MVA '98 IAPR Workshop on Machine Vision Applications, Nov. 17-19, 1998, Makuhari, Chiba, Japan

8—21 Mobile motion-tracking system for rescue work at destroyed buildings

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Abstract

We propose a new mobile motion-tracking system for rescue work, which is able to detect and track motion of buildings destroyed by disasters including earthquakes. This system includes two mobile computers with digital cameras to detect two-dimensional motion of the buildings from different angles. The two computers are communicated with serial interfaces and the two-dimensional position in an image plane of a camera can be transferred to another computer. So, three-dimensional motion of the buildings can be calculated by triangulation.

The performance of this system was checked for a frame object and it was confirmed that the 3-D motion could be tracked.

1 Introduction

We had intensely learned from the Great Hanshin Earthquake, which devastated Kobe area in January 1995, that it was a top priority to rescue survivors immediately after strong earthquakes occur. In rescue work, we needed to jack up the destroyed buildings to grab the survivors. For this purpose, The Rescue Robot has been developed in our institute[1]. It might be expected that the buildings further collapse in the rescue work. It was worried, however, that creaks of the buildings were drowned by booms of rescue vehicles, including helicopters and ambulances, and we hardly recognized the slow motion of the buildings ranging hours. So, a vision system, which is available for motion-tracking at the rescue scene because of its functioning with battery and its transportability, has been strongly required.

Many stereo-vision systems have been developed[2]-[4] to measure 3-D profiles, positions, or motions. These are mainly for indoor use, however, then functioning with AC100V is a prior condition, and baseline length are fixed and short(up to about 1m).

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The new tracking system, consisting of two mobile computers and digital cameras, is developed to present the 3-D motion of the buildings to rescuers and help them cease from the rescue work for security reason. This system operates with batteries carried in the computers. And also, its size is enough to transport for oneself. The principle of the new motion-tracking and its performance are presented in Section 2, and the experimental result and discussions are outlined in Section 3.

2 System Design and Performance

A principle of 3-D motion tracking by stereo vision is shown in Fig. 1. Two independent digital cameras are placed near the destroyed building. We adopt the triangulation to track the 3-D motion, in which motions of a point in two images lead to the 3-D motion. We assume that the baseline length L and the pan angles of the cameras, ϕ_L and ϕ_R are known. Three-dimensional positions of centers of camera lenses, F_L and F_R, are also known. We acquire 3-D positions of points p_L and p_R from their 2-D positions in the image planes and ϕ_L and ϕ_R.

