

# 1. IMPROVEMENT OF THE EFFICIENCY IN THE HIGHWAY FACILITIES INSPECTION SUPPORTING SYSTEM USING GROBAL POSITIONING SYSTEM

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**Abstract** :The objective of this study is to improve the performance in the Highway Facilities Inspection supporting System (HI-FIS), which have been developed by ourselves since 1993, for executing the effective inspection work. As for the feature of this system, various kinds of information related to the maintenance of road are managed in unitary with the distance mark(K.P data) corresponded to the video image. For calculating the K.P data accurately, the GPS(Grobal Positioning System) was applied to the HI-FIS as a new function. The effectiveness applying GPS are as follows:1)The simplification of operating for highway facilities inspection on board a car was achieved. 2)The video library on the inspection of road facilities could be producted efficiently. 3)Furthermore, the high precision of refering the information on highway facilities was obtained. As a new application of GPS, this study contributed to the development of image database system dealing with video image as well as stationary images for supporting the maintenance and management of road.

**Key words** : *inspection of road facilities, maintenance and management of road, grobal positioning system(GPS), image database, video image*

## 1. Introduction

With the extension and aging of the road, it has become more and more important to carry out the accurate and efficient maintenance and management of road. For supporting the daily inspection of road through repair planning and practice, various kinds of system on the maintenance and management have been developed<sup>1)</sup>.

In such circumstances we have engaged in the design and development of "HI-FIS" (HIGHway Facilities Inspection supporting System) which involves a video-image of the road inspection<sup>2)</sup>. In our past study, the following design guidelines for system development for supporting the road facilities inspection was summarized;

- 1)Conditions of recording videos, such as recording the road facilities, running speed of the inspection car, weather conditons, etc.
- 2)Design of the video library and its maintenance.
- 3)Access methods from the video image to the different types of the database on the road facilities.

However, while actually performing the inspection work and arranging the video library, new demands has come out for improving the performance of HI-FIS.

In HI-FIS, the time cord of the video image and the distance mark are corresponding to each other inside the system and various kinds of information are managed on a unified level. The inspection position on the road must be automatically measured with high accuracy and continuity.

As a trial to conduct such measurement work continuously and efficiently, a system development employing GPS has been attracting attention recently. In the construction field, a number of practical systems for land survey, topography, precise survey of fixed points, etc., have been made public<sup>3),4)</sup>. The expansion of GPS application areas is being expected.

Under these circumstances, the GPS was introduced to HI-FIS to achieve three purpose as follows:

- 1)to simplify the inspection work on the road facilities.
- 2)to make editing work for the video library more efficient.
- 3)to improve the accuracy of information retrieval on the road inspection.

## 2. The significance of this research

### (1)The existing applications of HI-FIS

In HI-FIS when damage or trouble of facilities is found on the video image, you can make it a static image for the moment and proceed to retrieve the information of the object facilities. The time cord of

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the video and the distance mark correspond to each other and various kind of information was managed in unitary with this distance mark.

**a) On the present inspection work**

In HI-FIS, in order to make the time-cord of the video and the distance mark correspond to each other, the running speed of inspection car must be kept as steady as possible. The passing time must be recorded for each distance mark in a specified interval. While the inspection is made, careful attention should be paid not to degrade the processing accuracy of the correspondence between the video time cord and the distance mark. By getting rid of these restrictions, the processing on the inspections and the video recording must be simplified.

**b) On editing work of the video-library**

When the running speed of the inspection car is greatly disturbed or the video recording is interrupted by ordinary cars running nearby, adjustment of the difference between the distance mark and the video time cord is required as well as the trouble of video editing work in the room. It is desired to make editing work on the video library more efficient.

