Numerical verification on
Wavelet-based VRA method
for bridge damage detection

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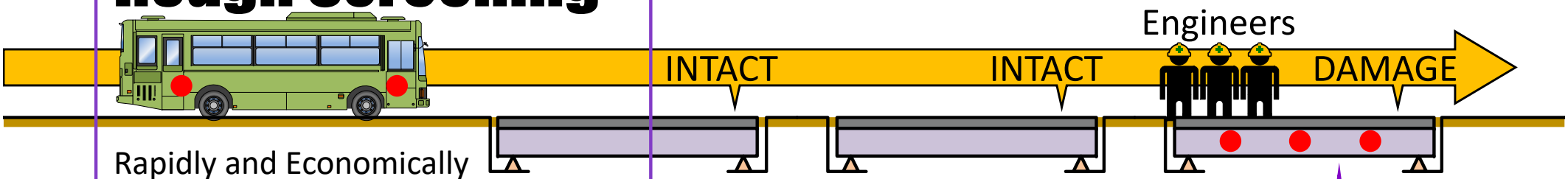
DEMAND OF OUR SOCIETY

STEP: 1

Rough Screening



Rapidly and Economically
Sensors on Vehicle

STEP: 2

Detailed Inspection only for "Suspicious Bridge"

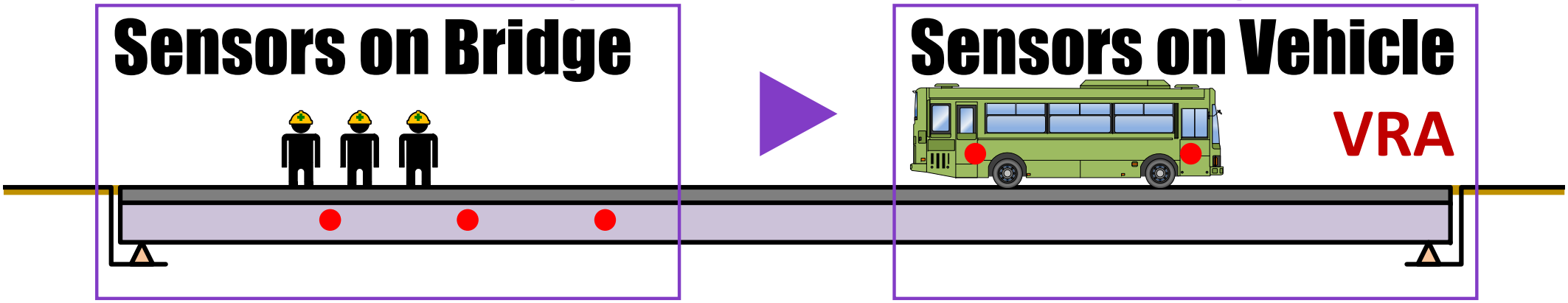
Strategic Allocation of Resources

Engineers & Money

in bridge maintenance beyond
the boundary of local governments

Traditional monitoring:

New monitoring:

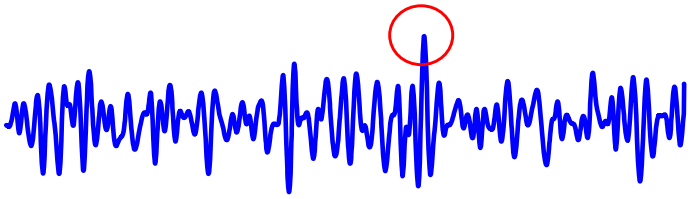


High	**Accuracy**	Maybe Low
Costly	**Cost**	Cheap
Veterans	**Engineers**	Drivers & Analysts
Few years	**Time**	10 sec. per one bridge

For Detailed Inspection **For Rough Screening**

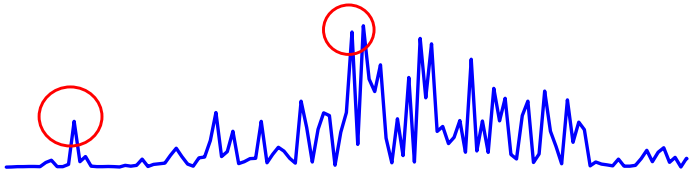
Traditional analysis:

Time Domain



Maximum amplitude

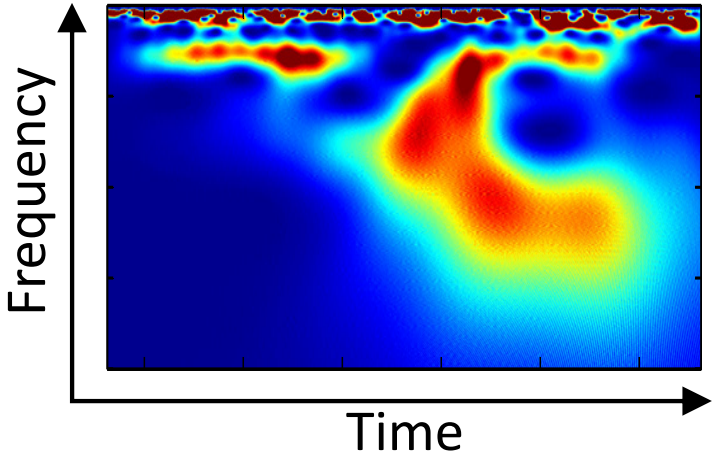
Frequency Domain



Peak frequency

New analysis:

Time-Frequency Domain



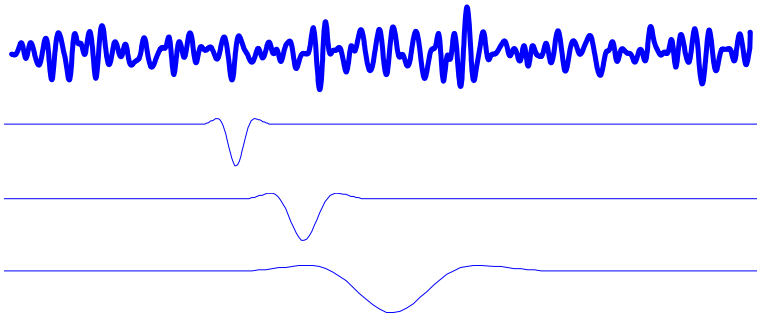
All information both in time and frequency domain alive

Frequency to scale

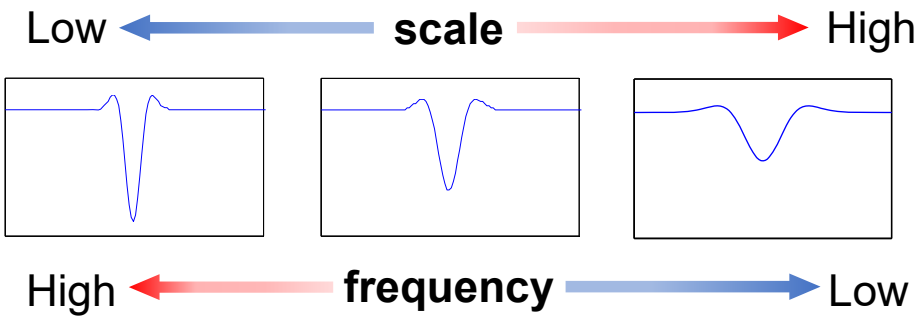
Continuous Wavelet Transform

$$\underset{\text{Wavelet Coefficient}}{Wf(t,s)} = \frac{1}{\sqrt{s}} \cdot \underset{\text{Signal}}{f(t)} \underset{\text{Convolution}}{\otimes} \theta_s(t)$$

Convolution



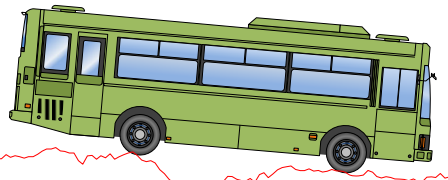
Mother Wavelet



Direct calculation

Repeat calculation

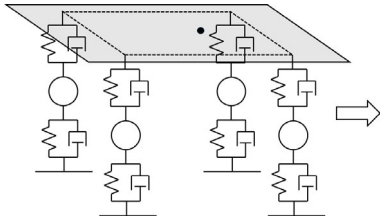
Vehicle-Bridge Interaction System



Non-Linear system

System parameters depending on the position of the vehicle (Un-steady: memory-consuming!)

