Development of Roadside Facility Management System with Video GIS Technology

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ABSTRACT

In this paper, we suggest a new spatial information system called video GIS where video is used for spatial data construction and is integrated with map. We develop a prototype system of video GIS and apply it to roadside facility management. The main functions supported by the suggested system are data collection, coordinate calculation and conversion, data construction, analysis, searching, and browsing. The stereo images and corresponding position data are collected by a vehicle named 4S-Van that has GPS, IMU, and cameras. The 3-D coordinates of the objects in the images, such as road sign, signal lamp, and building, can be calculated and constructed from the collected data. The spatial objects are displayed on both image and map, and can be searched and browsed, which enables visual and realistic browsing and management of spatial objects. Compared to conventional field survey used in roadside facility management, the method enables faster, easier, and more efficient construction of spatial data. The suggested video GIS can be applied not only to roadside facility management but also to many similar projects of central or local governments that are related to GIS.

Keywords : GIS, Video GIS, 4S-Van, Image, Roadside Facility Management

1. INTRODUCTION

As the GIS (Geographic Information System) is spread widely, the needs for more realistic information of spatial data are increasing. In GIS, spatial information can be expressed as various media including map, 3D graphics, image, and satellite imagery. However, most of conventional GISs mainly provide simple information expressed by map. Because such GIS is not so informative to human, many researches are being conducted about the management, analyze, and visualization of multimedia information in the field of GIS. Though the support by several media improves the usefulness of GIS, the relationships between the media are weak and cannot be fully integrated.

Especially, the information expressed by video, in nature, can provide the realistic information of spatial object that cannot be obtained from simple map. For this reason, video has been introduced and used for GIS as auxiliary information of map. The GIS supported by video information is being spotlighted as new approach that can overcome the weakness of conventional map-based GIS. However, up to present, video is handled just as an attribute of spatial object and link between location information and video data is established manually and inaccurately. Therefore, such GIS has a limitation that integrated management of map and video, based on location, is not supportable.

In this paper, we suggest video GIS technology that can interoperate video and map. We develop the prototype system and apply it to road facility management, which is one of the most suitable application areas of video GIS technology. To integrate position data with spatial data, stereo images and corresponding position data are collected by sensors equipped on a vehicle named 4S-Van. The 3-D coordinates of the spatial objects appearing in the images, such as road sign, signal lamp, and building, can be calculated and constructed from the collected data. The constructed spatial objects are displayed on the images or video, and can be searched, browsed, and spatially analyzed. The result is represented on the image or video as well as map, which enables visual and realistic browsing and management of spatial objects. Compared to conventional field survey method used in roadside facility management, the method enables faster, easier, and more efficient construction of spatial data, which needs enormous time and cost otherwise. The suggested video GIS is expected to be applied not only to roadside facility management but also to many application areas of central or local governments that are related to GIS.

The remainder of this paper is organized as follows. Chapter 2 provides a review of related topics. Chapter 3 describes overview of our suggested video GIS and its architecture. In Chapter 4, we suggest spatial data construction system and its application to roadside facility management. This paper concludes with a summary of our suggestions.

2. RELATED TOPICS

2.1 Mobile mapping system

Mobile mapping system is a moving platform where many sensors are integrated that can obtain 3-D location of spatial objects. It usually equips the sensors such as GPS, INS, and cameras in a vehicle. It collects image/video data by camera the moment when GPS and INS data is collected to determine the position and attitude of the vehicle. Once image and position/attitude data are collected, the spatial data can be visually browsed by S/W and 3-D coordinates of the spatial objects are calculated by photogrammetry.

Most impressive mobile mapping systems are GPSVan of Ohio State University [1], GPSVision of Lambda Tech International [2], and On-Sight of Transmap [3]. In Korea, ETRI has been developing a mobile mapping system named 4S-Van[4]. The sensors equipped on 4S-Van are GPS, INS, B/W CCD camera, color CCD camera, and additionally, laser in the near future.

Mobile mapping systems can collect image/video and position/attitude information and can construct spatial information fast and accurately. They can calculate 3-D coordinates of spatial object appearing in a stereo image by photogrammetry. While GPS provides position and velocity from the satellite signals with long-term stability, INS provides high-rate position, velocity, and attitude of the vehicle with short-term stability. In other words, INS and GPS show complementary error characteristics, so they are integrated to more accurate and enhanced navigation system. The mobile mapping systems are used in various fields that are related to spatial data, such as mapping, survey, and facility management.

