Numerical Verification of Bridge Screening Technology based on Vehicle Vibration

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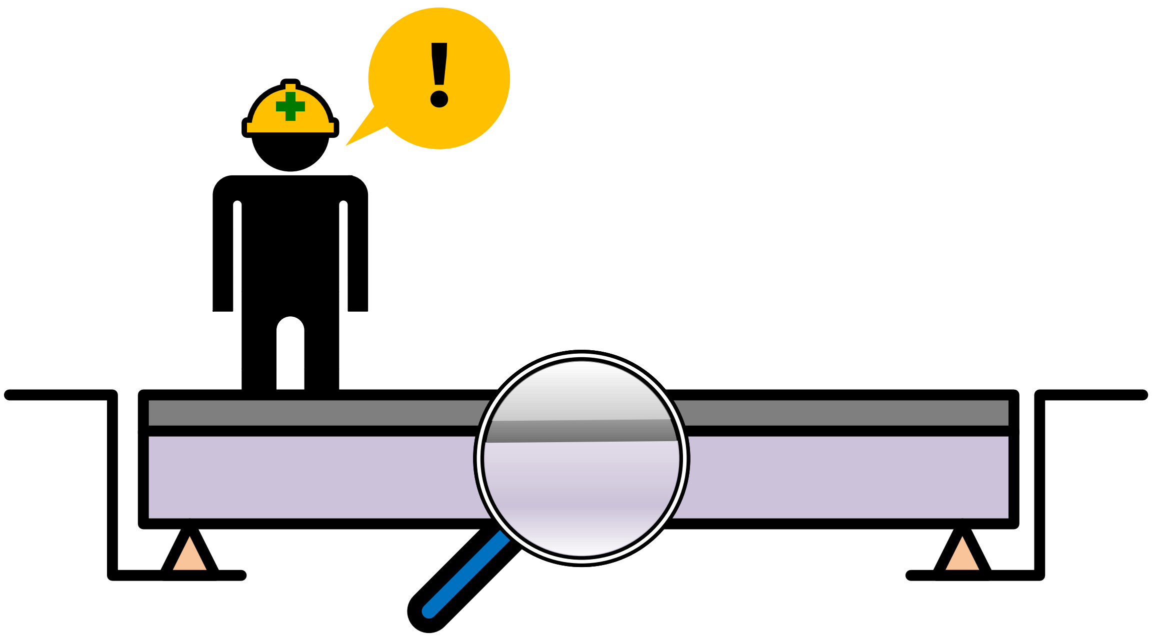
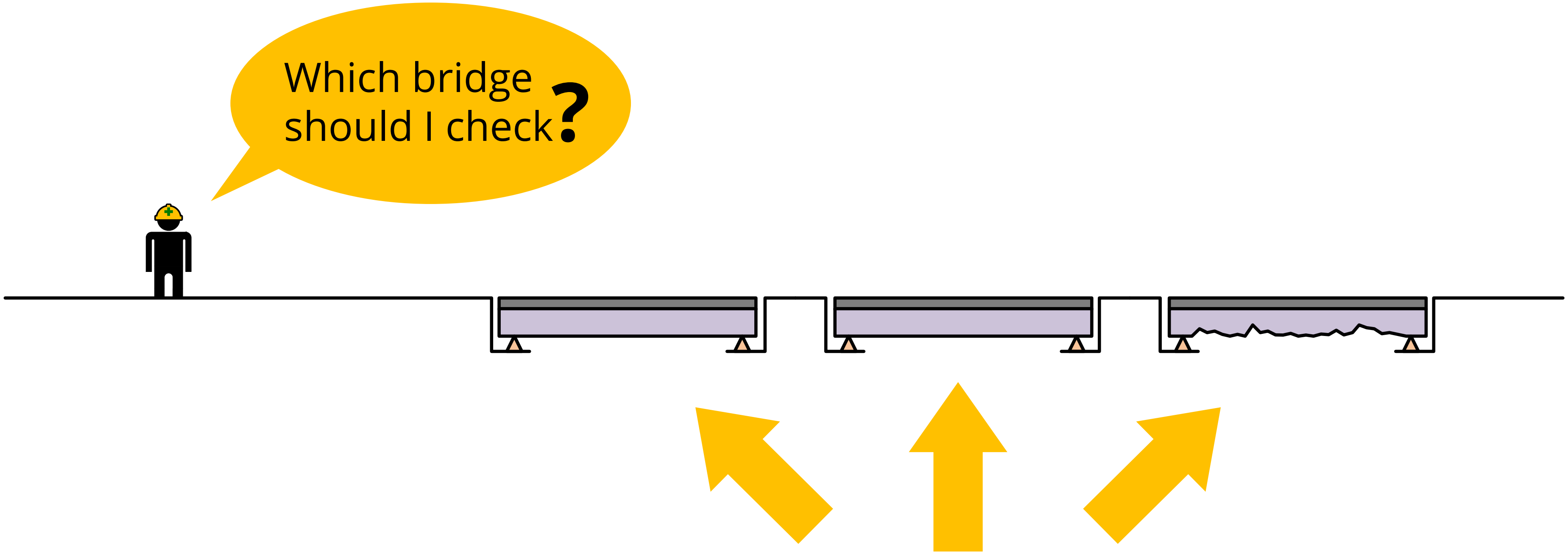
Background:

Bridge Inspections based on **Visual Check** by **Veteran Engineers**



Social Matter:

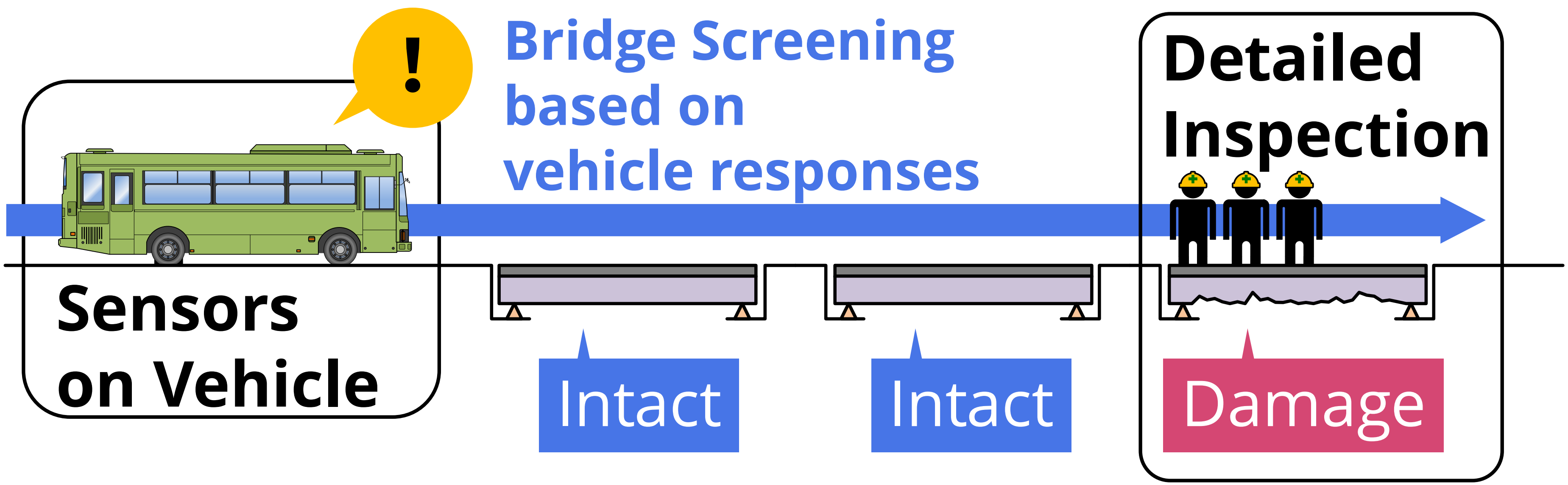
The Training of Engineers requires several years, though there is a **Large Number of Aging bridges**



To implement the priorities of bridges
we need to know the soundness before the inspections!?

Solutions:

Bridge Screening (Roughly Quick Inspection) enables **Strategic Allocation of Resources**



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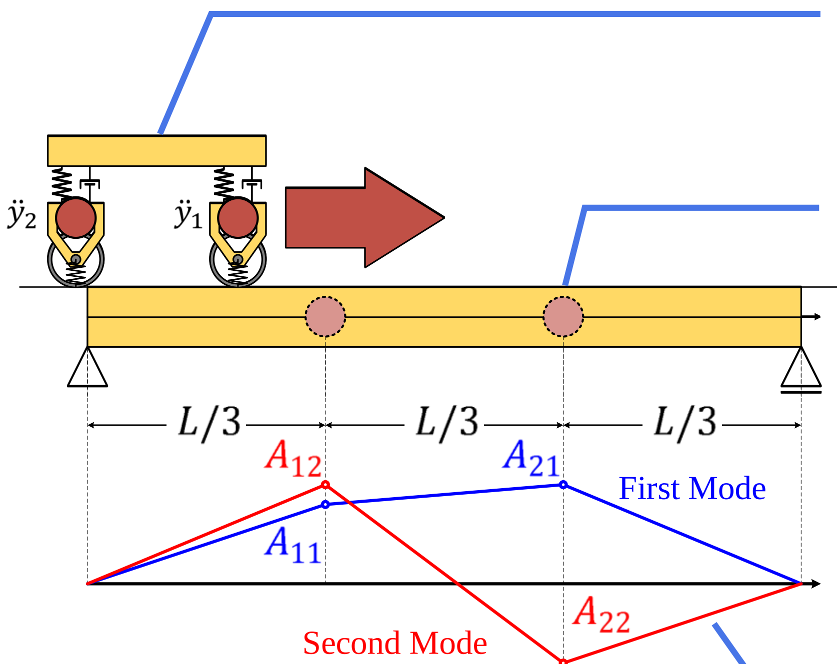
Technical issue:

How to estimate the **bridge status** only by using **vehicle vibrations**?