**c) On the retrieval accuracy of the information**

There is a problem of errors occurring while the correspondence between the video time cord and the distance mark is adjusted. As the countermeasure in HI-FIS, the information in a range of 300m in front and behind each from the distance mark where the video is made frozen was retrieved and displayed. After that, users finally select their desired information. In order to improve the retrieval accuracy of information, improvement of processing accuracy in the correspondence of the video time cord to the distance mark is required.

**(2) The feature of this research**

There are a number of systems employing GPS. However, judging from many literatures in Japan, there are no systems actually introducing GPS aiming to "support road facilities inspection".

In the situation abroad, Mapping Center in the University of Ohio has developed a car equipped with a combined system of GPS and a digital video camera. This is a system in which the car records facilities necessary to be repaired, dangerous locations, and positions of the site of accidents on video. These image was transmitted to the Mapping Center together with the position data of the inspection car.

The Road Bureau in Mont. has a prototype system

called GeoLink System linking GIS (ARC/INFO) to GPS. This is a maintenance management system in which position data of traffic signs and others are transmitted from inside a car<sup>1)</sup>.

In either case, the information obtained on the sites is transmitted to the control center. On the contrary, another type of system, in which the users can access the database of different road facilities through the site position and inspection data, is also expected to develop for the maintenance and management of road. HI-FIS has made this point its goal. This research and development is different from the traditional approaches which utilize GPS as a means of obtaining only position data.

**3. Outline of the research**

The outline of this research was shown in Fig. 1.

**(1) Feasibility study (Step 1)**

By examining the existing research and development examples employing GPS in the field on the road maintenance and management, the significance of the GPS introducing in HI-FIS for supporting the road facilities inspection is clarified(cf. Chapter 2).

**(2) Basic design of introducing GPS (Step 2)**

To improve the capability of HI-FIS, "the function to manage and offer the GPS information which is called "the GP-function" is developed. In HI-FIS, the following three functions have been already equipped<sup>2)</sup>;

- 1) Function to manage and offer the Common information called "the CO-function".
- 2) Function to manage and offer the Road Facility information called "the RF-function".

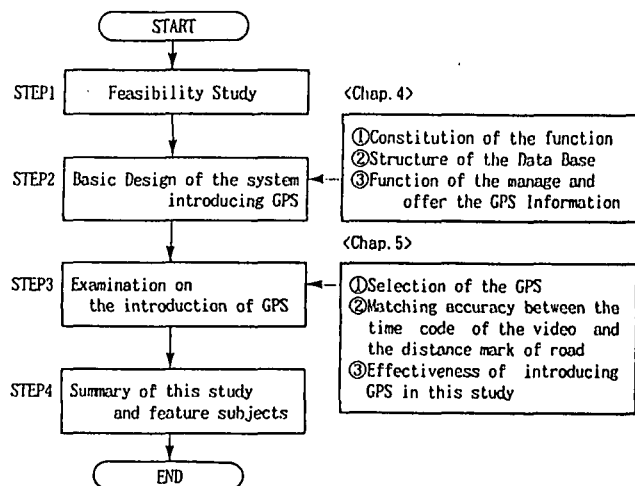


Fig.1 Outline of this research

3)Function to manage and offer the Video Information called "the VI-function".

After making clear the relations between the GP-function and three functions, the content of information treated in HI-FIS and functions required will be designed and developed. Furthermore, database structures for managing measured values by GPS and relative information is carefully designed. (cf.Chapter 4).

**(3)Introduction of GPS (Step 3)**

As HI-FIS is used in plural management offices, the cost-effectiveness including hardware and software is a very important subject. The higher the requirements for measurement accuracy, the higher the cost of the GPS system. The tolerable measurement accuracy and acceptable cost-effectiveness in the system improvement will be investigated for the system design and development (cf. Chapter 5).

**(4)Summary of this study(Step 4)**

No manual is needed in operating HI-FIS. Users have only to follow the instructions on the display to retrieve information. For making it more easy to understand flows of a series of processes, they are documented as a manual.

