Development of a hybrid camera system for bridge inspection

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ABSTRACT: As the record means of the bridge inspection in recent years, it is absolutely imperative to use technology of high resolution digital image and the data processing. However, structure of the bridge underneath is complex where columns and beams are crossed over. This makes bridge inspection quite difficult compared to tunnel wall inspection, so that inspectors need to spend more time to identify where to take photos for the inspection. We have developed new inspection system aiming at high resolution photos for specific areas as well as a whole picture of objects such as building using 360 degrees camera. This is referred to system covering "micro to macro on any objects" for bridge inspection which will practically produce more productivity. Authors proofed to apply this camera system that was designed to inspect truss bridge and executed when the truss bridge was surveyed.

1 INTRODUCTION

In these days, acquisition of high resolution digital images and processing techniques have been developed, which are applied to such as the tunnel wall inspection. In this study, we applied these techniques to huge bridge maintenances and management. However, we predicted that it is difficult to specify the taking a picture parts only with the individual detailed images, because huge bridges, especially truss bridge, is complicated with various components, compared with tunnel walls.

On the other hand, sphere image represented by the street view of Google map is taken while running vehicle with cameras, and we are able to grasp the situation of a spot at an equal interval.
However, we are not able to grasp to detail for inspection of the structure because picture resolution of the present sphere images is low.

By using sphere images and detailed images taken at the same time, we built Images Research System which use sphere images as an index, and examine application possibility.

We applied experimentally this system to the Akashi Kaikyo Bridge with a higher efficiency and laborsaving in image arrangement work. This paper describes the effectiveness of this System and remained problems.

Figure 1.1. Akashi Kaikyo Bridge

Figure 2.1. Location of the Akashi Kaikyo Bridge

2 THE OUTLINE OF THE AKASHI KAIKYO BRIDGE

The Akashi Kaikyo Bridge is the world's longest suspension bridge with 1991m of main span which located between Kobe and Awaji Island. It was opened to traffic in April, 1998 using the bridge technology in the world highest level under a severe design condition compared with foreign countries' one.

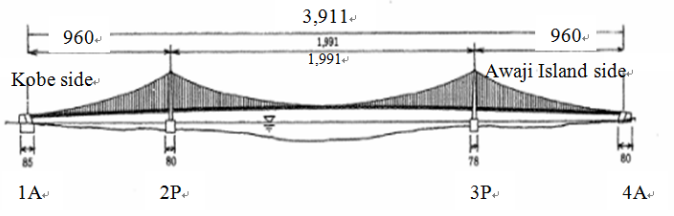


Fig 2.2. Side elevation

3 SUMMARY OF THE INSPECTION OF THE AKASHI KAIKYO BRIDGE AND PROBLEMS

Inspection parts of stiffing girder of the Akashi Kaikyo Bridge (Fig.3.1) are main truss, cross section truss, steel deck plate and suspender anchorage. Those are able to take images from wide inspection way, upper (lower) inspection way, maintenance vehicle. However, on taking images of 4km bridge, effective specification of the photography / inspection part is the problem. In this paper, we researched two panels in about 4km of stiffing girders from wide inspection way and maintenance vehicle. We verified a necessary condition and future problems in case of whole length stiffing girders. When we investigate a structure, we take many pictures and draw up a protocol. However, it is difficult to know shooting positions from those pictures after the investigation. Moreover, in order to compare with the past them, the pictures of the same angle is needed in many cases. In addition, in order to give information of shooting position, we sometimes take a picture with a commercial camera carrying GPS. However, since the picture didn't have exact accuracy of location and information of directions, we were not able to specify the details of a structure.

