An Interactive System for Creating a 3-D Graphical Road Map

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Abstract

Recently, Information Technology has been introduced to social systems for various purposes. The map that was the paper medium has been changed into an electronic form and digital maps have become familiar in our life such as the map for car navigation. They are also introduced in the Internet and mobile phones. Now, the demand on a 3-D map has rapidly risen to the digital map users. This is because a 3-D map excels in the visibility and is intuitively understood when the location information is passed on to a user three-dimensionally in the digital map.

This paper proposes a novel technique for creating a 3-D road map. It includes proposal of a vehicle that collects ground-view information of a road environment and an interactive graphic system for producing a 3-D road map employing the collected information. The function of the proposed technique is to make a 3-D map electronically by fitting measured data to a given 2-D digital map. In order to evaluate the proposed technique, we performed experiments at Paris (France) and Fukuoka (Japan), and produced a highly realistic 3-D graphical map of the road environment. This confirms the availability of the proposed technique.

Keywords: 3-D maps, road maps, car navigation, GIS, ITS, image processing

1. Introduction

Recently, Information Technology (IT) has been introduced to social systems for various purposes. The map provided by the paper medium has changed its style to an electronic and digital form. It has been introduced to car navigation. The Internet and mobile phones also employ digital maps. In this way, the digital map has become much familiar in our life.

A 3-D road map is the present concern of major map-related companies, since it may be easily accepted to people because of its realistic and therefore understandable nature, particularly in car navigation. Although lots of researches on creating 3-D road maps have been done so far using aerial or satellite photograph resources, methods of collecting geographic information without using such aerial view resources has a strong demand from map-related industries, since certain kinds of geographic information (roads in tunnels, roads hidden by street trees, building texture, etc.) are difficult or even impossible to collect their information using these resources. Particularly, in the field of car navigation, frequent map update is indispensable for providing a driver with most recent and exact geographic information having a driver's view.

In this circumstance, some studies have proposed methods of measuring 3-D shape of buildings and objects from a driver's view. There are established techniques such as the stereo vision [1] and the factorization [2] that use video images or still images measured by a camera. A method of using aerial photos [3] also exists as a passive technique. The literature [4] employs a laser range finder as a sensor. These techniques can recover actual 3-D shape, but they need much complicated post-processing to handle the obtained large amount of data and their noise reduction.

If these kinds of measurement information are arranged on the 2-D map with latitude and longitude information obtained from the Global Positioning System (GPS) receiver, it causes some difficulty in its accuracy because of the noise contaminated in the GPS signal.

In this paper, we propose a novel technique for creating 3-D graphical road maps that contain road environments. The technique includes a vehicle that collects road environmental information and an interactive graphic system for producing a 3-D road map from the information. The interactive system assumes the employment of a 2-D electronic map and aerial photographs as reference and creates a 3-D road map from the video images the vehicle provides. This procedure is done on the computer display by man-machine collaborative work. Visual operation of a user on the display supported by some automated procedures by computer is much effective. This system will certainly open up a new application field in the development of man-machine systems.

The paper is organized as follows. Section 2 outlines a method of data collection. Section 3 outlines a mapping method of measured data to a 2-D map. Section 4 explains how to make a 3-D map from the measured data. Section 5 shows experimental results on the data collection and the produced 3-D maps of the streets in Fukuoka (Japan) and Paris (France) using the proposed method. Discussion and conclusions are given in Section 6.

2. Data Collection

It is assumed in the proposed technique that the information obtained from the real world contains horizontal surfaces and vertical surfaces. We obtain the information on road surfaces as horizontal surfaces and the information on the walls of buildings, sign boards, etc., as vertical surfaces. It is also assumed that a 2-D electronic road map is available. In the technique, the measurement position on the 2-D map is specified by using horizontal geographic information, and after that, 3-D information is mapped by using vertical geographic information.The outline of the entire procedure on the proposed system is described in three parts (See **Fig. 1**).

The principal data obtained by the proposed vehicle measurement system is as follows;

A) Road image data for detecting the car position and collecting road surface information.

B) Scene image data for collecting geographic objects information such as buildings, traffic signals, etc.

C) Distance data for detecting the car position.

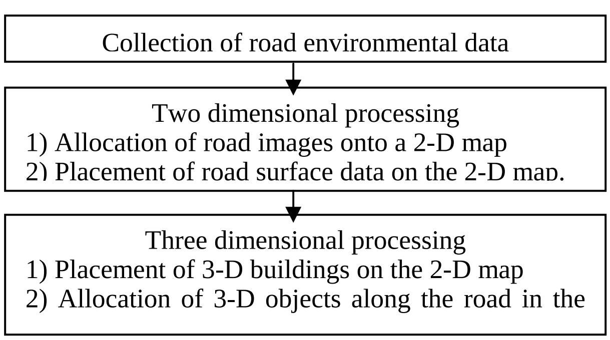


Fig. 1 Overview of the procedure.

