

Development of a License Plate Number Recognition System Incorporating Low-Resolution Cameras

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A multi-lane free flow (MLFF) toll collection system installed on a simplified gantry requires compact cameras for supervising enforcement. Because these compact cameras have low image resolution, it is also necessary to develop vehicle license plate recognition technology that uses dynamic image processing. Mitsubishi Heavy Industries, Ltd. (MHI) has developed three technologies based on the conventional license plate recognition system using still images; these technologies improve image quality, process plural images of a single vehicle, and utilize a reference database. Laboratory evaluation tests have verified that even a low-resolution camera system can successfully recognize license plate numbers at a rate of 95% or better, comparable to results from the conventional still image system. MHI is enhancing system robustness to enable application of these technologies to actual products.

1. Introduction

MHI has developed vehicle toll collection systems, including electronic road pricing (ERP) systems in Singapore and electronic toll collection (ETC) systems in Japan, where toll collection is controlled by communications between antennas installed on roadside gantries (or frames) and within in-vehicle units.¹

Demand for multi-lane free flow (MLFF) toll collection systems using simplified gantries is increasing worldwide, in order to reduce construction costs and preserve favorable scenery.

Conventional toll collection systems supervise enforcement using large, high-resolution cameras that produce high-quality still images to recognize vehicle license plate numbers automatically.

The simplified gantries used in the MLFF toll collection system require the supervision cameras to be more compact than those used in conventional systems. Because compact cameras produce lower image resolution, conventional license plate recognition systems are unable to achieve the required rate of successful recognition.

This paper presents novel image processing technologies that can achieve rates of successful recognition equivalent to those of conventional systems, even when using low-resolution supervision cameras.

2. Recognition of vehicle license plate numbers

MHI has applied vehicle license plate recognition technologies to components of vehicle classification units and to identify toll-evading vehicles. For example, Singapore's ERP system identifies the license plate numbers of toll-evading vehicles by using cameras installed on gantries to

record images of the license plates of noncompliant vehicles (such as those lacking an in-vehicle unit).

These photographs are transferred to the central computer system, where the built-in software program for vehicle license plate recognition identifies the vehicle numbers (Fig. 1).

MHI's vehicle license plate recognition systems have been in revenue service for more than 20 years and produce a highly successful recognition rate of 95% or higher.

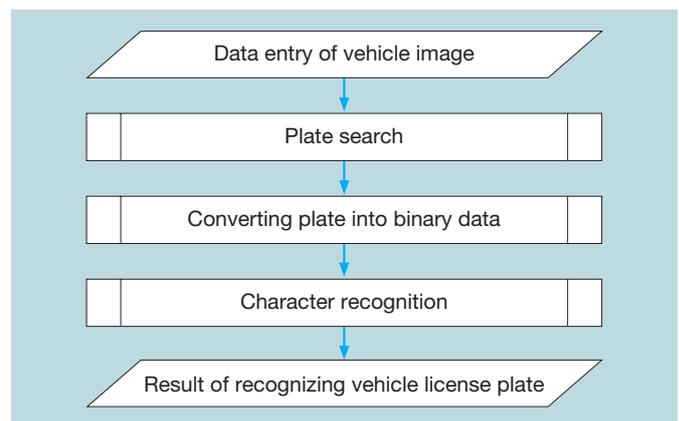


Fig. 1 Basic flow of the vehicle license plate recognition process

3. Technical problems

Singapore's ERP systems use large, high-resolution supervision cameras. They record one still image of each passing vehicle, which is sufficient because the cameras produce high quality, large-size images.

Compact cameras suitable for mounting on simplified

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gantries would produce lower resolution images than the current ERP system, causing concerns about degraded recognition accuracy.

Recent improvement in computer performance has enabled these compact, low-resolution cameras to process each vehicle using motion images. This is a distinct benefit, but requires the technology to process multiple images.

Vehicle license plate recognition systems using compact, low-resolution supervision cameras therefore face two main problems:

- (1) low image resolution, and
- (2) processing plural images for one vehicle.

3.1 Low image resolution

Degraded resolution tends to result in images with blurred and defaced character strokes.

The low-power lighting device associated with compact imaging devices also poses a problem of low brightness due to lack of light (Fig. 2).

3.2 Processing plural images for one vehicle

A motion image of one vehicle consists of plural, continuous images, making it possible to obtain the vehicle license plate number from each image.

