AUTOMATED MOSAICING FOR VIDEO IMAGERY CAPTURED FROM MOVING PLATFORMS

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ABSTRACT

This study focuses on an automatic image mosaicing system developed in Asia Air Survey Co., Ltd. for video imagery captured from moving platforms. An automated registration method with non-linear optimization called Levenberg-Marquardt algorithm is adopted in the system to find transformation coefficients between video frames. The system can merge series of frames into one image without using additional information such as altitude, location, speed of platforms. The system calculates translation, rotation and scale factor between frames without specifying corresponding points and compensates irregularity of motion of a platform. Thus the system can mosaic video imagery which is captured not only vertically but obliquely to the objects. Mosaicing of Airborne and car-mounted video imagery have been demonstrated by the system.

1. INTRODUCTION

Automated image mosaicing technique has been studied for about ten years. Anandan(1987) introduced an algorithm of automatic image registration with hierarchical estimation technique, and Hansen et al.(1994) implemented the algorithm on a hardware based system. These techniques can merge images into one image without additional information such as altitude, location, and speed.

Asia Air Survey Co., Ltd. has developed an automatic mosaicing system for the video imagery. This system is designed to run on personal computer and to automatically register and merge video sequence of up to 10,000 frames at a time. The system gives a quick and cheap solution to merging series of video frames captured from moving platforms such as airplanes, helicopters and cars. The system can process video imagery of vertical view as well as of oblique view. The output mosaic images can help us to grasp overall texture of long objects such as roads, power-transmission lines, and rivers, which is difficult to visualize in a single video frame.

After short description about the theory of automated image registration, we will introduce the automated mosaic system and its demonstration including results for aerial views of an urban area and power-transmission lines, and car-mounted camera views of an autobahn structures and a mall street.

2. THEORY OF 2-D IMAGE REGISTRATION

The algorithm of image registration adopted here is based on 2-D image mosaicing method which can automatically match one image with another. This algorithm assumes that correspondence of coordinates between two images is registered by projective transformation:

$$x' = \frac{h_1 x + h_2 y + h_3}{h_7 x + h_8 y + 1} \qquad y' = \frac{h_4 x + h_5 y + h_6}{h_7 x + h_8 y + 1}$$

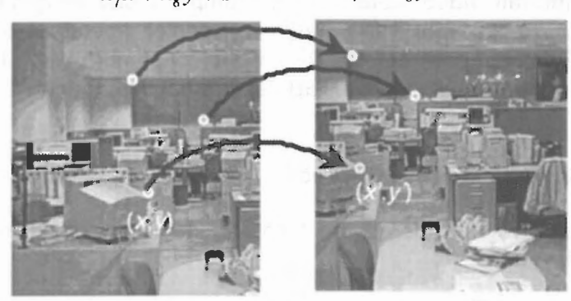

Image I Image I'

Figure1 Corresponding points between the image I and I'

where (x,y) and (x',y') are coordinates of Image I and I', $H(h_1,\ldots,h_8)$ is a set of coefficients of projective transformation.

Many studies on 2-D image mosaicing adopt Levenberg-Marquardt (LM) algorithm to calculate H automatically (Szeliski, 1994). The LM algorithm is a non-linear optimization which is an extension of least square minimization (Press et al., 1992). Here LM algorithm optimizes H which minimize the following evaluation function:

$$E = \sum \{I'(x', y') - I(x, y)\}^2 = \sum e^2$$

where $I(x,y)$ and $I'(x',y')$ are pixel value of image I and I'. In many cases 2-D image mosaicing employs coarse-to-fine strategy which refines precision by processing series of images structured hierarchically in different scales from coarse to fine. This strategy contributes to avoiding converge at local minimum of E, as well as reducing processing time.

3. Design of the Automated Mosaicing System

The automated mosaicing system is designed as an off-line video processing system, which processes imagery of digital video file format. Although the system is not real-time, it does not require any special hardware except a video capture board so that data can be processed at a low running cost.