**4. Basic design of the system introducing GPS**

As discussed in our past literature<sup>2)</sup>, details of the whole structure of HI-FIS are not mentioned. This paper focused the basic design of HI-FIS introducing GPS.

**(1)Function constitution of HI-FIS**

HI-FIS is mainly composed of four function groups shown in Table1. The relations between these functions was shown in Fig.2. The GP-function is the feature of this research. This function played important roles as follows;

- 1)One to one correspondence between measured data by GPS and the video time cord was achieved.
- 2)Calculation of the location of the distance mark (KP(Kilometer-Post) data).
- 3)Store and management of the KP data in the data base.

**(2) Basic structure of the data base**

The structure of the data base(DB) consists of "the basic information DB","the detailed information DB" and "the GPS information DB" as illustrated in Fig.3<sup>2)</sup>. The detail information DB accommodate a large amount of information derived from the basic

Table 1 Major Role of Functions

Functions	The kind of information managed and offered
①Function to manage and offer the video information (The VI-function)	·photo conditions ·road facilities and those locations ·video library ,etc.
②Function to manage and offer the Common Information (The CO-function)	·plane figures ·longitudinal profiles ·cross section profiles ·aerial photograph ,etc.
③Function to manage and offer the road facility information(The RF-function)	·12 kinds of Data Base classified according to the different kinds of road facilities
④Function to manage and offer the GPS information (The GP-function)	·data measured by the GPS ·video time cord ·index data between the distance mark and video time cord

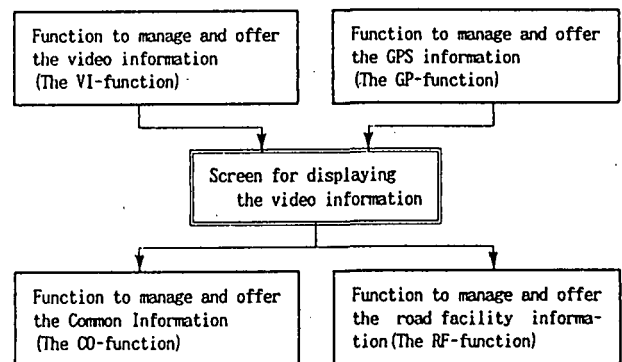


Fig.2 Constitution of functions

information DB. The GPS measured data and other relative information are stored and controlled in the GPS information database. HI-FIS is aiming at a man-machine system which can cope well with a variety of maintenance and management work of road.

**(3)Function to manage the GPS information**

**a)Operation environment**

As shown in Fig.4, the operation environment of HI-FIS is classified into following three parts;

- 1)inspection work environment on the site.
- 2)video-library editing work environment in the management office.
- 3)information retrieval and application environment.

In the inspection work and the video library editing work, the GP-function and the VI-function play their roles respectively.

**i) Inspection work environment:** While the road

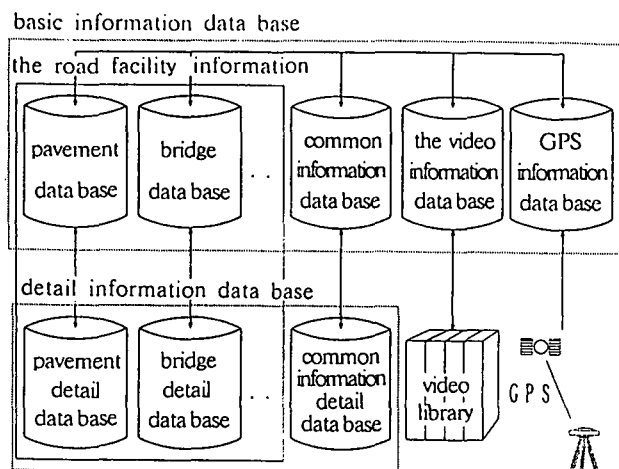


Fig.3 Basic structure of data base

facilities is recording by video on board a inspection car, GPS continuously measures its position coordinate. The measured data is automatically recorded on a floppy disk. By pushing the start switch, the GPS measurement operation starts synchronizing with the video recording without any troublesome work.