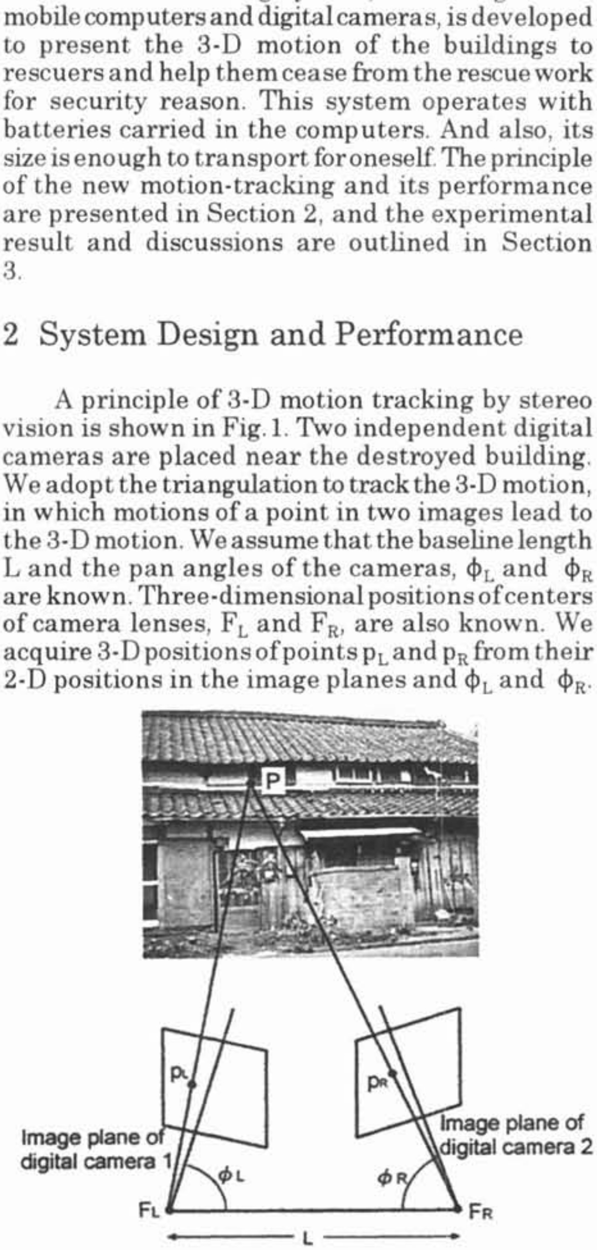


Fig.1 Measurement principle of 3-D motion tracking with stereo vision

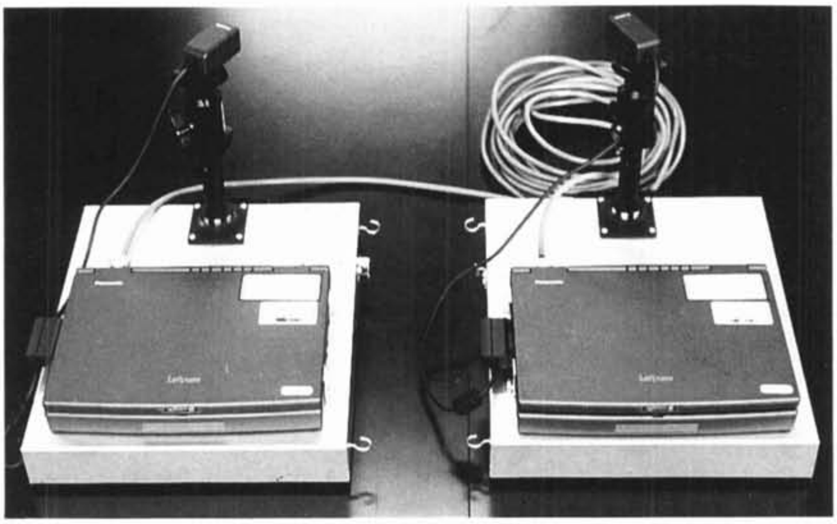


Fig.2 System overview

Formulated two lines, F_L-p_L and F_R-p_R, are extended and crossed at point P, so 3-D position of point P is calculated.

A system overview of the mobile motion-tracking system is shown in Fig.2. Specifications of each section are shown in Table 1. This system consists of two mobile computers and two digital cameras, which are directly connected with PC cards to each computer respectively. The two computers are communicated with RS-232C serial interfaces. Images of the devastated buildings are acquired in a constant interval and the acquisition is synchronized by one of two computers. Images taken with the cameras are stored in a 24-bit color bitmap format and processed to track the 3-D motion of the buildings.

The 3-D motion of the buildings was measured by the following processes, as shown in Fig.3.

Direction of the two cameras and distance between them were initially calibrated. A calibration overview is shown in Fig.4. We assumed that the altitudes of two cameras were not so distant that we can set them at the same altitude with vertical translation mechanisms. Parameters in the calibration include follows.

a)Baseline length, L
b)Pan angles of cameras, ϕ_L, ϕ_R
c)Tilt angles of cameras, ξ_L, ξ_R
d)Tilt angle of baseline, ψ

First in the procedure, two cameras are leveled, or the tilt angles of them, ξ_L, ξ_R are reduced to zero. Then, two cameras are vis-à-vis and images are acquired. The pan angles of cameras, ϕ_L, ϕ_R and the altitudes of them are adjusted with manual operation so as to move the camera positions in the two images to the centers of them. In the top of two cameras, ultrasonic distance sensors are placed, so we can read the baseline length L. Tilt angle of baseline ψ can be reduced to zero by these operations. Pan angles from baseline and tilt angles from the horizontal plane of the cameras are obtained with directing them to the tracking scene.

