Data Analysis Techniques and Challenges in Vibration based Structural Health Monitoring

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Centre for Infrastructural Monitoring and Protection

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Challenges in Data Analysis in SHM

from my understanding on vibration based

1. A large amount of data over time from numerous sensors and various sensor types
2. Environmental condition change and varying testing conditions
3. Significant noise effect in on-site sensor measurements
4. Uncertainties in testing/modelling/algorithms and possible sensor malfunction in real SHM project applications
5. Analysis under extreme events …etc

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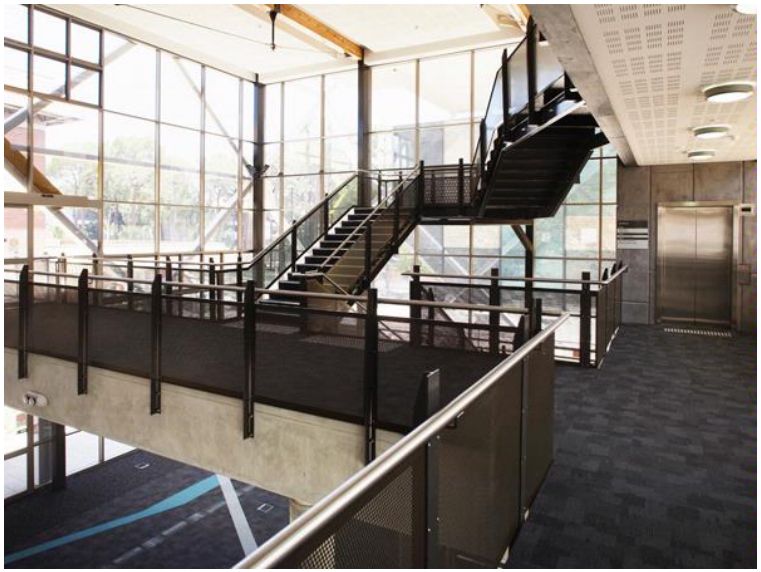
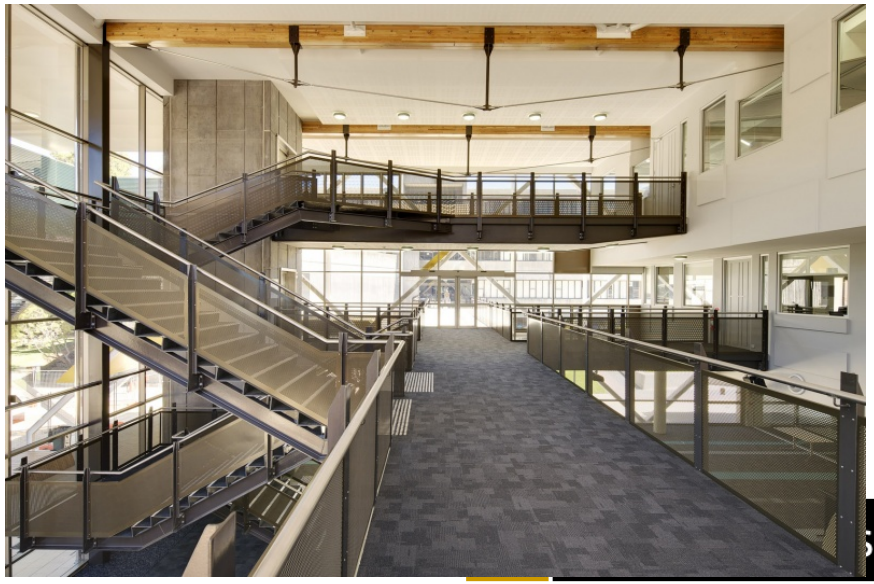
SHM Living Laboratory at Curtin





Installed Comprehensive Sensory Systems

- Ground motion
- Building global vibration monitoring

  tri-axial accelerometers
- Footbridge vibration monitoring

  accelerometers and strain gauges
- Stairs Monitoring: *accelerometers and strain gauges*
- Roof Truss Monitoring: *accelerometers and strain gauges*
- Weather station: Temperature, humidity, wind
- **Overall: 55 sensors**

A SHM testbed on an iconic building in WA

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1.Modal identification of time-varying structures