**ii) Video-library editing work environment:** The system manager receives the inspection video and floppy disk involving the GPS measured data from inspectors and edits the video library. Users attaches the video time-cord to the inspection video, inputs the GPS measured data into the system, conducts calculations of the distance-mark, etc.(cf.5.(2)). In case of the manager's absence, inspectors themselves can easily edit the video library.

**b) Information divisions**

In order to construct and utilize a flexible system, it is indispensable to clarify the information divisions. In HI-FIS, a distributed-type data base has been constructed, according to the three information divisions, such as "the common information", "the road-facility information" and "video information" divisions as shown in Fig. 5. As the additional information concerning GPS, the GPS system name, positioning method, GPS measured data, and KP data, etc., are included in the GPS data base.

**c) Structure of the GP-function**

The GP-function is divided into the following four functions. The relation of these functions is illustrated in Fig. 6.

**i) Input and update function:** The information data on GPS and videos collected in every inspection is stored with this function. The information already stored in the data base is also renewed.

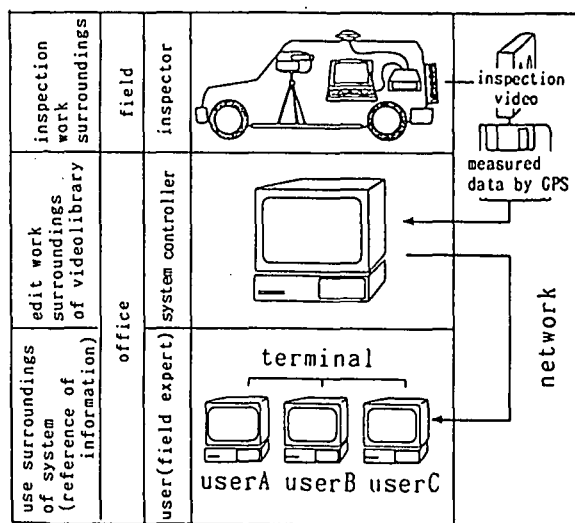


Fig.4 Environment of system operation

< Common information >	< The road facility information >	< The video information >	< GPS information >
Ichnography	①Traffic control device	Route name	GPS machine-type name
Longitudinal section	②Bridge	operation bureau name	measuring method
Cross section	③Cut slope	operation office name	Basic coordinate
Typical cross section	④Culvert	Photographing facility	KP data
Linear drawing	⑤Pavement	Photographing date	KP data name
Drainage system map	⑥Embankment slope	Photographer	Measured point data name
Soil map	⑦Tunnel	Weather	Measured point data
Feasibility report	⑧Traffic safety device	Photographing direction	(t1, x1, y1...)
Design calculation sheet	⑨Contact and rest etc. facilities	Photographing time	(t2, x2, y2...)
Conference report	⑩Geometric design	Lane division	(t3, x3, y3...)
Aerial photograph	⑪Planting	Up-down lane division	:
Satellite remote sensing data	⑫Traffic conditions	Photographing position	:
etc.	:	:	:

Fig.5 Information division

**ii) Database management function:** This function manage the information on GPS already stored in the data base. As the DBMS, basic functions such as retrieval, addition, deletion and processing of information are equipped.

**iii) Distance-mark calculation function:** This function make the video time-cord correspond to the GPS measured data and transform it to the distance-mark. The transformed distance-mark is stored in the data base and is linked with video information through indexes as shown in Fig. 6. The process is controlled by the system manager who edits the video library. It can be processed by a simple conversational operation.

