DRSTEREO- A Stereo Measurement System for the PC

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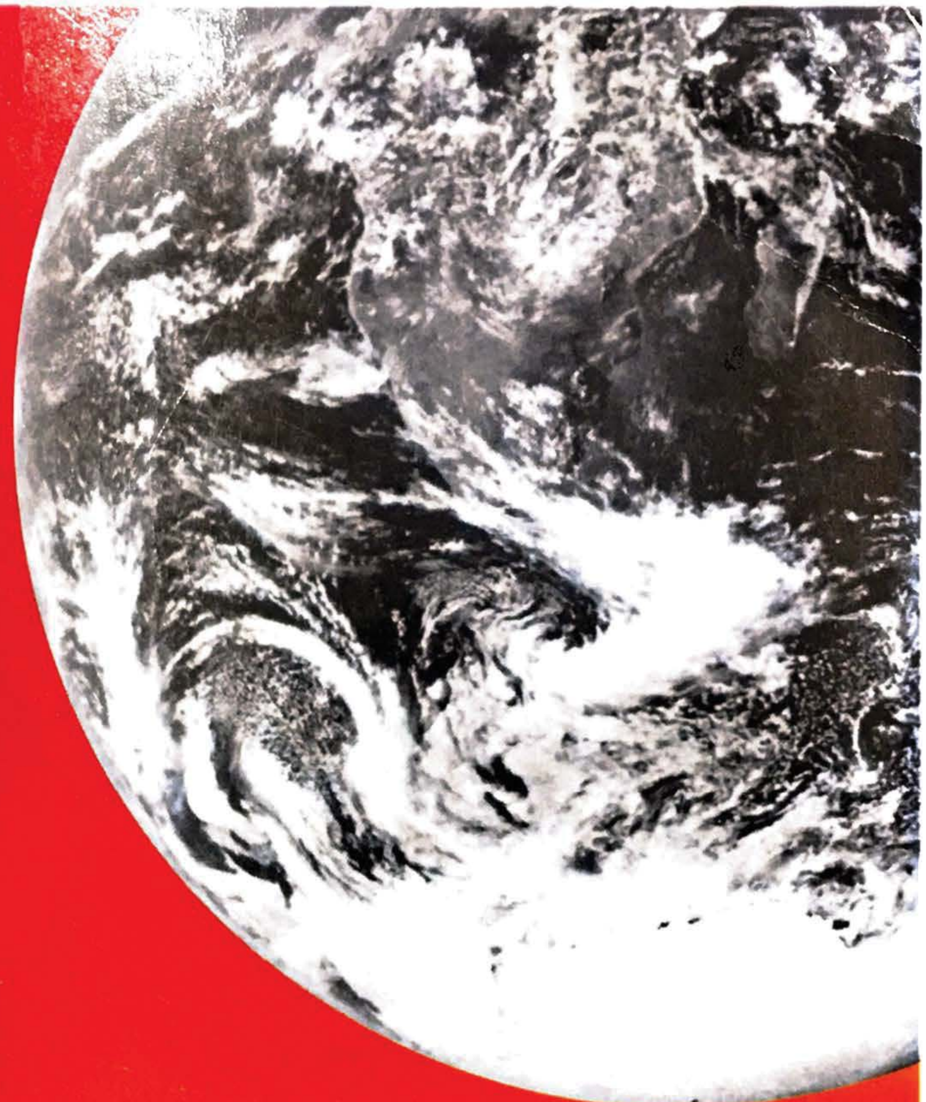

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DRSTEREO - A STEREO MEASUREMENT SYSTEM FOR THE PC

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ABSTRACT

DRSTEREO is a software package that is being developed to support video documentation of engineering construction. Stereo images acquired with a camcorder can be displayed on a VGA screen, and quantitative measurements such as heights, locations, distances, surface areas, and volumes can be measured using Dr. Stereo. Latest techniques in computer vision and photogrammetry will be incorporated into Dr. Stereo to assist the users in performing metric measurements. Test images acquired with a stereo camcorder system that has a base separation of 60 cm. Measurement accuracy better than 2 cm at distances up to 12 m were achieved.

