SINGLE CCD CAMERA BASED THREE DIMESIONAL MEASUREMENT SYSTEM FOR MOVING OBJECT

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ABSTRACT

This paper presents a sub-realtime 3-D coordinate measuring system with single CCD camera for a moving body .The signalised points of a moving body can be realtime-tracked and realtime -recorded in 50 times per second . A double light-paths collecting device which is placed in front of a CCD camera , is used to capture the stereoscopic image of a moving body . For 3-D measurement, the steroescopic pair can absolutely keep the synchronism of double-images . The double light-paths collecting device can be a simple double-reflecting mirrors orimaging optical-fiber device. The videoimage signal digitized with a A/D converter and input a micro-computer image processing system, which is used for the determination of feature points and the derivation of coordinated .A 3-D closed-range testfield is used for the detemination of the interior and exterior orientation of the camera and of parameters of lens distoration. The signalesed points on moving body are detected by automatic match algorithm with subpixle accuracy .This system has been using for the study of human gaits .Using simple reflecting-mirrors device in 5 meters view field, the accuracy of the first test can be as point nought five percent.

KEY WORDS: Computer Vision, Pattern Recognition, Image Match, Stereo-Photographing, CD Camera, Sub-Pixel Detect, DLT-Direct Linear Transformation.

1. INTRODUCTION

The recent developments in the fields of pattern recognition and computer vision open a new way to measure and analysis moving objects. The present-day realtime photogrammetry method normally adopts two and more TV or CCD cameras to perform stereophotography, and then the 3D-coordinates of the object points are derived by image matching. But this method has not yet popularized because of the complexity of the derivation by image match and mass amount of data to be processed. In practice, we can simplify this method according as the requirement for a analytical task. For example, for simplifiesthe mast complex steps of image matching, the relevant characteristic points an the body are marked by surtable pattern, and illuminated by fiashing light sources, whose direction of emission is coaxial to TV cameras and the realtime detecting and recording this signing points, The trajectories of little points describe the movement of the body.

Since seventies , the research of the motion analysis system has been very quick developed along with advanced of the computer technic. So far as based technic method , as stated above , they are based on the theory of the stereo-photogrammetry , which extracted 3D-coordination of the feature points from dynamic images of the moving body. There are typical systems , example SELSPOT system of Swedish (Woltring and Marsolais , 1980), VICON syatem of England Okford Company (Jarrett et al, 1976), Elite system of Italy (Ferrigno and Pedotti, 1985) , and Coda system (Mitchelson, 1975) . The new commercial product uninterruptelly push out. These systems have the high-grade headware, and the function of the software has been improved step by step. But they are expensive , therefore not yet popularized in the developing countrys.

In this paper a motion analysis system, which has a simpler compose and a completer function than abovementioned system, will be described. In this system a CCD state matrix camera , front which attached a double light-paths collecting device, is used to capture the stereo images of a body. These stereoimages of the moving body can be realtime recorded and restored as high quality by a recorder, and with a A/D converter inputed to a micro-computer image processing system-CVGR system('Computer Vision for Graph Reading' be called sth CV2. Lin Zongjian and Lu Jian et al, 1991). Because of stereoimages are got by a CCD camera, this two images were keep absolutely the synchronism, that it is benefit to survey for the moving body . CV2 system has multifunctional software, that can used to detect the marked points of the moving body with subpixel accuracy , to correct geometric distoration of the stereoimage, to perform 3D-coordinates derivation, and to analyse for the moving trajactories. This system now being used for the study of human body motion, and obtain the moving trajectories of the joints on the four limbs, when the human is walking, running, and jumping. When a field of view is 2.5m, this system can be to observe a complete cycie of human gaits. The accuracy of the surveying coordinates can be as point nought five percent on the first test . This system is desigened as a low cost system.

