Speed Traffic-Sign Recognition Algorithm for Real-Time Driving Assistant System

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Abstract - The purpose of this research is development of an algorithm for hardware implementation for number recognition applying in speed traffic-sign recognition system for car driving assistant. We recognize the speed limit of the speed traffic-sign using hardware oriented extraction algorithm. The numbers are recognized by comparing their feature values with the recognized features. The proposed hardware oriented number recognition algorithm achieves almost 100 % in recognition rate in 31 scenes in highways and 23 scenes in local roads.

I. Introduction

The traffic sign recognition would be very important in the future vehicle active safety system [1]. The most important information is provided in the driver's visual field by the road signs, which are designed to assist the drivers in terms of destination navigation and safe. The most important of a car assistant system is to improve the driver's safety and comfort. Detecting the traffic signs can be used in warning the drivers about current traffic situation, dangerous crossing, and children path. An assistant system with speed limitation recognition ability can inform the drivers about the change in speed limit as well as notify them if they drive at over speed. Hence, the driver's cognitive tasks can be reduced and safe driving is supported. However, meeting real-time performance for such a system is still a big challenge research, especially in compact hardware size. Our research targets to a smart and compact high performance speed traffic-signs recognition system on low resources Xilinx Zynq 7000 platform [2].

In general, our research aims to white line recognition, pedestrian recognition, vehicles recognition, and sign recognition system implemented on hardware for real time performance. As one of functions, the number recognition implementation on hardware for identifying the speed limit of a sign is proposed in this paper. In this algorithm, number recognition of speed traffic-signs is performed using feature quantity suitable for hardware processing. It aims to 100 % of the recognition rate.

The outline of the proposed system for speed traffic-sign recognition is shown in section II. The simple and smart feature quantity extraction algorithm for Number Recognition are shown in section III. The results of simulations are shown in section IV. The discussion and conclusions are shown in section V and VI.

Fig. 1. Eight-bit gray scale image (640x390 pixels).

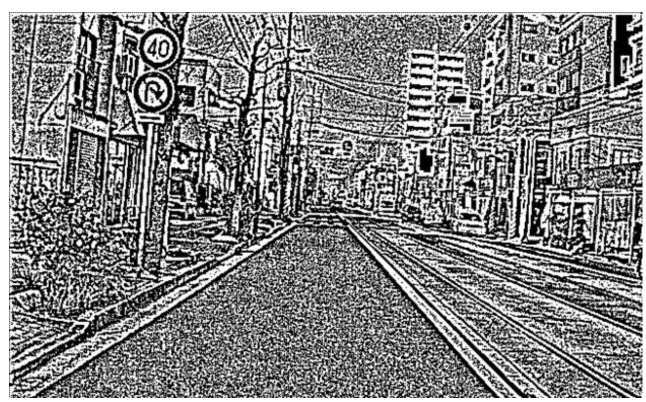

Fig. 2. Binary image (640x390 pixels).

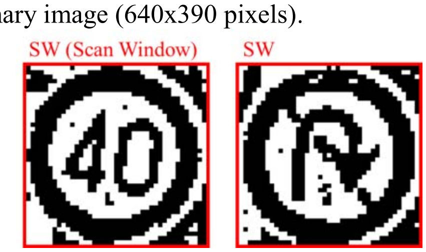

Fig. 3. Traffic-signs detected by the Sign Detection. (15x15 ~ 50x50 pixels)

II. System Outline

A. Flow Chart of this System

Fig. 4 shows the flow chart for the limited-speed recognition system, which recognize the limited-speed from a gray scale image.