INTRODUCTION

Recent research have clearly demonstrated that accurate geometric measurements can be made from video cameras equipped with charge-coupled-device (CCD) as focal planes (El-Hakim, 1986; Maas, 1991; Wong *et al*, 1992). Measurement accuracy better than 1 picture element (pixel) at the focal plane is now routinely achieved. At the same time, low-cost CCD video cameras called camcorders are fast becoming as common a household item as 35-mm cameras. The excellent geometric fidelity of these cameras, couple with their low costs and ease of operation, makes them an ideal tool for the video documentation of engineering construction.

DRSTEREO is a software package that is being developed to support video documentation of engineering construction. Stereo images of a portion of a construction site, or a part of a building, can be displayed on a video screen and viewed in three dimensions with the aid of a simple stereoscope. Quantitative measurements such as heights, locations, distances, surface areas, and volumes can be performed by simply moving a measuring point on each of the two images. The principle goal of DRSTEREO is to combine the cognitive and interpretive skills of an human operator with the computational power of a computer to facilitate the extraction of both qualitative and quantitative information from video images.

This paper will present the design objectives and current status of Dr. Stereo, as well as some test results that have been obtained with a stereo camcorder system.

DESIGN OBJECTIVES

The specific design objectives of Dr. Stereo are:

1. for use on personal computer (PC) equipped with a VGA monitor;
2. digital image of any array sizes;
3. stereoscopic viewing with the aid of a simple stereoscope;

4. independent movements of a pointing cursor in each image;
5. menus to assist users;
6. algorithms for: camera calibration, camera orientation, image matching, target centroiding, model scaling and rotations, and computing object–space coordinates;
7. file handling capability;
8. sub–pixel measurement accuracy on image plane.

CURRENT STATUS

Dr. Stereo is still in a stage of active development. Sufficient progress have been made to permit testing with actual images. Specifically, the display and measurement functions of the program are now fully functional. Figure 1 shows the general flow of the operational scheme, and Figure 2 shows the display format. A VGA monitor can display 640(horizontal) x 480(vertical) pixels at 16 different intensities. A good quality video image from a camcorder can typically consist of 512x512 pixels with 256 levels of gray intensities. It is therefore not possible to display two entire 512x512 images of a stereo pair side by side on a VGA screen at 256 levels of gray. As a compromise, it was decided to display only a portion of the two images at a time. In Figure 2, each image window consists of 300x260 pixels at 16 different gray levels. Different portions of the two images can be displayed on user command. There is no limit on the array size of the two digital images. This compromise on display resolution provides a good stereo model of the area of stereoscopic coverage when viewed through a mirror stereoscope, which can be mounted on a tripod and positioned in front of the monitor.

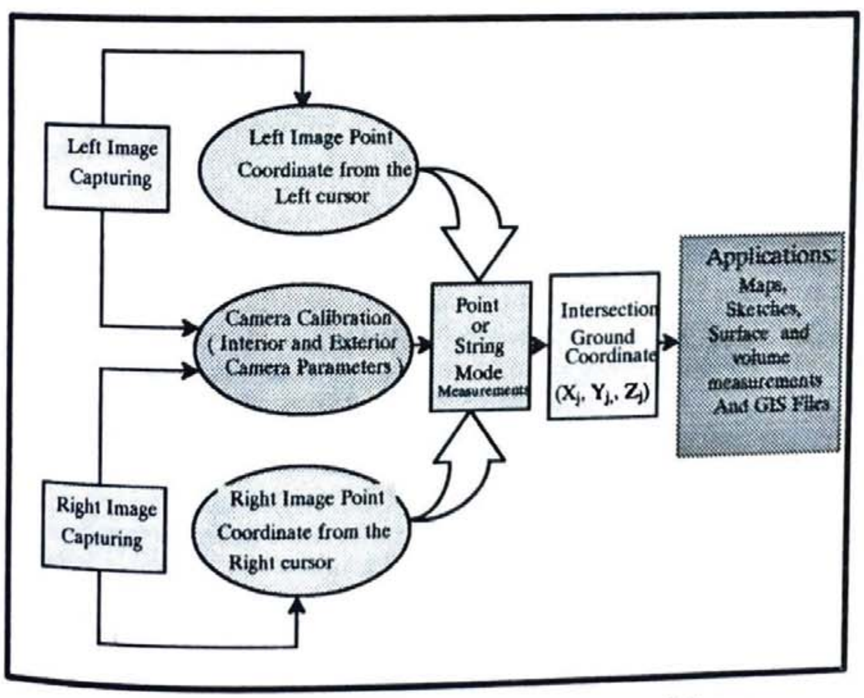

Figure 1: DRSTEREO Coordinate Measurement Scheme.