2. SYSTEM COMPONENTS

This system can be composed of a CV2 system added to a double light-path collecting device and a image recorder . CV2 is designed as a low cost system . The main hardware configguartion of it comprises :

- -- A personal computer Super 286
- -- A video frame grabber -- WTSM-CV2 board
- -- A CCD camera - GOOD LR-1002
- -- An image color monitor CTX
- -- A double light path collecting device
- -- A video image recorder

The systems is shown as Fig. 1.

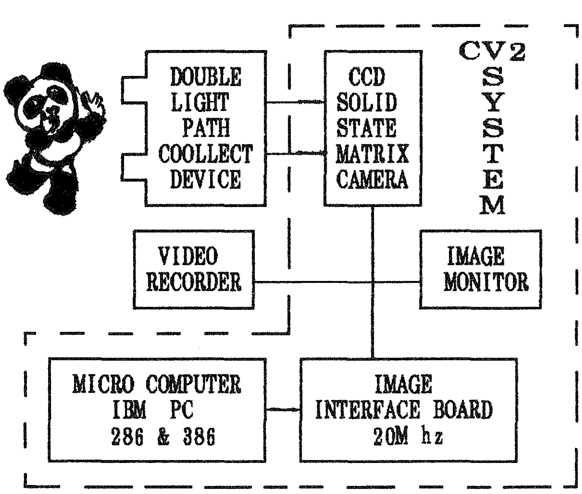


Fig. 1 System Componant

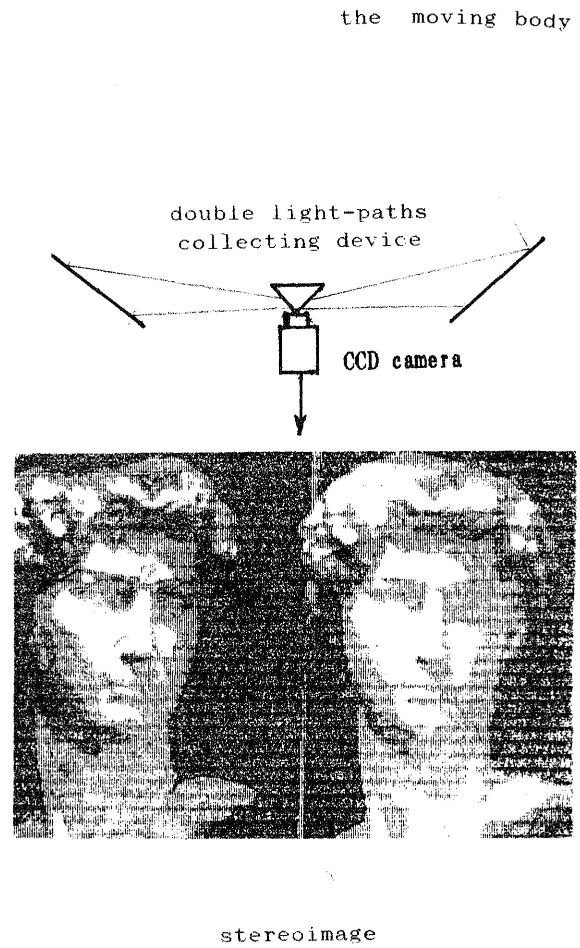


Fig. 2 Double Light Path Structure

2.1 Double Light-path Collecting Device

The structural principle of double light-path collecting device is shown as Fig. 2. A simple test device can compose of double-reflecting mirrors and prism parts, or assemble with imaging optical-fibers. Obvious in later case light path of object can be seted flexibly from most favourable observable direction.

2.2 Camera

The camera adopted are of the solid state CCD type, which allow the best definition in the images at working speed of 50 places per second. In addition a image recorder used to save and restore the image information with high quality.

