Evaluating Bridge Behavior Using Digital Image Correlation (DIC)

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Introduction

Motivation

- ❑ More than 45,000 bridges are structurally deficient in U.S
- ❑Annual cost of upgrading the U.S bridge system: $24.7 billion
- ❑Nearly 40 years to retrofit the backlog of deficient bridges

Technical Challenges

Structural deformation measurements are necessary to optimize load capacity evaluations and reduce cost

❑Conventional bridge deformation instruments:

- Expensive and time-consuming
- Require contact with the structure
- Require working at heights from scaffolding

Civil Infrastructure Vision (CIV) System

❑Integrated hardware/software system developed at UTSA
❑Principles of Digital Image Correlation and spatial triangulation
❑Monitors structural deformations at all scales

Bridge Load Test using CIV system

1. Position cameras for desired field of view
2. Attach High Contrast Physical Targets (if needed using extension and from ground)
3. Start recording position of selected targets on bridge surface and/or HCPT
4. Move loaded truck into position
5. Full test can be done in less than 2 hours

CIV System Accuracy

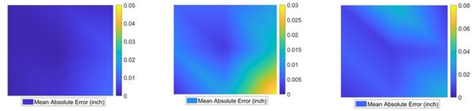
Accuracy quantification

❑NIST certified gage blocks

Gage block device

NIST certified gage blocks

Sample accuracy results at 70ft distance



❑In-plane translation accuracy better than out-of-plane
❑Best accuracy in center of Field of View

Image Quadrant	Gage Block Size (in.)	Y direction Mean Absolute Error (in.)	Z Direction Mean Absolute Error (in.)
Top Left	0.5 1	0.0085	0.0851
Middle Left	0.5 1	0.0146	0.2292
Bottom Left	0.5 1	0.0046	0.0761
Top Center	0.5 1	0.0383	0.1476
Middle Center	0.5 1	0.0068	0.0602
Bottom Center	0.5 1	0.0139	0.1451
Top Right	0.5 1	0.0052	0.2685
Middle Right	0.5 1	0.0137	0.2122
Bottom Right	0.5 1	0.0351	0.1098

Light Variation

❑Robust DIC algorithms result in only a few 1/1,000 inch translation when moving from full sun to full shade

Field Demonstration

Application on Steel Continuous Multi-Girder Bridge

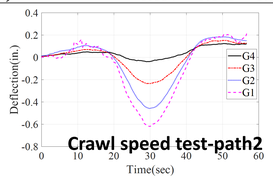
❑ Location: Farm Rd 1047, Lometa, TX
❑ Three continuous spans (60’ - 75’ - 60’)

Fixed-location test-path 1 (midspan deflection)

Girders	G1	G2	G3	G4
CIV (in.)	0.055	0.256	0.515	0.689
Displacement transducer (in.)	0.049	0.280	0.526	0.755
Difference (in.)	0.006	0.024	0.011	0.066

Fixed-location test-path 2 (midspan deflection)

Girders	G1	G2	G3	G4
CIV (in.)	0.729	0.510	0.281	0.072
Displacement transducer (in.)	0.692	0.556	0.298	0.077
Difference (in.)	0.037	0.046	0.017	0.005



Scaffolding for contact instruments used for validation

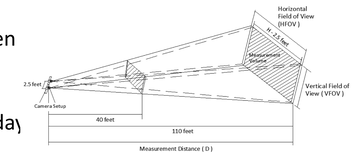
Capability Highlights

Accuracy

- ❑ Accuracy for in-plane movement on the ***order of a few 1/1,000th inch*** to a few 1/100th of an inch depending on measurement distance
- ❑ Accuracy lower for out-of-plane movement

Measurement Volume (MV)

- ❑ Up to 110 ft distance from cameras when for a bridge application



Field Benefits

- ❑ Fast testing – 2 hours instead of several da
- ❑ Access to bridge underside not required
- ❑ Ability to monitor any point over a large FOV

Concluding Remarks

- ❑ Fast load tests: hours instead of days using contact instruments
- ❑ Safety improved for the driving public by elimination of lane closures
- ❑ Safety improved for highway workers with reduced exposure to traffic and working at heights
- ❑ Lane closure for measurement for only a few minutes
- ❑ Significant cost savings (fraction of traditional methods costs)

Next steps: Implementation

❑ UTSA and TxDOT will evaluate up to 10 bridges by the end of FY2022
  - ❑ Improve efficiencies of the load testing process.
  - ❑ Achive load test at fraction of cost of conventional evaluation

Acknowledgement

Dr. Mary Beth Hueste at Texas A&M University for sharing displacement transducers measurement data for system validation