**iv) Distance-mark display function:** As shown in Fig.7, it is a function to display on the screen the

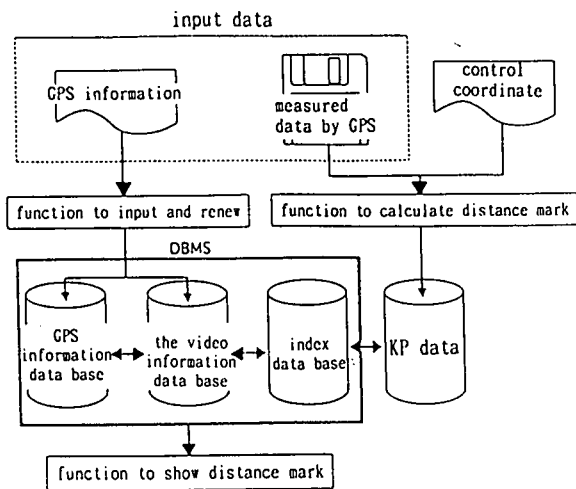


Fig.6 Constitution of the GP-function

value of distance-mark of the site which is shown in the video image(cf. Fig.7). By the distance mark, information can be controlled on a unified level, which allows us to retrieve common and relative information displayed on the menu.

## 5. Studies on GPS introduction into HI-FIS

### (1) Problems of GPS system selection

The GPS is composed of an independent positioning system(IGPS:Independent GPS), or absolute positioning system and a differential positioning system(DGPS:Differential GPS).

a)IGPS: This system is widely applied to car-navigation. Site positioning and small-sized hand-held-type devices have been also developed. The accuracy of the position measurement varies from 10 to 100m, which cannot be used for survey applications but the price is as low as several hundred thousand yen.

b)DGPS:The system is composed of the "translocation system" and "interference positioning (IP) system." In the former, ordinary receivers can be used as they are. For the latter, surveying receivers must be used which is equipped with differential carrier-phase measurement and high-level processing software. Furthermore, the IP system consists of kinematic IP system and static IP system. The error of position measurement in the translocation system is about 2 to 10m, while that of the kinematic IP system is about 2 to 5cm.

To keep continuous differential positioning for a long distance on a real time level, communication devices like wireless machines are required. The cost

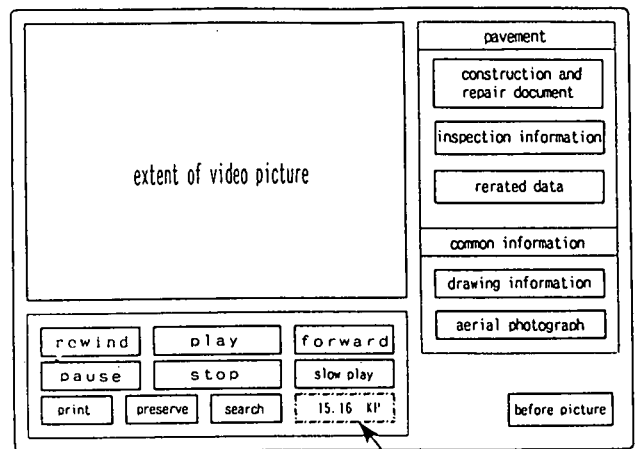


Fig.7 Example of displaying the distance mark

of one system for DGPS including a mobile station and the communication system will be about 10 to 20 million yen. As the basic unit of information controlled in the system is 100m, the position measurement accuracy for "cm unit" is not required. In introducing one GPS in plural management offices, the total cost must be kept as low as possible and system handling must be as simple as we could.

According to above these conditions, IGPS is adopted to HI-FIS and the accuracy of measurement on distance mark was investigated.