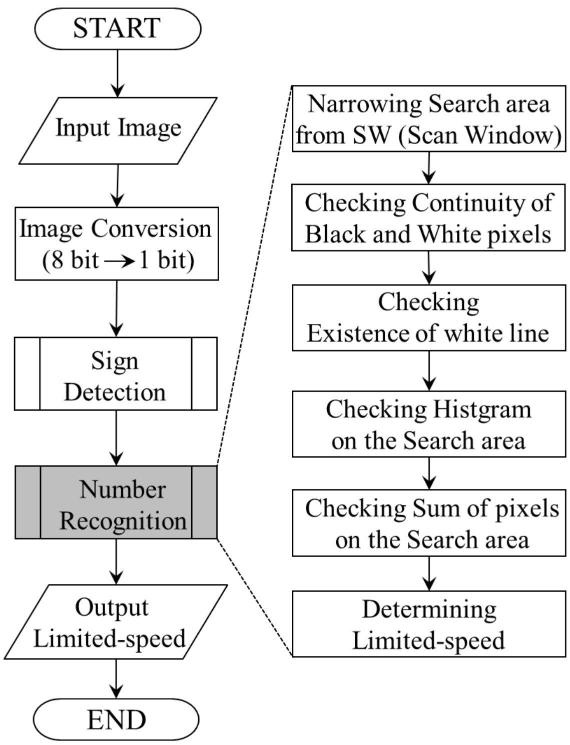

Fig. 4. Flow chart of this system.

1. Input Image.
   Input of our system is 8 bit gray-scale image of 640x390 pixels as shown in Fig. 1.
2. Image Conversion.
   The 8 bit gray-scale image is converted into binary image as shown in Fig. 2. This conversion also applies a sign enhancement filter to increase features of the sign.
3. Sign Detection.
   Speed traffic-sign areas are searched in the 8 bit gray-scale image by our Rectangle Pattern Matching algorithm [3]. Areas, which are detected as traffic-signs, are defined as SW (Scan Window) as shown in Fig. 3. Overview of the "Sign Detection" is shown in Fig. 5.
4. Number Recognition
   The number recognition is used to define the number located inside the sign candidates areas. This module analyzes the binary image in Fig. 3 to find the limit speed. This paper emphasizes to explain about the Number Recognition. Overview of the "Number Recognition" is shown in Fig. 5. The examples of a "Speed-signs" and "Not speed-signs" are shown in Fig. 6.
5. Output Limited-speed.
   The recognized limit speed is given to the assistant system to notify the drivers if necessary This system notifies drivers with Limited-speed.

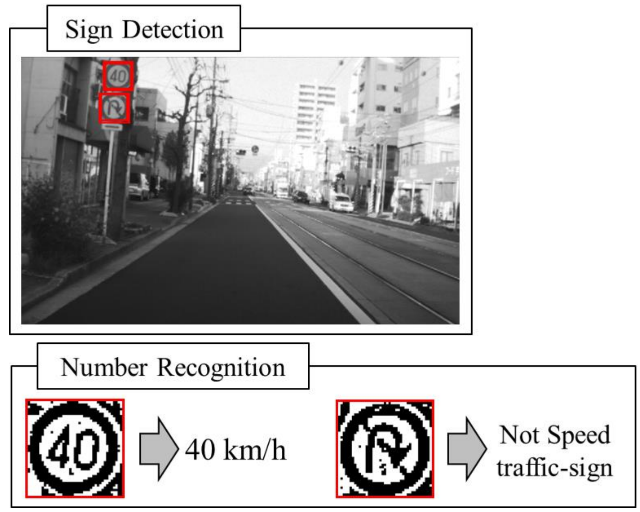

Fig. 5. Overview of Sign Detection and Number Recognition.

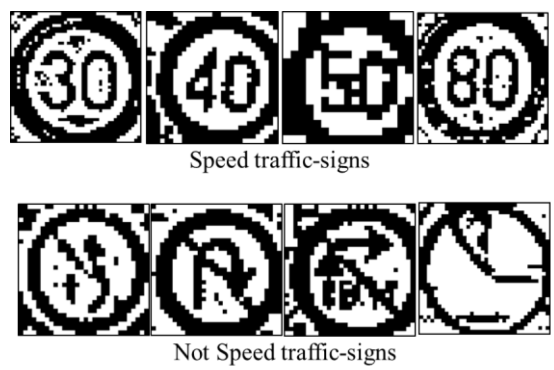

Fig. 6. The example of "Speed traffic-signs" and "Not Speed traffic-signs."