Vehicle System



modeled by

RBSM

Road Unevenness

Bridge Vibration

Vehicle Vibration

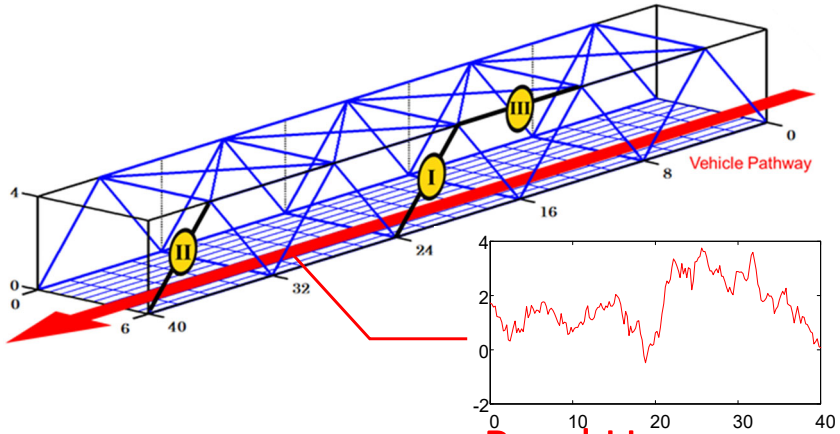
Contact Force

Bridge System

modeled by

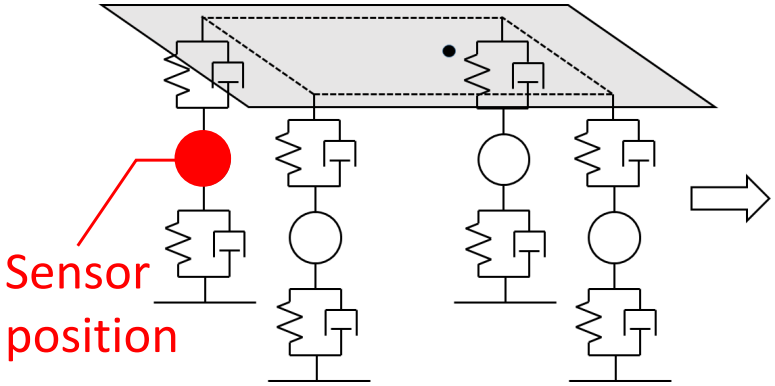
3D-FEM

Model parameters



Bridge Model

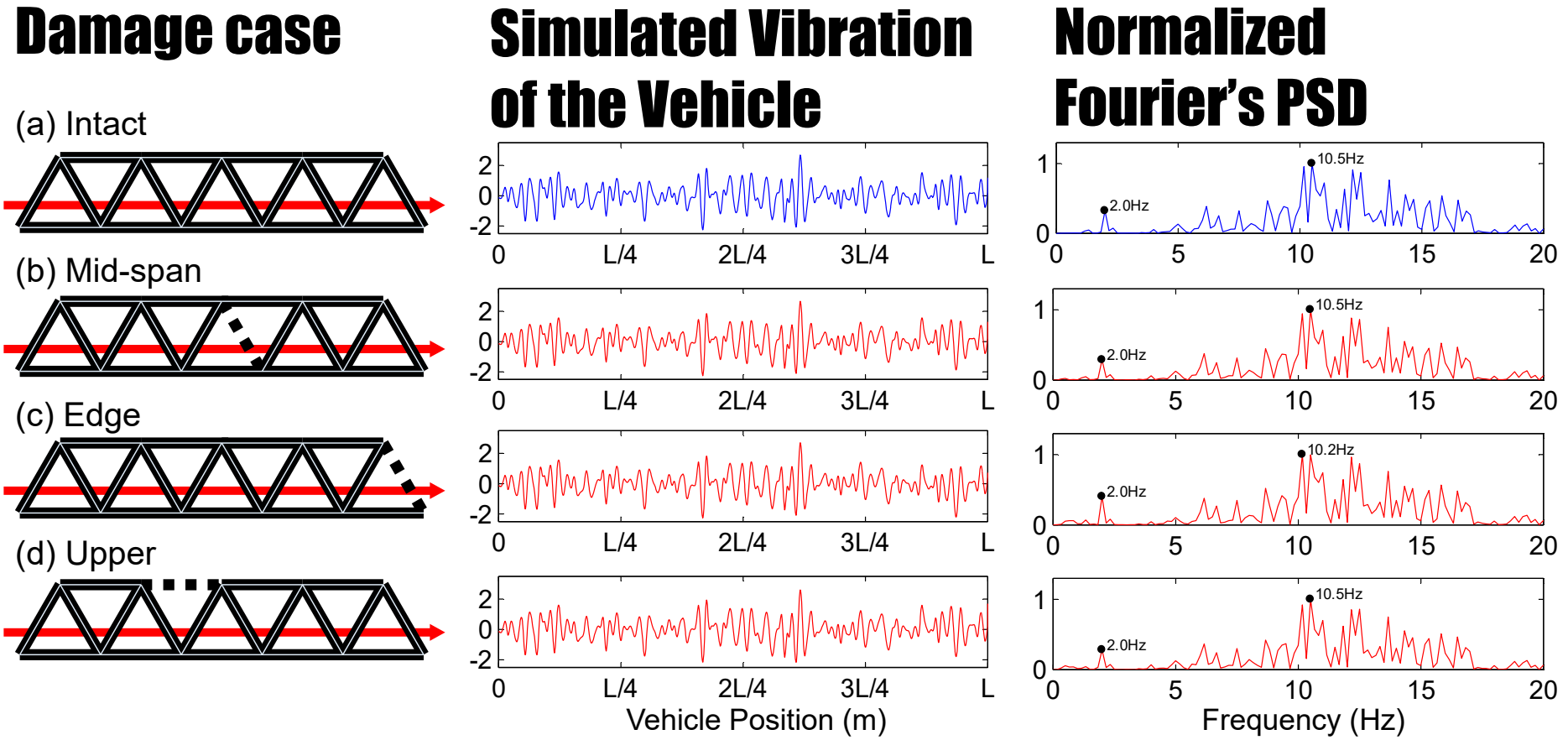
Global	Span Length [m]		40.0
	Width [m]		6.0
Deck	Element Division	Axial Direction	20
		Cross Direction	10
	Density [kg/m^3]		2400
	Thickness [m]		0.40
	Young's Modulus [Pa]		25×10^9
Truss Member	Density [kg/m^3]		7800
	Young's Modulus [Pa]		200×10^9
	Cross Section [m^2]		0.020
	Second Moment of Area [m^4]		1.0×10^{-4}
	Shear Modulus of Rigidity		78×10^9
	Second Polar Moment of Area [m^4]		1.0×10^{-6}



Vehicle Model

Sprung-	Mass [kg]	18,000
	Damping [kg/s]	10,000
	Stiffness [kg/s^2]	1.0×10^6
	Inertia Moment (Pitch) [kg m^2]	65,000
	Inertia Moment (Roll) [kg m^2]	15,000
	Length [m]	2.750
	Width [m]	1.800
Unsprung-	Mass [kg]	1,100
	Damping [kg/s]	30,000
	Stiffness [kg/s^2]	3.5×10^6
	Run speed [m/s]	10.0

Simulated vibrations and considered cases



Difficult to find change in **Time** and **Frequency** domain!