### (2) Making the video time cord correspond to the distance mark

a)Calculation of the distance mark : The relation between the data measured by GPS and distance mark is shown in Table2. "The coordinate(x,y(m)) of GPS position" and "measurement time(s)," were recorded on a floppy disk every second. The starting point of the running is set as the origin. The accumulated distance  $KP_n$  (m) is calculated every second. As a interval between the distance marks is 1,000m, the distance mark n' is calculated by dividing the accumulated distance by 1,000.

b)Evaluation of the calculation accuracy on the distance mark :The correctness of the correspondence between the video time cord and distance mark agrees with the evaluation of the difference between the accumulated distance( $KP_n$ ) of the standard distance mark and the accumulated distance( $KP_n$ ) calculated from the GPS measured data. (cf. Table 2)

Fig. 8 shows an concept of the measurement on the site. The error is the difference between  $KP_n$  and  $KP_n$

which correspond respectively to the moment when the car passes the standard distance mark.

In case an inspection car runs at the speed of about 80 km/hr, it moves about 20 to 25 m per second. It was decided that the interval of standard distance marks should be 0.1km everywhere.

It should be noted that the time of the car passing the standard distance mark is not always reported correctly because of a mistake made by the inspector. It is also difficult to specify the exact point where the car is passing. In order to exactly evaluate the accuracy of position measurement for a moving body by GPS, it is necessary to place plural sensors along the road which can sense the moving body passing the standard points. As mentioned above, such strict accuracy as obtained by employing a sensor system is not required in this study. The accuracy evaluation resulted in the inclusion of errors of about a few dozen meters.

Now, putting it aside, we will proceed to the next research subject to study how much improvement can be expected for the measurement and management of information in the distance mark unit.

**c) Accuracy of the distance mark calculation:** As for the accuracy of the distance mark calculation, the error which has been accumulated with the expansion of the distance must be analyzed (herein-after referred to as the accumulated error). The following two cases were set up.

- i) **Case 1:** A moving distance per second (the unit-moving-distance) is added to the standard point accumulatively from which the inspection starts.
- ii) **Case 2:** In the Case 1, the longer the distance from the standard point, the larger the accumulated errors. As a countermeasure, other standard points (the re-established standard point) were set up, and the

Table 2 Relation between The Data Measured by GPS and Distance Marks

basic distance mark (KP) data		measured data by GPS		acceleration distance KP <sub>n</sub> (m) B	error (m) between A and B
KP <sub>n</sub> on field (m) A	KP <sub>n</sub> coordinates on field (m)	GPS measuring coordinates (m)	measured times (sec)		
KP <sub>0</sub> =0	KP <sub>0</sub> (0, 0)	G <sub>1</sub> (0, 0) G <sub>2</sub> (22, 15) .	1 2 .	KP <sub>0</sub> = 0 KP <sub>0.1</sub> =10 .	3000-2930 = 70
KP <sub>n</sub> =3000	KP <sub>n</sub> (2500, 1520)	G <sub>14</sub> (2490, 1550) .	14 .	KP <sub>2930</sub> =2930 .	
KP <sub>n</sub> =n*1000	KP <sub>n</sub> (5100, 2600)	G <sub>t-1</sub> (X <sub>t-1</sub> , Y <sub>t-1</sub> ) G <sub>t</sub> (X <sub>t</sub> , Y <sub>t</sub> ) G <sub>t+1</sub> (X <sub>t+1</sub> , Y <sub>t+1</sub> ) .	t-1 t t+1 .	KP <sub>n-1</sub> KP <sub>n</sub> =n*1000 KP <sub>n+1</sub> .	

注1)  $KP_n = KP_{n-1} + \sqrt{(X_t - X_{t-1})^2 + (Y_t - Y_{t-1})^2}$  (m)