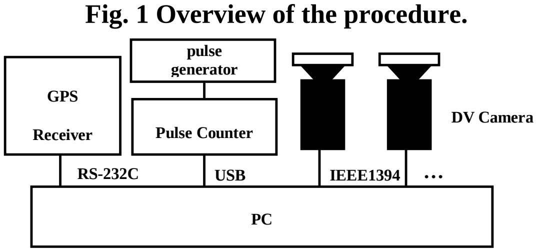


Fig. 2 Configuration of the devices employed in the measurement vehicle.

In this data collection, synchronization between the car position/time and the sensor data is important. Therefore, we propose the measurement system as shown in **Fig. 2**.

In **Fig. 2**, multiple digital video cameras are employed to obtain the data A and data B above. The images of the cameras are recorded on DV tapes, and time code is recorded on the personal computer to synchronize the pulse generator. The pulse generator that is connected to the computer through the pulse counter makes equidistance information (The pulse generator is set up at the rear wheel of the measurement vehicle). GPS is connected to the computer to obtain the rough position of the car. All the data obtained from these sensors (DV cameras, a GPS receiver, and the computer time) synchronize by the signal of the pulse generator. Herewith, the DV time code (i.e., DV images) and the GPS data (i.e., rough position of the car) are obtained at an equidistance interval.

3. Two-dimensional Processing

A method of producing initial state of the 3-D map from measurement data by two dimensional processing is described in this section.

3.1 Data improvement & allocation of road images onto a 2-D map

3.1.1 Geometrical conversion of road images

In order to obtain the road surface images from the original road images in the video taken by the camera in the vehicle, geometrical conversion is applied to the original image. Here, we assume that the road has a flat surface, and the gradient value (roll) of the car is vanishingly small.

In the first place, the point marks are arranged in front of the car in the form of the lattice and having equal intervals to obtain geometrical conversion parameters, and it is recorded with a DV camera (See **Fig. 3**). In the second place, coordinates of each quadrangle that consists of four point marks in the image are obtained and geometrical conversion parameter (pseudo affine transformation parameter) is calculated. The pseudo affine transformation is given as follows;

$$x' = axy + bx + cy + d\ , \qquad (1a)$$

$$y' = exy + fx + gy + h\ . \qquad (1b)$$

The result of having applied Eq.(1) to the quadrangle image in Fig. 3(a) is given in (b). It is the image of the lattice observed from above and is called an ortho-image.

Referring to the time code, the original road image in the video is separated horizontally to make rectangle patches on the computer display, to each of which Eq.(1) is applied and the rectangle patch is transformed into an ortho-image. The separation of the road is done by a user, whereas the transformation to the ortho-image is performed by computer. In this way, the ground-view road images obtained from the frontal camera in the vehicle measurement system is converted into corresponding ortho-images which are then placed on the 2-D road map.

3.1.2 Extraction of crossroads

In this technique, crossroads are considered to be a checkpoint on the 2-D map. Checkpoints are basic points of measurement data at the position on the 2-D map.

In this section, the technique is explained for extracting the candidate of the checkpoint by recognizing the crosswalk from the ortho-image.

Extraction of white line edges

To extract white line edges of a crosswalk, some image processing algorithms are combined. The following four processed images are examined whether or not there are frequent white areas on the images (See **Fig. 4**).

1) Emphasis of Contrast
2) Thresholding - Emphasis of Contrast
3) Emphasis of Contrast - Minimizing Average Error - Median Filter (5 times)
4) Thresholding - Emphasis of Contrast - Minimizing Average Error - Median Filter (5 times)

The Sobel filter in the horizontal direction is applied to the above four images and vertical edges are extracted in the images.

Recognition of crosswalk

A crosswalk is judged by the number of intersections of the horizontal straight line that passes the center of the image and the extracted vertical edge. It is recognized as a crosswalk if the number of the intersection is larger than a threshold on at least one of the above four preprocessed images.

3.1.3 Allocation of road images onto a 2-D map

Road surface images (See **Fig. 5**, for example) can be made, using Eq.(1), from the ground-view images obtained from the frontal downward camera equipped in the vehicle and distance data. A road interested is separated into successive rectangle patches as shown in Fig. 5. They are transformed ortho-images. The patches are roughly arranged onto the corresponding road on the 2-D map automatically according to the GPS information. Since the GPS information is not very exact, crossroads at the junctions along the road are detected by the technique stated in 3.1.2. These crossroads specify check points on the 2-D map. Two check points between the adjacent crossroads are combined on the 2-D map by computer by fitting a NURBS (Non-Uniformed Rational B-Spline) [5] curve along the road. The road patches are then rearranged on the NURBS curve automatically to get their exact locations. This map is the initial state of the 3-D map produced and is called an initial 3-D map.