1. To measure the vibrations of the **passing vehicle**
2. To transform them to vibrations at the **fixed points**
3. To estimate the **mode shapes** of the bridge

Spatial Singular Mode Angle:

$$\theta = \tan^{-1}\left(\frac{A_{21}}{A_{11}}\right) = \tan^{-1}\left(-\frac{A_{12}}{A_{22}}\right)$$

The Purpose:

To examine the applicability of SSMA to the Bridge Screening

Bridge Vibration

$$\boldsymbol{y}(t) = \mathbf{A}\boldsymbol{q}(t)$$

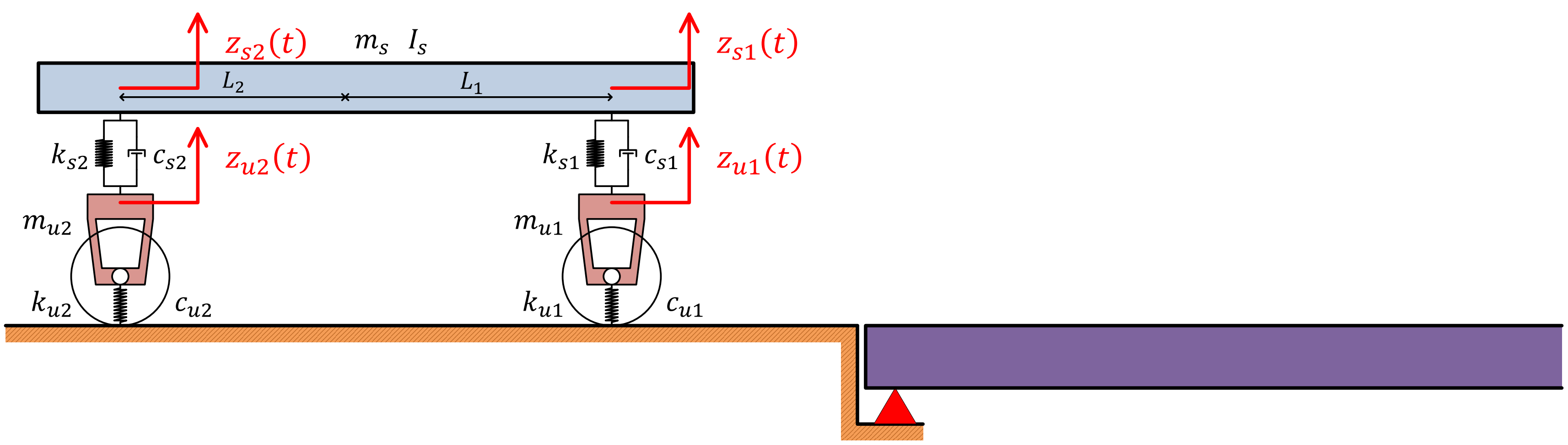
Bridge Vibrations measured at Moving Positions

$$\mathbf{N}(t)^{-1}\widetilde{\boldsymbol{y}}(t) = \mathbf{A}\boldsymbol{q}(t)$$