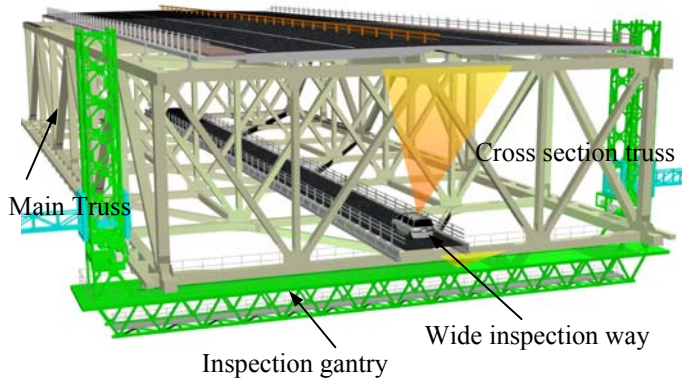


Figure 3.1. The outline of stiffing girder

4 PICTURE RESOLUTION FOR INSPECTION

We have so far verified about resolution and possibility of checking crack width and detailed parts in various investigations and research. Fig. 4.1 shows the relationship the deficit and rust of a bolt that been took a picture by digital camera from a long distance and resolution that we can validate them. It indicates that in order to checking the state of a bolt with a diameter of 30 mm, the resolution is required for higher than 3 mm/pix.

5 TAKING IMAGE SYSTEM AND THE PROJECT

We took pictures to investigate various structural members of stiffing girder of the Akashi Kaikyo Bridge by four methods shown in Fig.5.1. From wide inspection way, we took pictures, running vehicle which has a camera for taking sphere image (Ladybug3) and 16 industrial measurement cameras for taking detailed image (Grasshopper) at 15 km/h. Moreover, we experimentally set another one Grasshopper which has 5 mega pixels (hereinafter referred to as MP) and synchronized it with Ladybug3. Thus, we identified shooting position of detailed image which use sphere images as an index.

About outside parts which cannot be checked only from inner stiffing girder, we used inspection gantry that cameras were set on its floor face and telescopic scaffold, and took images continually running. But, since there are few pages, this paper describes only the shooting method from wide inspection way.

