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Photogrammetric Transformation with Panning

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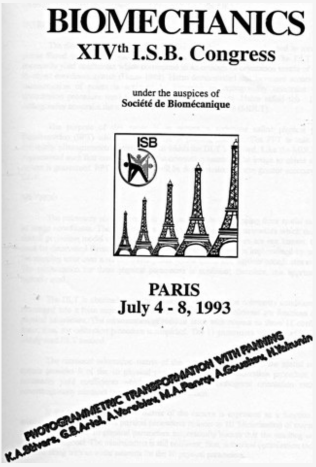

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Photogrammetric Transformation with Panning

This article by K.A Stivers, G.B. Ariel, A. Vorobiev, M.A Penny, A. Gouskov, and N. Yakunin from the International Center for Biomechanical Research, presents a new technique called physical parameter transformation (PPT) which allows the use of panning cameras. The PPT is built upon the colinearity photogrammetric relations from which the direct linear transformation (DLT) is derived.

The DLT is a commonly used technique to locate spatial points filmed with two or more cameras. However, it does not necessarily yield coefficients which correspond to an orthogonal orientation matrix of the image to object coordinate system. The PPT, like the modified direct linear transformation (MDLT), is implemented such that orthogonality of the orientation matrix of the image to object coordinate system is guaranteed.

The article demonstrates that PPT with panning has greater accuracy than the DLT. The PPT may easily accommodate panning cameras if the displacement of the camera relative to its calibration position is known. The PPT with panning yields about one sixth the DLT error in reconstructing the noncalibration object, showing better extrapolation characteristics than DLT for the test data.

The article concludes that the PPT with panning was more accurate than the DLT, probably due to the increased digitizing resolution made possible with panning and the PPT's satisfaction of the orthogonality condition.

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PHOTOGRAMMETRIC TRANSFORMATION WITH PANNING

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INTRODUCTION

The direct linear transformation (DLT) is a technique commonly used to locate spatial points filmed with two or more cameras. (Marzan and Karara, 1975). The DLT does not necessarily yield coefficients which correspond to an orthogonal orientation matrix of the image to object coordinate system (Hatze 1988). Hatze demonstrated that increased accuracy for the reconstruction of points is achieved by imposing an orthogonality constraint upon the optimization procedure used to obtain the DLT coefficients. Hatze called this DLT with orthogonality constraint the modified direct linear transformation (MDLT).

The purpose of this paper is to present a technique called physical parameter transformation (PPT) which allows the use of panning cameras. The PPT is built upon the colinearity photogrammetric relations from which the DLT is derived. Like the MDLT, PPT is implemented such that orthogonality of the orientation matrix of the image to object coordinate system is guaranteed. PPT with panning will be demonstrated to have greator accuracy than the DLT.

METHOD

The colinearity photogrammetric relations provide the mapping from spatial coordinates to image coordinates. The mapping is a function of 16 physical parameters which describe the central projection model of a camera. In general the 16 parameters are not known; thus, they must be determined through a calibration procedure. Calibration is implemented by minimizing the mapping error over a set of control points whose spatial and digitizer coordinates are known. The minimization for these physical parameters is nonlinear; therefore, this approach is not typically used.

The DLT is obtained from the colinearity relations. The colinearity conditions may be rearranged into a form requiring 11 coefficients. These 11 coefficients are functions of the 16 physical parameters. The minimization of residual error with respect to these 11 coefficients is linear; thus, the calibration procedure is simplified. The 11 parameters are the coefficients of the widely used DLT method.

The rotational orientation matrix of the camera with respect to the spatial coordinate system provides 9 of the 16 physical parameters. The DLT calibration procedure does not necessarily yield coefficients which correspond to an orthogonal orientation matrix. This nonorthogonality increases error in spatial reconstruction.

If the rotational orientation matrix of the camera is expressed as a function of three suitable angles, the number of physical parameters reduces to 10. Minimization of mapping error with respect to these 10 physical parameters automatically insures that the resulting orientation matrix is orthogonal. The minimization is still nonlinear; thus, numerical optimization technique is required along with an initial estimate for the 10 physical parameters.

The 10 physical parameters may be expressed as functions of the 11 DLT coefficients; thus, the DLT provides a good initial estimate for the 10 physical parameters. Newton's method was employed to iterate from the initial estimate to the 10 optimum physical parameters.

This photogrammetric procedure involving 10 physical parameters is called the physical parameter transformation (PPT). Like the DLT, once the mapping parameters are known for two or more cameras, spatial locations of points whose digitizer coordinates are known may be obtained by solution of a linear system.

The PPT may easily accommodate panning cameras if the displacement of the camera relative to it's calibration position is known. In addition to the camera's orientation matrix, the location of the projection center provides three physical parameters which may vary with the panning angle. Both camera orientation and projection center are transformed via the displacement yielding PPT coefficients for a panned camera position.

In this study, single axis panning was considered. The panning angle was provided by an optical encoder yielding 10 minutes of resolution. Panning axis location and direction were determined by performing 2 normal PPT calibrations corresponding to different panning angles. The two calibrations yield positions of the camera which only differ by a rotational displacement about the panning axis; thus, the calibrations provide enough information to determine panning axis location and direction. Since the displacement may be expressed as a function of panning angle, axis direction, and axis location, the PPT coefficients corresponding to any panning angle about a single axis is determinable. Since the location and direction of the panning axis relative to the panning camera is constant by construction, this special calibration procedure needs to be performed only one time.

Accuracy of the DLT and PPT with panning were investigated by filming two control objects each comprised of 15 symmetrically located points. Each object was 1 cubic meter. Coordinates of all control points were located within 3mm. The two control objects were horizontally translated 3 meters apart. The axis location and direction calibration procedure was performed by calibrating each object.

Three cameras were used. A side panning view and a front still view was used for the panning data. A side still view which was displaced far enough away from the control objects such that all points were visible was used along with the front still view for evaluating the DLT.

The object most positive in x henceforth referred to as the right object was used for calibration in all methods. Accuracy of each method was evaluated by calculating root mean squared error in reconstructing each object.

RESULTS AND DISCUSSION

Reconstruction error of the non calibration object (left object) was 29.8mm and 5mm for the DLT and PPT with panning respectively. Reconstruction error for the right calibration object was 5.4mm and 4.6mm for the DLT and PPT with panning respectively. Since the PPT with panning yeilds about one sixth the DLT error in reconstructing the noncalibration object, PPT with panning has better extrapolation characteristics than DLT for our test data.

CONCLUSION

A photogrammetric data processing technique (PPT) was presented which allows the use of panning cameras. The PPT was developed such that the rotational matrix of the camera is guaranteed to be orthogonal which is not the case with DLT.

For our experimental data, the PPT with panning was more accurate than the DLT. This improvement is probably due to the increased digitizing resolution made possible with panning and the PPT's satisfaction of the orthogonality condition.

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