3.1 Hardware Configuration

The system works on a personal computer (OS: Windows95) with a video capture board. Figure2 shows hardware configuration of the system.

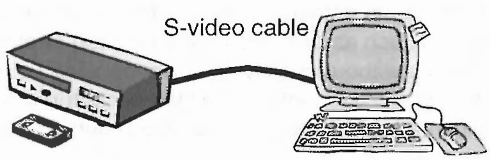

Figure2 Hardware Configuration

Use of high-speed hard disks is desirable because the transfer speed of hard disk will be bottleneck for high-frame-rate video capturing. For example, a disk array with two 10,000 rpm HDD has the transfer speed of 27 MByte/sec and can realize video capturing with 15 frame/sec in 640 x 480 (RGB depth 5:5:5 bits) format.

3.2 Software Specification

We have considered the following items for designing software.

User Interface of the system:
User interface of the system has been developed on Windows95. The opening window is shown in Figure3.

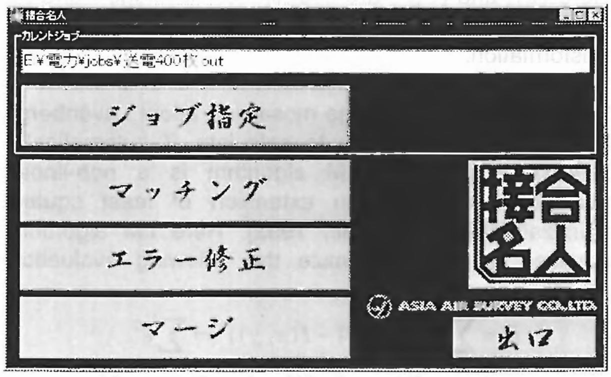

Figure3 Opening Window of the system

Limits in amount of input frames:
The sytem can process up to 10,000 frames in one registration. This allows users to merge 5 minutes of video sequence captured in the rate of 30 frames/sec.

Selection of parameters for image registration:
(1) Types of Transformation
We have implemented various types of transformation including projective transformation. Affine transformation, Hermert transformation, and simple transition. Hermert transformation or simple transition works better than projective since platforms normally move along straight lines.

(2) Image Enhancement
Video imagery of low-texture objects, such as snow or ice coverage, often causes failure of image registration. Some types of image enhancement such as Laplasian of Gaussian (LOG) filter can be applied as pre-processing.

(3) *Parameters of LM Method*
Although all parameters of LM optimization have default value, an operator can change these parameters to desired values through GUI.

Error Modification:
The system provides error modification interface with which an operator can change the results of image registration if registration error occurs.

4. DEMONSTRATIONS OF VIDEO MOSAICING

Four cases of demonstrations of video mosaicing with our system are presented here: mosaicing of vertical view of airborne video imagery, oblique view of airborne video imagery, vertical view of car-mounted video imagery, and oblique view of car-mounted video imagery. Table1 shows conditions of each demonstration.

4.1 Mosaicing Vertical View of Airborne Video Imagery

Figure4 shows a mosaic image of vertical view of an urban area captured by an airborne video. Note that irregularity of motion of platforms, such as rotation, change of speed, and change of moving direction, have been compensated in the resultant image. This is not possible by linear CCD sensors unless other geometric information such as location, rotation, etc. are given. The resultant image can be regarded approximately as an ortho image along the course of motion.

4.2 Mosaicing Oblique View of Airborne Video Imagery

Oblique view of video imagery is sometimes more useful than vertical view for grasping terrain and appearance of the structures. Figure5 shows the result of the image sequence of power-transmission lines. Registered by simple transition, video frames are well merged although the scene includes various scales of objects.