Next, a rescuer chooses some points for attention, which are supposed to be easy to present

Table 1 Specifications of each section

	Type	Specifications
Mobile computers	**Panasonic Let's note AL-N2T 515 J5**	**CPU: MMX Pentium 150MHz** **Card slots: Type II ×2 slots** **Weight: 1.54kg** **C++ language is used for image processing**
Digital cameras	**Canon Power Shot 30T**	**Imaging device: 1/4 inch CCD** **Image size: 320×240 dots** **Weight: 120g** **Focal length of lens: 5.7mm** **F value: 2.8** **Directly connected to mobile computers with PC cards .**

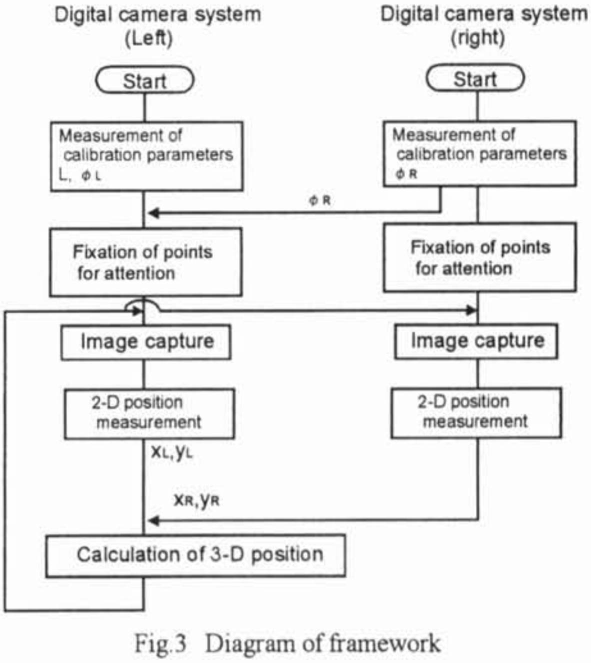


Fig.3 Diagram of framework

the motion, for a first taken image including the sky, the ground, or other structures with manual operation.

Then two images are synchronously captured by the two digital cameras. Unfortunately, the cameras used in experiments cannot be controlled with the program we coded. So, one of the computers commands that the latest image be processed.

We adopt a pattern matching procedure shown as follows to track the 2-D motion. Eleven-pixel square images around these points for attention are defined as reference patterns. Then, the patterns scan matching areas in the following input image, which include about 40×40 pixels around the points for attention in the former image. At each position, squares of intensity differences between the reference patterns and matching patterns in the matching areas are summed. We assume that the points for attention are moved to the points, where the summations are minimum, and the reference patterns are replaced to the patterns around the new points for attention. These procedures are concurrent for two mobile computers and repeated for following input images. Two 2-D position data contribute the triangulation and the 3-D movement of the building is obtained for a set of input images. With this 3-D information, the rescuer could judge whether the building is falling further or stable.

A remarkable advantage of this system is that each mobile computer can independently measure the 2-D motion of the building, and we can keep a digital camera from another. With RS-232C cable, the distance between the cameras can be 15m. By using modems, we can greatly expand the distance. Its portability is also advantageous to the practical use.

3 Experimental Results and Discussions

We used a frame model made by aluminum bars to evaluate the performance of this system and made it deform. Figure 5 shows a frame object in the following experiment. The object was 0.52m wide, 1.31m deep, and 0.91m high. Sheet with a periodical pattern is pasted on the object to ease