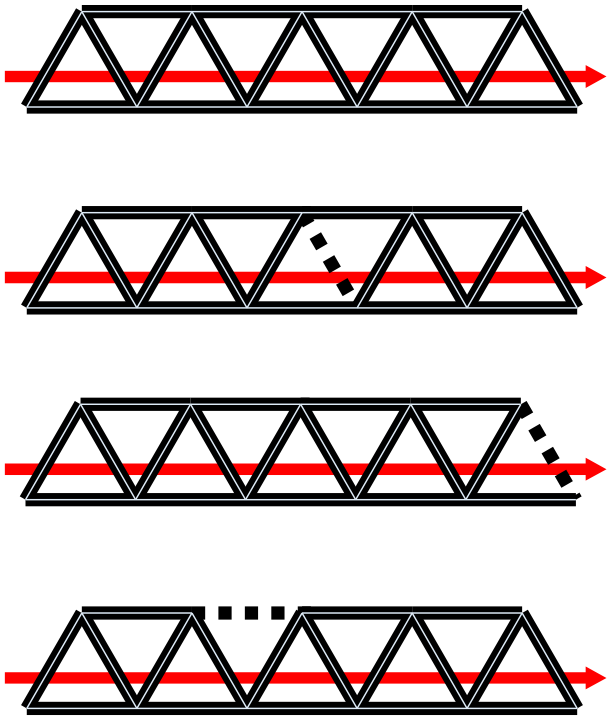
Damage case

(a) Intact

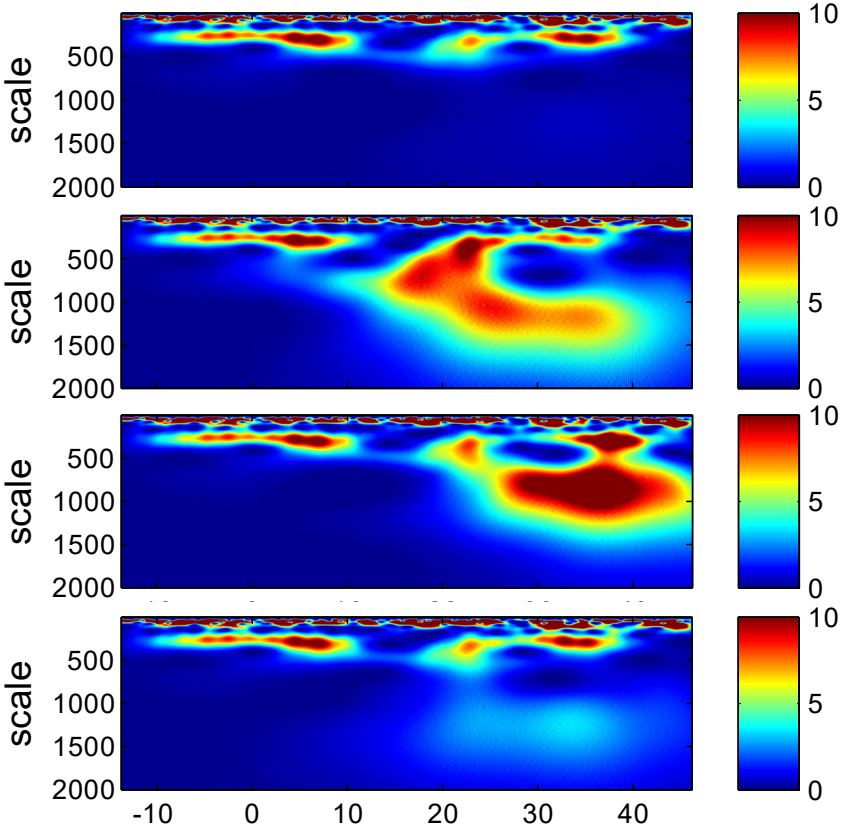
(b) Mid-span

(c) Edge

(d) Upper

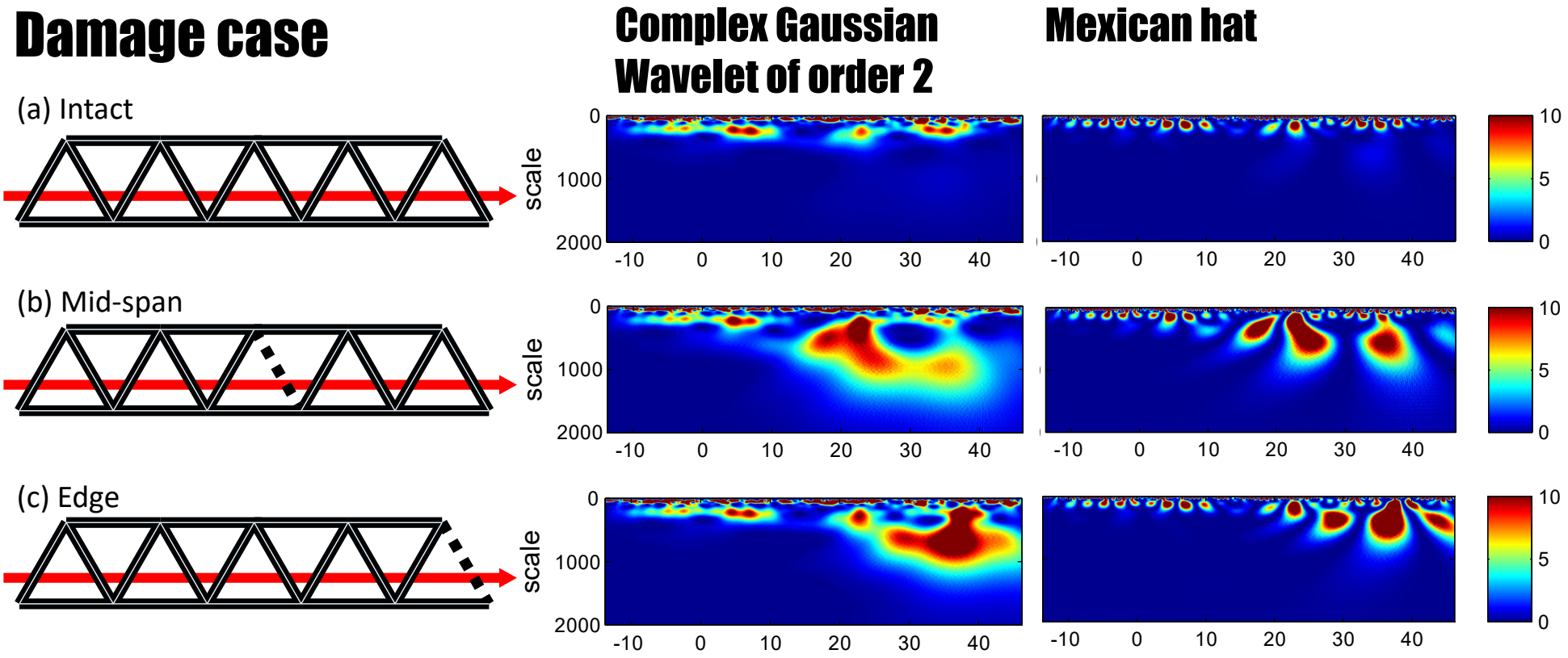


Spectrogram



Easy to find change in **Time-Frequency** domain!

Affect of mother wavelet



- **Every mother wavelet** can detect change
- The scale in which change appears is **different**

Traditional analysis:

Time Domain

Acceleration

Local

