Image-Processing Traffic Flow Measuring System of the Hokuriku Expressway

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ABSTRACT

The section between Nadachi-Tanihama,Niigata Prefecture and Asahi,Toyama Prefecture(59.9km) of the Hokuriku Expressway was opened on July the 20th in 1988. This means that all the line of the Hokuriku Expressway was opened. This area has 22 tunnels and we built Image-Processing Traffic Flow Measuring System as the part of NEC ITV System.

It consists of 11 image-processing equipments and 54 ITV cameras. The image-processing equipment processes the image signal from ITV camera control equipment and measures traffic parameters. It transmits the result of measurement to the central control computer and outputs the warning signal to electrical information boards. In this paper We report the detail of this system.

1. INTRODUCTION

Sumitomo Electric has been conducting research into the basic system configuration and vehicle detection algorithms for use with image-processing traffic flow measuring systems using ITV camera in conjunction with Institute of Industrial Science of Professor Takaba, Tokyo University, since 1981. Sumitomo Electric has developed a real-time processing method and algorithm for automatic brightness adjustment, a problem of concern for outdoor measurement and processing. Using these techniques, the first commercially viable image-processing traffic flow measuring system using ITV cameras in Japan was developed and deployed in the Enasan Tunnel on the Chuo Expressway in 1985.

The Hokuriku Expressway takes 476km from Maibara ,Siga Prefecture to Kurosaki ,Niigata Prefecture.(see Fig.1) The section between Nadachi-Tanihama and Asahi was opened on July the 20th in 1988. This area has 22 tunnels. So about the half of this area is in tunnels. At present, large long tunnels must be equipped with ITVs for the supervision of the traffic condition, as well as for the prevention of disasters. We built a new image-processing traffic flow measuring system at 12 large long tunnels in this area. It consists of 11 image-processing equipments and 54 ITV cameras. In this paper we desclibe this system .

2. FEATURES OF THE SYSTEM

This system has the following features.

(1) It measures trffic flow with using images of ITV cameras for the supervision. So it doesn't need any additional ITV cameras.
(2) An image-processing equipment can process 7 images (maximum) of ITV cameras at the same time.
(3) It can measure the traffic volume, the velocity of vehicles, the rate of congestion and the distance of two vehicles.

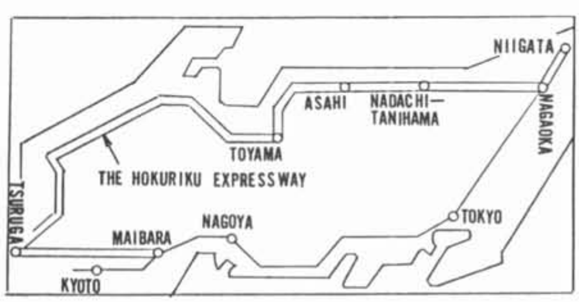


Fig.1 Location of the Hokuriku Expressway

(4) It transmits the traffic volume, the mean velocity and the congestion rate to the central control computer and give drivers the warning of high velocity or short distance of vehicles.

A number of techniques are available for processing images produced by the cameras; one such system developed by Sumitomo Electric is shown in Fig.2. In this system, pixel data, hereafter called the sampling point, for a specified measuring zone is extracted and compared with a reference illumination level for that spot to the presence of any vehicles.

3. ALGORITHM FOR VEHICLE DETECTION

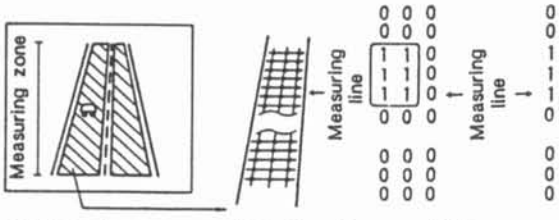
In this system the presence of vehicles is determined by the presence of light-pairs(headlights or talelamps). The detail of the algorithm for vehicle detection is shown below.

(1) Sampling points(picture element positions) are arrayed within the measurement zone of the ITV camera to measure at equal intervals on the road. The brightness at each of these points is used for measurements.

(2) Vehicle presence is determined by the reference brightness comparison technique : the brightness of the input image is compared with the standard brightness of the road at the sampling point to determine whether a vehicle is present or not.