2.2 Connection with image and map

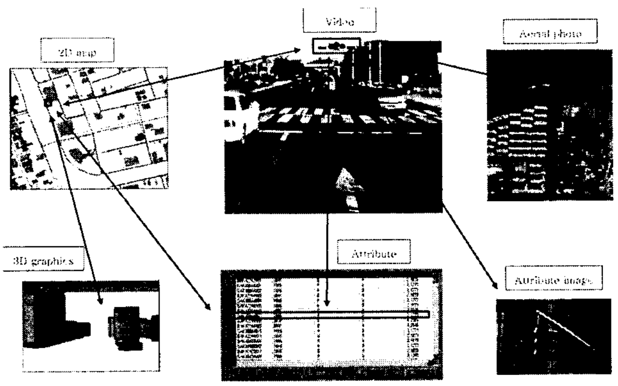
The mobile mapping systems discussed above implicitly support the connection between map and video/image. Besides the systems, the technologies are introduced that extend the conventional map-based GIS and provide the connection between image and map. MediaMapper [5], a desktop S/W produced by Red Hen Systems, can provide image, video, and map integrated. Although it provides image output from the search on map, the reverse is not supported. Iwane Video GIS [6] is another video-based GIS of Iwane. Ltd. It consists of applications for road, railway, public utilities, river, and sightseeing. Each system support map-to-video search, while video-to-map search is still not supported. Though the systems have some insufficiencies till now, they suggest the usefulness of video in the field of GIS.

3. VIDEO GIS

3.1 Overview of video GIS

Video GIS is a system that can support integrated management of spatial data expressed by video. The information expressed by video, in nature, can provide the realistic information of spatial object. The video GIS can overcome the weakness of conventional map-based GIS by photographing the spatial object, supporting the connection to map, and adding realistic visualization. The video GIS technology combines location information with video data and thereby provides two-way search, browsing, and analyses. The basic functionalities that video GIS should have are data collection, 3-D coordinate calculation and conversion, data construction, two-way search, browsing, and analyses between image and map.

The media that represent spatial data may be extended to various media types such as aerial photo, graphics, attribute image, and satellite imagery. Such data types make users to have richer information with various and complimentary characteristics. The overview of such extended video GIS can be illustrated as Fig. 1.

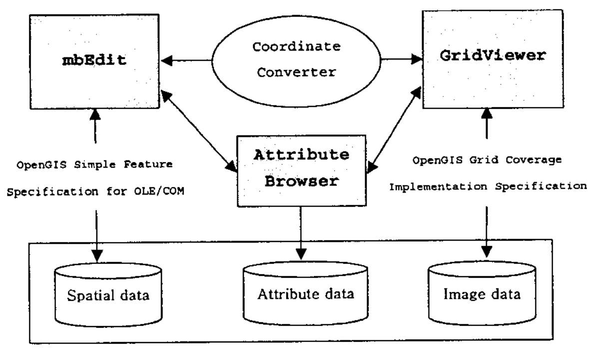


[Fig. 1] Overview of video GIS

In this paper, we implement video GIS technology on 4S-Van platform and develop its prototype. In our developed system and subsequent discussion, still images collected with 1-second interval are used, instead of real video clips. The study on the real video clips is under way, and we are expecting that most of the developed methods are also applicable because video can be considered as set of still images.

3.2 Architecture of video GIS

The architecture of the suggested video GIS is shown in Fig. 2. The *mbEdit* and *GridViewer* are used as map viewer and image viewer, respectively. The description of each component is as follows.



[Fig. 2] Architecture of suggested video GIS

Map display/edit component

Map display/edit component is a component that can create, display, edit, search, and manage 2-D map. In our video GIS suggested in this paper, we use *mbEdit* component that has developed by the research "Open GIS component S/W" performed by ETRI [7]. The *mbEdit* component conforms to "OpenGIS® Simple Features Specification for OLE/COM" of OGC(Open GIS Consortium). It can create, display, edit, search, and manage 2-D map between the heterogeneous GIS systems.

Image display component

Image display component is a component that supports display and management of image data. In our video GIS suggested in this paper, we use *GridViewer* component, also developed by ERTI. Its interfaces conform to "OpenGIS® Grid Coverages Implementation Specification." Besides the basic functions of image display, vector drawing on image and some miscellaneous functions are implemented.

