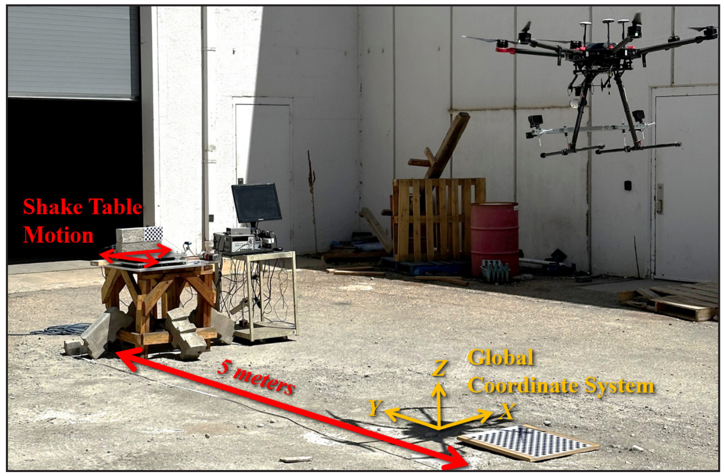
MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 24-553 (project 680) | September 2024

Noncontact Dynamic Three-Component Displacement Measurement with a Dual Stereovision-Enabled Uncrewed Aerial System



the ISSUE

Understanding structural dynamics is critical for evaluating long-term structural performance and decision-making regarding maintenance and operation of the structure. Quantifying the displacement of structural vibration is an important means to evaluate the dynamic performance of structures under various dynamic loading, such as winds, traffic, and impact loading. Instrumentation of structures such as bridges is complex, requiring careful placement of sensors and management of wires or wireless systems. Such systems are difficult to relocate after installation. Non-contact remote sensing systems using cameras or laser Doppler have been deployed, but safe placement for such a system may be difficult. Previous research using uncrewed aerial systems showed promise, but has only been proven in a small-scale laboratory setting with close camera-to-structure distance.

the RESEARCH

The study aims to overcome challenges of traditional displacement measurement methods, particularly in inaccessible locations. The researchers used a dual stereovision-enabled uncrewed aerial system (UAS) to measure the dynamic displacements of structures. The UAS is equipped with four optical cameras, configured in two stereo pairs. One pair tracks the three-component (3C) motion (x, y, z) of the structure, while the other measures the six degrees of freedom motion (rotational and translational) of the UAS itself.

To ensure accuracy, a dual-camera calibration process is used. First, each camera undergoes individual calibration, followed by stereo vision rectification within each camera pair. A novel calibration technique is then employed to align the two camera pairs. Natural features on the structure are identified and tracked using optical flow, eliminating the need for artificial targets. The UAS motion is compensated using a mathematically derived transformation matrix, allowing the system to record the true dynamic displacement of the structure.

Laboratory experiments validated the system's precision, achieving sub-millimeter accuracy in stationary tests and millimeter-level accuracy in dynamic tests, even with significant UAS movement.

MOUNTAIN-PLAINS CONSORTIUM REGION 8

A University Transportation Center sponsored by the U.S. Department of Transportation serving the Mountain-Plains Region. Consortium members:

Colorado State University
North Dakota State University
South Dakota State University
University of Colorado Denver
University of Denver
University of Utah
Utah State University
University of Wyoming

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Project Title

Development of a New Airborne Portable Sensing System to Investigate Bridge Response

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the FINDINGS

The researchers demonstrated that the dual stereovision-enabled UAS effectively measures 3C dynamic displacements of structures with high accuracy. The system compensates for UAS motion, achieving sub-millimeter root-mean-square error in stationary tests and millimeter-level accuracy in dynamic tests. It was successfully validated in laboratory experiments, showing minimal errors despite significant UAS movement. The technique eliminates the need for artificial targets, using natural features for tracking, making it suitable for hard-to-reach structures. This approach provides a practical and portable solution for structural health monitoring in various environments.

the IMPACT

The research could have a significant impact on real-world structural monitoring and maintenance. By using a dual stereovision-enabled UAS for dynamic displacement measurements, it provides a portable, non-contact solution for assessing the health of civil structures such as bridges, dams, and tall buildings. The system's ability to measure 3C movements without the need for artificial targets or fixed sensors makes it ideal for hard-to-reach or hazardous locations. The innovation could improve the safety, maintenance, and longevity of critical infrastructure, benefiting public safety and resource management.

For more information on this project, download the Main report at https://www.ugpti.org/resources/reports/details.php?id=1200

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.