With Pinghe Ni, Yong Xia

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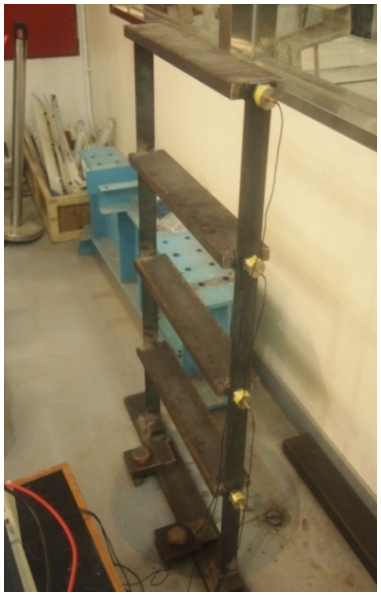
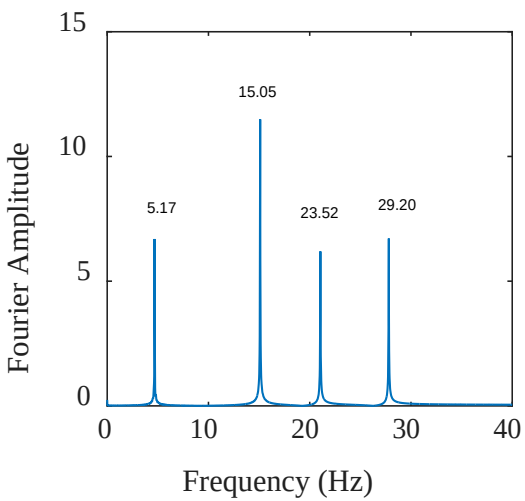
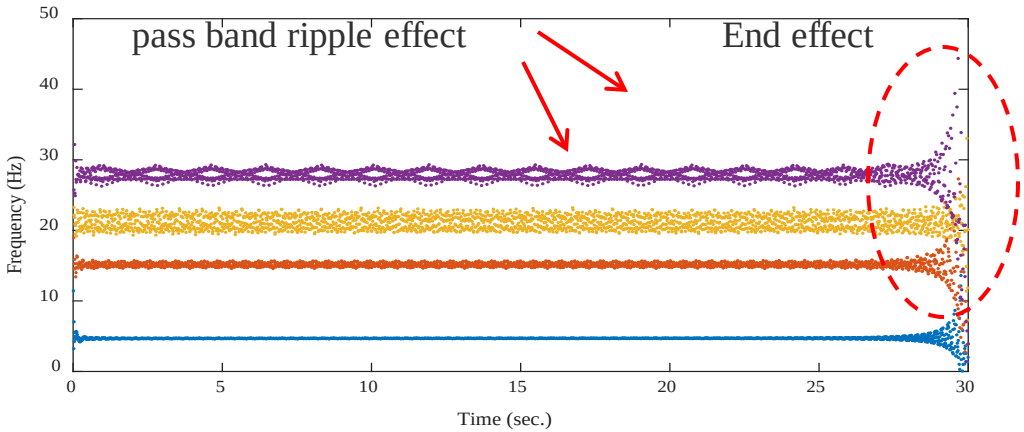
Experimental verification (1)



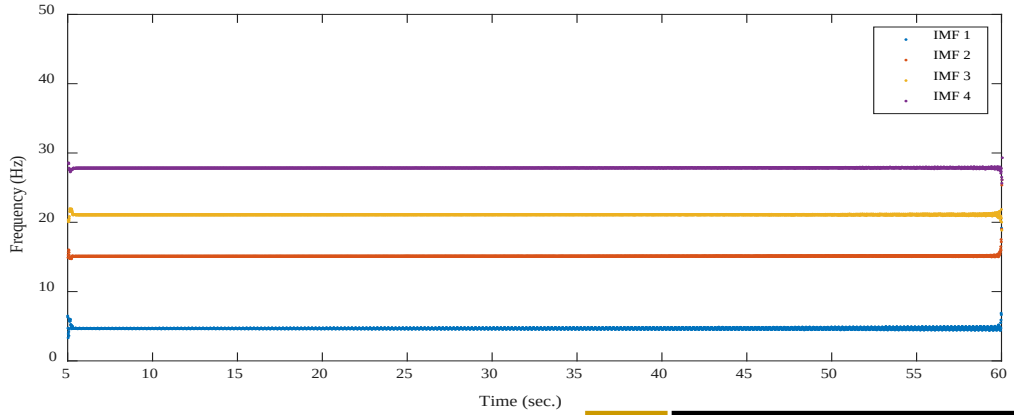


Improved HHT method



Bao, Chunxiao, Hong Hao, Zhong-Xian Li, and Xinqun Zhu. "Time-varying system identification using a newly improved HHT algorithm." *Computers & Structures* 87, no. 23 (2009): 1611-1623.