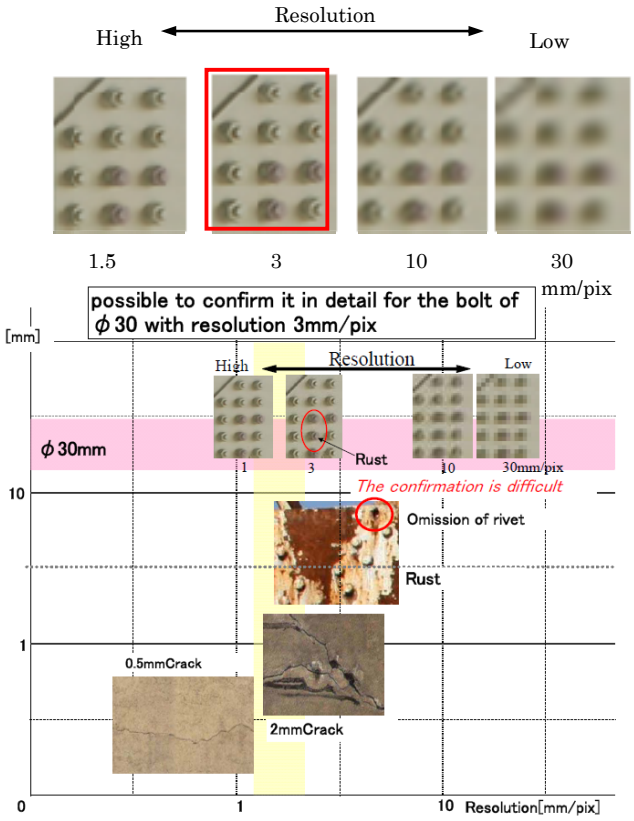


Figure 4.1. Resolution-Visibility Chart

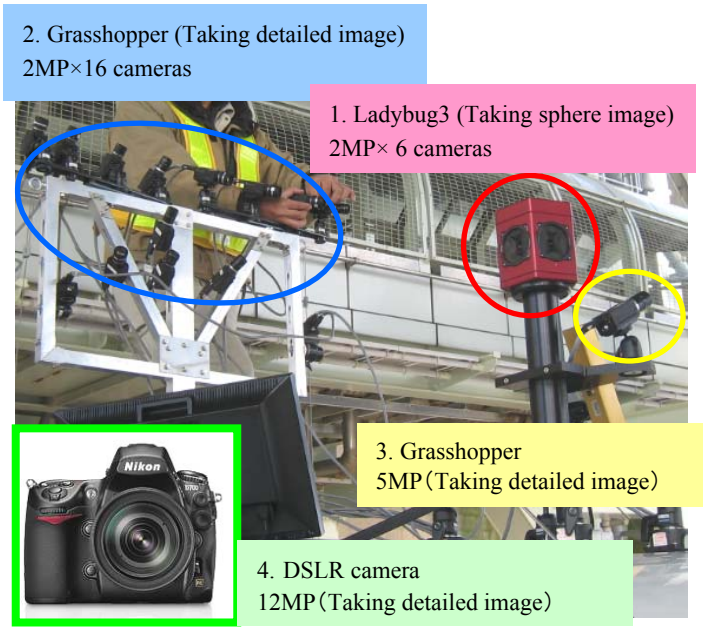


Figure 5.1. Taking image with 4 kinds of method

5.1 *Taking image system in the stiffing girder*

5.1.1 *Taking sphere image system*

On taking whole structural images, this research used the system Ladybug3 (Point Grey Research Co.) that takes sphere images while running, which is widely used for multiple researches.

This machine is compose of 6 cameras of 2MP, takes 15 images in 1 second. It is possible to check the outline of the structure from the automatically composed sphere images.

However, CCD size of camera is very small 6.9mm×5.2mm, and also lens is wide range3.3mm. When the subject is located 7m, resolution is 10mm/pix, and it is difficult to grasp details of the subject.

In addition, Fig.5.4 shows range of applications in the case using sphere camera in the Akashi Kaikyo Bridge. It indicates that when a picture is taken from wide inspection way located in the center, since the resolution at main truss located in seaward side is only 20 mm/pix, we can grasp only outline.

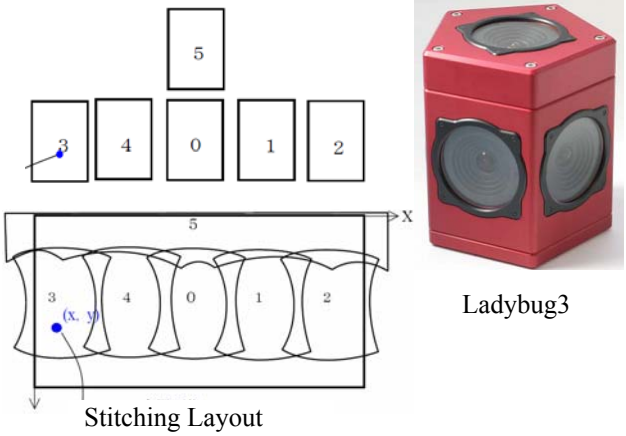


Figure 5.2. Specification of Ladybug3 and Stitching

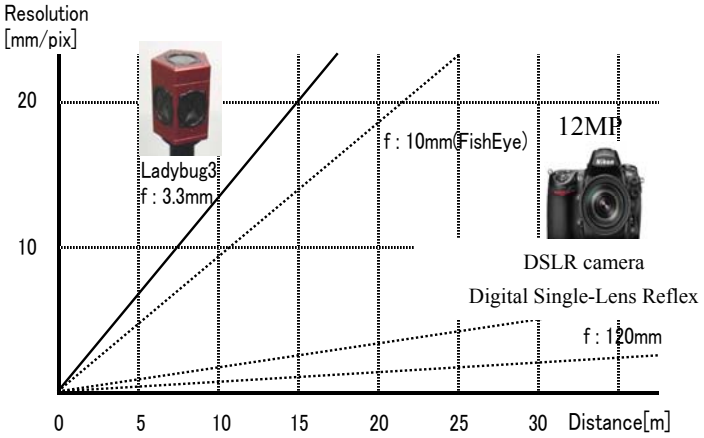


Fig 5.3 Resolution of Ladybug3 and DSLR camera

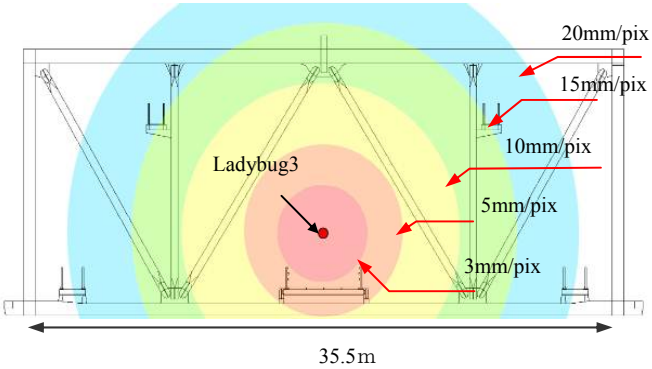


Figure 5.4. Resolution of Ladybug3 in each distance

5.1.2 *Taking detailed image system*

We used Mobile shooting camera system (FULLCAP) as taking detailed images system. This system makes it possible the continuation photography with which several industrial measurement cameras (Grasshopper, 2MP) synchronizes.

