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Dynamic Monitoring of Bridges using Video Cameras

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, monoconona







Brief History – Video Measurement

- First known example is the Tacoma Narrows Bridge, in 1940.
- Increasing use by researchers from 1980s onwards.
- Iconic use in crash testing, but principles used in motion capture, optical mice, and many optical measurement systems.
- A number of companies offering laboratory solutions.
- Imetrum is the only commercial system optimised for external use.













Brief History – Video Measurement

- Visual Inspection still a mainstay of any structural survey, and the key idea behind video work.
- At Tacoma, Prof Farquharson took this further he recorded what he saw, and then took measurements from it to help with analysis using a ruler on the screen.
- Work in Bristol University in the late 1980s & early 1990s helped to automate the 'ruler on the screen' – by using pattern recognition & image correlation to match a bullseye target pattern, and then calculate where that had moved to in the next image and so on.
- Simultaneous work at USC and elsewhere on applying this method to determine what was happening across a whole image (what is now commonly known as DIC).









History – Tacoma Narrows







Rickmansworth Demonstration

- Suggested by Ashok Pamar, supervised by Jonathan Cooper.
- Vertical deflection of each beam near bearing plate.
- Before and after works to pack one of the beams that was know to have excessive deflections.
- No direct access to structure.



- Multiple steel beams patterning of beams used as 'targets'.
- Distances from camera to various points on structure used to scale images (and get engineering units).
- Displacement of 18 points simultaneously, at 15 Hz.





Site Specific Setup

- 3 camera Video Gauge system, mounted on a single tripod.
- Battery powered, with test control using a tablet PC.
- Approximately 10 load events on each day (2 hours on site).







Rickmansworth Screen Capture

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Vertical Displacement - Before







Vertical Displacement - After









How Digital Image Correlation works

- 1. Set up a camera. Make sure it is stable. And will remain stable.
- 2. Identify a pattern in an image.
- 3. Accurately model exactly where that pattern is (it's an analogue world). This is the key to making it useful.
- 4. Find the same pattern in the next frame.
- 5. Record the difference between this location and the starting location.
- 6. Continue until the end of the test.
- 7. Interpret and analyse the data to determine appropriate repair / maintenance / monitoring strategies.











Benchmarking – HST on Rail Bridge



- Really? Can we trust this?
- People's lives depend on us after all.

- Year long project lead by UK National Measurement Office (NPL).
- Comparisons with conventional and new methods.
- Use in various weathers.







Benchmarking - Road Bridges

2



Laser Tracker offset by 1mm to make comparison clearer

Displacement vs Time Static 9

- Setup 45m away in car park
- Resolution of 0.02 mm.
- Testing at night.







Benchmarking - Vibration Analysis





- Traces from an accelerometer and the Imetrum system show how the Camera system is able to respond to and record vibration events. This particular trace is caused by a bus hitting a sunken manhole on Tuckton Bridge, Dorset.
- The deflection trace indicates the overall load being applied to the span in question, plus the impact event of each axle.







Benchmarking – Rain & Sun



- Part of NPL benchmarking process as a rule of thumb, rain doubles the noise of the measurements.
- Consider changes in lighting carefully Day/Night can work when done well.
- Consider solar gain carefully for long term.



A week at the NPL footbridge, measuring every 15 minutes day/night, including 3 load tests. IR lighting.





Case Study – Detail Investigation









Case Study – Detail Investigation







Case Study – Detail Investigation







Road Bridges

- Used for Dynamic Testing under normal traffic conditions, and also specific Load Testing.
- Access costs minimised, and resolution increased over other non-contact techniques.







Road Bridge Screen Shot







Rotation Data



Smoothed Rotation (Avg over 1s)







Rotation Data



-CL - West v. Whole - CL - East v. Whole





Technology Summary

- Imetrum have developed & patented specialist software that measures movement in structures highly accurately in real time.
- The system is a point to point and full-field optical measurement system we use pattern recognition technology and sub pixel interpretation of video images ie non-contact.
- Benchmarked by NPL (National Physical Laboratory), Strainstall & Airbus.
- UKAS Calibration to BS/EN/ISO 9513, class 0.5 and ASTM (E83) calibration to class B-2.
- Resolution and frame rate are camera and setup dependent. Reliably 0.1mm resolution for a 10m FoV.
- The main setup challenges: Camera movement, pattern quality, weather.
- Usually 10 100Hz, but up to 1kHz possible real time.
- Videos & data can be stored for analysis later, or processed in real time.
- Multi-camera systems enable detailed understanding of structural movement.





Conclusions

- A flexible system, offering potential for time & cost savings.
- Turn up and measure solution for a wide range of structures.
- Potential for extremely high resolution.
- What could you use it for?







Tunnel Monitoring



- Convergence & Ring Separation.
- Track Monitoring within tunnels.
- Demonstration project with Crossrail / CSIC.
- 250 measurement points, with 4 cameras.
- Infra-Red lighting used, so no obvious visible clue of monitoring ongoing, and no negative impact of work lights.
- Measurement resolutions of 0.1mm or better (unfiltered).
- Remote access to equipment, and live reporting of results.





Tunnel Monitoring







Extensions Over Three Months







Case Study – Track Deflection



- Dynamic deflection monitoring of track, sleepers & ballast.
- Information on ground movement, track displacement / bending, gauge separation.
- Measurements taken at distance, under train loading.
- Set up between 3 60m from track. Camera measuring at up to 300Hz. Up to 30m track visible with 1 camera.
- Targets spray-painted to track where not enough natural pattern. Ballast & clips usually do not need paint.





Rail, Sleeper & Ballast Movement - WCML



- Dynamic response of various parts of the track bed identifiable.
- Vertical and Longitudinal displacement.
- Resolution much better than 0.1mm.





Case Study – Factory Crane 3D Deflection

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# **Vibration Analysis**



- One of the most common research applications for Imetrum system within Civil Engineering.
- Suspension Cables and Conductors.
- Hard to access pipework.
- Vibrating machinery and components