(3) The brightness of the road surface at the sampling point is continually adjusted to the environment by exponential smoothing.

(4) The binarization is executed at each sampling point according to the brightness data of the sampling point and the standard brightness of the road surface.



(1) Measuring zone in the picture (2) Setting of sampling point (3) Presense of vehicle

Fig.2 Schematic picture of measurement
(▨ ;measurement zone, • ; sampling point)

(5) What lights (headlight, talelamp or other) are found is determined according to the distance and the size of them.

4. FUNCTION OF THE SYSTEM

This system measures the next five traffic parameters.

(1) Traffic Volume
A light-pair that is detected over two times in the measurement zone is considered as a passing vehicle. Traffic Volume is the sum of passing vehicles per unit time (5 minutes).

(2) Vehicle Velocity
Vehicle Velocity is determined according to the distance of light-pairs detected over two times in the measurement zone and the difference of deteeted time. (See Fig. 3) When light-pairs are detected two times, Vehicle Velocity is $\frac{L1}{T2-T1}$. When light-pairs are detected three times, Vehicle Velocity is $\frac{L2}{T3-T1}$.

(3) Mean Velocity
Mean Velocity is the average of velocity of passing vehicles per unit time (5 minut-es).

(4) Congestion Rate
Congestion Rate is divided to 3 levels according to Mean Velocity and Traffic Volume. Table1. shows judgement of 3 levels. Level 0 indicates no-congestion. Level 1 indicates low-congestion. Level 2 indicates high-congestion.

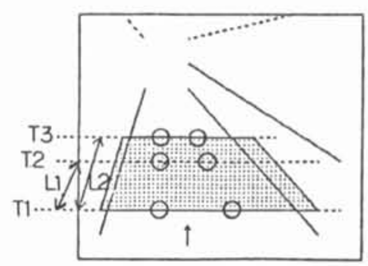


Fig.3 Principle of measurement in tunnels
(○ ; headlights or talelamps)
[T1, T2, T3 ; detected time]
[L1, L2 ; the distance of light-pairs]

Table 1. Congestion Rate Decision Table

	V ≦ V2	V2 < V ≦ V1	V > V1
Q ≧ Q1	Level 2	Level 1	Level 0
Q < Q1	equals the last one		Level 0

Q : Traffic Volume V : Mean Velocity

(5) Vehicle Gap

Vehicle Gap is the distance from a detected vehicle to the last detected one.

Vehicle Gap is given by ;

$$VG = (t2 - t1) \times v1$$

VG : Vehicle Gap
t2 : detected time of a vehicle
t1 : detected time of the last vehicle
v1 : velocity of the last detected one

The result of measurement is given to the road-manager in the control center and drivers in tunnels. An image-processing equipment transmits Traffic Volume , Vehicle Velocity and Congestion Rate to the central control computer. They are shown on the traffic condition display board in the control center. So road-manager can understand the traffic condition in tunnels easily. And for drivers it outputs warning signals to electrical information boards when their velocity is very high or their vehicle gap is very small.

5. HARDWARE OF THE SYSTEM

A picture of the image-processing equipment is shown in Photo.1. Its main units are reviewed below.

① Terminal Unit has terminals to connect with external cables.

② Relay Unit makes the fault signal when the system down occurs.

③ I/O Panel 1 shows the traffic condition that is measured by the equipment and has output-boards to the central computer and information boards in it.

④ The measurement constants are set with the operation of I/O Panel 2. It has I/O boards to display lamps and read switches on I/O Panels in it.

⑤ FDD Unit has a 8-inch floppy disk drive.

⑥ Video Terminal outputs image-processed video signal.

⑦⑨Cooling Panels have some air-fans.

⑧ Processing Unit is the most important unit of the equipment and has some image-processing boards in it.

⑩ Power Supply Unit 1 has DC power supply. It is supplied to Processing Unit.

⑪ Power Supply Unit 2 has constant voltage transformers. It supplies AC100V to units of the equipment.