This investigation used 16 cameras with lens (50~150 mm) so as to catch the details of member. And we added the grasshopper (5MP).

The basic system consists of an industrial CCD camera (2MP, 1 pixel = 4.4μm) and an uncompressed image recording system, FULLCAP. When taking image of track systems, it is necessary to unify the resolution per pixel by synchronizing more than one camera.

Therefore, we constructed a taking and recording system using industrial digital cameras connected via IEEE 1394 that could photograph 15 frames per second in order to taking images successively at 15 km/h.

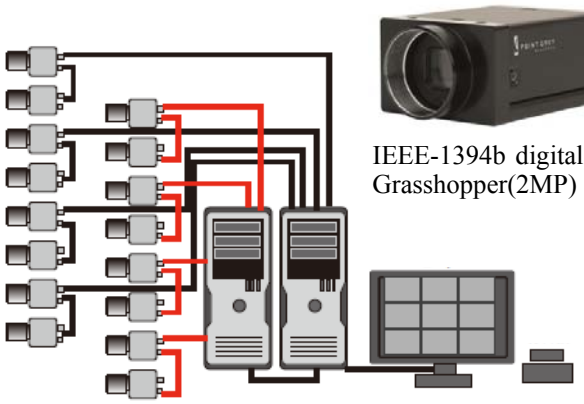


Fig 5.5 The system of FULLCAP

5.1.3 *Taking image plan*

Based on plans, we reproduced stiffing girder of truss structure with 3DCG-model, and examined camera range and angle from measurement car in advance. This examination was initial check with the object, and was taken as the level which can check the lack of bolts, and generating of rust. Each camera was set in 3mm/pix referred to Fig. 5.6.

We constructed a jig to set cameras (Fig.5.6) which is similar to structure of stiffing girders so that taking images of stiffing girders could be done efficiently from member components. This jig and 16 of industrial measurement cameras were set on the upper measurement car so as to make resolution in 3mm/pix, and took images continually running in 10 km per hour. From the prior examination by CG, since the trussed construction components was 14m in length, the lens was used so that each components might be caught with three cameras, and a picture was taken by arranging cameras.(Fig5.7)