B. Outline of "Number Recognition"

The Number Recognition module extracts the feature quantity of the SW and compares it with the standard quantity of various numbers "0 ~ 9" to find the match for recognition. It has 3 steps below.

1. Narrowing Search area from SW.
   The SW area (detected sign area) is narrowed down to search area, where the numbers are located, befor analyzing to detect the features of numbers inside.
2. Extracting the feature quantity from the number.
   Those features are explained in section III. B ~ E.
3. Determining Limited-speed.
   By comparing the feature quantity extracted from the search area with the standard features of numbers, limited-speed is determined.

III. Algorithm and Feature Set for Number Recognition

The input image in Number Recognition are binary images with the size in a range from 15x15 to 50x50 pixels.

A. Narrowing the Number Search Area form SW

The search area is narrowed down from the sign size to the size of the number as shown in Fig.7. (a). The number features of the search area is then extracted. SW size is defined as "S pixels." Size of the search area relies on the size of the SW as shown in Fig. 7. (b). The max size of search area is 27 pixels when the SW size is 50x50 (max SW size).

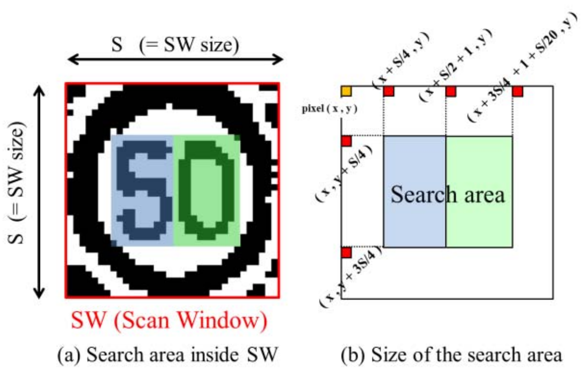

Fig. 7. Definition of search area in SW.

The original search area is extended to 4 other derivative areas by shifting the original to the left, right, up and down as shown in Fig. 8. The number successfully recognized among those 5 search areas is defined as the speed.

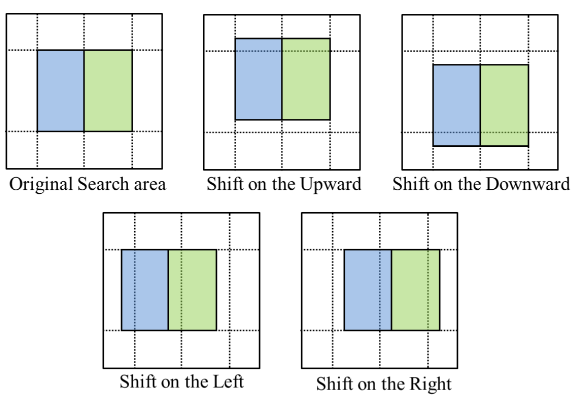

Fig. 8. Five derivative search areas created from the original search area by shifting.

B. Feature in continuity of black and white pixels

There are common features of "0" number, in which the middle of number "0" has continual white pixels and the two vertical edges of "0" has continual black pixels. Middle of the number is analysis for continual black and white pixels. If the features are meet, the number is "0" as shown in Fig. 9. Since all the speed traffic-sign in Japan, ended with "0," a sign candidate is considered as speed traffic-sign if the above features of "0" number are meet at the right side of the search area.

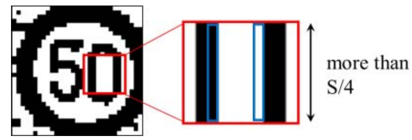

Fig. 9. Black line and white line feature of number "0".

C. Feature in Existence of the Vertical White Line in Blocks

If each number is divided into four blocks as shown in Fig. 10, existent and location of the white lines can be used as feature for the numbers recognition.

However, with this feature quantity only, when there are many noises (like the number "7" of Fig. 10) available, a number may be unable to be recognized correctly.