3.2 Placement of road surface data on the 2-D map

Road features are obtained from road surface images. We input stop lines, lane lines, traffic lights, crosswalks, etc., to the initial 3-D map by referring to the road surface images on the 2-D map and aerial photo.

4. Three-dimensional Processing

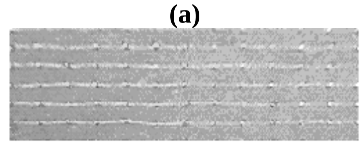
A method of producing a 3-D map employing the obtained video data and the initial 3-D map is described in this section. Here, the 3-D map does not contain exact 3-D shapes of real buildings, trees, or others, but it contains their pseudo shapes registered in the system.

4.1 Placement of 3-D buildings on the 2-D map

A 3-D object is displayed by 3-D volume data that is made from building 2-D frames of the object (See **Fig. 6**).

The wall texture obtained as vertical geographic information is put on the building.

(a)



(b)

Fig. 3 Image of the lattice in front of a vehicle and its ortho-image.

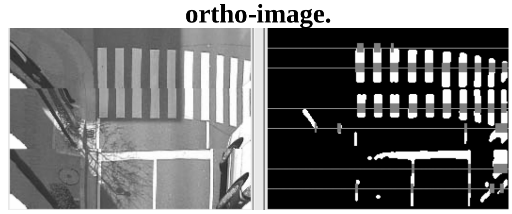


Fig. 4 Ortho-Image (left), and the extracted white area image (right)

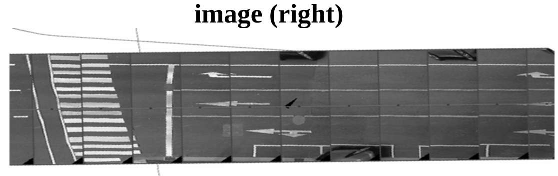


Fig. 5 Road surface image segmented into rectangle parts.

4.2 Allocating traffic objects and plants along the road on the map

There are some typical objects along a road such as street-lights, trees, traffic signals, traffic signs, *etc*. The developed system stores their 3-D models in a database. Once they are observed along the road in the video image, their models are chosen by a user and placed at appropriate positions in the 3-D map.

5. Experimental Results

Experiments were performed to show the performance of the proposed technique.

5.1 Experimental environment

Five cameras were installed in the vehicle. Two of them (Cam 1, Cam 2) were used to measure the road surface data, and other two (Cam4, Cam5) were used to measure the wall of buildings, etc. The last one was used to measure the signs, signals, etc. Also, to obtain distance data, the magnetic pulse generator was set in the vehicle. Additionally, GPS and note PC were set. The road images were taken in Paris, France, and in Fukuoka, Japan, with these devices. We rented a vehicle in the locale, and all the devices were set up in the vehicle.

5.2 Results

Figure 7(a) shows a photo of a road environment in Paris and (b) is the created 3-D map. Satisfactory correspondence is obtained between the 3-D map and the actual road environment. It may provide enough information for driving this route.

Similar result was obtained with Fukuoka.

6. Discussion and Conclusions

In this research, we proposed a simple and useful method of producing a 3-D geographical map by mapping onto a given 2-D map the data measured in the street using video cameras and several sensors on the vehicle. In the experiment, it was confirmed that allocating the measurement road surface data that are difficult or even impossible to collect using the aerial or satellite photograph resources in the 2-D map was possible. Moreover, we were able to produce a highly realistic three -dimensional map with the acquired data. The work efficiency has been raised 30% than before with respect to the production time.

In the future, to raise the work efficiency of the post-processing of the measurement data, we plan to introduce image recognition techniques more in the procedure and a new measurement method, so that we can develop an easy and simple 3-D map production application.

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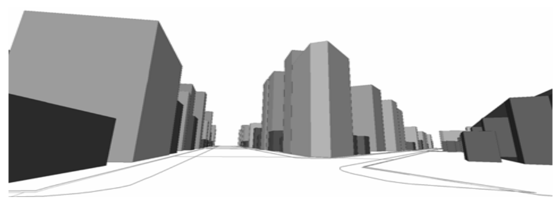

Fig. 6 Buildings on the 3-D map produced automatically

(a)

(b)

Fig. 7 Photo of a road in Paris and its 3-D Map