Vehicle Vibrations

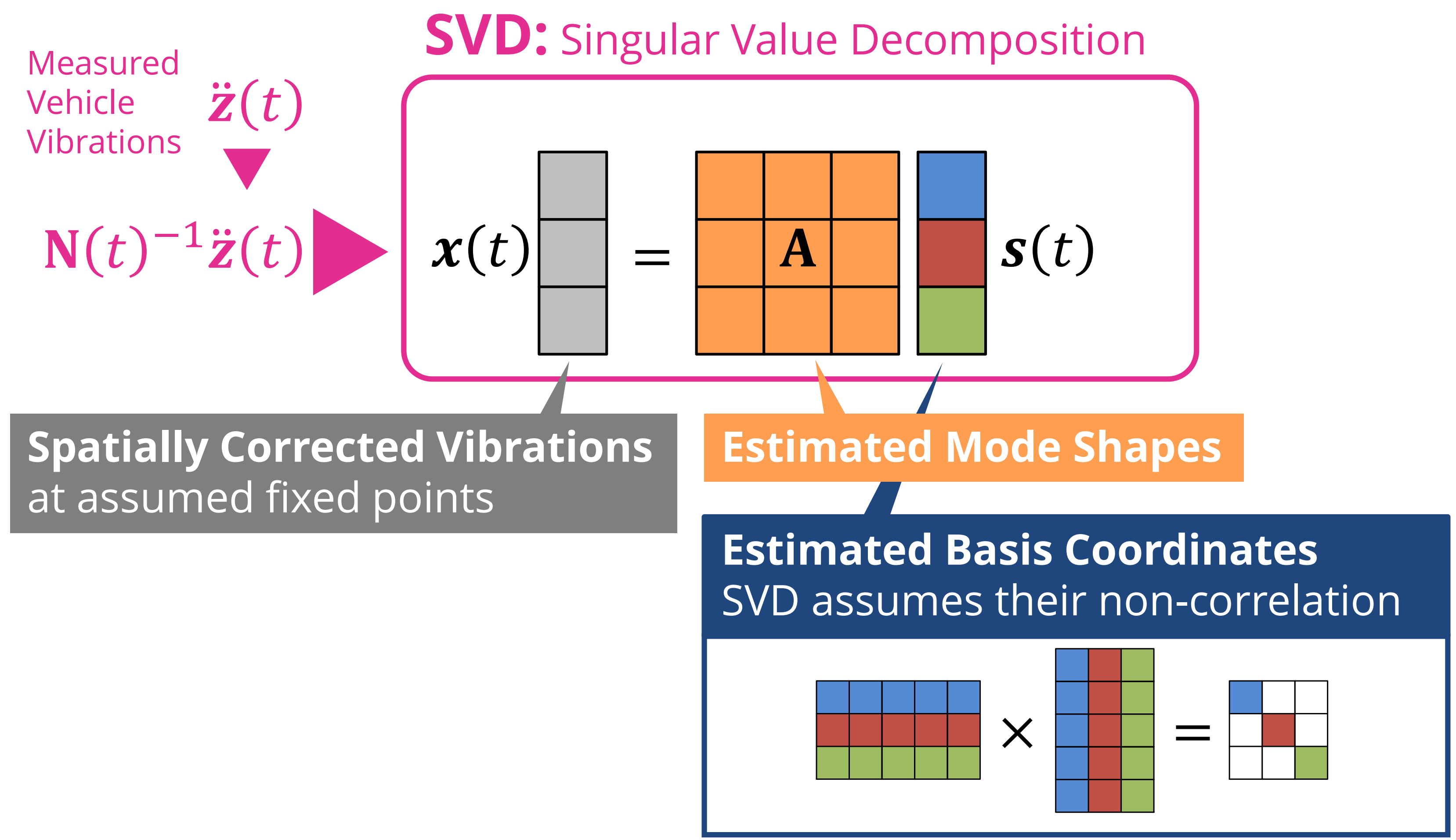
(1) Bridge vibrations
(2) Road Roughness
(3) Vehicle Body vibrations

$$\mathbf{N}(t)^{-1}\ddot{\mathbf{z}}(t) = \mathbf{A}\boldsymbol{\sigma}(t)$$



The Proposed Method:

Application of **SVD** method to **the spatially corrected vibration data**



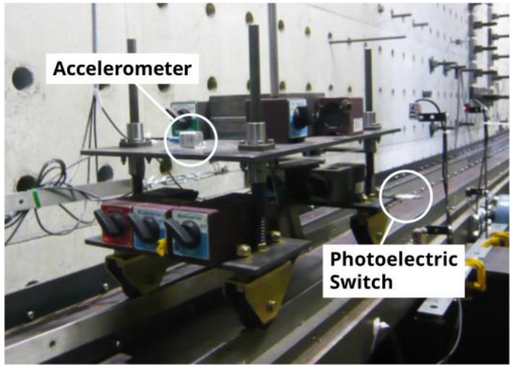
The Methodology:

Experimental & Numerical Verification

Data Acquisition ▶ **Application of the proposed method**

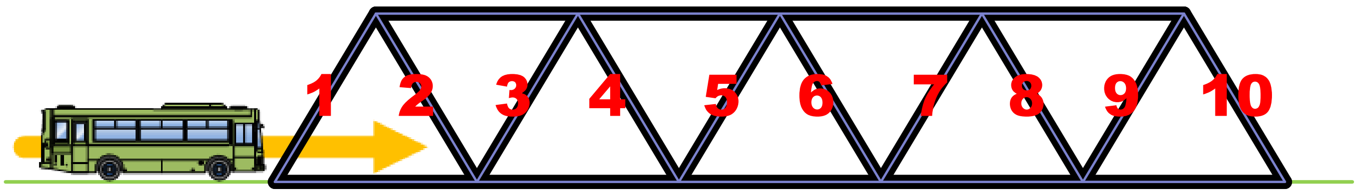
▲

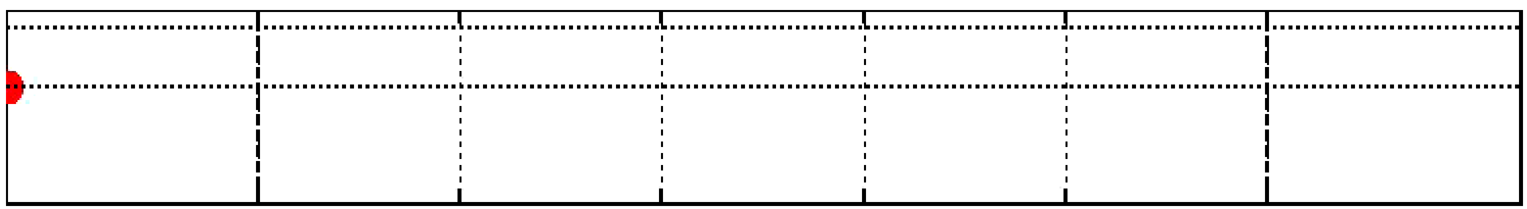
Numerical Simulation
Field Experiment
Laboratory Experiment