Our approach



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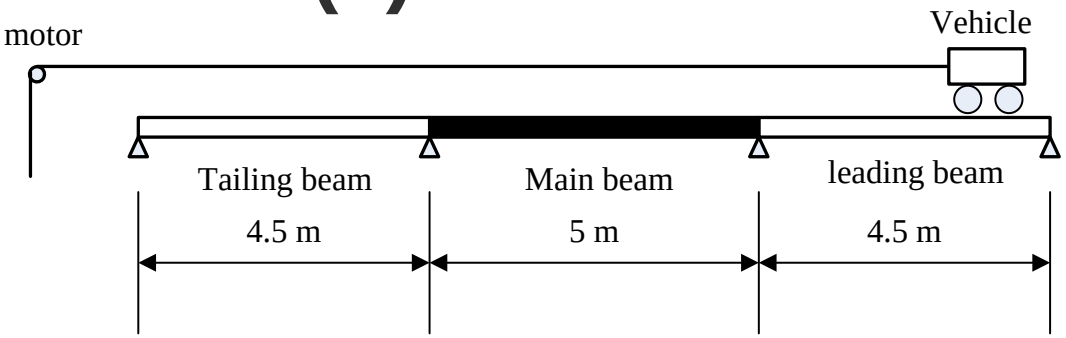
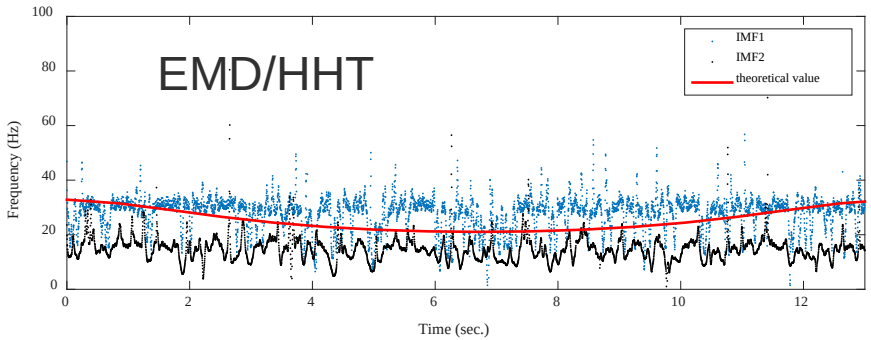
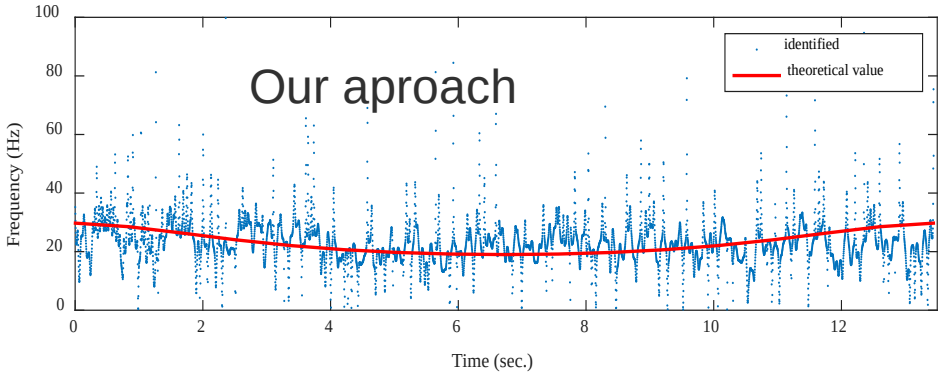
Experimental verification (2)



A vehicle went through a bridge with a speed 0.4m/s. The vehicle/bridge weight ratio is 1/1.5. The vehicle is very heavy and the moving of vehicle will changes the frequencies of the bridge





The fluctuations in the identified frequencies around the true values may caused by the interaction effect of the bridge-vehicle system and measurement noise.

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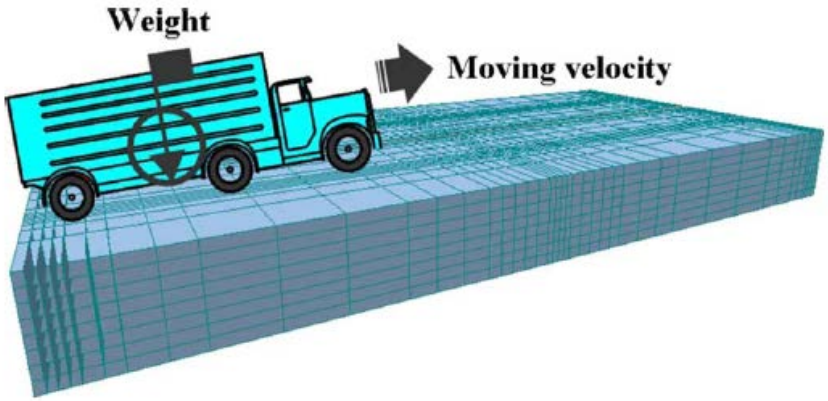
2. Vibration phase technique for bridge damage detection under moving loads

