MAPPING TECHNOLOGY WITH TWO SPHERICAL CAMERAS AND ITS APPLICATIONS

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ABSTRACT: As a cutting-edge technology of Mobile Mapping System, IMS3 (Dual Cam) has many features and innovative applications compared to the mobile mapping systems using laser and inertial measurement units, Besides, IMS3 (Dual Cam) are much more feasible than IMS2 (Single Cam) to assure absolute position precision in the area where is not available to receive satellite signal. IMS3 is being applied to many fields such as various maintenance, management, and inspection projects, as well as disaster prevention projects, outdoor advertisement board surveys, mapping and 3D modeling, etc. By connecting to geographic information systems, IMS3 can be applied to many different types of simulations, including sightseeing areas, landscaping, and flooded area management. By mounting the IMS3 on different moving vehicles, the scope of application can be expanded further. The 360 degree full spherical geo-referenced video made by the IMS3 and its many potential applications are going to be developed widely in the near future.

1. INTRODUCTION

In scope of Moving Survey System(MMS), mobile mapping system is one of the best automatic methods for acquiring and updating geospatial data, and has strong and wide appliance potential in many fields including field surveying, urban planning, environment simulations, intelligent transport, and numerous others. Therefore, research and development of MMS has been very active in the field of geographic information.

As a state of the art technology of MMS, the IMS3 (Dual Cam) has many features and innovative applications compared with the MMSs using laser and inertial measurement unit (IMU). The IMS3 is a compact unit with simple composition and robust configuration. As shown in Figure 1, the IMS3 consists of two omni-directional cameras (ladybug 3 cameras), a vertical sensor, a single positioning GPS, a post process kinematic GPS, a controller unit, and 2 hard disks.

The functions of the different components are as follows: the cameras are able to shoot full spherical photographs at up to 15 frames per second (fps). The vertical sensor is used to compensate changes in the vertical direction of the camera due to the motion of the vehicle. The single positioning GPS acquires time and position information. The post process kinematic GPS is used to receive highly accurate position information. The controller unit and hard

disk are used to store the visual and positional data.

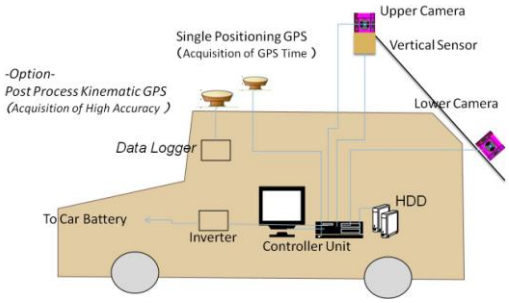

Fig.1 System structure of IMS3

The IMS3 can easily be mounted on any type of vehicle, and used to acquire high-resolution 360 degree full spherical geo-referenced images data as the vehicle is moving. Measurements can be easily and conveniently made, the surveying work can be finished safely and efficiently. So, even in heavy traffic, measurement could be conducted as long as the video was shot. In this paper, the configuration and mechanism of IMS3 (Dual Cam) will be covered first, followed by an overview of some current and prospective applications.

2. METHODOLOGY AND PRECISION

Camera vector (CV) is the core technology of the IMS3. CV value means camera vector with six degrees of freedom of shooting camera which are three dimensional positions and attitude angles of camera when shooting. The process for figuring out CV value is called CV calculation. As shown in Figure 2, before carrying out CV calculations, images can only be viewed. However, after the CV calculations, the images can be used to measure coordinates of objects depicted within frames.

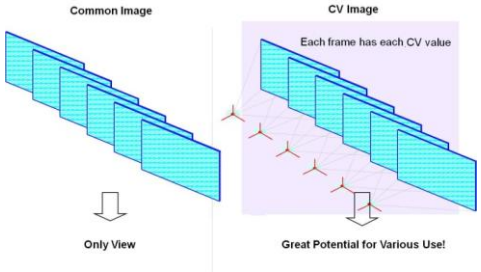

Fig.2 Comparison between common image and CV image

The mechanism of CV calculation is as follows: As shown in Figure 3 and 4, without using Inertial Measurement Unit (IMU), IMS3 is able to work only by processing and analyzing images indirectly showing the momentary relative position and attitude angle of cameras when shooting. The relative position information (x, y, z) and attitude angle (θx, θy, θz) of cameras can be figured out by extracting motionless feature points in images. This process above is called CV calculation.

It is able for CV Calculation to decrease error and realize high-precision measurement by tracking motionless feature points between flames and forming numerous triangles for triangular surveying towards each object. Dual cam style can form more triangles comparing with single cam style because feature points of object can be extracted out by two cameras simultaneously. As shown in Figure 5, it is able for the formed triangle to require much higher relative position precision by adding the fixed distance between two cameras from calibration as

additional calculation conditions.