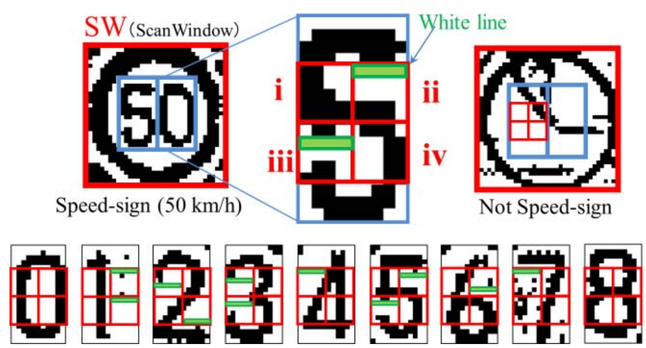

Fig. 10. Vertical white line feature of numbers.

D. Feature in Histogram of the Number

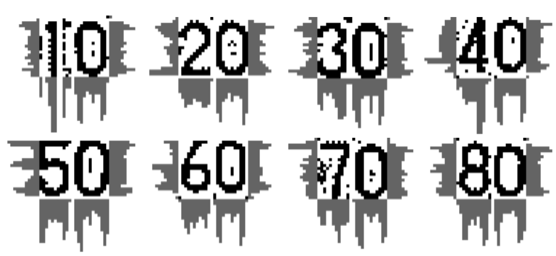

Fig. 11. Histogram of the numbers on the speed traffic-signs.

Histogram of the sign candidate area is calculated in vertical and horizontal axes and divided into 7 blocks with overlapped as shown in Fig. 12. and Fig. 13. Quantity of the maximum and minimum of the histogram in each block are used for number recognition.

Two flags are used for the maximum of histogram in each block. The first one will be set if the maximum histogram get over 70 % of the high (H) or width (W) of the number area. The other will be set if the maximum of histogram in a block is over 50 % but smaller than 70 % of H or W. Example about locations of maximum in histogram of a number is shown in the Fig. 12.

Similarly, the minimum of the histogram of blocks VI and VII are also a feature for number recognition.

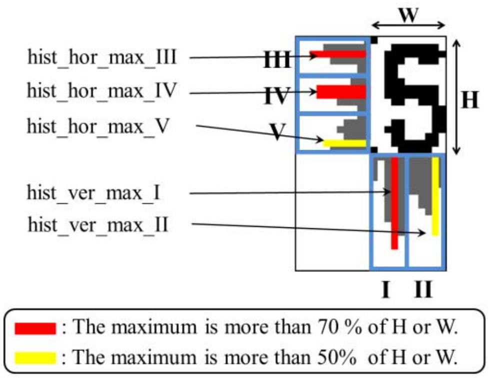

Fig. 12. Maximum of histogram of every block.

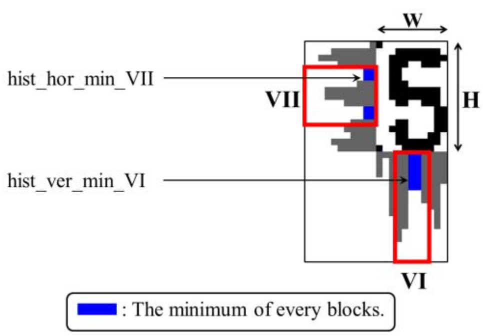

Fig. 13. Minimum of histogram of every block.

E. *Feature in Rate of Black Pixels on the Search Area*

TABLE I shows the rate of black pixel in different numbers. It can be used in number recognition. If the rate of black pixels in the search matches the condition in TABLE I, the search area can be considered as speed traffic-sign.

TABLE I
The rate of the black pixel in search area.

Number	Judgment conditions
0	Less than 66 %
1	Less than 40 %
2	Less than 46 %
3	Less than 43 %
4	Less than 50 %
5	Less than 54 %
6	Less than 48 %
7	Less than 44 %
8	Less than 61 %

F. *Number Recognition Using Histogram and Existant of White Line Features Quantity*

Fig. 14 shows the histogram feature quantity and existant of white line feature of numbers 0, 4, 5 and 8. The features extracted from the search area are compared with the standard features in Fig. 14 to find the match. By that, the speed number is recognized.

