A target-independent sensors-based stereo camera calibration technique enabling 3D-DIC for large structures

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Abstract. Stereo-calibration is a critical step in 3D Digital Image Correlation (DIC) that measures the relationship between structural displacements or deformations captured in image coordinates and their corresponding real-world coordinates. The traditional method of stereo-calibration for large structures can be very challenging and time-consuming, as it involves rotating and translating a calibration target within the desired field of view (FOV). This often requires a large size calibration target board to cover the entire structure. The present study proposes a simplified stereo camera calibration technique that does not depend on conventional calibration targets. Instead, by using the known position of artificial features which are placed in the FOV and a laser sensor to target the detected stereo-matched KAZE features of the reference object to measure the depth. As a result, this developed approach provides a streamlined strategy for interpreting the world coordinates to estimate the projection matrix, thereby enhancing precision and accuracy in the calibration process. Further, the correlated coordinates will be utilized for 3D reconstruction to perform modal analysis on an aircraft wing of 5.5m span.

Possible Sessions

<u>19.</u> Optical and DIC techniques, <u>22.</u> Non Destructive Evaluation and Structural Health Monitoring

Introduction

The calibration of cameras for mapping the pixel values to the real-world coordinate units is an essential component for measuring the structural characteristics of large structures [1]. This process is vital for reconstructing 3D images from captured stereo images by determining both the intrinsic and extrinsic parameters of the cameras. The combination of intrinsic and extrinsic parameters is represented by the projection matrix, which is calculated using image coordinates and their corresponding world coordinate values. However, it is challenging to calibrate stereo-vision systems for a large Field of View (FOV) and difficult to manufacture large calibration targets precisely for the complete FOV of more than 1m in size. Moreover, to accomplish a successful camera calibration, it is necessary to cover the whole structure with the calibration boards and these boards are rotated and translated to obtain the camera parameters. Several studies have addressed the issue of camera calibration for large FOV, such as the study presented in [2], where the authors utilized a multi-sensor approach including a stereo camera, laser, and thermal sensors for calculating the extrinsic parameters with targetless cross-modal calibration. Some deep learning methods exhibit fast convergence but typically provide relative estimates rather than absolute values, which are necessary for Digital Image Correlation (DIC) to calculate structural displacement and deformation [3].

Methodology and Preliminary Analysis

This study establishes a stereo-calibration technique independent of calibration targets. The proposed technique is divided into various steps as illustrated in Figure 1. The stereo images acquired from left (I_L) and right (I_R) cameras are first processed by the KAZE feature detector and descriptor algorithm to establish image correspondence due to its property of providing high repeatability and distinctive features. After successful feature matching, the prominent stereo-matched features ($I_LF(u_l,v_l)$, $I_RF(u_r,v_r)$) are selected by the proposed technique to determine the world coordinate values (X_W, Y_W, Z_W). To measure the world coordinates, two major components are used, which are artificial features points with known positions and laser sensors to exclude the dependency on calibration target boards. Some artificially created feature points (see Figure 2) are placed in FOV to deduce X_W, Y_W, whereas the laser sensors are mounted on top of the cameras to point the beam on the selected stereo-features for calculating Z_W depth. Later, these world coordinate values (X_W, Y_W, Z_W) and the image coordinates (u,v) are used to estimate the projection matrix 'P' using the Pinhole Camera Calibration model to obtain the calibration parameters. Further, these correlated coordinates are employed to reconstruct the 3D model of the target structure for evaluating the dynamic characteristics of the large structures through their natural frequencies and the respective mode shapes.