All the images processed must produce the same recognition result. If (a) two or more different results are

Image		
Camera	Large, high-resolution camera	Compact, low-resolution camera
Contrast	Good (bright)	Poor (dark)
Sharpness	Good (sharp characters)	Poor (blurred, defaced characters)
Character separation	Good (characters well separated)	Poor (characters poorly separated)

Fig. 2 Technical problems due to degraded image quality

obtained from the images of a single vehicle, or (b) each of the recognition results includes one or more illegible characters, an additional process is required to identify the correct result (Fig. 3).

4. Features of the developed technology

4.1 Image processing algorithm compatible with low-resolution images

To solve the problems associated with low image quality discussed in section 3.1, MHI has developed three kinds of image processing algorithms based on the conventional vehicle license plate recognition algorithm:

- (1) plate extraction process,
 - (2) contrast improvement process, and
 - (3) character isolation process.
- (1) Plate extraction process

A lack of sharpness in a license plate image may result in a low-resolution or a low-contrast image, causing the system to select noise components erroneously as part of the plate data.

An image sharpening process was added to help achieve consistent plate extraction.

This image sharpening process is a combination of a noise filter and a sharpening process, improving image sharpness while suppressing noise.

An enlargement process was also introduced to prevent an increase in blurred or defaced characters due to low resolution; this process incorporates the gradient in peripheral brightness (Fig. 4).

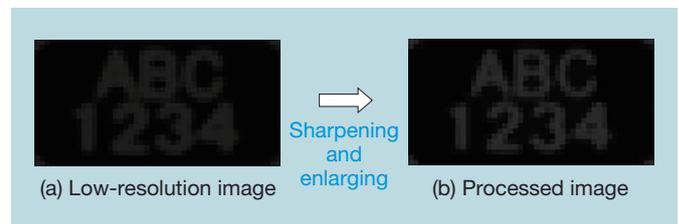


Fig. 4 Effect of sharpening and enlarging images

Time	Photographs	Same recognition results for all	(a) Two or more differing recognition results	(b) One or more unidentified characters in each recognition result
t		Recognition result: ABC123	Recognition result: AB?12?	Recognition result: AB?12?
t+1		Recognition result: ABC123	Recognition result: ABC123	Recognition result: A?C12?
t+2		Recognition result: ABC123	Recognition result: ABD123	Recognition result: ABC?23
t+3		Recognition result: ABC123	Recognition result: A8C123	Recognition result: ?B?1?3
Problem		—	Singling out correct recognition result is required.	Recognizing unidentified characters is required.

Fig. 3 Problems with recognition results using motion images

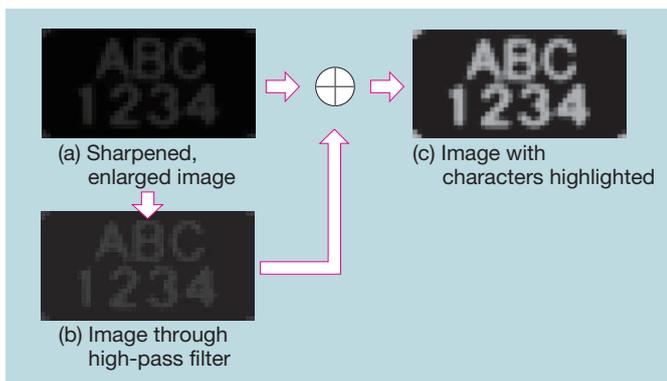


Fig. 5 Highlighting characters using high-frequency image superimposition

(2) Contrast improvement process

A low-contrast image due to lack of light makes it difficult to accurately convert characters into binary data.

Therefore, MHI developed a pre-processing algorithm. This algorithm analyzes statistic brightness information with respect to the extracted plate and judges the contrast quality, which in turn improves the brightness of each pixel and automatically produces an optimal contrast.

The contrast-improved plate image goes through a high-pass filter to highlight the frequency components of the characters. The highlighted image is superimposed on the original image to increase the brightness difference between the characters and the background (Fig. 5).

(3) Character isolation process

Degradation in image quality can cause blurred or defaced characters to merge. The enlargement solution described above cannot solve this particular problem because enlargement will not separate characters if they are connected in the original image.

On the basis of statistical information obtained mainly from the brightness histogram, MHI developed a new process by which minute brightness changes can be distinguished within the clearances between characters, enabling identification of boundaries between characters.

4.2 Algorithm utilizing plural recognition results

To solve the problem discussed in section 3.2, MHI further developed a process to integrate the plural recognition results obtained from one vehicle (Fig. 6).

The process first scores each character based on the character recognition results. Score points are a numerical expression of the likeliness between each character and the registered character templates. Higher score points indicate higher accuracy of character recognition.