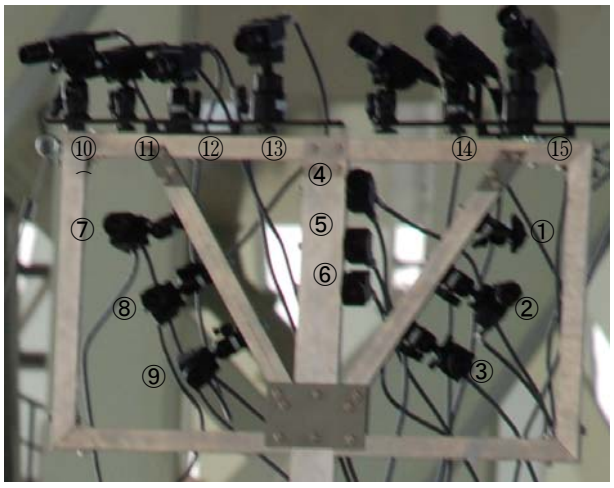


Figure 5.6 Camera position

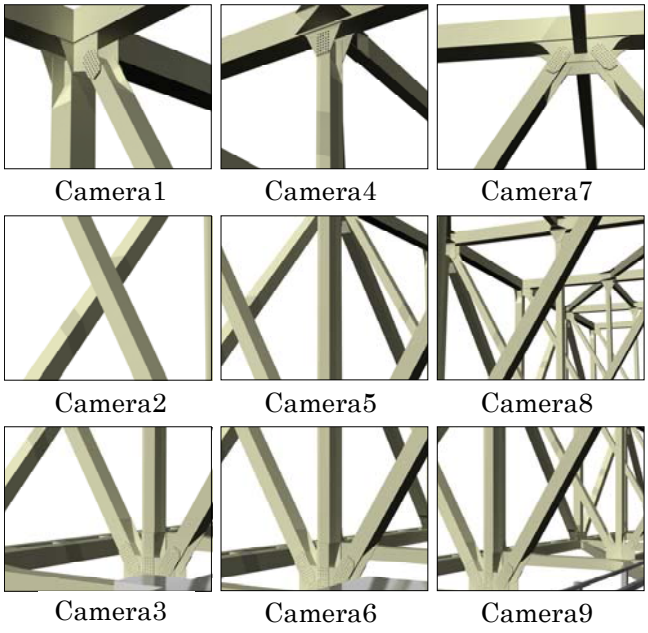


Figure 5.7 The examination of range and angle

5.2 *Situation of taking image*

Fig 5.8 shows the situation of measurement. PC to measure and control was set in the car.

When taking image by industrial measurement cameras take sphere images and detailed images which will be shown in monitors and stored in PC with information at the same time (Fig.5.9). In addition, detailed images (5MP) will be shown in same monitor, too. (Fig5.10)

Figure 5.8. The situation of measurement

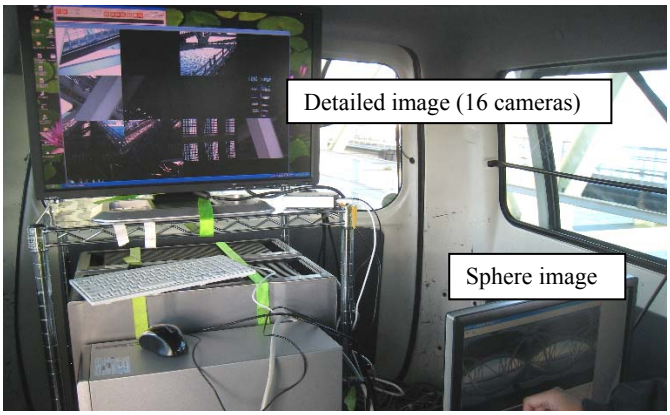
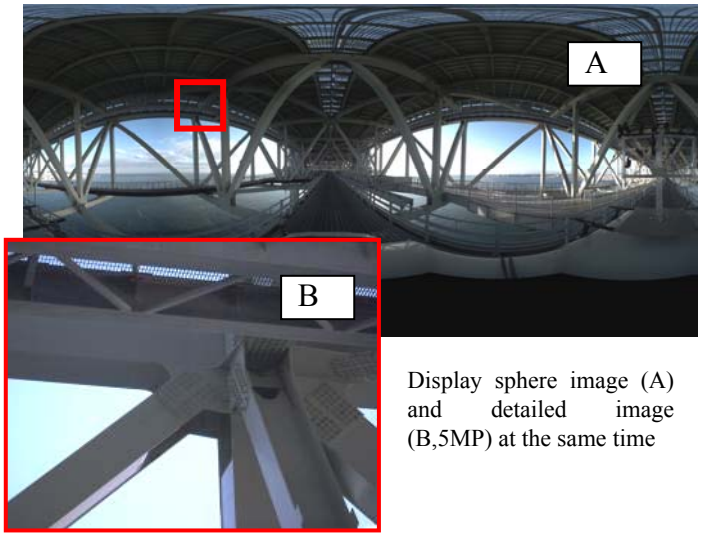


Figure 5.9. The situation in the measurement car



Display sphere image (A) and detailed image (B,5MP) at the same time

Figure 5.10. The display example of 5MP image (Red flame shows the range of 5MP image.)

6 RESULT AND EXAMINATION

6.1 *Sphere image*

Fig.6.1 shows the images taken using Ladybug3. As previously mentioned, Ladybug3 can take the images using 6 cameras equipped itself, and can make sphere image of those images. In addition, since that can display sphere images continuously on PC, we can check the parts in every direction. Furthermore, Ladybug3 can also display the images which were removed strains and the centroclinal images and so on.