A point cursor, consisting of a single pixel and is red in color, is provided for pointing in each of the two display windows. The two cursors can be made to move either together or separately. The following procedure is used to measure object–space coordinates from a stereo pair of images:

1. display the common overlap area of the two images;

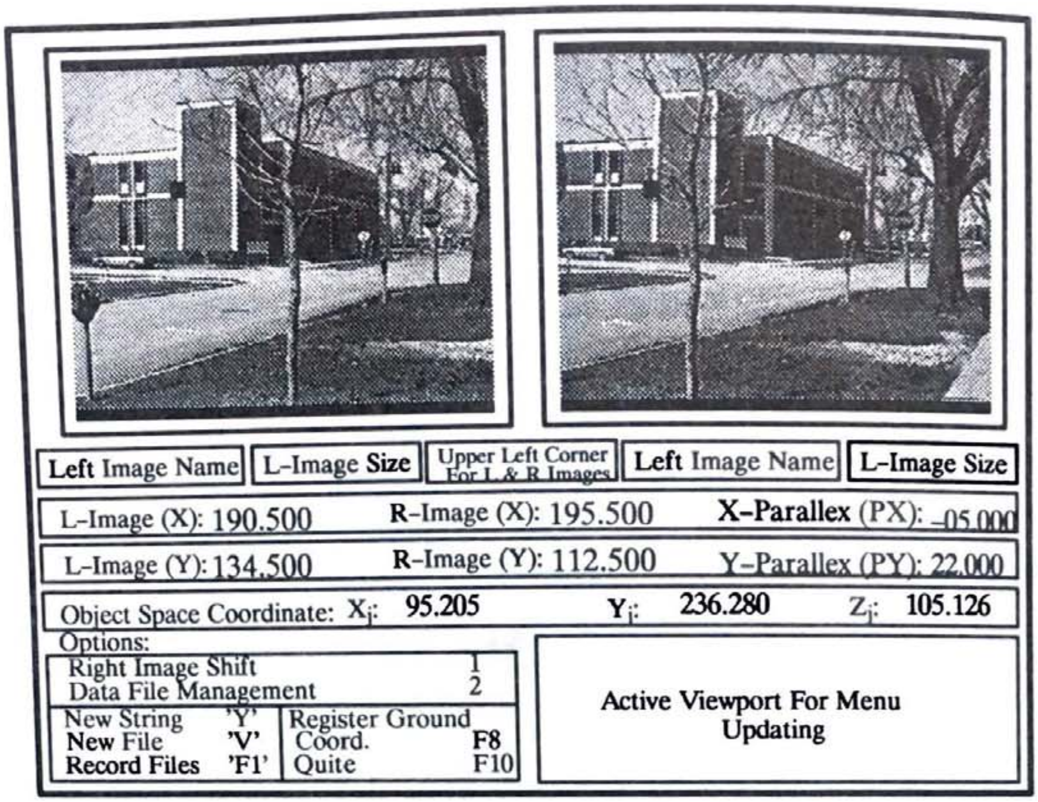

Figure 2: DRSTEREO Main Display Menu
(■ represents the two movable cursors in the left and right images)

2. either enter the camera orientation parameters through an on-screen menu, or specify the names and locations of the files that contain these information;
3. move the cursor in left image window to the desired image point;
4. move the cursor in the right image window to the conjugate image point;
5. press a command key to either display the 3-dimensional object-space coordinates of the point, or to record the coordinates onto a specified files;
6. repeat steps 3 to 5 for as many points as desired.

The data points can be recorded individually point by point, called the point mode, or as a continuing sequence of points, called the string mode. Comments and codes can also be entered with each point. Thus, data collection is conducted in the same manner as total station surveys in topographic mapping.