Next, score points are allocated to each character in order (i.e., first character, second character, and so forth).

Finally, the character with the highest allocated score total points is selected as the final recognition result.

4.3 Improving recognition accuracy utilizing a database

To further improve the accuracy of vehicle license plate recognition, MHI developed a recognition accuracy

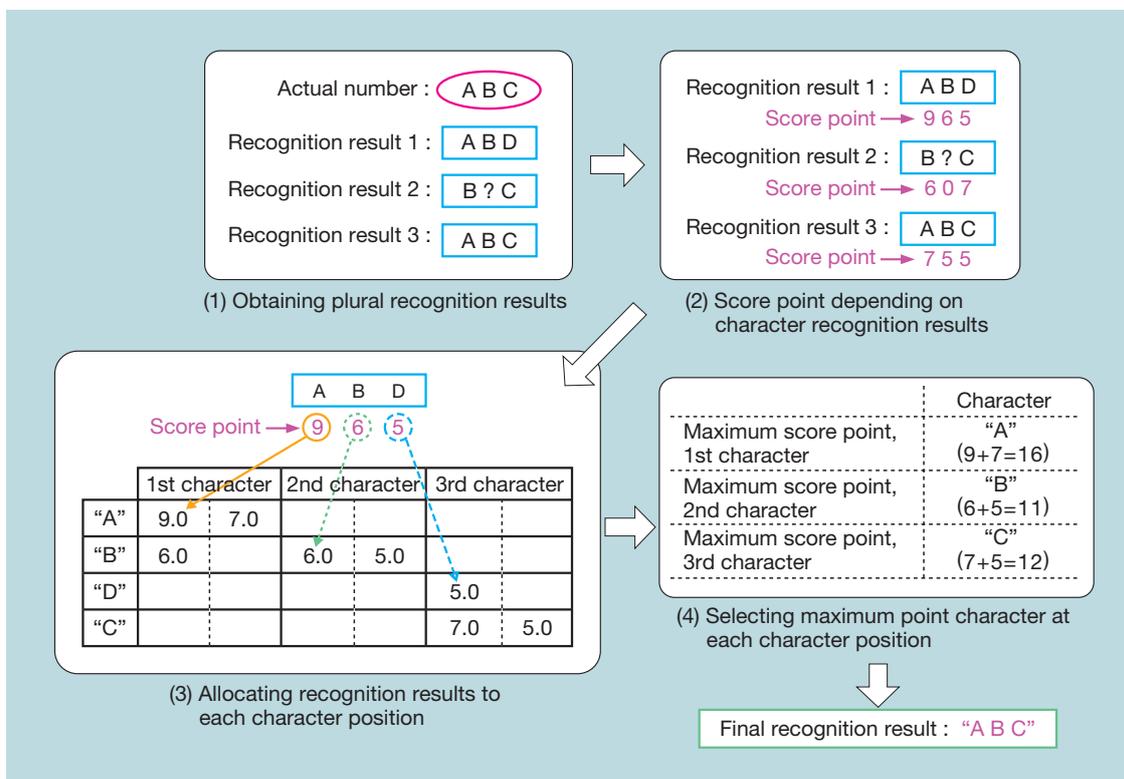


Fig. 6 Integration process of plural recognition results

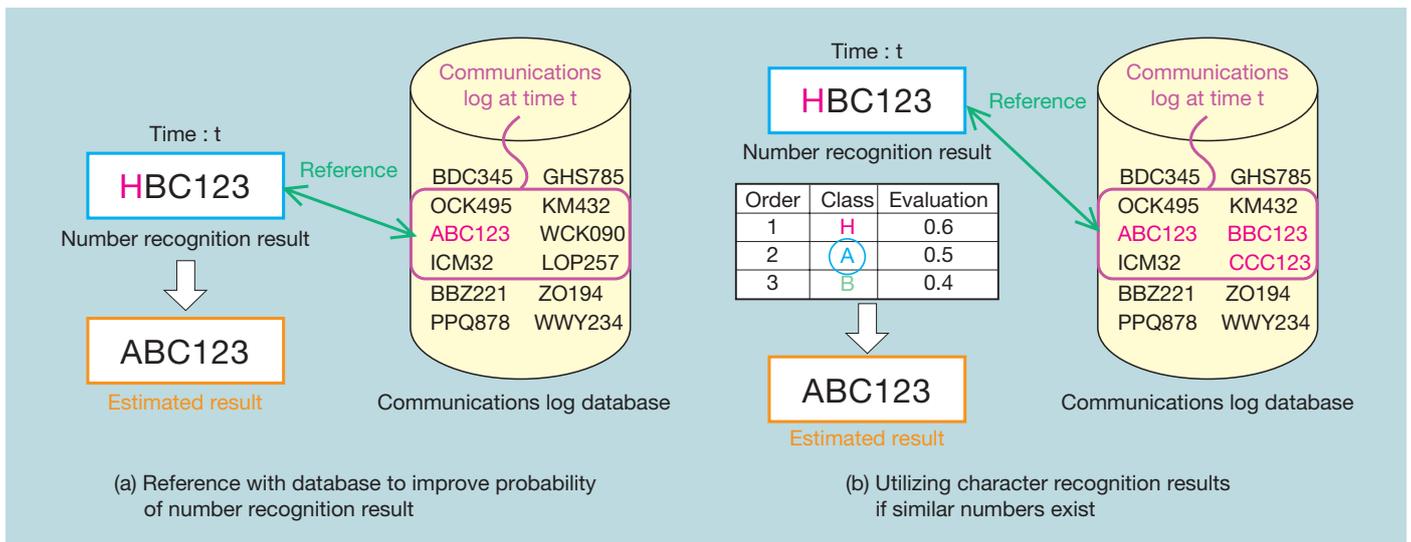


Fig. 7 Reference with database

improvement technology that utilizes a database (Fig. 7).

A central computer system stores the database for a toll collection system, including a communications log with in-vehicle units and registered vehicle license plates.

A recognition result of a vehicle license plate proves to be correct if it agrees with one of the registered vehicle license plates recorded in the database at that particular time.

Even if some characters are unidentified as a result of the recognition process, the communications log in the database can identify a vehicle that is registered with similar characters, producing highly accurate recognition results.

However, the recognition process may fail if many characters are unidentifiable or if a search of the communications log results in two or more vehicles as candidates.

To cope with this problem, MHI developed a database search technique that incorporates character recognition results and a matching evaluation process.

5. Laboratory test evaluation