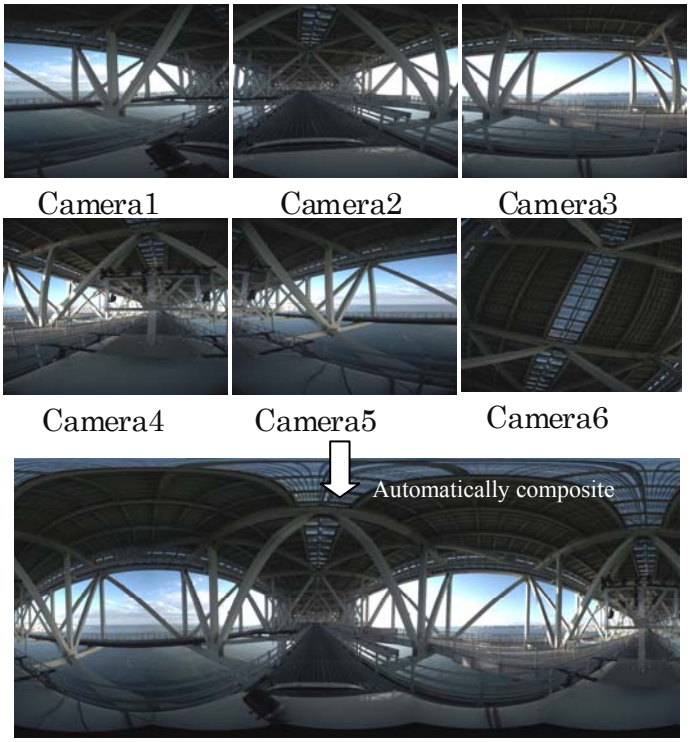


Figure 6.1. Sphere image

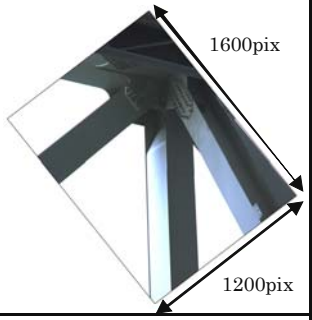
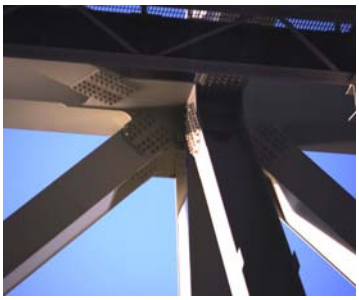
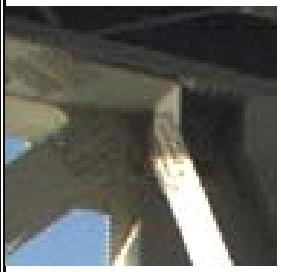
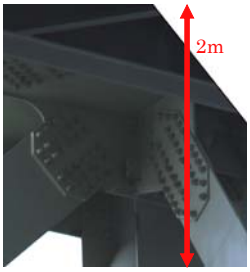
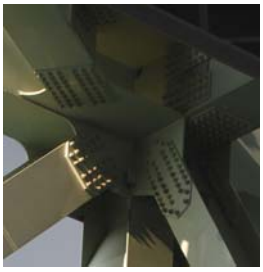
6.2 *Results*

Fig.6.2 shows images taken by FULLCAP were sufficient quality for inspection of bolts and rust both in vertical components and horizontal components. When taking pictures with a DSLR camera, thought 2 cameras captured one component, they were sufficient resolution images. The pictures taken from maintenance vehicle were enough to check not only bolts, but also inspection gantry rails and suspender socket.

Table.6.3 shows images which the part located in 20 m from camera position with 4 kinds of cameras. As we mentioned above, the resolution of capturing sphere images by Ladybug3 is 20 mm/pix, and although we could check the form of parts, we were not able to check the lack of bolts and the existence of the generating of rust.

The resolution of the expanded parts taken by 5M camera and a DSLR camera D80 was high definition at 0.6mm/pix. However, D80 can catch larger area by one time. It is because that CCD size of a DSLR camera is three times as large as that of an industrial measurement camera. Moreover, since a DSLR camera has higher color reproduction characteristics, and easy to acquire information from images, we can check more smoothly than using images taken by industrial measurement camera.