Sources of excitations in deterministic identification

Treat the moving vehicle as the exciter



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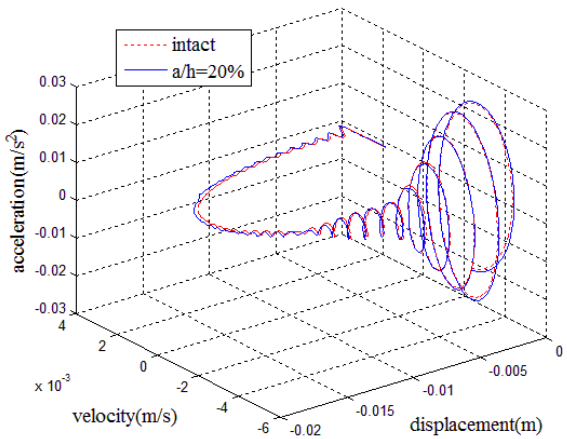
Damage index with multi-type measurements and vibration phase technology

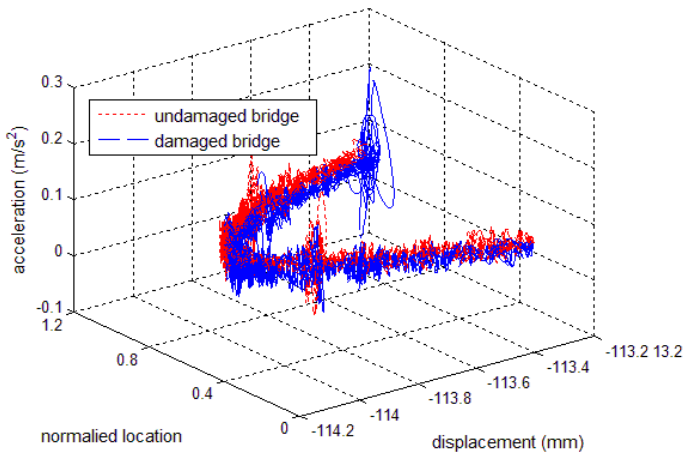
A three-dimensional vibration phase, i.e. displacement – Velocity – acceleration

$$DI = \sqrt{\left(u_d^{x'} - u_0^{x'}\right)^2 + \left(v_d^{x'} - v_0^{x'}\right)^2 + \left(a_d^{x'} - a_0^{x'}\right)^2}$$



A two-dimensional vibration phase, i.e. displacement – acceleration

$$DI = \sqrt{\left(u_d^{x'} - u_0^{x'}\right)^2 + \left(a_d^{x'} - a_0^{x'}\right)^2}$$



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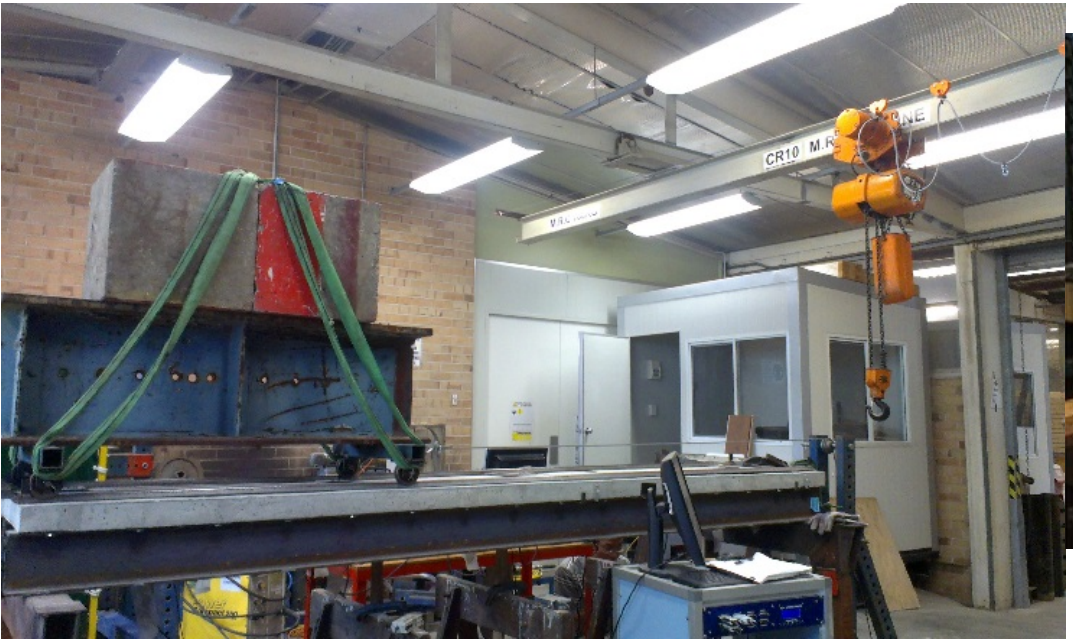
Experimental Studies