Table1 Conditions of demonstrations

Platform		Airborne		Car-Mounted	
Object		Urban Area	Power-transmission line	Autobahn Structures	Mall Street
Camera	View (direction)	Vertical	Oblique	Vertical	Oblique
	Focal Length [mm]	16	4.8	8	8
	Altitude(Distance) [m]	300	120 - 150	20	10
	Velocity [km/h]	---	---	40 - 60	30 - 40
Frame Captureing	Resolution [pixel]	320 x 240	282 x 72	78 x 240	60 x 240
	Interval [fps]	15	15	30	30
	RGB Depth [bit]	5 : 5 : 5	5 : 5 : 5	5 : 5 : 5	5 : 5 : 5
	Number of Frames	200	200	180	400

4.3 Mosaicing of Car-Mounted Video Imagery (Vertical and Oblique View)

To make mosaic image of car-mounted video imagery, the data have to be digitized at higher frame rate than of airborne video imagery due to the reasons below:

Larger Parallax:
Distance between camera and objects is so close that image registration between long frame-intervals tends to fail due to long parallax.

Moving Objects:
Moving objects such as cars and pedestrians may cause mismatching.

Figure6 and 7 are the results of mosaicing: Figure6 shows vertical view of autobahn structures from car-mounted video, while Figure7 shows oblique view of a mall street. The video sequences for processing were digitized at the rate of 30 frames/sec, which was twice of the rate for the airborne video mosaicing.

Although slight mismatching occurred and was modified manually in both imagery, panoramic imagery along the roads were easily obtained.

5. SUMMARY

We have developed automated mosaicing system for video imagery captured from moving platforms. The system can handle large amount of frames and easy interfaces allow users to make mosaic image quickly.

The system enables users to grasp an overall texture of long structures at a glance. The system can produce ortho-like mosaic image from vertical view of airborne video imagery as well as bird-view picture from oblique view of them. Mosaic images of scenes of mall streets and sideways of autobahn can be used for virtual reality application.

We are planning to improve the algorithm for mosaicing digital camera images or aerial photographs in the future.

6. ACKNOWLEDGMENT

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Figure4 Mosaic Image of Urban Area (Vertical Airborne Capturing)

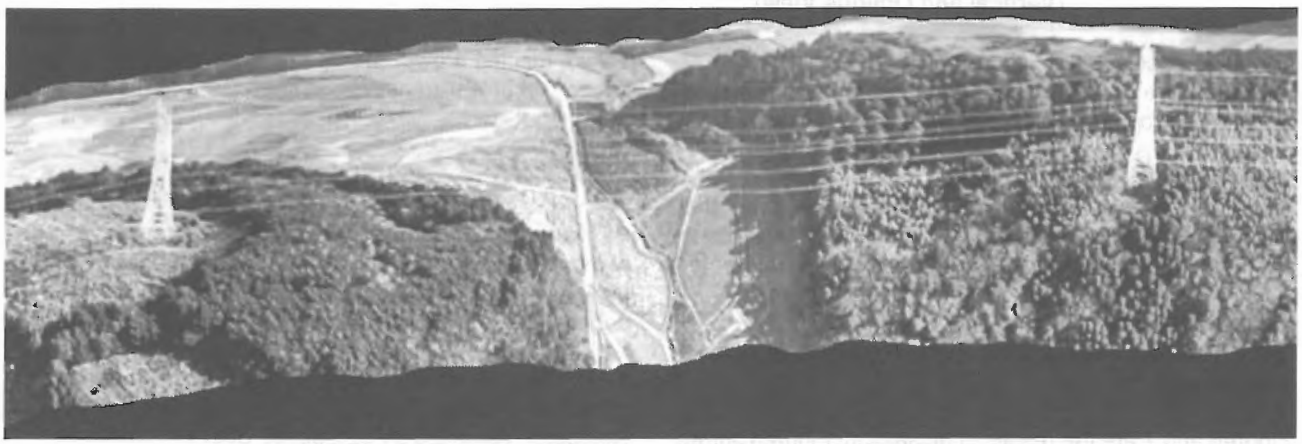

Figure5 Mosaic Image of Power-Transmission Lines (Oblique Airborne Capturing)
(Presented by Power Engineering R&D Center in Tokyo Electric Power Company)

Figure6 Mosaic Image of Autobahn Structures (Vertical Car-Mount Capturing)

Figure7 Mosaic Image of Mall Street (Oblique Car-Mount Capturing)