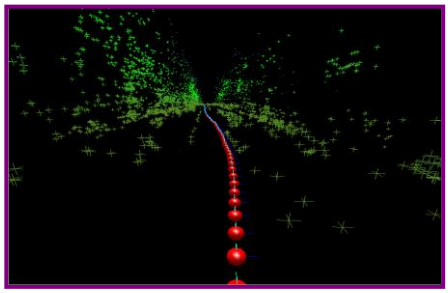

Fig.3 Extracted feature points

Fig.4 Tracks of camera positions

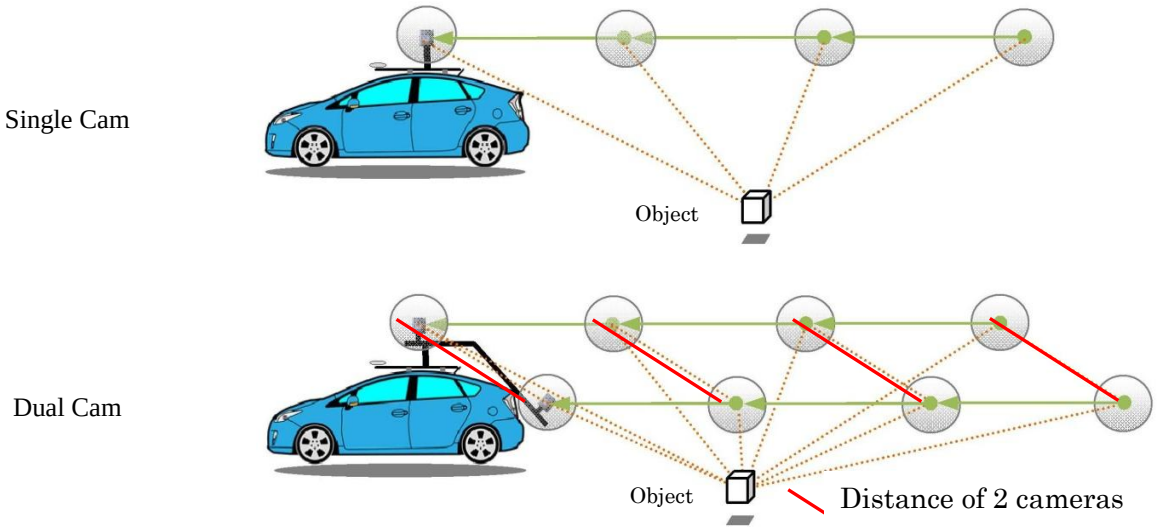

Fig.5 Tracking method of feature points

After the CV calculations, the absolute coordinate of each camera at the time of shooting can be figured out after being compensated for the geographic coordinate's information received from GPS, GLONASS per second (i.e. CV compensation). Finally, by adding above analyzed results into video, high-resolution 360 degree full spherical geo-referenced video data is obtained.

When CV compensation data cannot be acquired in the area where is not available to receive satellite signals, the precision of absolute position can be assured by setting Ground Control Points (GCP). As for single cam style, since the relative position of cameras is unfixed, it is necessary to set points at intervals of 25 meter for acquiring high absolute precision. As for dual cam style, since relative position is fixed between two cameras, high absolute precision can be assured by setting points at intervals of 100 meter(Table 1).

To sum up, both single cam style and dual cam style are feasible to assure absolute position precision. But in the area where is not available to receive satellite signals, dual cam style is much more suitable due to its fixed relative position precision of two cameras.

Table 1 Ground Control Point Setting and Precision

Style	Point number	Absolute position precision
Single Cam	1 Point / 25m	< 0.1m
Dual Cam	1 Point /100m	< 0.1m

Table 2 shows precision verification results of IMS3 (Dual Cam). Verification method was conducted over the whole verification interval through both compensation method using high-precision GPS data and compensation

method using GCP data.

Table 2 Precision verification of IMS3 Dual Cam

Verification Results of Precision		Standard Deviation		
		X(m)	Y(m)	Z(m)
precision verification results using accurate GPS data	Urban area(1km)	0.045	0.048	0.039
	Rural area(1km)	0.053	0.045	0.053
precision verification results using ground control points(GCP)	Urban area(1km)	0.060	0.061	0.064
	Rural area(1km)	0.065	0.050	0.067

3. APPLICATIONS

The high-resolution 360 degree full spherical geo-referenced video of IMS3 has many applications in such fields as geospatial measurement and urban planning and management.