- Bridge-vehicle system in the lab



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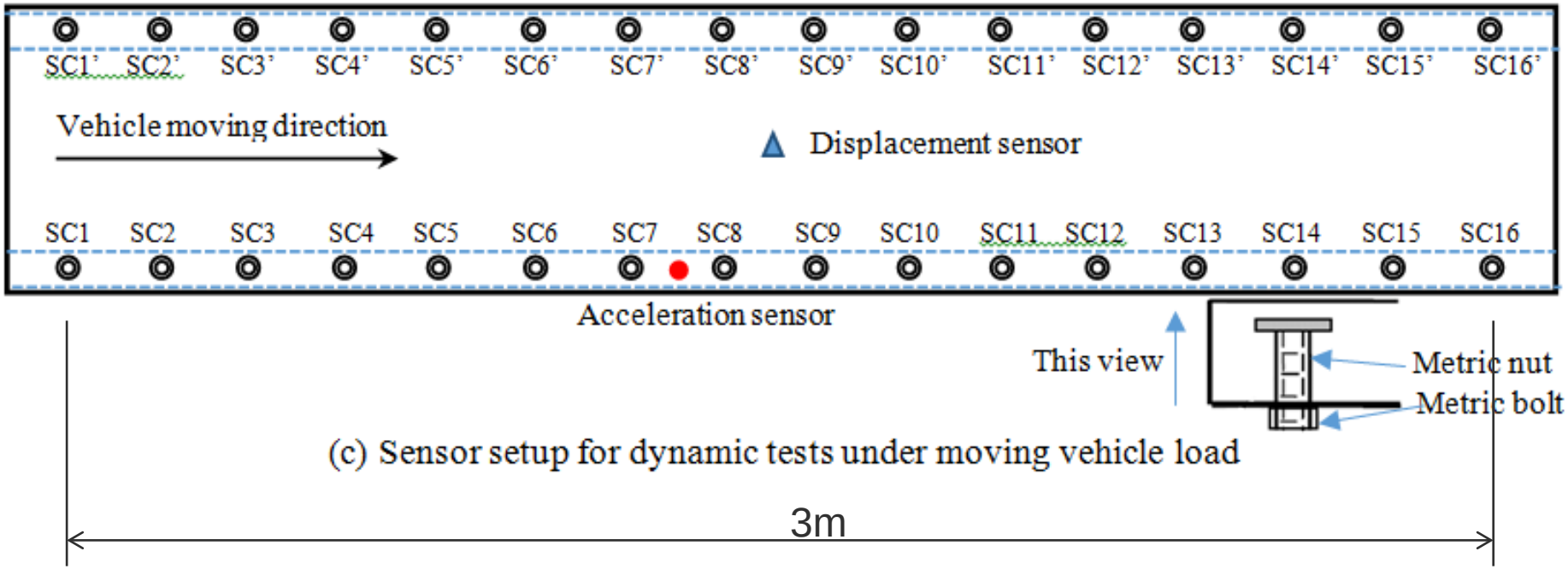
Shear connectors in the lab and sensors setup



Only a laser displacement sensor and an accelerometer are used for measuring the bridge responses for damage detection

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Damage Scenarios in the experimental studies

Damage Scenario		Removed shear connectors	Damage region
Scenario 1	damage 1	SC15 and SC15’	2.8m
Scenario 2	damage 1	SC15 and SC15’, SC14 and SC14’	2.6m~2.8m
	damage 2	SC2and SC2’, S3 and SC3’	0.2m~0.4m