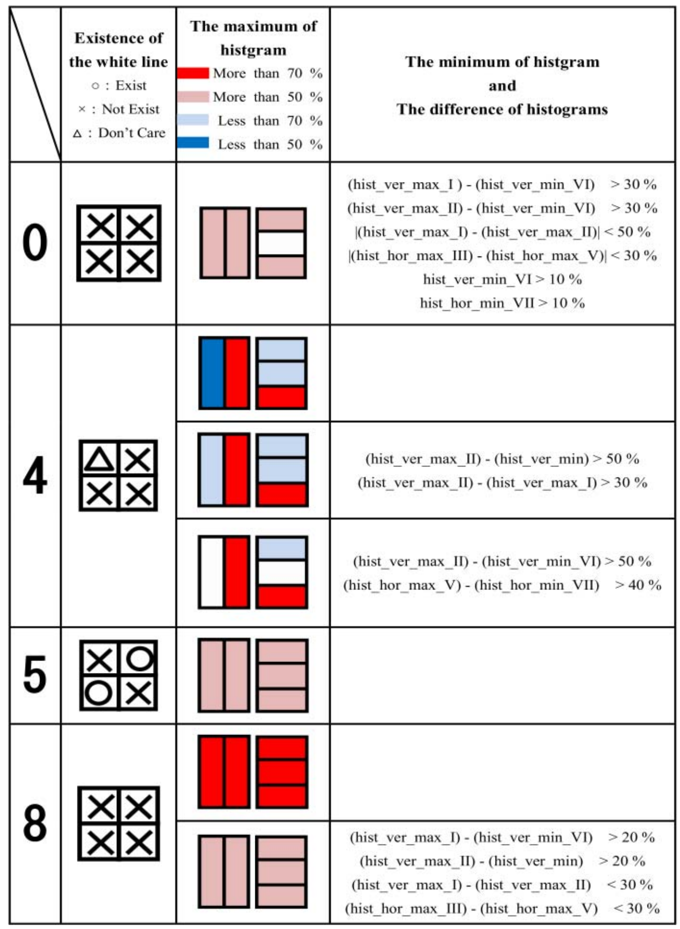

Fig. 14. Standard features quantity of four numbers.

IV. Simulation Result

A scene consists several frames, in which the same speed traffic-sign appears on them. The *Recognition_rate* of speed traffic-sign is defined in equation (1), and is computed on each scene. "*#All_SW*" is number of traffic-sign detected by Sign Detection and "*#Correct_SW*" is number of traffic-sign correctly recognized for limited-speed. *Recognition_rate* of one scene in local road and highway are shown in Fig. 16 and Fig. 18, respectively. The SW size (size of a sign) of the scene in the local roads and in highways are shown in Fig. 15 and Fig. 17.

$$Recognition\_rate\ [\%] = \frac{\#Correct\_SW}{\#All\_SW} \times 100 \quad (1)$$