Table 6.3 The comparison table of the each image

Camera	Ladybug3	FULLCAP	Grasshopper	DSLR(Nikon D80)
Pixels	2MP	2MP	5MP	10MP
Taking image	Sphere Image	Detailed Image	Detailed Image	Detailed Image
Full Image				
Size	1616×1232	1600×1200	2448×2048	3872×2592
Extended Image				
Resolution	21.5mm/pix	3.0mm/pix	0.6mm/pix	0.6mm/pix

Vertical member Horizontal member

Fig 6.2 Detailed image

6.3 *Comparison between the feature of a DSLR camera and an industrial instrumentation camera*

Table.6.4 is comparison between the feature of a DSLR camera and an industrial instrumentation camera.

A DSLR camera has deep depth of field and can take high quality pictures with focus. Besides, color reproduction characteristics and the photography flexibility in backlighting is high, because of the sensitivity is high, and dynamic range is wide. However, it is difficult to synchronize sphere image camera with multiple DSLR camera because restriction of the number of cameras and frame. That is the problem to consider the taking picture system.

On the other hand, an industrial measurement camera is suitable for the continuation photography because of the electronic shutter. However, the adjustable range of a lens and an iris diaphragm is narrow, and the operatively is low. Therefore, it takes time to adjust camera angle and lens focus.

Whichever method we use, invisible areas exist because truss is complicated with multiple components. Therefore, it is necessary to acquire images aiming at important check point.

7 DATA CAPACITY

We took sphere and detailed images in 15 flames per second while running at 10km/h. It is especially laborious work to extract the necessary images from a large amount of images taken by industrial measurement camera, and the capacity of image data becomes huge. Based on the number and capacity of taking images at 2 panels in this examination, we examined about it if we inspect the all area of the Akashi Kaikyo Bridge. The even capacity of images which took only 2 panels was huge ones (117GB).If we apply the present system to inspecting the all area of the Akashi Kaikyo Bridge, the data capacity will be about 17000GB (17TB).It's not efficient in view of keeping and analysis data.

Therefore, we considered about optimization of speed and number of taking image. When the running speed of measurement car is about 10km/h, it is possible to catch the each target member in 1～2 frames per second. If we take only the necessary images of the all area with the same method in this examination, we guess that the data capacity will be about 1000GB. (1TB)

8 CONCLUSIONS

Although some subject remained, we can confirm the possibility of application through the experiment of using high resolution images for inspection of the bridge which has many a complex members.

Recent progress in digital camera techniques and image processing software make it possible to take images in high resolution and to process easily. Therefore, these methods are getting necessary to keep records as a possible method when doing visual inspections. It is expected that improvement in speed, reduction of labors, standardization, multifictionalization, reliability improvement, the visualization of a results, and electronization by using digital images in high resolution in the initial check.

We verified that this system which takes pictures by sphere image camera-Ladybugs3, specify the inspection parts, and then takes detailed image (FULLCAP) is able to apply for inspecting such as long regular structural forms bridges. Additionally, in such bridge, it is necessary to adjust camera angle and lens focus were adjusted sufficiently because it takes pictures while running. However, accurate adjustment makes it possible to take images effectively.

Industrial measurement camera is inferior to DSLR cameras in camera angle, operability, flexibility. Considering the number of cameras and image quality, the usage of Industrial measurement camera is restrictive. Therefore, it is necessary to consider about replacing industrial measurement cameras with multiple DSLR cameras and synchronizing with computer.

From this, it will be possible to take images with efficiency, and the quality of images will be higher. In addition, this method will make it possible to reduce the data capacity because this method is able to take wider range image in 1 shooting than industrial measurement cameras.

Furthermore, it is necessary to create a management system. This system is able to search the detailed images taken at over time and verify the state of bolt and rust based on the sphere image taken as index.

In addition, the subject remained about invisible parts. Therefore, we considered a simply method that we took images continually with Ladybug3 while walking. In this method, we will use the sphere camera system while absorbing walking vibration with the vibration control device.