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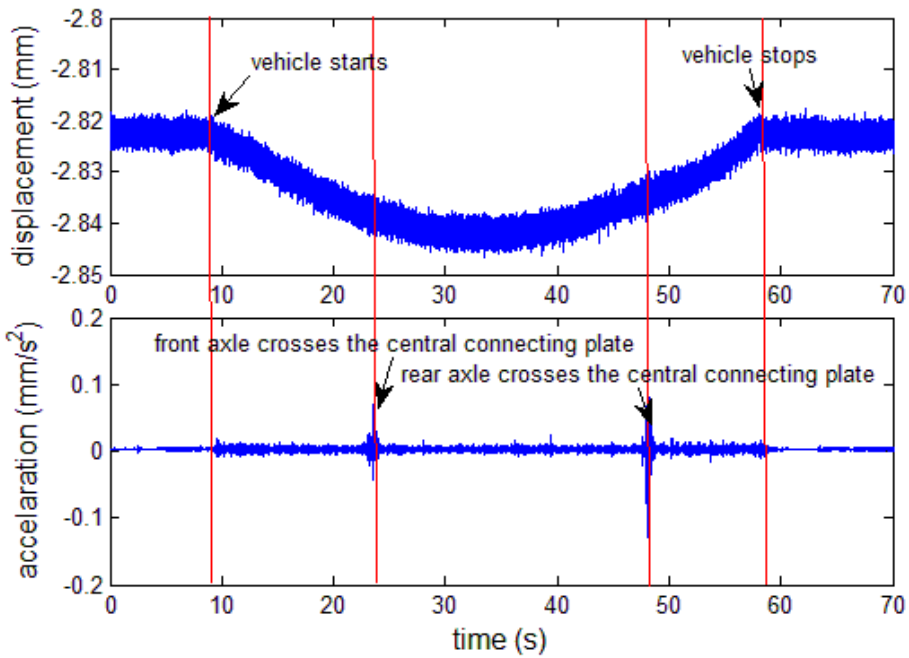
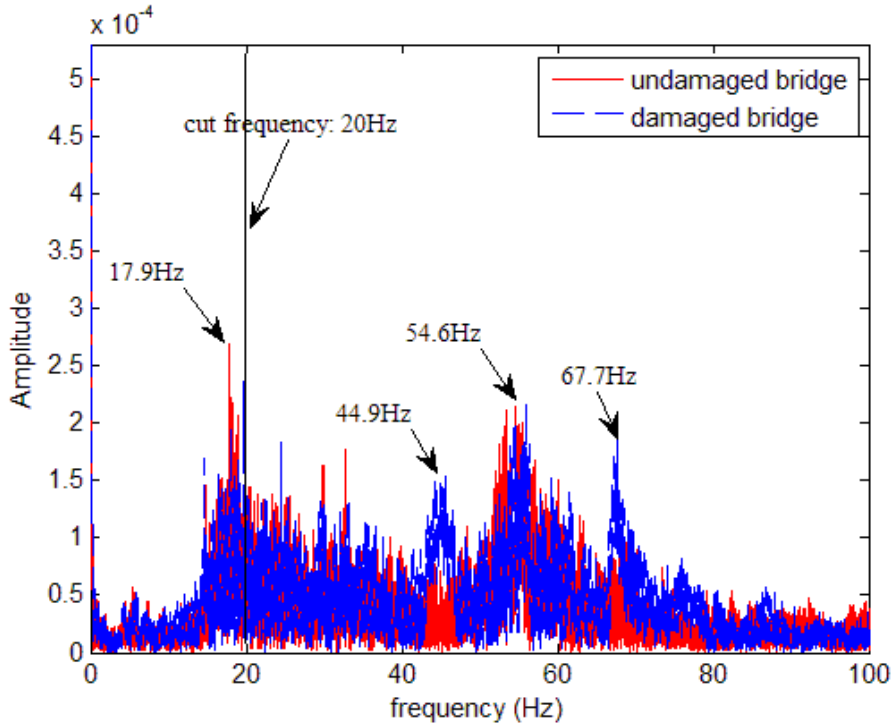
Measured responses and their FFT spectrum





Measured displacement and acceleration responses from the undamaged state

Fourier spectrum of the measured acceleration from the undamaged state and Damage Scenario 1