2.3 Signal Converter-Board A/D and D/A (A Video Frame Grabber)

It is used for transferring the video signale acquired by CCD camera to the digitized from and for the simultaneous display of the image on the monitor. It has four 512*512*8 bit image frame memory blocks. The digital images obtained by CCD cam ra or from disk can be registered in one of the memory blocks and both be directly displayed on the monitor and processed in the computer. At present , a new multimedia board has be used to input image from recorder.

2.4 Main Software

The basic operation package which consists of ninety four subroutines, provided for constructing application programs . The programs written

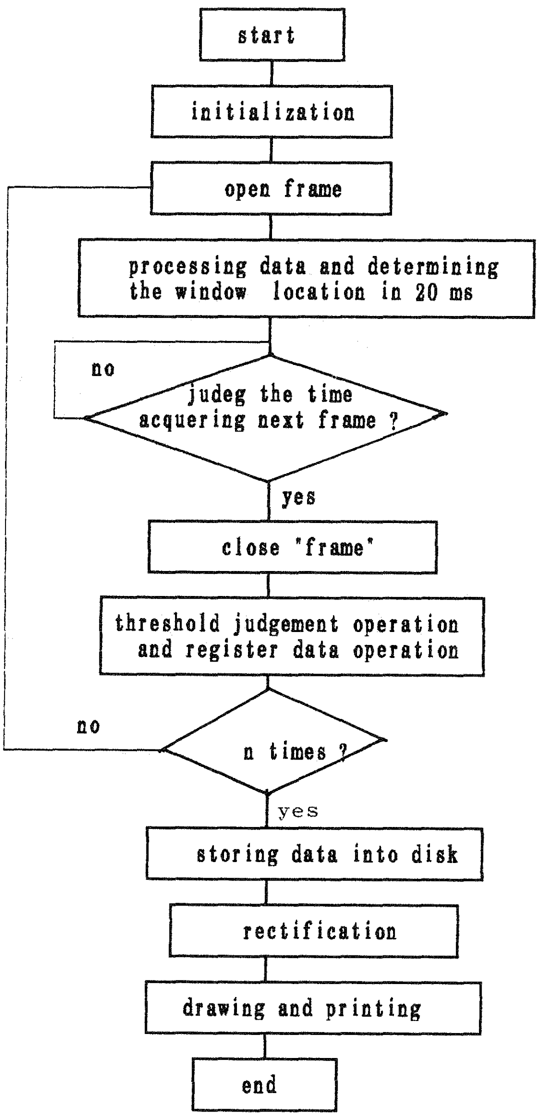


Fig. 3 Operation Procedure 1

with IBM-PC 8088 ASM, FROTRAN-77 and Turbo PASCAL have been provited for the function of the real-time tracking of the signning points, of the match feature point, of the registration of data, of the analysis of restoration, of the calculation of 3D-coordinate , and of the analysis of motion track.

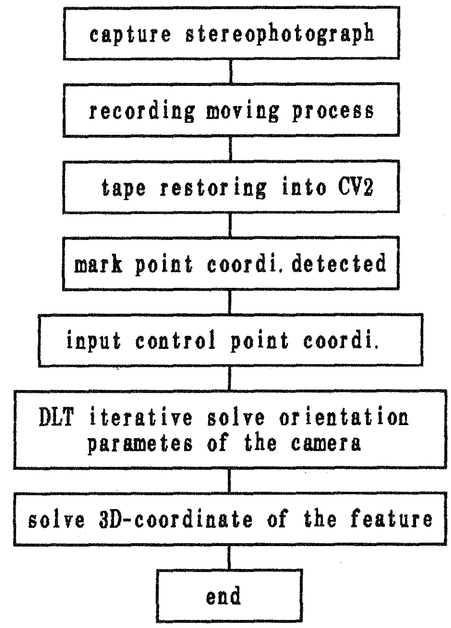


Fig. 4 Operation Procedure 2

3. OPERATION PROCEDURE

This system has two oprational modes:
1. Realtime tracking and recording of the marked points, then to derive and analyse of the coordinate. The procedure is shownFig. 3.
2. Rrecording video image signal , then restore image by a recorder and inpute into computer for processing and analysing. The procedure is shown in Fig. 4 .