Coordinate conversion component

Coordinate conversion component performs conversion between pixel coordinate and 3-D real coordinate. We have developed a coordinate conversion component named *CoordCon*. The input parameters for the map-to-image conversion are camera position(x, y, z), camera attitude(ω ,ψ ,κ), and lens constant (distortion, focal length, principal point). For the image-to-map conversion, camera position(x, y, z) of left/right image, camera attitude(ω ,ψ ,κ) of left/right image, lens constant (distortion, focal length, principal point), and maximum correlation/maximum iteration parameters are required.

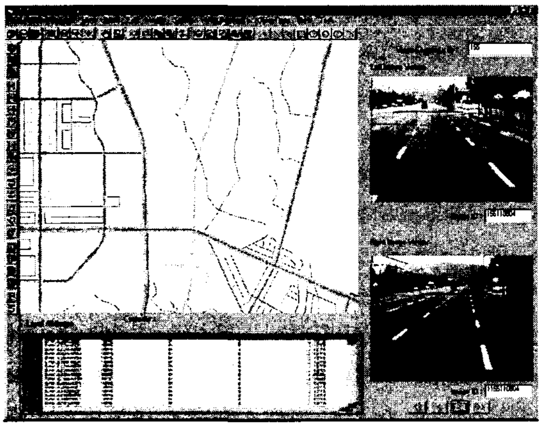
Database

We use ZEUS as the DBMS to store spatial data, attribute data, and image data. The unit of video data is video sequence. Besides the data, some additional link information is necessary for image-map cross-referencing, 3-D coordinate extraction, and management of outline of spatial object. The detail descriptions of data model and link information are shown in [8] and implemented as database schema.

4. ROADSIDE FACILITY MANAGEMENT SYSTEM WITH VIDEO GIS

In this paper, we study about application of video GIS to roadside facility management system, one of the most representative fields of spatial data construction. With the video GIS technology applied to roadside facility management system, spatial data can be constructed fast, easily, and efficiently, and two-way search and browsing of spatial objects can be supported.

The development tool and environment is Visual Basic 6.0 on Windows 2000, and the system is implemented in component-based architecture using the components described in the previous chapter. We select several roads in Daejon as the target area, where 4S-Van collects image and location data. Fig. 3 shows a screenshot of developed system.



[Fig. 3] Screenshot of roadside facility management system

4.1 Data collection

The first step of data collection by 4S-Van is self-calibration, where the focal length, principal point, and lens distortion of camera are determined. Accurate determination of focal length and principal point is necessary and important for the calculation of exterior orientation and 3-D coordinates. The self-calibration method has an advantage that exterior orientation can be obtained as well as the three values above. This step includes camera attitude correction by surveying fixed points with known coordinates.

After the step, 4S-Van runs along the roads and collects the images by photographing the roadside facilities. The images are collected by a certain interval, and GPS and INS collect the raw data with synchronized to the interval. The data collected by above steps are processed by GPS/INS integration that yields exterior orientation (position and attitude) of each image.

The set of images that are collected when running along the road are divided and managed in a certain criteria, for example, road name. In this paper, the set of stereo images, or management unit, is called video sequence.

4.2 Construction of spatial object

With regard to a video sequence, the 3-D coordinates of spatial objects appearing in images are calculated and input to database. From all kinds of roadside facilities, five types of target objects are selected: building, street light, signal lamp, manhole, and sign (road sign, restriction sign, caution sign, etc.).

The program for the spatial data construction consists of a map window associated with *mbEdit* component, two image windows associated with *GridViewer* component, and an attribute browser (Fig. 3). The map displayed in map window and image displayed image window, synchronized with each other, show the spatial object that is selected or on the process.

The process that constructs 3-D coordinate of spatial object from a video sequence is as follows:

