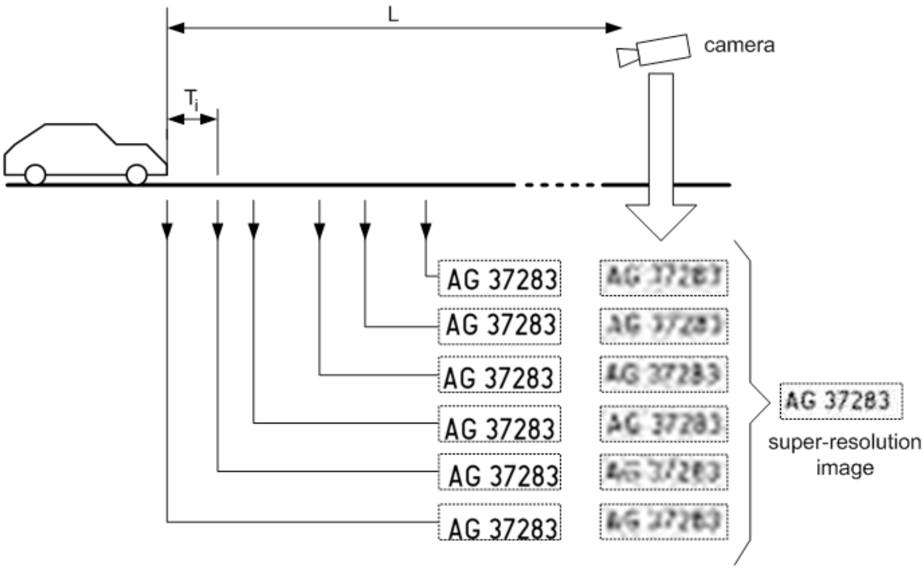

Fig. 6. The illustration of the idea of non-coherent sampling (asynchronic triggering)
Source: [own work]

The sampling distance of the *i*-th frame is calculated as:

$$T_i = T_{i-1} + T \cdot \left(1 + S \cdot rand\right), \qquad (1)$$

where *S* denotes the allowed disturbance (10% or 100% in our experiments) and *rand* is the pseudo-random number within the range < -1 ; 1>. The constant sampling distance for the constant speed and frame rate is denoted as *T.*

The idea of the coherent and non-coherent sampling is illustrated in Figs. 6 and 7. Presented images indicate the fragments of acquired frames representing the register plates. It is assumed that their size is constant due to the far located camera, so that:

$$L >> \sum_i T_i \,. \qquad (2)$$

The reconstruction has been performed using the Anti-Lamenessing Engine (ALE) software based on Irani-Peleg back projection algorithm [3,4]. For this purpose 16 randomly shifted (according to the assumptions discussed above) low resolution frames have been used for each type of sampling and each register license plate. Example results are shown in Figs 7-10 for each type of sampling.

A useful information related to the process of super-resolution reconstruction can be the average matching percentage being in fact a measure of similarity of the low resolution images used during the calculations. The results obtained for the four exemplary plates are presented in Table 1. Analyzing these values one may be surprised by the fact that the lowest values of matching have been obtained for the random sampling leading to certainly the best quality of resulting images. This is caused by a specific property of the super-resolution algorithm which uses primarily the data related to dissimilarities of the input images. In that case the average matching cannot be interpreted neither as the quality metric nor its exact opposite.

Regardless of the fact that lower values indicate more differential information present in some input images, which may be used by the super-resolution algorithm, even lower values may suggest the completely different images. In that case the average matching should be combined with some of the image quality assessment techniques [9] in order to obtain more useful information, which may be used for the automatic and reliable assessment of the results obtained by the super-resolution algorithm.

4. Conclusion and future work

Super-resolution algorithms can be applied not only as supplementary methods for the register plate recognition systems but also for the improvement of vertical road signs recognition [10] or vehicles' tracking.

Table 1. Average matching percentages.

Sampling method	Average matching for exemplary register plates
Uniform	AG37283 – 87,6% HX17048 – 90,6% JF57504 – 89,9% VS31175 – 90,9%
Partially random (10% of pixel's height vertical)	AG37283 – 91,0% HX17048 – 90,6% JF57504 – 90,9% VS31175 – 91,3%
Partially random (10% of pixel's width and height in both directions)	AG37283 – 87,6% HX17048 – 90,7% JF57504 – 91,0% VS31175 – 90,6%
Random	AG37283 – 86,5% HX17048 – 85,7% JF57504 – 86,0% VS31175 – 88,8%

For the automatic verification of the results obtained using various methods, both for motion estimation [5,6] and reconstruction [3,4,7] some specialized image quality assessment methods would be useful. Since the typical usage of such methods is related to the assessment of images containing some typical distortions such as noise, blur, lossy compression etc. they may be even useless for this purpose.

The main contribution of some recently proposed image quality metrics, such as e.g. Structural Similarity [11], is much better correlation with subjective evaluations in comparison to classical Mean Squared Error and similar metrics [12,13]. Such well correlation is not necessarily equivalent to high recognition accuracy of register plates. Since in some systems the recognized images are binarized, the applicability of modern metrics is limited.

Another problem related to the image quality assessment is the full-reference character of most metrics. It means that the full knowledge of the ideal image without any distortions is required for the comparisons. In practical applications the use of the super-resolution algorithm

Fig. 7. Reconstructed images obtained using the super-resolution algorithm for the uniform sampling
Source: [own work]

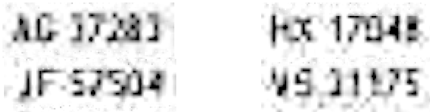

Fig. 8. Reconstructed images obtained using the super-resolution algorithm for the uniform sampling with 10% horizontal and vertical disturbance
Source: [own work]

Fig. 9. Reconstructed images obtained using the super-resolution algorithm for the uniform sampling with 10% vertical disturbance
Source: [own work]

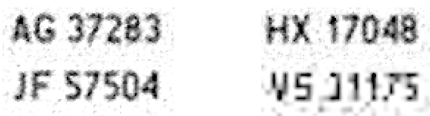

Fig. 10. Reconstructed images obtained using the super-resolution algorithm for the random sampling
Source: [own work]

is based only on several low resolution video frames and the high resolution reference image is not available. In such case the automatic choice or modification of some parameters of the algorithm or the camera has to be performed using the data which is available. In such case the only possible solution of automatic image quality assessment is the use of some no-reference ("blind") methods [14]. Unfortunately, such existing methods are rather specialized and sensitive on only one or two types of distortions e.g. blur [15] or JPEG compression [16], so the development of a "blind" image quality assessment method for super-resolution images seems to be an interesting direction of further research.

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