A. Result of Simulation at a Local Road

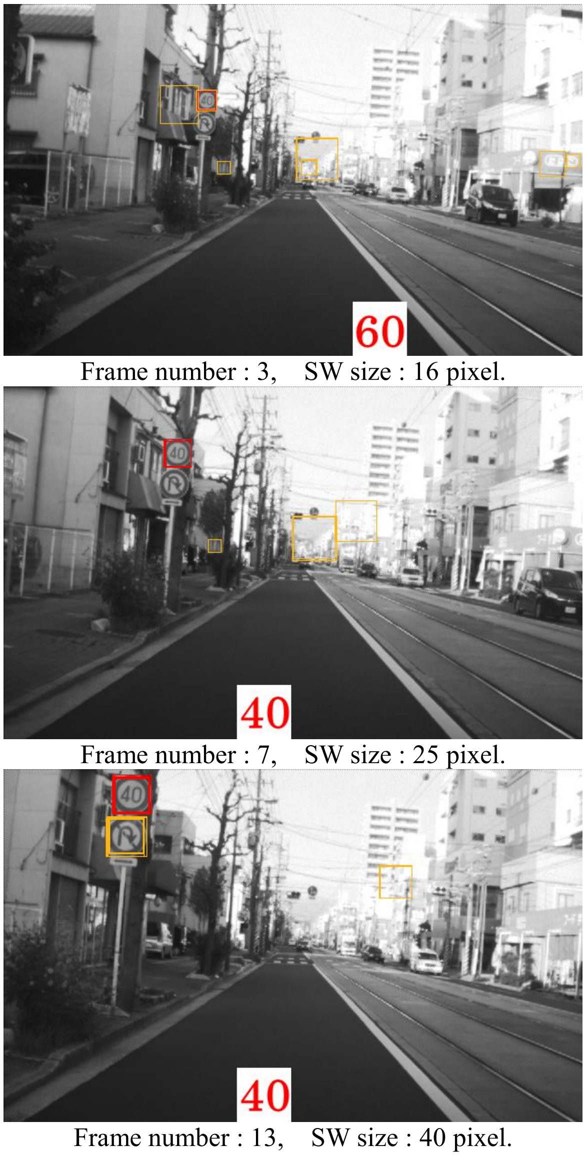

Fig. 15. Result of Sign Detection at a local road.

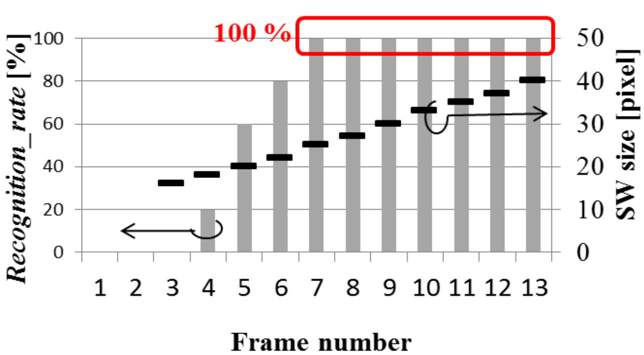

Fig. 16. *Recognition_rate* per frame of scene at the local road.

B. Result of Simulation at a Highway

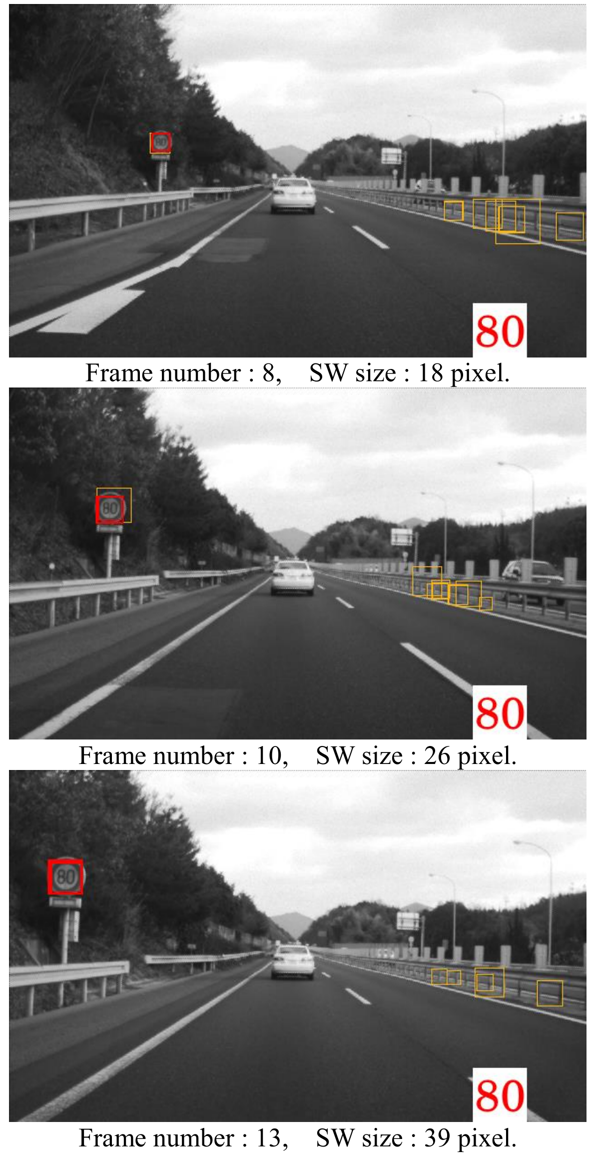

Fig. 17. Result of Sign Detection at a highway.