Frequency Domain

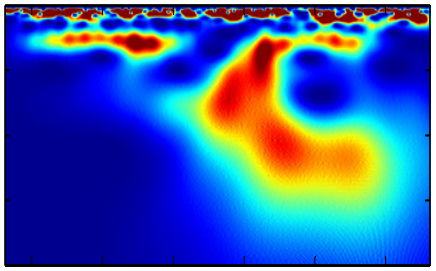
Fourier Transform

Stiffness Decreasing

New analysis:

Time-Frequency Domain

CWT



Bridge Damage

= Local Stiffness Decreasing

Conclusion & Technical issues

Conclusion

I. CWT can detect the bridge damage in the **High scale**.

II. CWT can identify the damaged location.

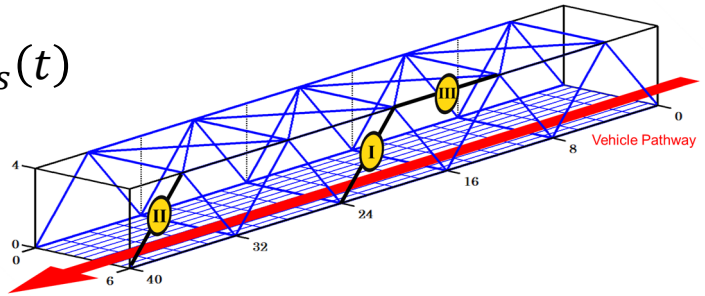
III. Bridge damage affects the **low frequency.**