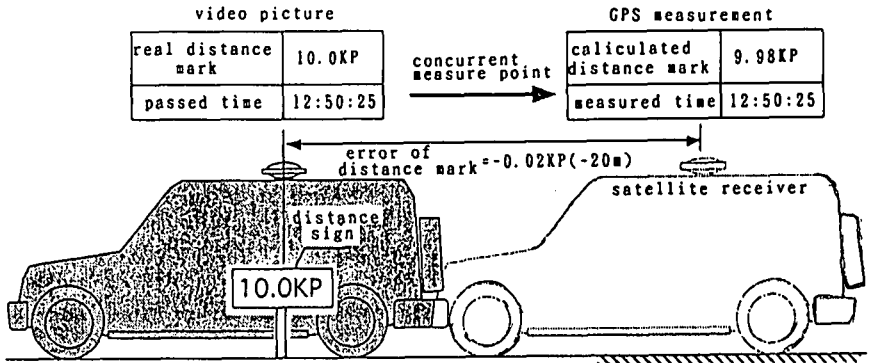


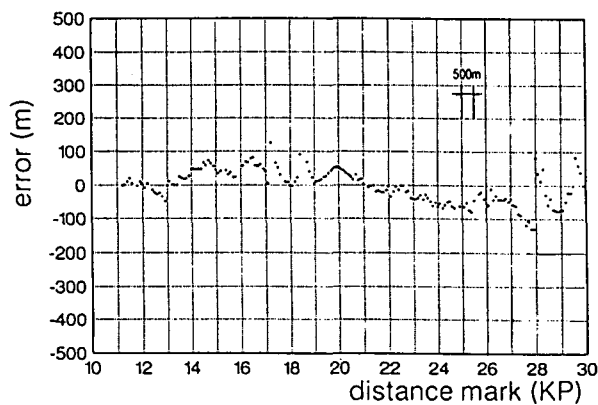
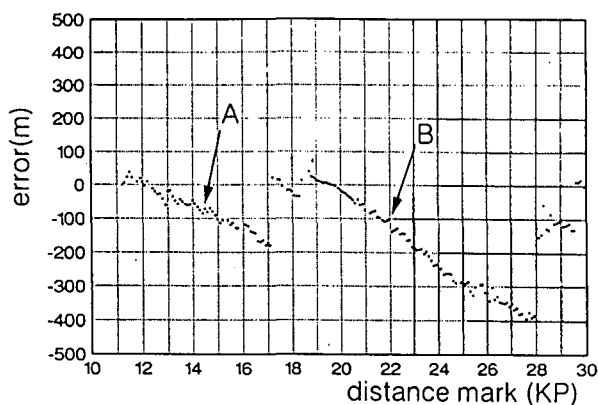
Fig. 8 Concept on the error of calculation for the distance mark

and the unit-moving-distance is accumulated.

Accumulated errors in Case 1 are shown in Fig.9(a). Against the position of the standard distance mark which the inspection car passed (horizontal axis), the distance mark errors, figured out by accumulating the unit-moving-distances from the GPS measured values, are plotted (vertical axis; in meter).

The value greatly changes at the 17 Distance-Mark because at this point the system is made reset to examine the rate of accumulated errors. The plotted line A and B show approximately parallel with each other. From the slope of these lines, it was found that errors are being accumulated at the rate of about 80m per one distance-mark.

In the case 2, in order to keep the calculation accuracy within ±100m for one distance-mark movement, the reestablished standard points were set up at intervals of 500m and the accumulated error was calculated. The result is illustrated in Fig. 9 (b).



(a)Case 1: non-use of the reestablished standard points (b)Case 2:use of the reestablished standard points

Fig.9 Error of the distance mark calculation based on the GPS data

It was confirmed that the calculation accuracy is settled within about  $\pm 100\text{m}$ . As a result, Case 2 was adopted for the distance mark calculation in HI-FIS.

**(3)Efficiency of GPS introduction into HI-FIS**

The above investigation will bring about the three following efficiency of GPS introduction.

**a)Simplified inspection works on the road**

As for the former condition on the inspection by HI-FIS, the inspection car had to keep its speed as steady as possible to make the video time cord correspond to the distant mark. Furthermore, the time of which the car has passed just in the side of distance mark must be recorded at a fixed interval by the inspector.