This system has a hierarchy hardware architecture that is composed of a main-processor M-CPU (Master CPU) and some preprocessors S-CPU (Slave CPU) to do image-processing efficiently. See Fig.4. In Processing Unit there are one M-CPU and some S-CPUs. The number of S-CPU equals the number of video signals to

No	Unit Name
①	Terminal Unit
②	Relay Unit
③	I/O Panel 1
④	I/O Panel 2
⑤	FDD Panel
⑥	Video Terminal
⑦	Cooling Panel 1
⑧	Processing Unit
⑨	Cooling Panel 2
⑩	Power Supply Unit 1
⑪	Power Supply Unit 2

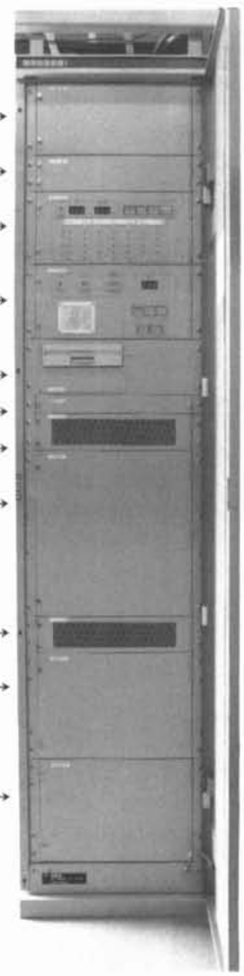


Photo.1 Picture of the image-processing equipment (height = 2350mm)

do image-processing. The equipment is able to have 7 S-CPUs at its maximum. The function of S-CPU is to determine the presence of lights. M-CPU gets the information of them from S-CPUs with access to dual-ported memories of S-CPUs. It determines the existance of vehicles and calculates traffic parameters.

The specification for the image-processing boards is shown in Table 2. M-CPU, S-CPU and VFM are main parts of them.

(1) M-CPU

M-CPU is the only one that can become the system bus master. It gives instructions to PI/O, FDC and S-CPU. So M-CPU controls the whole of the system.

(2) S-CPU

S-CPU has a DMA controller that can work simultaneously even when CPU do the job not to reduce the system performance. S-CPU and VFM are connected with the specific inner bus. So CPU and DMA controller are able to do high-speed access to VFM.

(3) VFM (Video Frame Memory)

VFM converts the analog video signal to 8 bit/pixel 256-level brightness digital data, stores the input image to memories and freezes it. VFM has two special functions that are called Address Converter and Data Converter to do image-processing easily. The function of Address Converter is to set sampling points on the imput image and make sampling point access by S-CPU easier. And S-CPU gets binarized data with access to VFM through Data Converter.

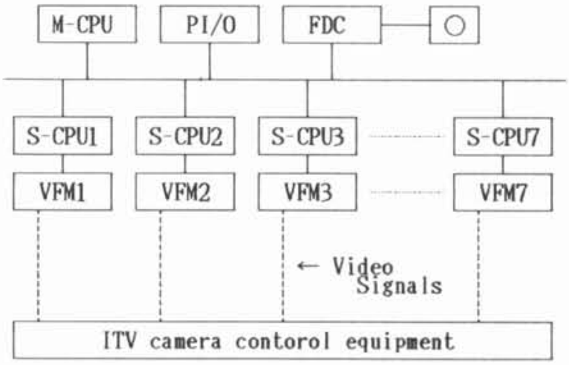


Fig.4 Hardware architecture

Table2. Specification for the processing boards

No.	Item	Contents
1	system bus	IEEE-796
2	M-CPU (Master-CPU)	"Measuring traffic parameters" CPU : MC68000(10MHz) Memory : 2MB
3	S-CPU (Slave-CPU)	"Detecting lights" CPU : MC68000(12.5MHz) high-speed DMA function
4	VFM (Video Frame Memory)	"Freezing input-image" Memory: 512 x 512 x 8bit Address Converter Data Converter
5	FDC	Floppy Disk Controller
6	PI/O	Parallel I/O Controller

6. CONCLUSION

We reported Image-Processing Traffic Flow Measuring System of the Hokuriku Expressway. We checked the error rate of Vehicle Velocity before opening the road. The error rate of it is within 9.2% , and its average is 3.1%. But evaluation data are a little volume. Now we are collecting field data of it to evaluate it exactly. We will report the result of evaluation at IAPR Workshop in October.

REFERENCE

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