No significant difference in FFT spectrum

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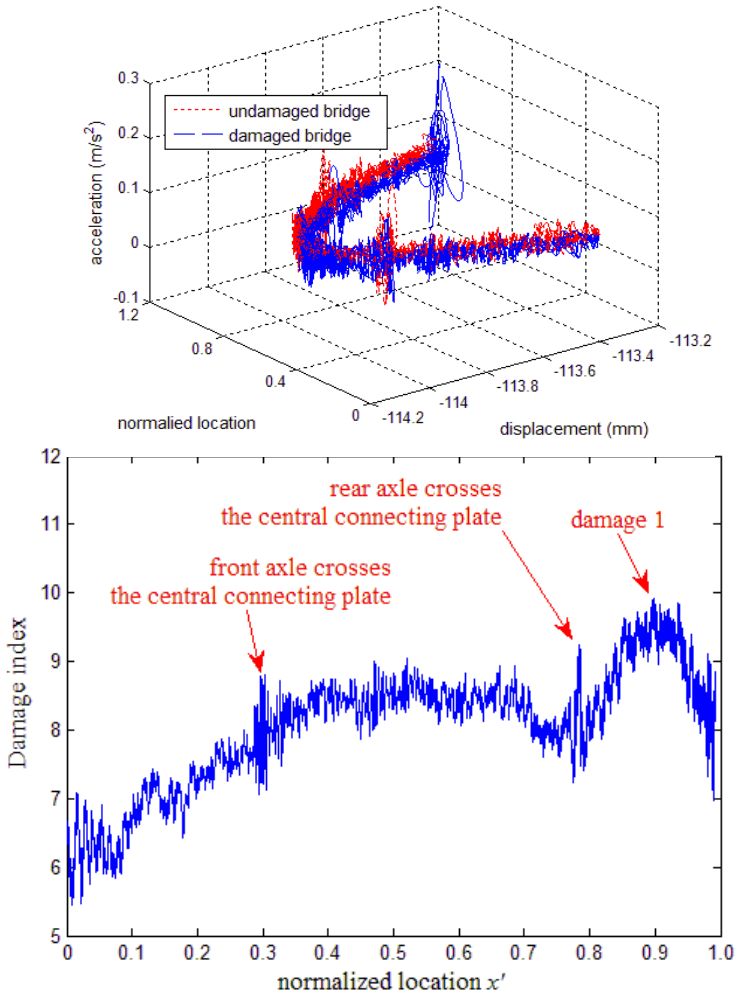
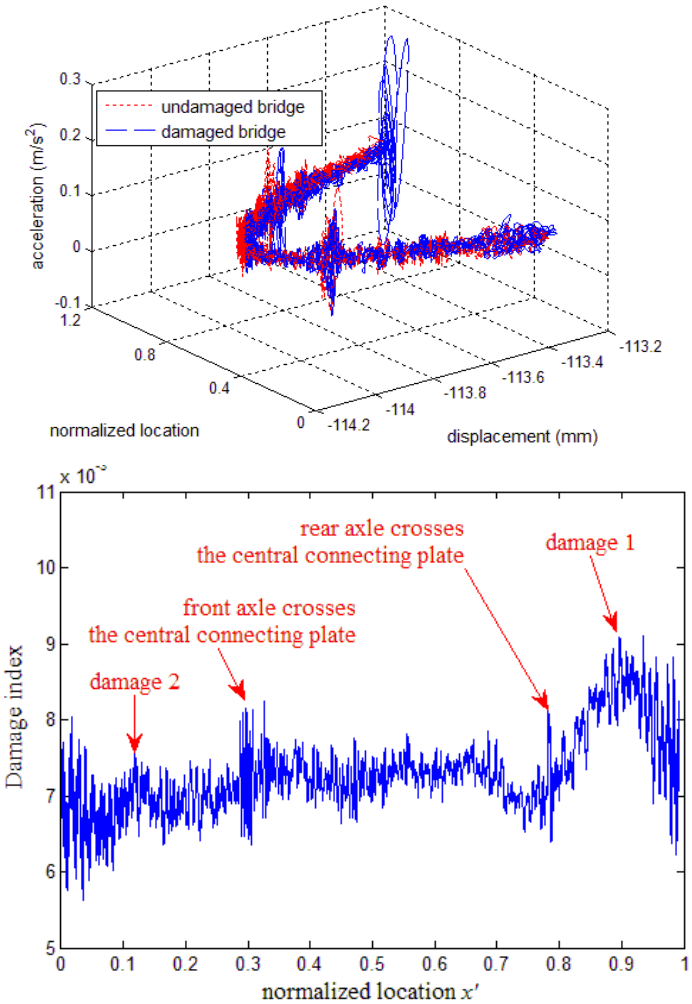
Phase trajectories and damage detection results



(a) Scenario 1



(b) Scenario 2

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Damage identification results

Damage scenario		Ture damage location	Identification results	
			Time instant (s)	Location (m)
Scenario 1	damage 1	2.8m	44.89	2.79
Scenario 2	damage 1	2.6m~2.8m	44.81	2.79
	damage 2	0.2m~0.4m	5.90	0.24

Summary

- Make use of multi-type sensor measurements；
- Damage index is sensitive to the minor damage；
- Strongly capable of resisting noise effect；
- A few sensors are used.