4. SEVERAL PROBLEMS

4.1 Camera Calibration

4.1.1 The 3D-Control Field For geometric calibration of the this system, a three-dimension close range testfield is built. The testfield consists of 20 targets arranged in a wall and two vertical pillars (shown in Fig. 5). The coordinates of the marked control points are determined by intersection of directions measured by two 2" theodolites located six metres from the test field. Each control point has 3D-coordinates with accuracy of 0.3 mm. This control field is used for the calibration of CCD camera.

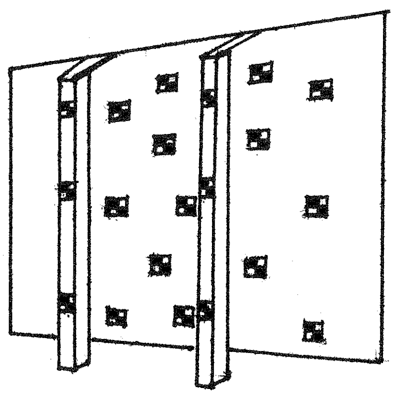
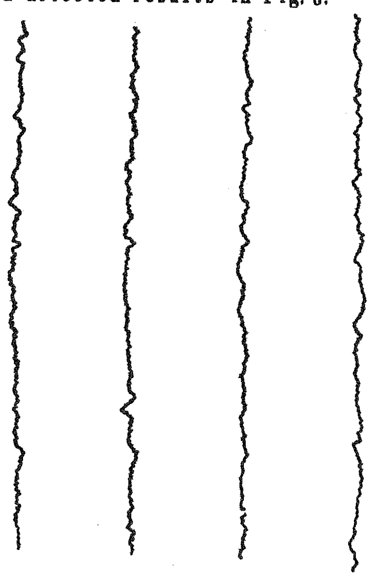


Fig. 5 A three dimension control field

4.1.2 Line Jitter Test

Line jitter is caused by the horizontal line synchronization error. In the "plumb-line" test, the maximum line jitter error of GOOD LR-1002 CCD camera has been detected about 0.25 pixel in X direction. The RMS (root mean square) is about 0.08 pixel. In this test we are used four plumb-lines, and detected results in Fig. 6.



Line No.	No. 1	No. 2	No. 3	No. 4
Max. residual	.251	.250	.165	.243
Min. residual	.079	.078	.070	.073

Fig. 6 Line Jitter Detected Results

4.1.3 Calibration of Geometric of CCD Camera

(1) Calibration of the interior and exterior orientation parameters.
The interior and exterior orientation parameters can be determined by DLT or spatial resection.
(2) Calibration of lens radial distortion.
In order to reduce the lens radial distortion, the following correction function is added in DLT equation :

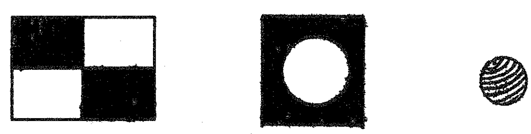
$$dx = k1 \cdot (x-x0) \cdot r^2$$
$$dy = k1 \cdot (y-y0) \cdot r^2$$

where, $r^2 = (x-x0)^2 + (y-y0)^2$, k1 is the lens radial distotion coefficient. By calculation, k1 is obtained about 10^{-7}.

4.2 Mark Point Location

4.2.1 Mark Pattern Design

In the test selected the mark pattern show Fig. 7. The test results show, that using pattern (a), the accuracy of location is highest. The pattern (b) for seting it on the moving body is easy and it can located with sub-pixel the precision. The pattern (c) is made of a small plastic ball with diameter 8 mm, pasted with a reflecting paper. It has strong reflectance under a general illumination by artificial light. On its image the s / n ratio is higher. The system with uncoded passive markers allow the analysis of a great number of markers.