In step 3 and 4 above, the two cursors can be positioned in the two windows either monoscopically or stereoscopically. A least-squares correlation algorithm has been coded and tested outside of Dr. Stereo, and will be implemented to provide computer assisted correlation to place the right cursor to sub-pixel accuracy.

Software for camera calibration, relative orientation, and absolute orientation have all been developed, and will be incorporated into Dr. Stereo package.

TEST IMAGES

In order to test the measurement functions of Dr. Stereo, test images were collected with a stereo camcorder system. See Figure 3. Two Sony CCD-F55 video camera recorders were mounted on a fixed base, about 60 cm apart, to provide stereo images that are normal to the base. Tilting stages permitted alignment of the two focal planes so that the epipolar lines coincides with the rows in the two focal planes (Wong and Lew, 1990). The focal planes of the two cameras measured about 16.9 mm along the diagonal and consisted of 250,000 effective pixels. The cameras were equipped with a 8x powered zoom lens, which had a range between 8.5 mm and 68 mm. For the purposes of this experiment, the zoom lenses were locked at a focal setting of 8.5 mm for both cameras. The stand on which the two cameras were mounted was placed on a rolling platform. Before using the camera system to capture images, it was first positioned in front of a three-dimensional control field and images recorded of the control field. See Figure 4. These images were used later to determine the interior and exterior orientation parameters of both cameras (Wiley and Wong, 1992).

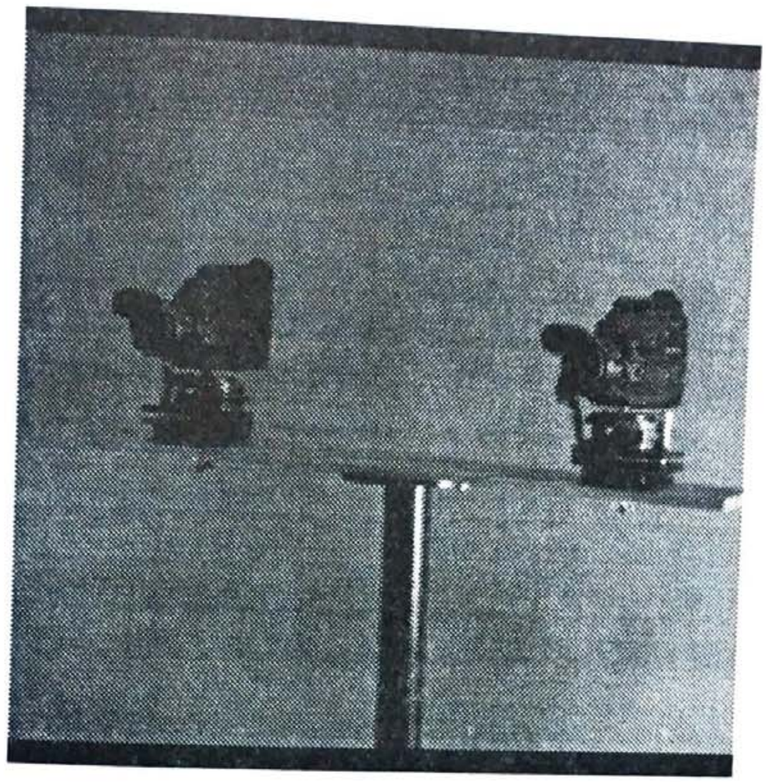

Figure 3: Stereo Camcorder setup

The rolling camera platform was then moved around, and images were recorded of scenes located both indoor and outdoor.

A Zenith 16-Mhz 386/AT, equipped with an EPIC frame grabber, was used to digitize the video images. The Sony camcorder was connected to the frame grabber through a video connection. With the camera operating in the playback mode, individual images were captured on command from the computer keyboard. The resulting digital images each consisting of 1040(H)x480(V) pixels in 256 levels of gray. Shown in Figure 2 are portion of a stereo pair of images of an outdoor scene. Thirty-three pairs of stereo images were obtained in this manner.