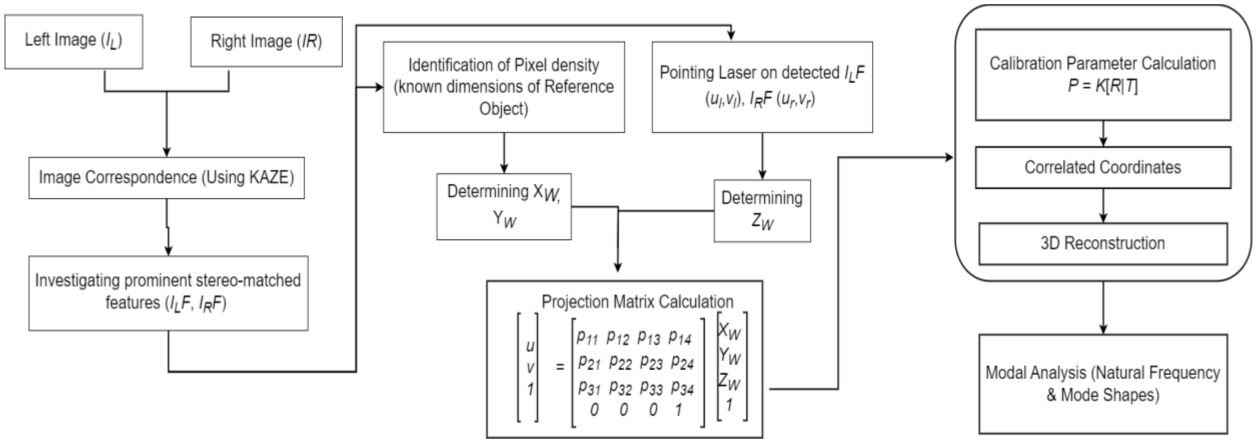

Figure 1. Proposed stereo-calibration technique using feature points and lasers.

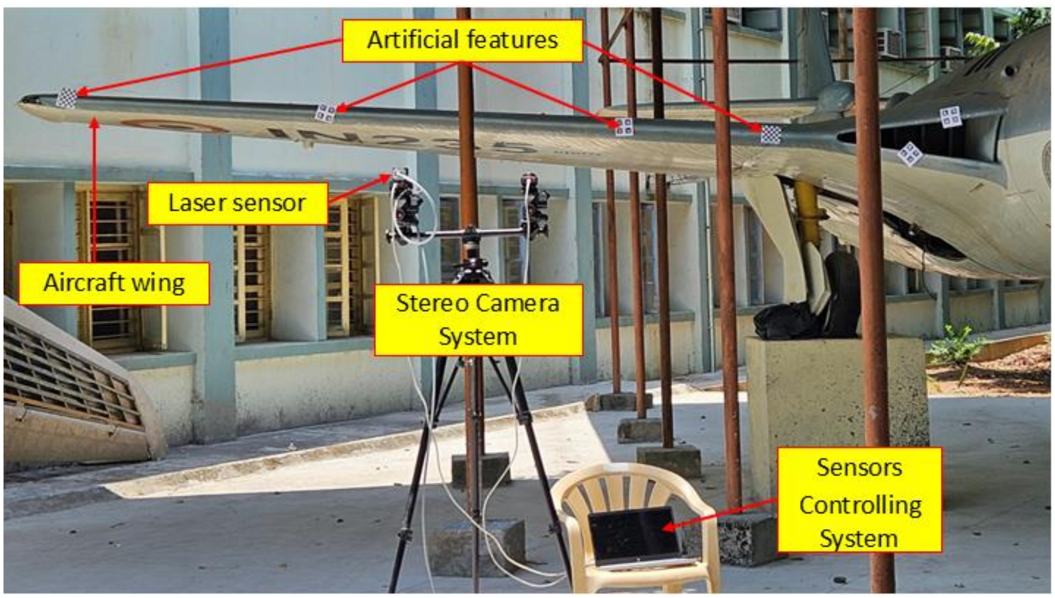

Figure 2. Experimental setup for the proposed stereo-calibration technique

Conclusion

A stereo-calibration technique is developed that does not require any calibration target to measure the intrinsic and extrinsic parameters of cameras while performing DIC for structural displacement/deformation analysis of large structures. The developed stereo calibration approach is being tested on an aircraft wing of 5.5 m span.

References

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