The performance of the novel license plate recognition process incorporating low-resolution images was evaluated

using a number of vehicle images.

Vehicles were photographed using low-resolution cameras. The images were treated to include noise, reduced contrast, lack of focus, and other defects to simulate the disturbing influence of direct sunlight and shadows caused by changes in climate, dirt on license plates, and deformation of license plates.

The evaluation tests revealed that the system successfully recognized vehicle license plates at an accuracy of 95% or higher. The results of this novel process (patent pending) are as accurate as those of systems using conventional high-resolution images (95%; see Fig. 8).

6. Conclusion

The MLFF toll collection system enables vehicles to move freely, without necessitating the stops required at tollgates. Demand for this type of system is expected to increase due to its ability to reduce traffic jams and fuel consumption.

MHI's novel system is based on the compact, low-resolution cameras that are used in the MLFF toll collection system. Its performance has proven to be equal to or better

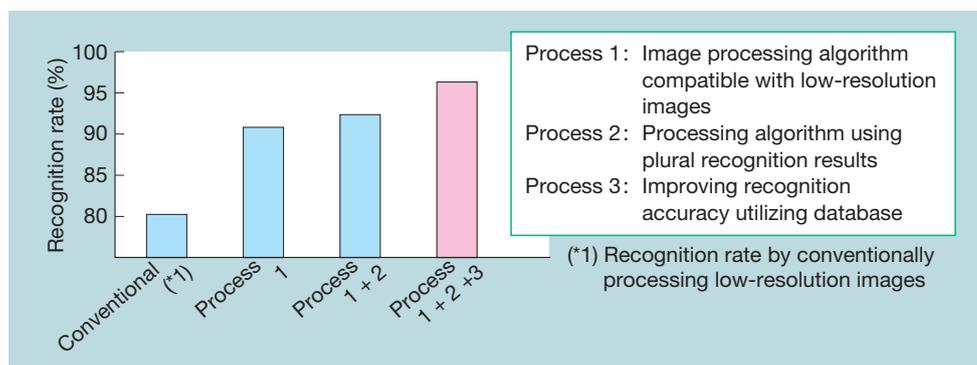


Fig. 8 Results of performance evaluation of developed technologies

than results from conventional systems that use high-resolution images.

This development can offer MLFF toll collection systems highly accurate enforcement with flexible revenue operation.

To ensure that the system becomes even more robust for use in actual systems, MHI will continue to improve the process by evaluating more image data.

References

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