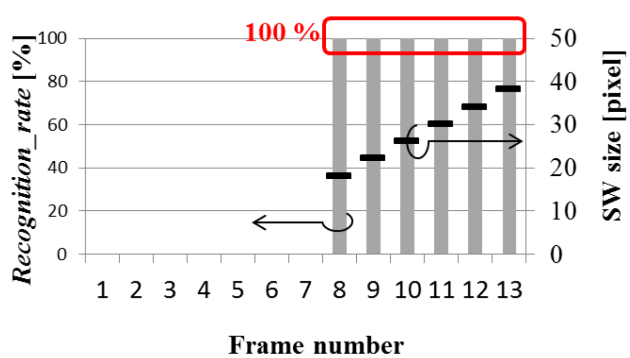

Fig. 18. *Recognition_rate* per frame of scene at the highway.

C. Summary of the Results of Simulations

When the camera gets closer to the sign, the size of speed traffic-sign become bigger and the *Recognition_rate* increase and gets 100 %. This occurs to all the scene of daytime, and so, the *Recognition_rate* for all the scene in daytime is almost 100 %. Table II shows the classification of speed traffic-sign of all the scenes used for the simulation. 1st lane means the car runs on the lane next to the sign. 2nd lane means that the car is at the farther lane with the speed traffic-sign. In other words, speed traffic-sign recognition in 2nd lane is more difficult than in 1st lane.

I will explain result of simulation at a local road shown in section IV as an example of the dependability of *Recognition_rate* on the size of the SW. A. The speed traffic-sign (SW size: 16 pixel) can be detected by the Sign Detection module at frame number 3. However, the *Recognition_rate* at the Number Recognition module is 0 % (unsuccessful) due to the small number of pixels in the search area (8x8). When the size of the speed traffic-sign becomes bigger (SW size: 25 pixel) at frame number 7, the size of the search area increases to (13x13), and the *Recognition_rate* becomes 100 % (successful).

TABLE II
The classification of the speed sign in all scenes.

Speed Traffic-Sign [km/h]	Scenes			
	Highways		Local loads	
	1st lane	2nd lane	1st lane	2nd lane
40	3	1	3	
50	3	1	12	6
60	7	1	2	
80	10	5		
TOTAL	31		23	

V. Discussion

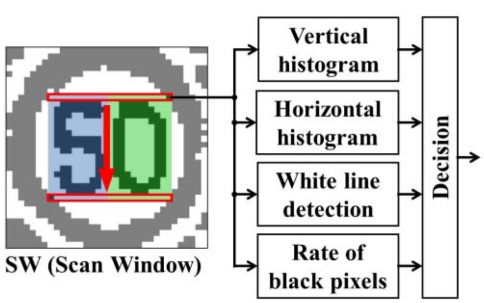

Fig. 18. Overview of number recognition module, which scan image only one time for decision.

The number recognition algorithm shown in section III is one time image scanning. As shown in Fig. 18, by scanning one line of the search area at one clock from the top to the bottom, the Number Recognition module extracts the feature quantity shown in section III (Histogram, White line and Rate of black pixels), and generates the result. Since the 1 pixel in SW is 1 bit, max of the number in bit of one SW line is 27 bits. For this reason, using 32 bit Block-RAM in the Zinq-7000, one line scanning at one clock is possible. The Number Recognition algorithm is realized by adders only, and so, it is suitable for hardware implementation.

VI. Conclusions

The hardware oriented algorithm on number recognition for speed traffic-sign identification has been developed. The simulation result shows that the proposed algorithm achieves almost 100 % in recognition rate with 31 scene in highways and 23 scenes in local roads in daytime.

Acknowledgements

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