(a) (b) (c)

Fig. 7 mark pattern

4.2.2 Mark Detecte Algorithms

The measurement accuracy of the 3d- coordinate is depend on detecte accuracy of feature point in the image. Therefore center coordinates of the mark must be located with the sub-pixel precision. The system has one important feature, that is the mark detection algorithms, which work on the shape and size of the mark rather than on their brightness. IT used Multistage Matching-Fitting Method (Fig. 8), which consisted of following algorithms.

-- Mark Pattern Match

-- Weighted gravity center algorithms .
-- Gradient Parabolic Interpolation
-- Sample Moment Match
-- Least Squares Straight-line Fitting

The test results show that , for location mark of the control point using the mark pattern match and least squares straight-line fitting algorithms, the precision of location is higher, for location mark of the feature point on the moving body using the weighted gravity center algorithms the precision of location is satisfactory and the computing is easy and stable .

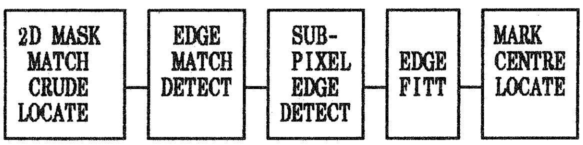


Fig. 8 Mark Point Detected Procedure

4. 3 Objective Points Positioning

The equation of 3D-DLT (Direct linear transformation) can be written as :

$$x+k1*(x-x0)*r2-(L1*X+L2*Y+L3*Z+L4)/(L9*X+L10*Y+L11*Z+1) = 0$$
$$y+k1*(y-y0)*r2-(L5*X+L6+Y+L7*Z+L8)/(L9*X+L10*Y+L11*Z+1) = 0$$

if all signing points are the same plane , which vertical with the light axis of the CCD camara, the equation can be transformeted into 2D-DLT equation:

$$x+k1*(x-x0)*r2-(L1*X+L2+Y+L3)/(L7*X+L8*Y+1)=0$$
$$y+k1*(y-y0)*r2-(L4*X+L5*Y+L6)/(L7*X+L8*Y+1)=0$$

5. TEST AND CONCLUSIONS

The some primitives tests have been performed for study human movement, as shown in the Fig. 9 and Fig. 10. On Fig. 9 some trajectories of feature points on a moving human is exhibited. Here (a), (b) and (c) respectively is walking, running and jumping. On Fig. 10 some analysis results is shown , here (a) is the stick diagram when a human running, (b) is a angle-time picture of knee, (c) is a angle-time picture of ankle.

By adopting this system and its moving object surveying method, the sub-realtime measurement of the moving body can be realized. It can also perform the description of the loci, velocity and acceleration of the movement of the body. The initial experiment on the human gait measurement has indicated that this system can fulfil the requirement of medical analysis .