Table 6.4 Comparison between the feature of a DSLR camera and an industrial instrumentation camera

Blue : merit
Red : demerit

	DSLR camera			industrial measurement camera		
	Feature	Sensitivity	Depth of field	Feature	Sensitivity	Depth of field
Lens	Large	High	Wide adjustable range	Small	Low	Small adjustable range
Iris diaphragm	Wide adjustable range	Wide adjustable range	Wide adjustable range	Wide adjustable range	Small adjustable range	Small adjustable range
Shutter	Mechanical shutter	-	-	Electronic shutter	occurrence of smear	-
Imaging device	Large	Wide dynamic range	Shallow	Small	Small dynamic range	Deep

This device makes it possible to take images stability and to store them at the same time while walking. Moreover, it is possible to display the walking route on the map by this devise connected with GPS and watch the taken images easily and move them freely around 360 degrees with mobile tablet PC. For example, using sphere images taken before, we will be going to check the damaged part easily at the next research.

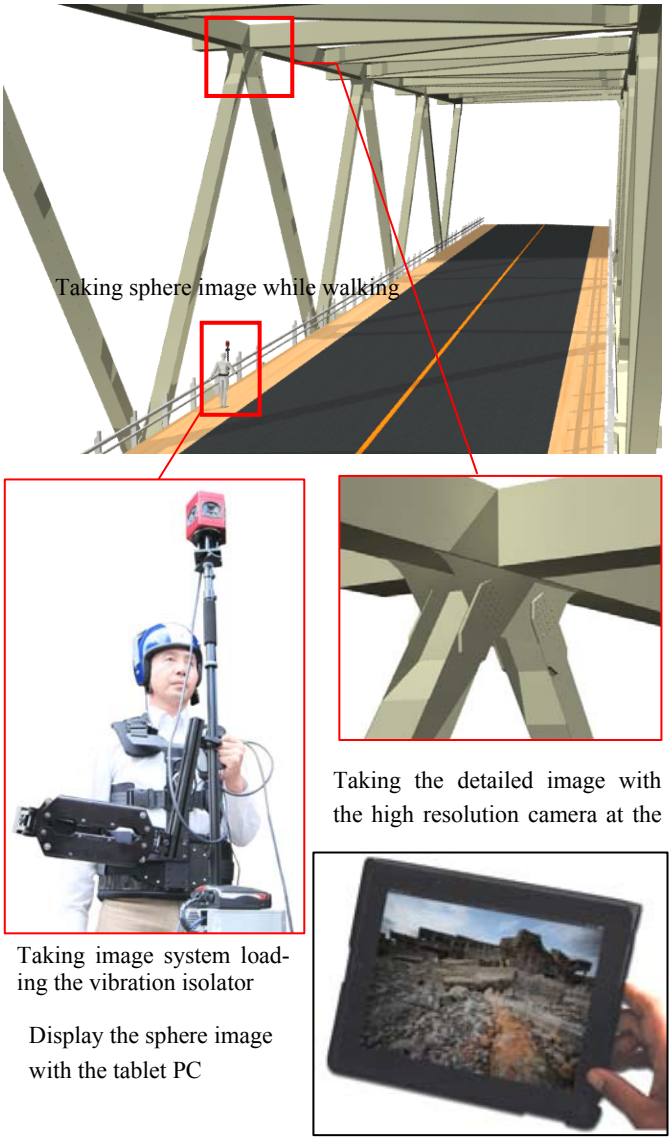


Figure8.3. Taking sphere image while walking

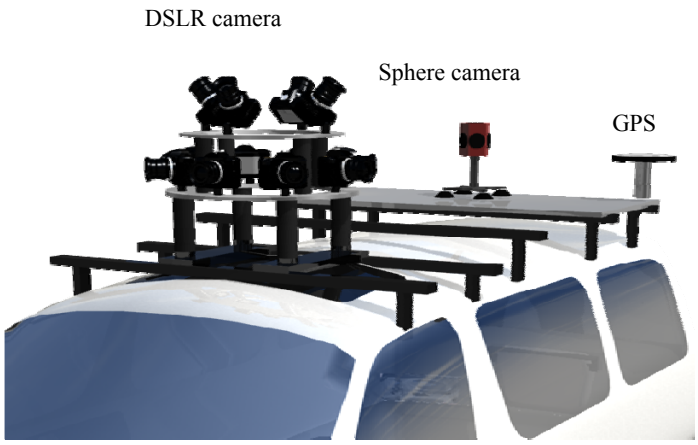


Figure 8.2. Loading the sphere camera and multiple DSLR camera on the car

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