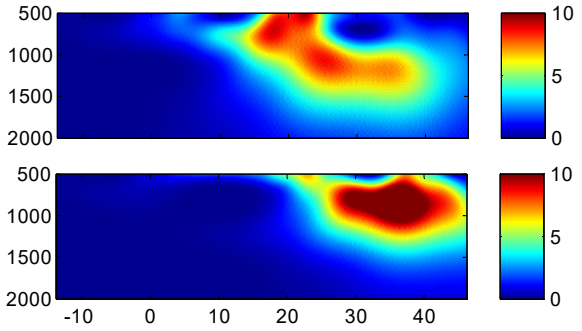
Technical issues

I. Impossible to measure the **super low frequency** of acceleration

II. Consider the **appropriate** mother wavelet for signal

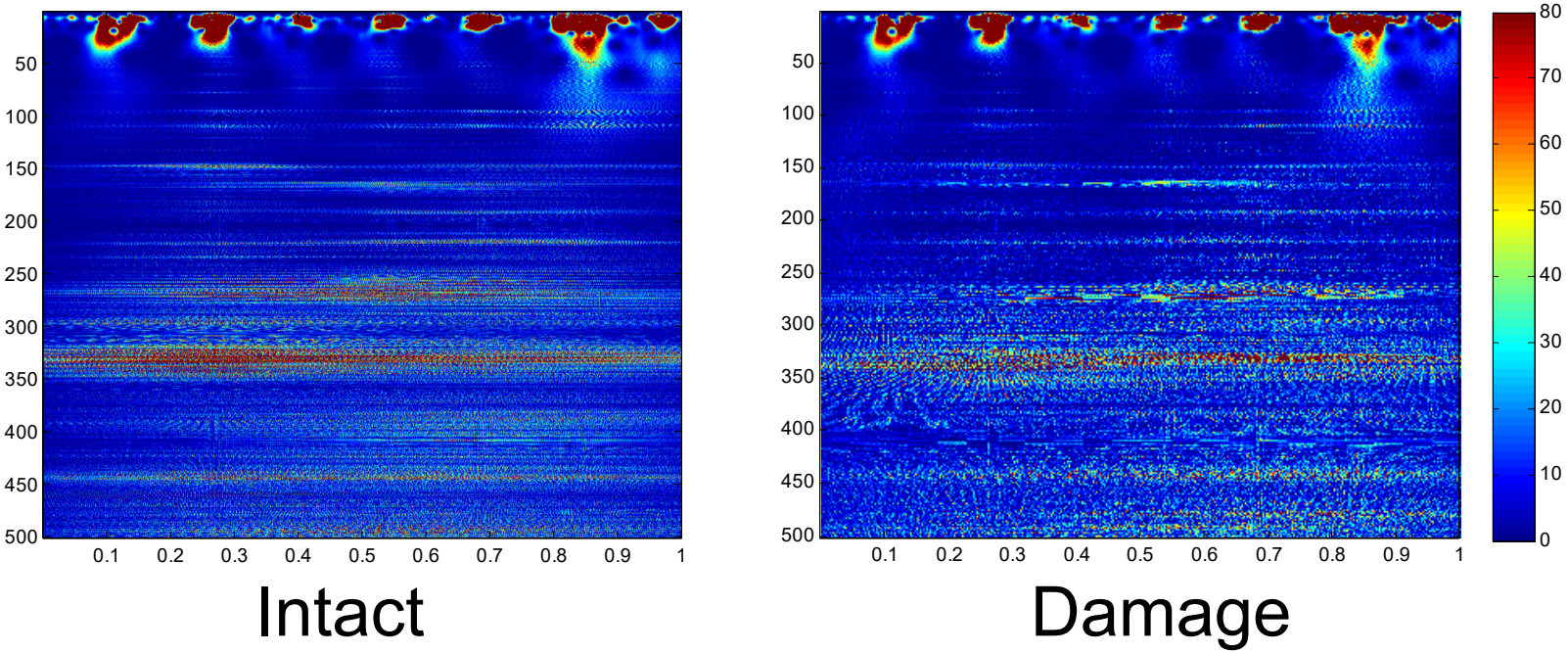
$$Wf(t,s) = \frac{1}{\sqrt{s}} \cdot f(t) \otimes \theta_s(t)$$





Experiment of actual bridge

- can **Not** detect



Intact

Damage