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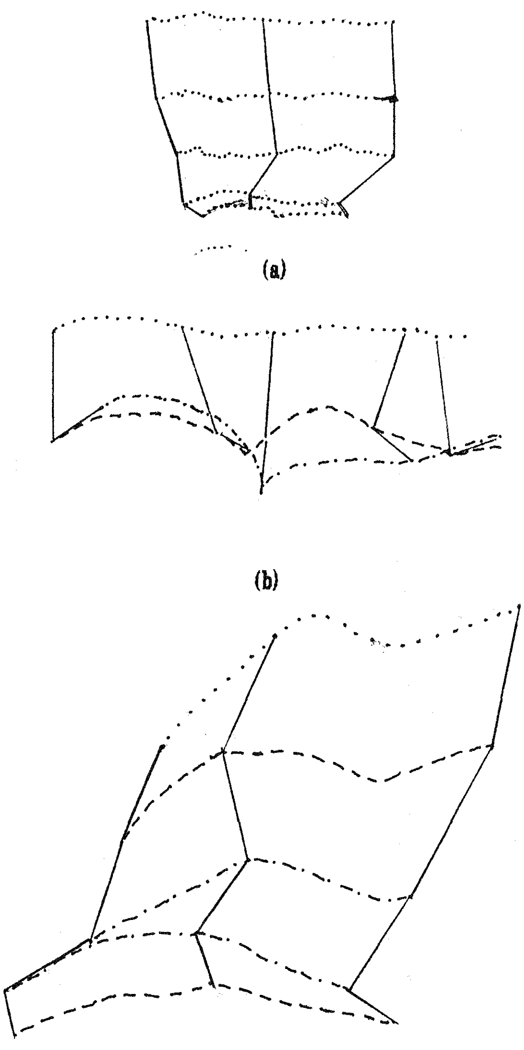
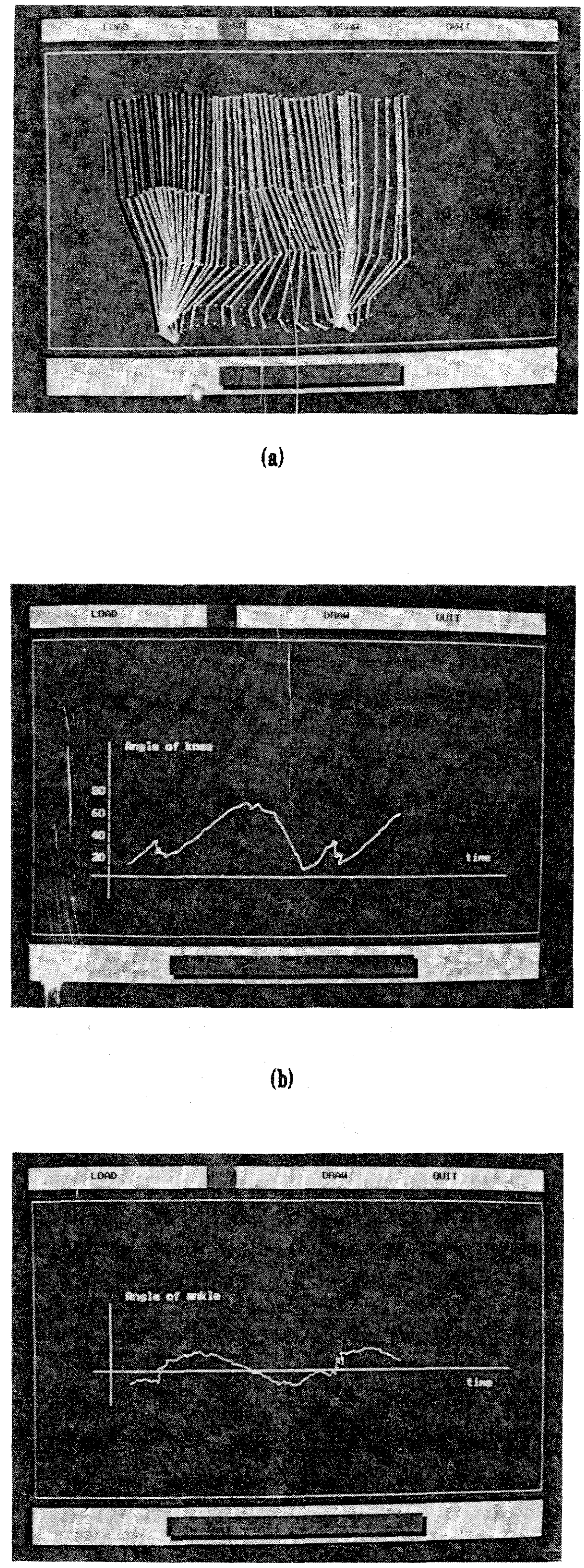


Fig. 9 Trajectories of feature points on a moving human



(c)

Fig. 10 Analyze results