Spatial data construction

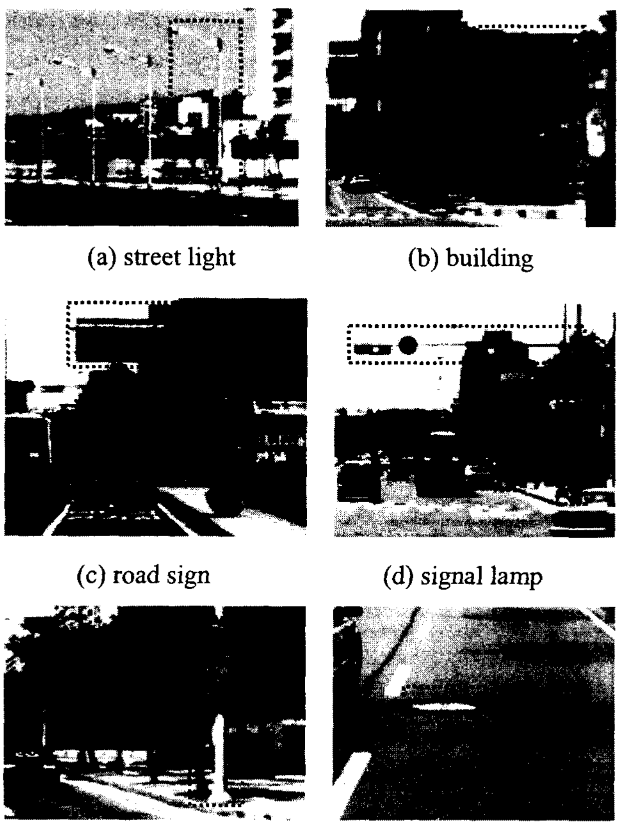
(1) Select a target area or region for spatial data construction
(2) Display the map of selected area at map display window
(3) Select the target road by selecting a road at the map display window
(4) Open the video sequence that corresponds to the road
(5) Open the first stereo image of the video sequence and display them in the image display windows
(6) Select a spatial object, and calculate and input to database its 3-D coordinate
(7) Draw the outline of already constructed object on the image display windows
(8) Repeat (6)~(7) for the next spatial object
(9) On finish the input for a stereo image, move to next stereo image and repeat (6)~(8)

4.3 Outline of spatial object

Our video GIS system displays the outline of already constructed spatial object on image, and thereby identifies spatial object, supports visual browsing, and prevents duplicative input of an object. Prevention of duplicative input is important, because when the next stereo image is loaded and displayed, the user is likely to be confused whether the input of an object is already done or not.

The outline of spatial object is basically created automatically from the 3-D coordinate of the object. The shape of outline varies from the type and size of the object. For example, outline of building is wireframe cubic, and street light is rectangle (Fig. 4). A layer of spatial objects is distinguished from other layers by displaying the outline with different color. Though the outline is created automatically, user can resize and adjust inaccurately created outline on image window.

In addition to outline of object, visible area of camera corresponding to current stereo image is displayed as fan-shaped area in the map display window to help the understanding of user.



(a) street light (b) building

(c) road sign (d) signal lamp

(e) restriction sign (f) manhole

[Fig. 4] Outline of spatial objects

4.4 Search and browsing of spatial objects

The search and browsing are supported between the map and image, in both directions, which enables visual management and change detection of the roadside facilities. For the search, image-map link information and coordinate conversion are necessary. The search processes are as described below.

Image-to-map search

(1) Open the video sequence
(2) Select a stereo image in the video sequence
(3) Select a spatial object, displayed with outline, on one of the stereo image by pointing
(4) Search the object in the database and display it in the map display window (reload/zoom/unzoom/ panning of map should be done if necessary)

Map-to-image search

(1) Open the map and corresponding video sequence
(2) Select a spatial object on map by pointing
(3) Search and display the image in which the object appears (in case that such image is more than one, the first image is displayed)
(4) Display the outline of the object as highlighted

5. CONCLUSIONS

Because the information expressed by video provides the realistic information of spatial object that cannot be obtained from simple map, many GIS systems have been introduced and used the video data. In this paper, we suggest video GIS technology that interoperates and manages map and image. We also suggest the method that constructs spatial data by the video GIS. With the video GIS technology, the prototype system is developed and applied to roadside facility management field. The video GIS is a new technology that can construct spatial data fast and easily, and can reduce the cost of spatial data construction when used for application fields such as roadside facility management. In the suggested video GIS, two-way search between map and image is supported, which enables visual management and change detection of spatial objects. The video GIS technology also can be applied similar projects of central and local governments, as well as roadside facility management.

Though the method suggested in this paper provides accurate spatial data, our 4S-Van suffers from some sensor error, which makes the constructed data inaccurate. To solve the problem in the future, better sensors are required and better integration algorithm should be developed. Furthermore, because we have developed system that can handles video sequence, not real video clips, the system for handling real video data should be implemented. For the purpose, the research about coding location data in video data files and development of corresponding technologies are required.

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