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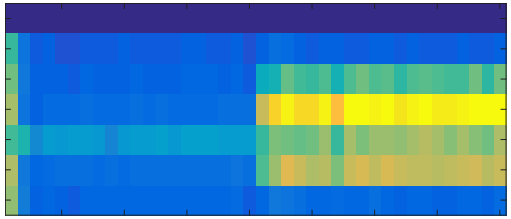
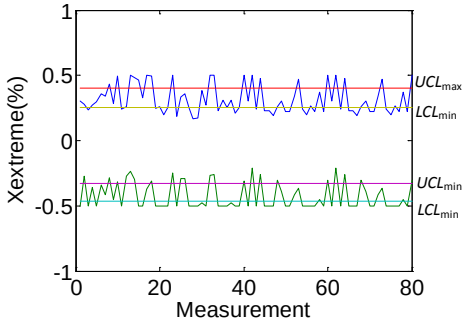
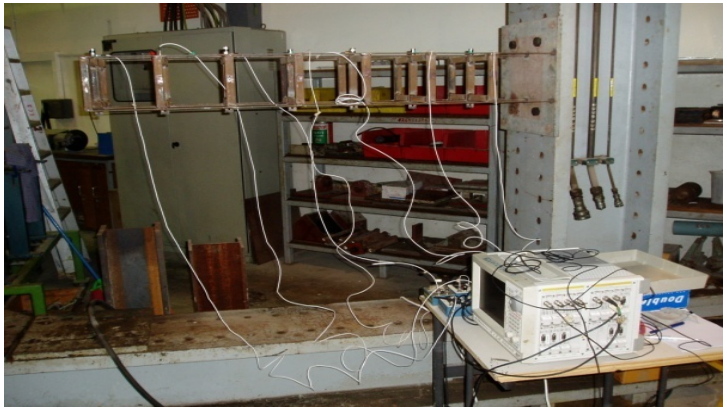
3 Damage detection considering sensor degradation and malfunction

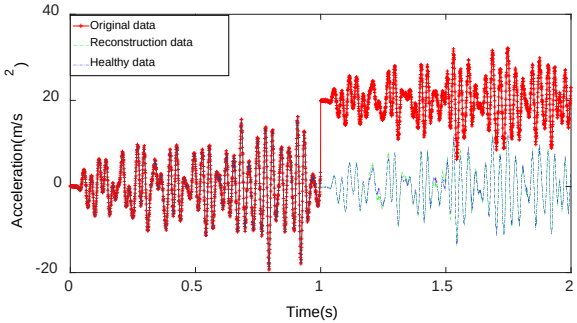
Isolate and distinguish abnormal response

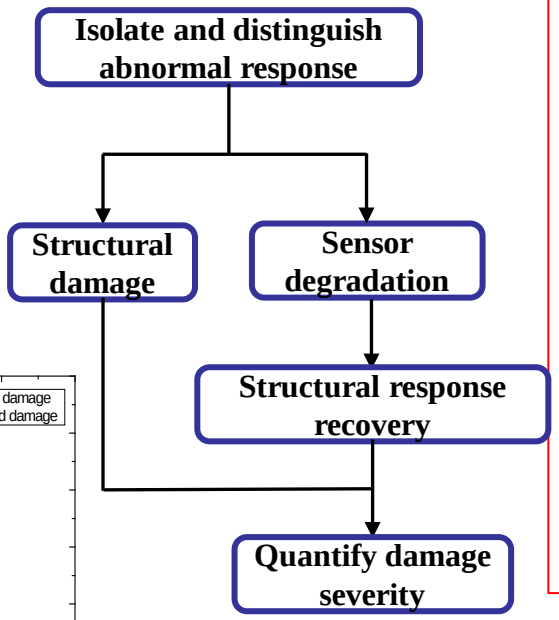






Structural response recovery





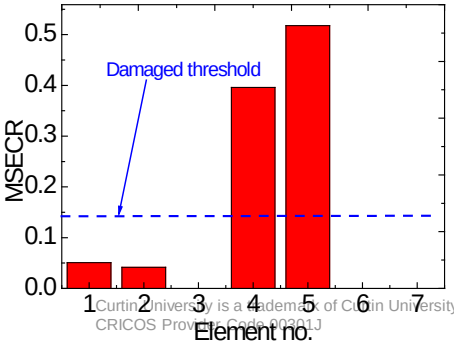
Current work includes:

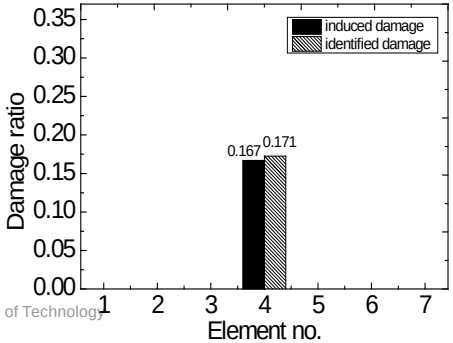
1) new indices that are more sensitive to degraded signal

2) Structural response recovery approach based on improved multi-scale PCA

3) New optimization method to accurately detect damage

Quantify damage severity





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4. Concluding Remarks

- Modal identification of time varying structures;
- Development of vibration phase technique in condition assessment of bridges under moving loads;
- Validation and investigation on the SHM testbed building at Curtin

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Thank you for your attention!

Welcome comments and collaborations.

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