

Sensors Comparison for Observation of floating structure's movement

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Abstract : The objective of this paper is to simulate the dynamic behavior of a floating structure model, using image processing and close-range photogrammetry, instead of the contact sensors. Previously, the movement of structure was presented through the exterior orientation estimation of a single camera by space resection. The inverse resection yields the 6 orientation parameters of the floating structure, with respect to the camera coordinate system. The single camera solution is of interest in applications characterized by restriction in term of costs, unfavorable observation conditions, or synchronization demands when using multiple cameras. This article discusses the theoretical determinations of camera exterior orientation based on Direct Linear Transformation and photogrammetric resection using least squares adjustment. The proposed method was used to monitor the motion of a floating model. The results of six degrees of freedom (6-DOF) by inverse resection show that the appropriate initial values by DLT can be effectually applied in least squares adjustment, to obtain the precision of exterior orientation parameters. Additionally, a comparison between the close-range photogrammetry and total station results was feasibly verified. Therefore, the proposed method can be considered as an efficient solution to simulating the movement of floating structure.

Key words : floating structure, 6-DOF, space resection, tracking, displacement, DLT

Introduction

Methods to determine the dynamic motion of structure

- Contact type
 - Accelerometer
 - Strain gauges
 - Global Positioning System
- Non-contact type
 - Laser Doppler Vibrometer
 - Image-based method

Non-contact type using close-range photogrammetry

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    graph TD
      A[Floating structure with a target pattern] --> B[Image]
      A --> C[Target matching]
      A --> D[EDF by DLT]
      B --> E[Space resection by collinearity condition]
      C --> E
      D --> E
      E --> F[6 DOF of floating structure]
      F --> G[Comparing with total station]
    
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<Movement measurement procedure by a camera in close-range photogrammetry>

Methodology

Least square adjustment using control points

- Collinearity equations

$$F_1 = (x - x_0) + f \frac{U}{H} = 0$$

$$F_2 = (y - y_0) + f \frac{V}{H} = 0$$
- Linearized form of collinearity equations

$$v + B\Delta = f$$

$$f = \begin{bmatrix} -F_1 \\ -F_2 \end{bmatrix} = \begin{bmatrix} -(x - x_0) - fU/H \\ -(y - y_0) - fV/H \end{bmatrix}$$

$$v = [v_1, v_2]^T$$
 : Image coordinate residuals

B: The matrix of partial derivatives of the two functions in collinearity equations
 Δ: The vector of nine corrections to approximate the parameters

Methodology

Initial values of exterior orientation by space resection

- Collinearity equations


$$x_u = x_0 - f \frac{m_1(X_u - X_0) + m_2(Y_u - Y_0) + m_3(Z_u - Z_0)}{m_4(X_u - X_0) + m_5(Y_u - Y_0) + m_6(Z_u - Z_0)}$$

$$y_u = y_0 - f \frac{m_7(X_u - X_0) + m_8(Y_u - Y_0) + m_9(Z_u - Z_0)}{m_4(X_u - X_0) + m_5(Y_u - Y_0) + m_6(Z_u - Z_0)}$$
- Direct linear transformation

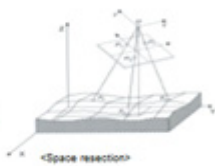
$$x = \frac{L_2 X + L_3 Y + L_4 Z + L_6}{L_9 X + L_{10} Y + L_{11} Z + 1}$$

$$y = \frac{L_5 X + L_8 Y + L_7 Z + L_6}{L_9 X + L_{10} Y + L_{11} Z + 1}$$

x, y: image coordinates
 X, Y, Z: coordinates of the reference points in object system
 L1 - L11: DLT parameters to be estimated from the parameters of interior orientation and exterior orientation



<Control points arrangement>



<Space resection>

Methodology

6-DOF by inverse resection

- The relationship between the coordinate of a point in the object system in the camera system

$$x' = X' + Bx''$$
- 6-DOF by inverse resection

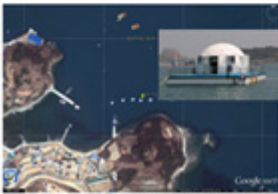
$$x' = R^{-1}(X - X_0)$$

x' : Coordinate with respect to the camera system of a point on the object
 X: Position of a point in the object coordinate system
 X₀: Coordinates of projective centre within object coordinate system
 R: Rotation matrix of projective centre within object coordinate system