By introducing GPS, the car gets rid of these restrictions and is free to change its speed. the inspector has only to push the On-switch in the system before the running start and can concentrate on the inspection work while running. There is no need for special operation at all. Now the inspection works are extremely simplified.

**b)Improvement in the efficiency of the video library editing works**

When the car speed changed or video image was interrupted, data adjustments by using editors and other troublesome operations used to be needed to keep the correspondence between the video time cord and the distance mark normal. By introducing GPS, the correspondence is made automatically through computer processing.

After inspection work is over, the inspector bring the floppy disks and video tapes, on which the GPS measured data is recorded, back into the room. Following the message on the display provided by the GP-function as shown in Fig.10, everyone can edit the video-library more efficiently.

calculation of distance marks	
please input conditions	
route name	jouban expressway
operation office	mito
road facility	pavement
up-down lane division	down lane
lane division	first
route condition	dry
weather	fine
startKP	11.2
endKP	29.8
date	1995/03/18
start time	10:03:12
inspector 1	Syouji Hattori
inspector 2	Yasusi Kasanatu
GPS data name	95318002.GPS
control name	Jyol-0306.STD
calculation of distance marks	end

Fig.10 Example of menu for making video library

**c) Improvement of the accuracy for the retrieval of the inspection information**

Up to now, because of the inferior accuracy of the correspondence of the video time cord to the distance mark, the information in the sphere of 300 m in front and behind with respect to the standard distance mark (0.6KP interval), at which the video image was interrupted, was retrieved.

After the introduction of GPS, since the correspondence accuracy of video time cord to distance mark is settled within  $\pm 100\text{m}$  (0.2 KP interval), the accuracy of retrieving and displaying information in the distance mark unit including retrieval speed has been improved about three times as much as it used to be.

**6. Concluding remarks**

The results of the research are summarized as the following four points;

### 1) Requirements for system development

In order to improve the HI-FIS capability, the basic requirements with the introduction of GPS was investigated including the problem of cost-effectiveness. Through investigating the traditional research and development applications for supporting the road facilities inspection, the position of this research and its significance was clarified.

### 2) Studies on functions and structure of HI-FIS

The required functions accompanied by the introduction of GPS were studied. The new GP-function was designed and developed. Through this function, it has become possible to store and manage the information concerning GPS including video data with efficiency.

### 3) Development of functions and its evaluation

The function, which calculated the distance mark from the GPS measured values and make it correspond to the video time cord, was designed and developed. Through the in-situ measurement, it was confirmed that the accuracy of the distance mark calculation is tolerable enough for the information management on a unified level.

### 4) Evaluation of HI-FIS as a total system

In making the correspondence between the video time cord and the distance mark, there is no need for the troublesome work during inspections or afterward in the office. Through computer processing, works are automatically processed and video library editing is carried out more efficiently. As a result, the three development goals, set up at first, simplifying inspection works, making video-library editing more efficient, improving the accuracy of information retrieval, has been achieved.

The future subjects of this study are as follows:

1) According to the information division on the road facilities as shown in Fig.3 and Fig.5, various kind of information must be collected and have been continuously stored in the data base.

2) As occasion demands of users, the kinds of data base must be added and have been constructed.

It is a long time since media such as video and GPS have become popular. The recent tendency of unifying such media through a communications network, the so-called system-oriented trend as multi-media has attracted a number of people's attention.

It should be noted, however, that the introduction of plural medium does not always lead to the improve-

ment of the system performance including the response-time and the turn around-time.

Whichever you may apply the ever-evolving media to, the system design and development must be started after clarifying basic system requirements, such as cost-effectiveness, functions to be provided and the quality and quantity of the information to be treated.

As a new application of GPS, this study contributed to the development of image data base system dealing with video image as well as stationary images for supporting the inspection of road facilities. We hope that the content of this research must be of any help not only for road facilities inspections, but also the approaches on the system development over the whole field on the maintenance and management of road.

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