TEST RESULTS

The interior and exterior orientations of the two cameras were determined using the calibration images. The interior orientation parameters included the image coordinates of the principal point (x_p,y_p), the effective focal length (f), scale differential between the horizontal and vertical directions, one parameter of radial symmetric lens distortion (L_1), and two parameters of asymmetric lens distortions (p_1,p_2). The root-mean-square (RMS) residual errors of the image coordinates of the control points were computed to be ± 0.06 pixels. Thus, excellent characterization of the interior geometry of the two cameras were obtained.

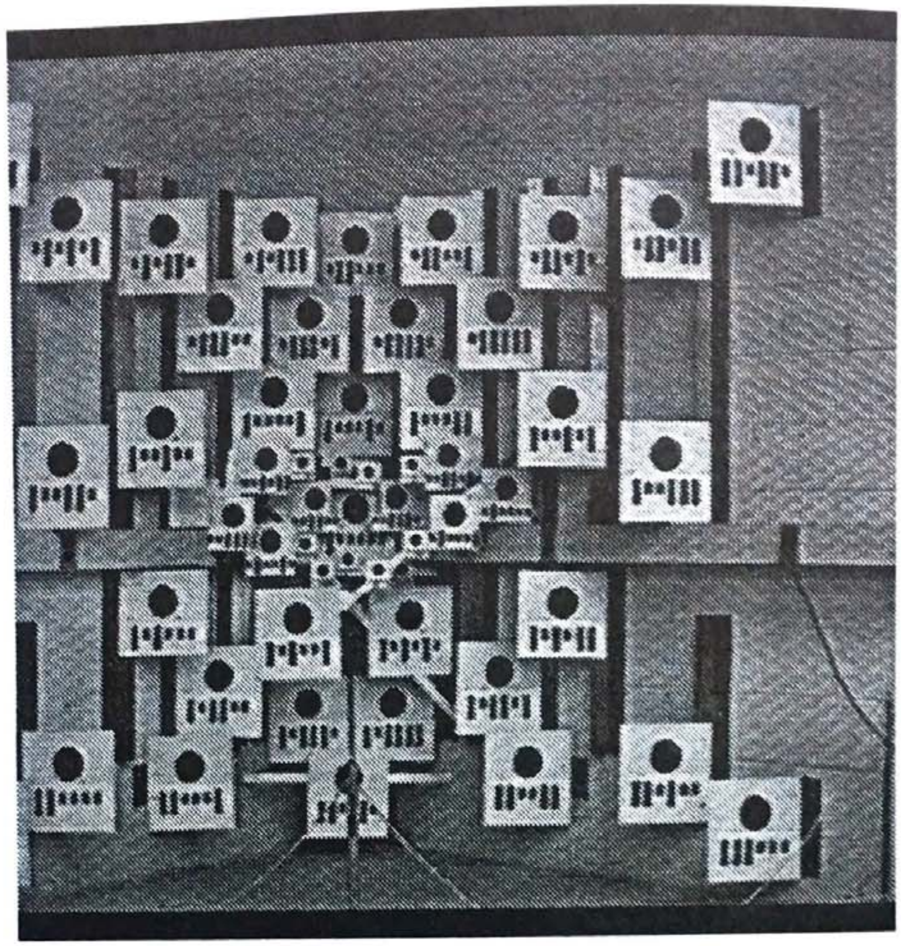

Figure 4: Camera calibration control field

Several dimensions of various objects were measured using the test images and Dr. Stereo. Table 1 compared these measured dimensions with their correct values. Relative accuracy of the measurements ranged from 1/40 to 1/490. The actual measurement errors ranged from 1mm to 23 mm, while the distances of the cameras to the objects ranged from 2.6m to 12m. The small base separation (60 cm) between the two cameras obviously limited the accuracy of depth measurement. It was also be expected that measurement accuracy would degrade rapidly with increasing distance from the camera. Nevertheless, the ability to measure dimensions to mm-level accuracy at distances of several meters is a good indication of the geometric stability of this type of cameras.

This test was conducted primarily to verify the display and measurement functions of Dr. Stereo. It is not intended to be a rigorous test of the accuracy potential of the method of measurement. Obviously, measurement accuracy will depend on many factors including the imaging geometry, geometric fidelity of the cameras, as well as mathematical rigor of the measurement system. More rigorous tests will be conducted as Dr. Stereo is developed.