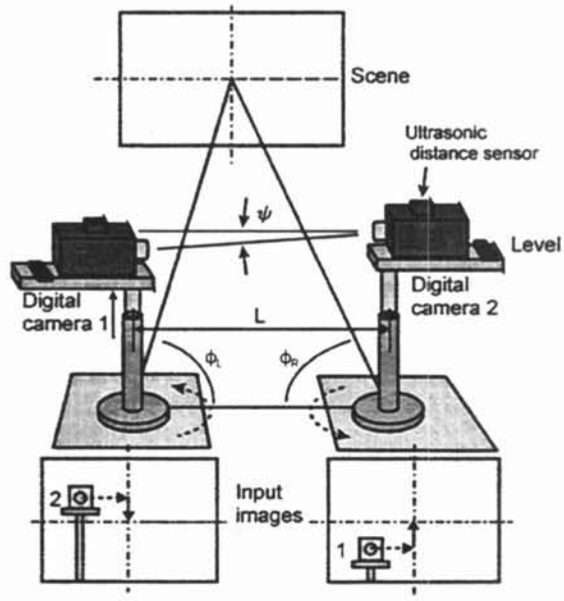


Fig.4 Calibration of camera direction

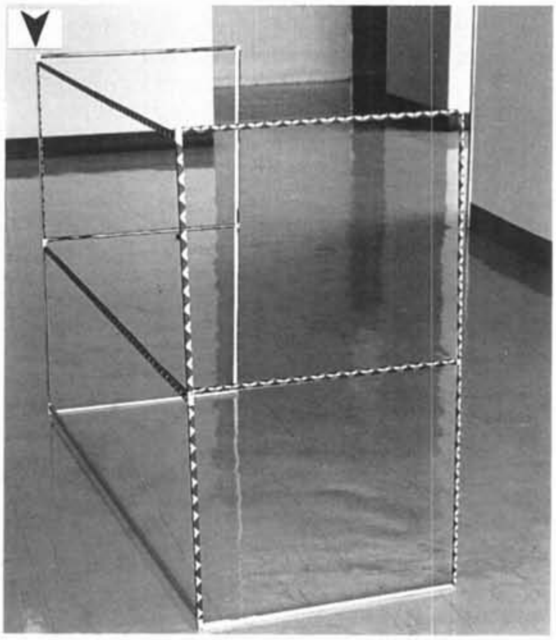


Fig.5 Frame object used in experiment

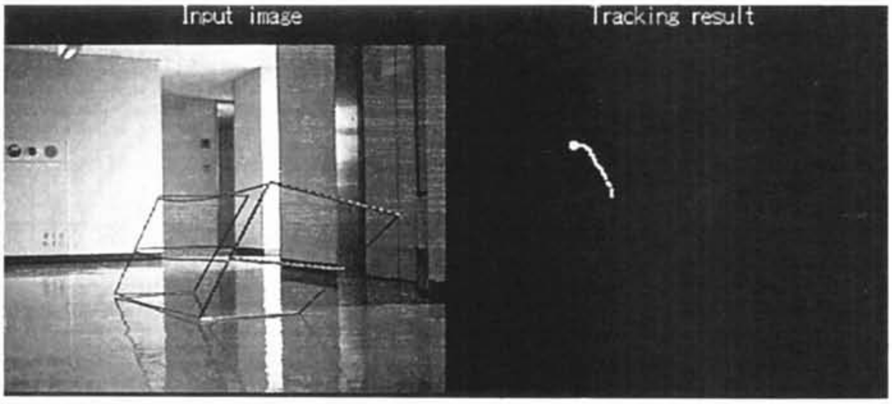


Fig.6 Tracking result of 2-D motion with a mobile computer

the pattern matching. The baseline length L and pan angles of cameras, ϕ_1, ϕ_2 were set at 2.12m, 70deg, 70deg, respectively. A time interval of image acquisition was 1sec. We appointed a point for attention, as shown in Fig.5 by an arrow. We tied a fine thread to a bar and pulled it to make the structure deform.

An experimental result of the 2-D motion measurement with the left digital camera is shown in Fig.6. The number of total input images to a computer was 73. The left image indicates the last input image and dots in right side indicate the locus of the point for attention. The big dot in right side indicates the point for attention in the first image. It is confirmed that we can track a point from frame-model images taken once per second. The 3-D movement was calculated with these 2-D position data. Three-dimensional motion calculated with the triangulation is shown in Fig.7. It was detected that the structure collapses toward the tracking system.