A prime application is for the maintenance and management of roads, rivers, and tunnels. As shown in Figure 6, slope and width measurement of a road can be conveniently obtained from the video data of IMS3. The video quality is also sufficient to determine the condition of the road surface.

Fig. 6 Measurement by high-resolution 360 degree full spherical geo-referenced video

As shown in Figure 7, the IMS3 video footage can also be used to inspect the tunnel wall conditions, to check if there are some potential dangers.

Fig. 7 Tunnel wall inspection by IMS3

As shown in Figure 8, video footage can also be used to determine potential landslide areas or inspect and manage hazardous locations.

Fig. 8 Road disaster prevention inspection

In Japan, because of landscaping regulations, outdoor advertisement boards are regulated locally in prefectures and cities, towns and villages. Besides, there are also road traffic signs and management ledgers making projects. As shown in Figure 9, the distance and area of traffic navigation boards and road facilities can be measured using the IMS3 video footage.

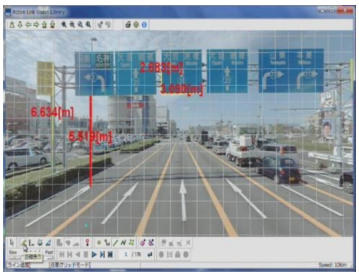

Fig. 9 Advertisement boards survey

Fig. 10 Video of sightseeing area

Figure 10 shows an example of using the video in sightseeing area. It is possible to add the geotags to video footage, which can be uploaded and shared over the internet. In this way tourists can access this information online and use it to enhance their sightseeing experience.

Because geographic coordinates of objects can be shown in 360 degree full spherical geo-referenced video, it is capable of creating 3D models of structures and objects from the video footage as shown in Figure 11. It is also possible to add textures to these models from the video data. Finished CG models can also be repositioned as required in the video footage.

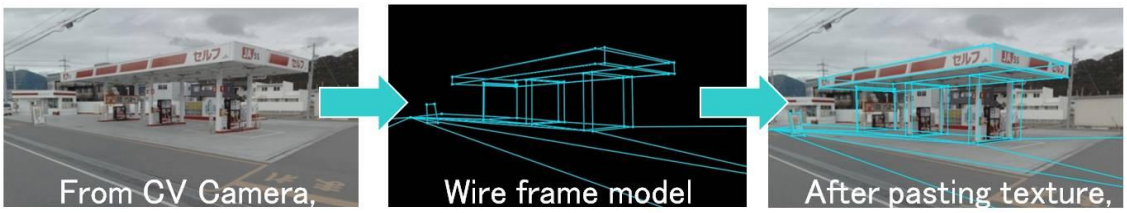

Fig.11 3D Modeling

Figure 12 shows a landscape simulation. The left-hand image shows the actual scene, while right-hand image shows the scene with cherry tree CG models. In this instance trees were added to the landscape. Besides that simulations can also similarly be conducted for street lights or billboards.

Fig. 12 Landscape Simulation

Figure 13 shows how the video data can be used for mapping. The IMS3 comes with software which can be used to generate maps from the video footage. Road markings and traffic signs can be automatically extracted and objects can be vectorized by tracking the terrain in the video manually. The blue lines in the figure were drawn manually, while the orange lines were automatically extracted. This makes it possible to take cross sections through the data. The time required for producing maps could be shortened by using this sort of auto-processing technology.

Fig. 13 Road design making and output

Besides the applications mentioned above, the video footage is also capable of connected with existing geographic information system (GIS) and route and position information can be shown on the digital map in real time.

Moreover, the IMS3 can be mounted on any moving object, so that many innovative applications are possible. For example, it can be mounted on a boat. This way, river bulkheads, bridge piers and other objects, which are difficult to identify from land, can be surveyed. In addition, It is also possible to mount the IMS3 on hand-drawn carts and even carry it by hands. This way, places where vehicles cannot access can also be surveyed. The 360 degree full spherical geo-referenced video of IMS3 and its many potential applications are going to be extended widely in the near future.

4. CONCLUSION AND DISCUSSION

The IMS3 (Dual Cam) is a cutting-edge mobile mapping technology with potential applications in a wide variety of industries. The high-resolution 360 degree full spherical geo-referenced video footage can be used for making highly accurate 3D measurements. The video footage can also be used for carrying out maintenance, management and inspections of roads, rivers, and tunnels.

The IMS3 makes such measurements without requiring relatively expensive lasers and high-precision IMU. Therefore using the IMS3 can reduce costs for making spatial measurements.

It is expected that there will demand for Mobile Mapping Systems in an increasing number of fields in the near future. The IMS3 and its high resolution 360 degree full spherical geo-referenced video is a good candidate for meeting this demand.

ACKNOWLEDGEMENT

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