CONCLUSIONS

Ideally, a video documentation system for engineering construction should be able to automatically generate three-dimensional coordinates of all visible features in the stereo scene, as well as recognizing the status of features that are relevant to the construction process. It would require the capabilities for automatic mensuration and recognition. Such a system will be able to communicate with a data base so that construction progress can be quantified and verified in real-time. Unfortunately, full implementation of such a system is a long time in the future.

Recognizing the technical difficulties of feature recognition as well as the potential role of camcorders in engineering documentation, Dr. Stereo is intended to by-pass the technological bottleneck by making full use of human skills in cognition. While the software is intended for applications in engineering construction, it is expected to find applications in many other fields, including: manufacturing, medicine, archeology, crime and accident investigations, robot control, and bioengineering.

Table 1: Results of some measurements by DRSTEREO

X_j (m)	Yj (m)	Zj (m)	Calcul. Distance (m)	Actual Distance (d) (m)	Diff. in Distance (Δ) (m)	Distance from camera (m)	Relative accuracy (Δ/d)	Descriptions
101.334 101.333	201.928 201.968	101.312 101.039	0.276	0.278	-0.002	3.543	1/140	computer depth
101.003 101.135	202.020 202.017	100.825 100.826	0.132	0.133	-0.001	3.614	1/130	box width
101.285 101.441	201.113 200.917	101.227 101.228	0.251	0.252	-0.001	2.610	1/250	plane control field
101.279 101.349	201.118 201.086	101.151 101.075	0.108	0.107	0.001	2.697	1/110	plane control field
101.279 101.279	201.118 201.112	101.151 100.998	0.153	0.154	-0.001	2.710	1/150	plane control field
101.279 101.070	201.118 201.204	101.151 100.920	0.323	0.322	0.001	2.756	1/320	plane control field
100.318 101.198	205.114 205.312	101.879 101.884	0.902	0.906	-0.004	6.808	1/230	shelf width
100.318 100.330	205.114 205.124	101.879 101.601	0.278	0.277	0.001	6.714	1/280	shelf depth
101.432 101.652	204.574 203.614	101.701 101.701	0.985	0.987	-0.002	5.689	1/490	poster width
101.056 101.964	210.311 210.011	100.892 100.899	0.956	0.963	-0.007	11.756	1/140	corner width
101.488 101.518	210.282 210.488	100.956 102.084	1.147	1.170	-0.023	11.980	1/50	board depth
100.471 101.377	206.205 206.104	100.823 100.833	0.912	0.915	-0.003	7.750	1/310	window width
101.382 101.377	206.231 206.096	102.706 100.820	1.891	1.902	-0.011	7.759	1/170	window depth
101.444 102.524	204.275 204.676	102.057 102.054	1.152	1.163	-0.011	6.071	1/110	width of building sign
101.444 101.459	204.275 204.317	102.057 101.485	0.574	0.590	-0.016	5.891	1/40	depth of building sign

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REFERENCES

1. El–Hakim, S. F., 1986. "Real–Time Image Metrology Using CCD Cameras". *Photogrammetric Engineering and Remote Sensing*, Vol. 52, pp. 1757–1766.

2. Maas, Hans–Gerd, 1991. "Digital Photogrammetry for Determination of Tracer Particle Coordinates in Turbulent Flow Research". *Photogrammetric Engineering and Remote Sensing*, Vol. 57, pp. 1593–1597.

3. Wiley, A. G.; and K. W. Wong, 1992. "Geometric Calibration of Zoom Lenses for Computer Vision Metrology". *A paper prepared for presentation at the XVII ISPRS Congress*, Washington, D. C., August 2–4, 1992.

4. Wong, K. W.; Y. Ke; M. Slaughter; and R. Gretebeck; 1992. "A Computer Vision System for Mapping Human Bodies". *A paper prepared for presentation at the XVII ISPRS Congress*, Washington, D. C., August 2–4, 1992.

5. Wong, K. W.; and M. Lew; 1990. "Stereometric Vision". Technical Papers 1990 ACSM–ASPRS Annual Convention (Denver, CO; March 18–23), Vol. 5, pp. 128–136.