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Experimental verification



◀Accommodation unit▶

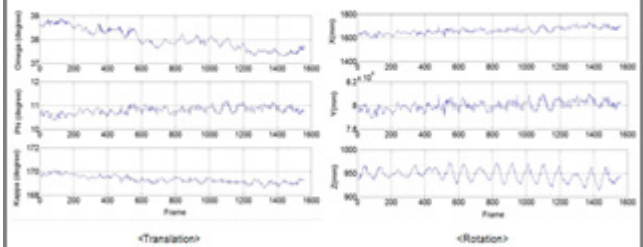


◀Experiment view▶

- Floating model at Kyung do island
- Tracking devices: Total station TS15 A1TR400 and camera Nikon D800

Experimental results

Initial values of exterior orientation by DLT



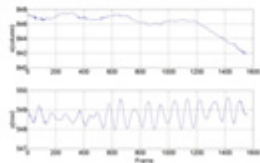
Experimental results

Automatic tracking results of reference points using image processing

- Interest points and matched pairs

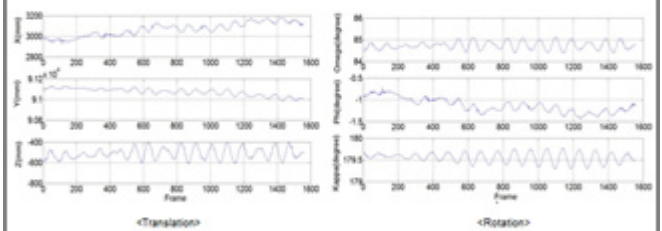


- Automatic tracking results of reference point



Experimental results

6-DOF of floating structure by least square adjustment and inverse resection



Experimental results

- Affine transformation results

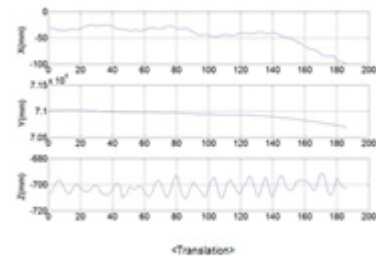
	Rotation	Translation
	0.999310	0.001086
	0.000345	1.000342
		-0.834424

- Matching pairs and transformation errors

First image		Second image		Error (pixel)	
Column	Row	Column	Row	Column	Row
847	549	847	550	0.30	0.94
967	549	968	549	-0.26	0.29
718	539	718	539	-0.12	0.09
843	624	843	625	0.12	-0.31
914	629	913	629	0.37	0.03
1078	542	1077	541	0.65	0.70
978	621	968	620	0.39	-0.04
777	545	776	554	-0.09	0.54

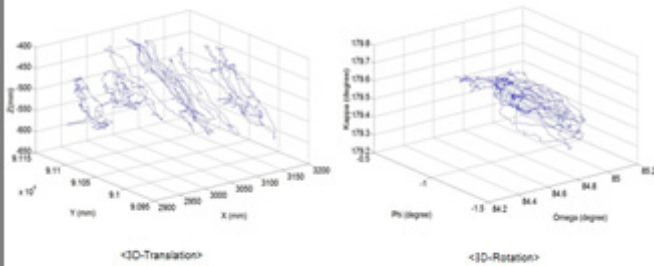
Experimental results

Displacement of floating model measured by Total station



Experimental results

6-DOF of floating structure by least square adjustment and inverse resection



Conclusion

- This paper proposed a methodology for measuring the movement of floating structure using a camera video
 - ✓ The technique bases on image processing and close-range photogrammetry to provide an effective solution.
 - ✓ In order to verify this research, a field experiment was carried out with a floating accommodation using a digital camera with 29fps video.
 - ✓ A comparison between the close-range photogrammetry and total station results was feasibly verified
- Proposed method can be considered as a cost-effective, simple, and safe procedure, to be used in surveying instead of existing sensors.
- Further research will be conducted in regard to fully integrating the modeling methodology using more than one camera in movement observation.

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