Let us consider the measurement accuracy. It is believed that the measuring range d from the baseline and baseline length L influence the accuracy of the measured distance. Let the pixel interval of a CCD device and the focal length of a camera lens be p_c and L_F, respectively. The resolution R_t and R_d in the transverse distance and object distance, is determined as follows.

$$R_t = \frac{p_c d}{L_F} \tag{1}$$

$$R_d = \frac{2 p_c d^2}{L_f L} \tag{2}$$

With the values of p_c=0.01mm and L_F=5.7mm for the digital cameras used in the system, and L=1.06m, R_t was 8.8mm and R_d was 41mm, at d=5m.

Calibration error also brings measurement error. The measurement errors in L, ϕ_L, ϕ_R, ξ_L, ξ_R all contribute to the error of the 3-D position. However, the ultrasonic distance sensors and levels could not be procured in the experiment, so the influence of the calibration error was not available in this time.

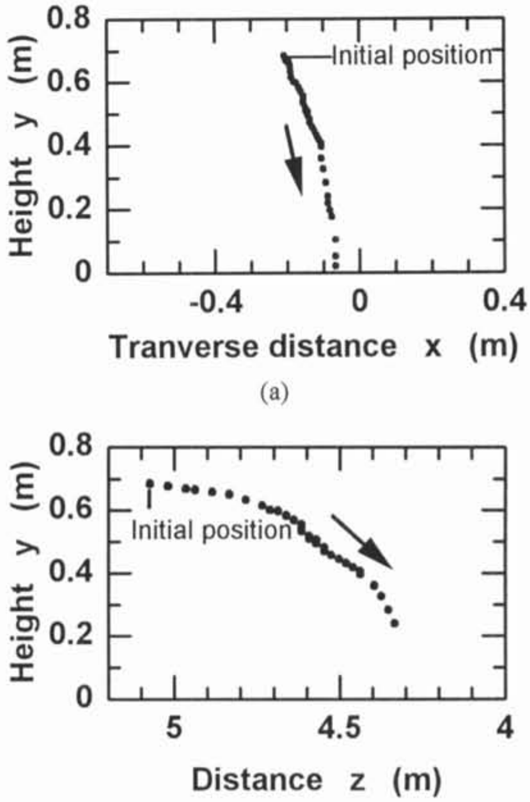
4 Conclusions

We have proposed a new mobile tracking system of the 3-D motion of devastated buildings for rescue work. The performance was checked and it was confirmed that the 3-D motion of a frame object could be certainly tracked with the tracking system.

The proposed system has the following advantages.

(1) It is easy to set the apparatus, measure with it, and move it by oneself, so it can be effectively used when disasters occur.

(2) As an RS-232C serial cable can be extended over tens of meters with modems, we are able to apply this system to monitoring of huge structures.



(b)

Fig.7 Three-dimensional motion of frame object
(a) Motion in x-y plane
(b) Motion in z-y plane

Some room for improvement remains, especially in calibration procedure and camera interface.

Acknowledgments

The authors wish to thank Prof. Minemoto of Kobe University and Dr. Jitsumori of Mitsubishi Electric Corp. for their valuable advice and discussion.

References

[1] G.Abe, M.Aritoshi, T.Shimazu, and M.Sugimoto, "Development of Easy-Operation Type Rescue Machine" ,Proc.15th Annual Conf. of Robot Society of Japan, 3F14(1998), in Japanese.

[2] K.Sato and S.Inokuchi,"Range finding input system based on space-encoding", Trans. IEICE,J68-D,3, 369 (1985), in Japanese.

[3] S.C.Thomopoulos, and L.Nillson,"3-D motion tracking using stereo camera and range radar", Proc.SPIE, 1260,10(1990).

[4] N.Kita, S.Rougeaux, Y.Kuniyoshi, and Sakane," Thorough ZDF-based localization", Proc.MVA'94, 190(1994).