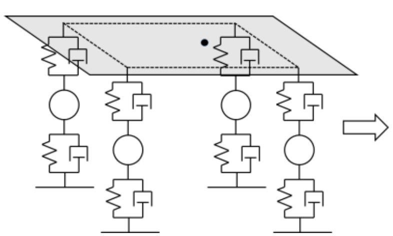
The Numerical Simulation:

RBSM Vehicle & FEM Bridge

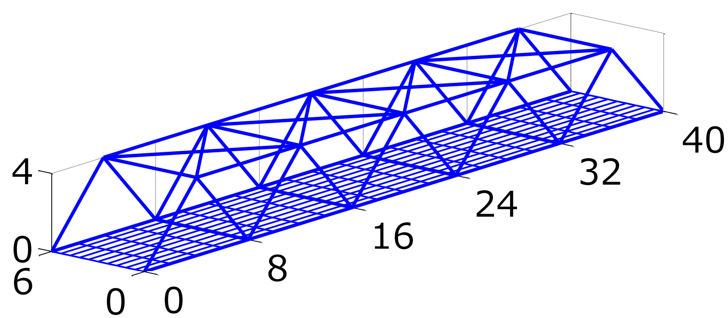




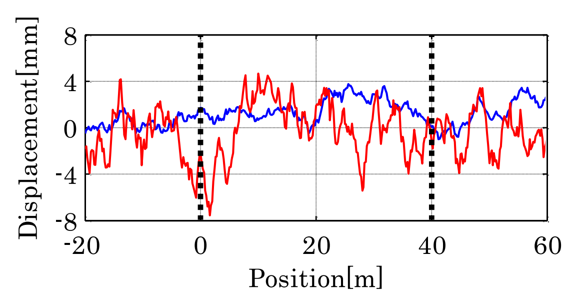
20t (=200kN)
Vehicle Model



40m span Steel Truss Bridge



Road Unevenness



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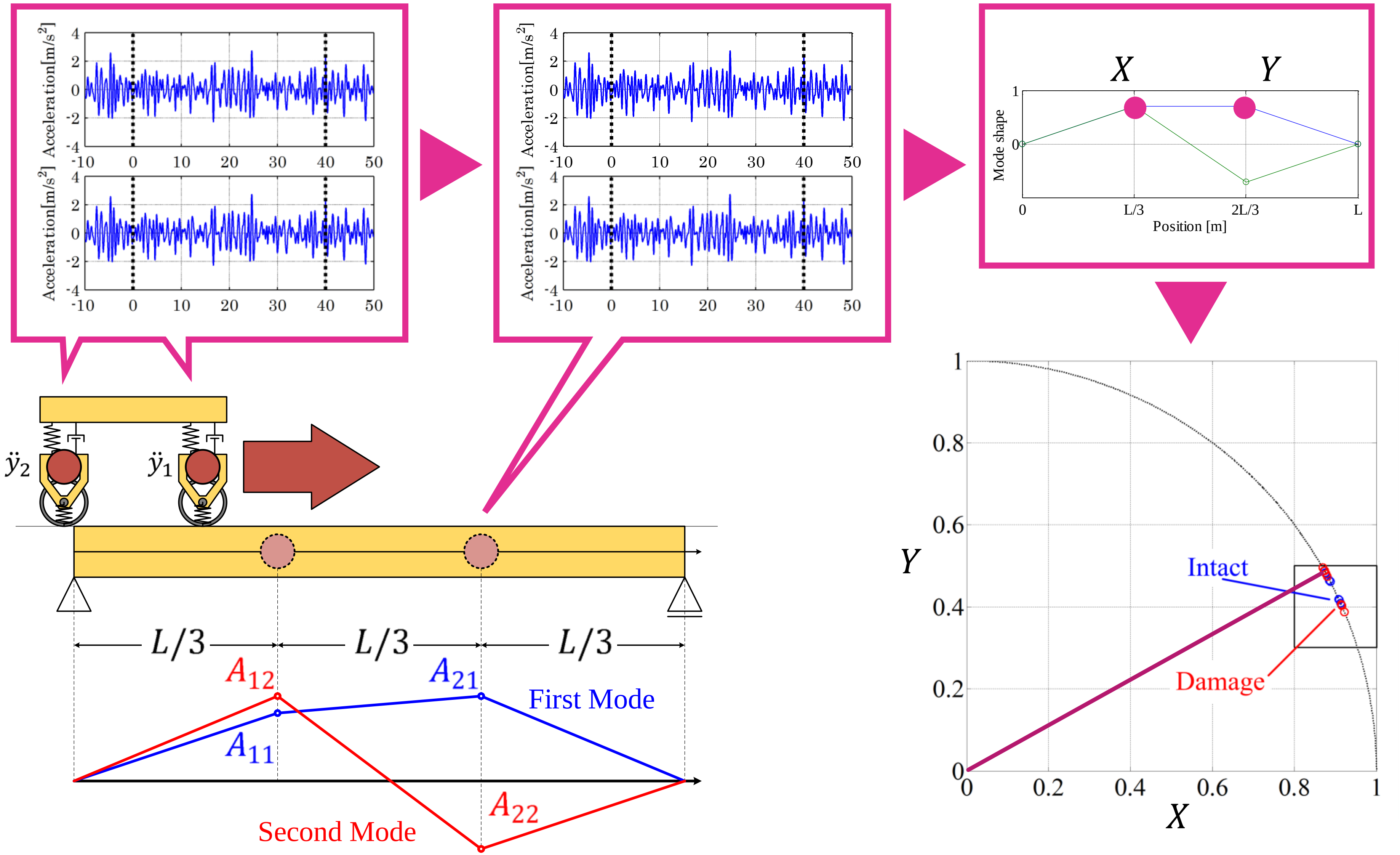
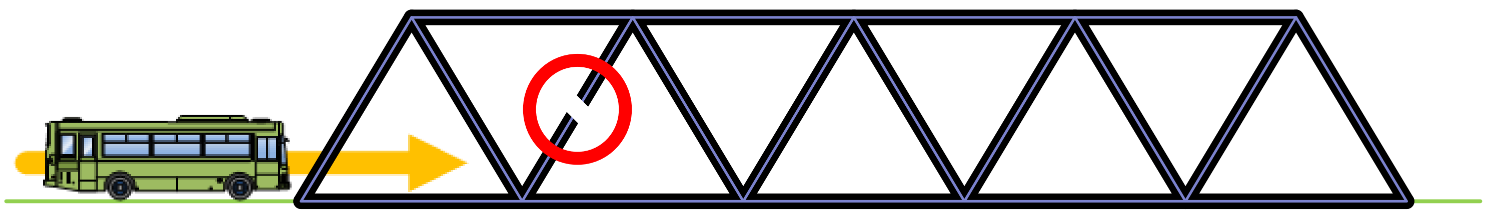
The Procedure to calculate SSMA:

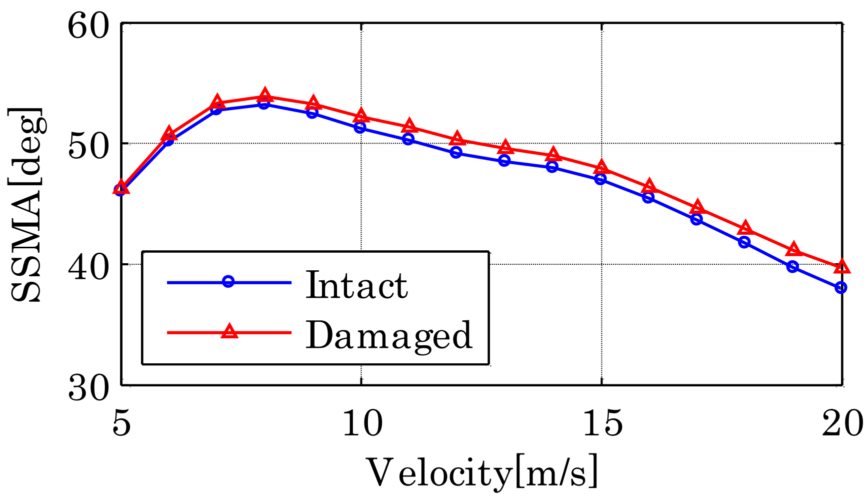
Spatial Correction & Mode Decomposition



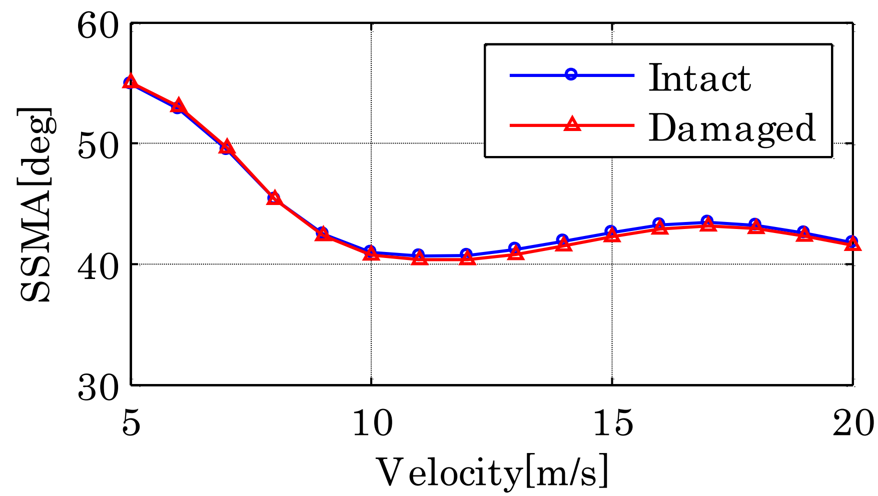
The Results of Numerical Simulation:

SSMA Applicability to the damage detection when varying **velocity** & **road roughness**





Smooth Road



Rough Road

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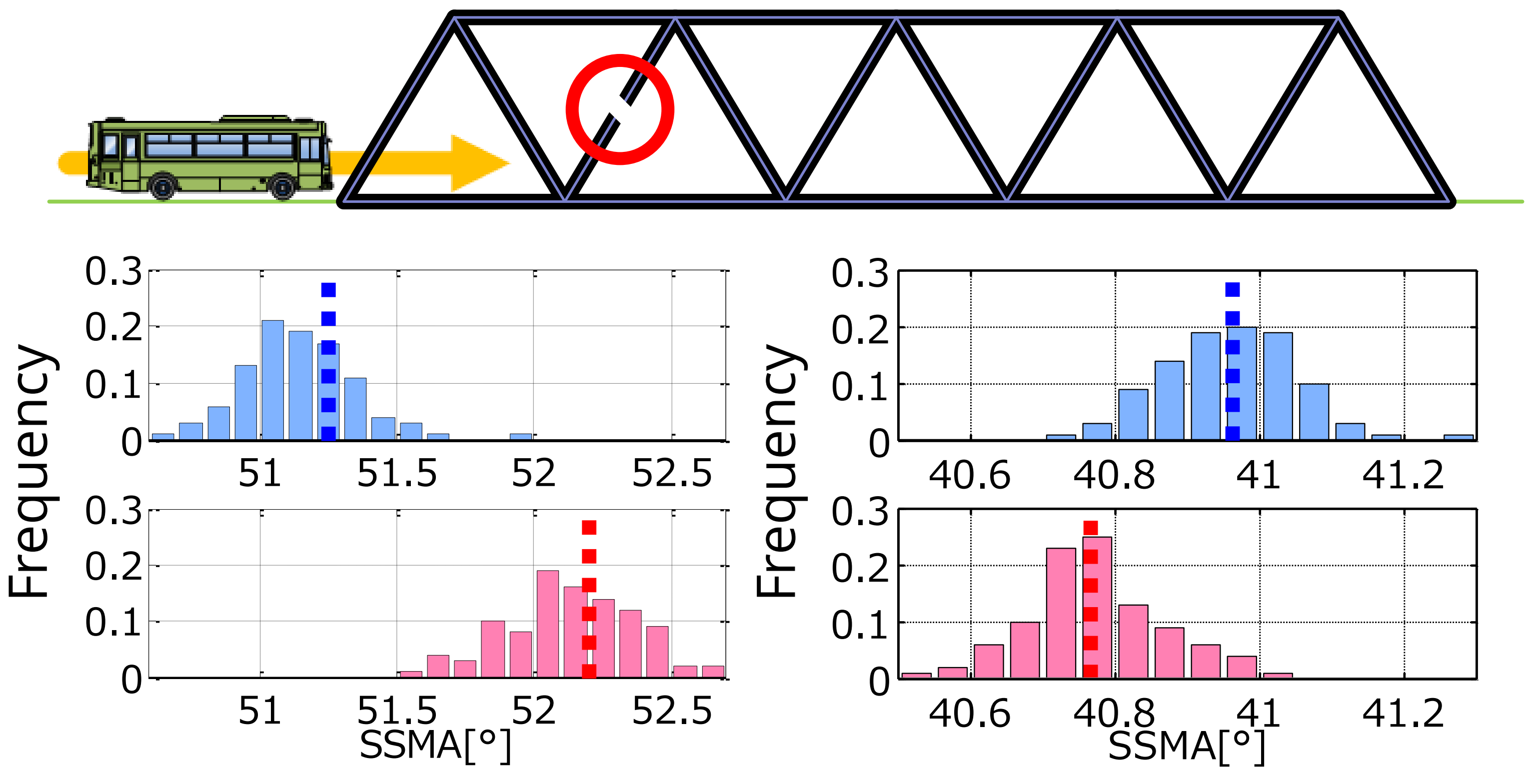
The Robustness:

It is found that **SSMA** has the high sensitivity to a local bridge damage



Smooth Road **Rough Road**

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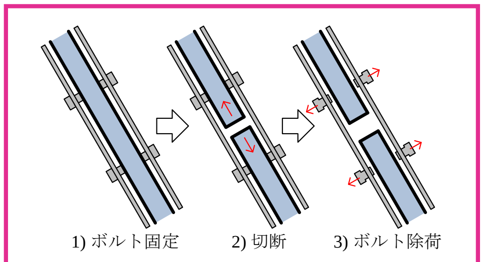
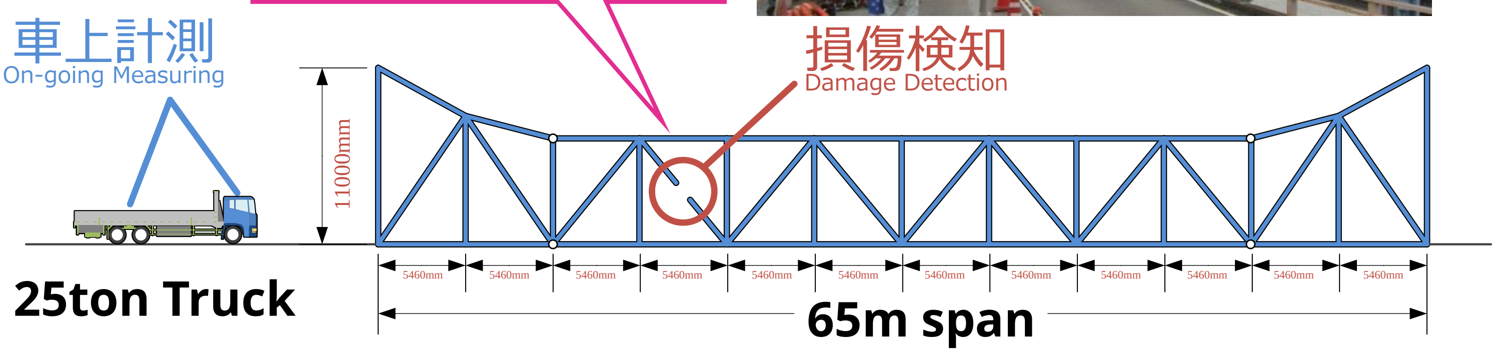
The Field Experiment:

SSMA Applicability to the damage detection on **the actual steel truss bridge**



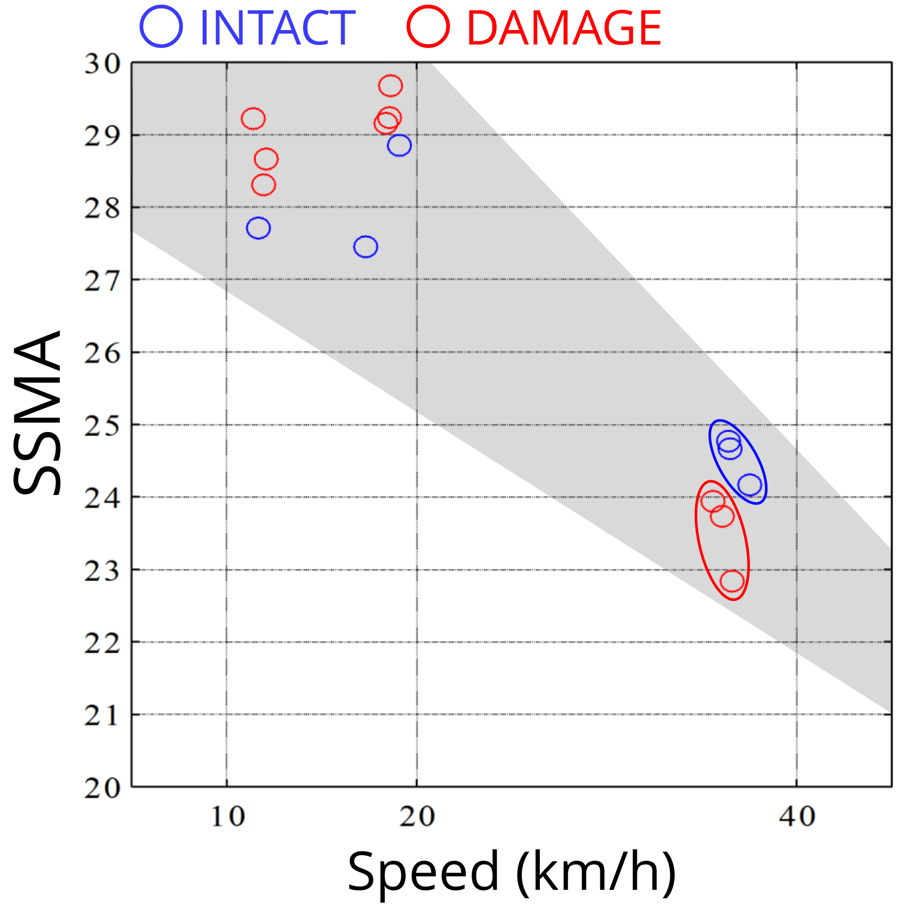


	Front (kN)	Rear (kN)	Total (kN)	INTACT 10(km/h)	INTACT 20(km/h)	INTACT 40(km/h)	DAMAGE 10(km/h)	DAMAGE 20(km/h)	DAMAGE 40(km/h)
First Day	87.4	165.8	253.2	First	First	First			
Second Day	87.8	170.6	258.4		Second	Second Third	First Second Third	First Second Third	First Second Third

The Results of Field Experiment:

High sensitivity to the **damage detection**

Low Accuracy to the damage identification



Because the mode shape is independent from the vehicle speed, it means the **low estimation accuracy** of SSMA.

The **high sensitivity** to damage because the angle changes distinctively after damage.

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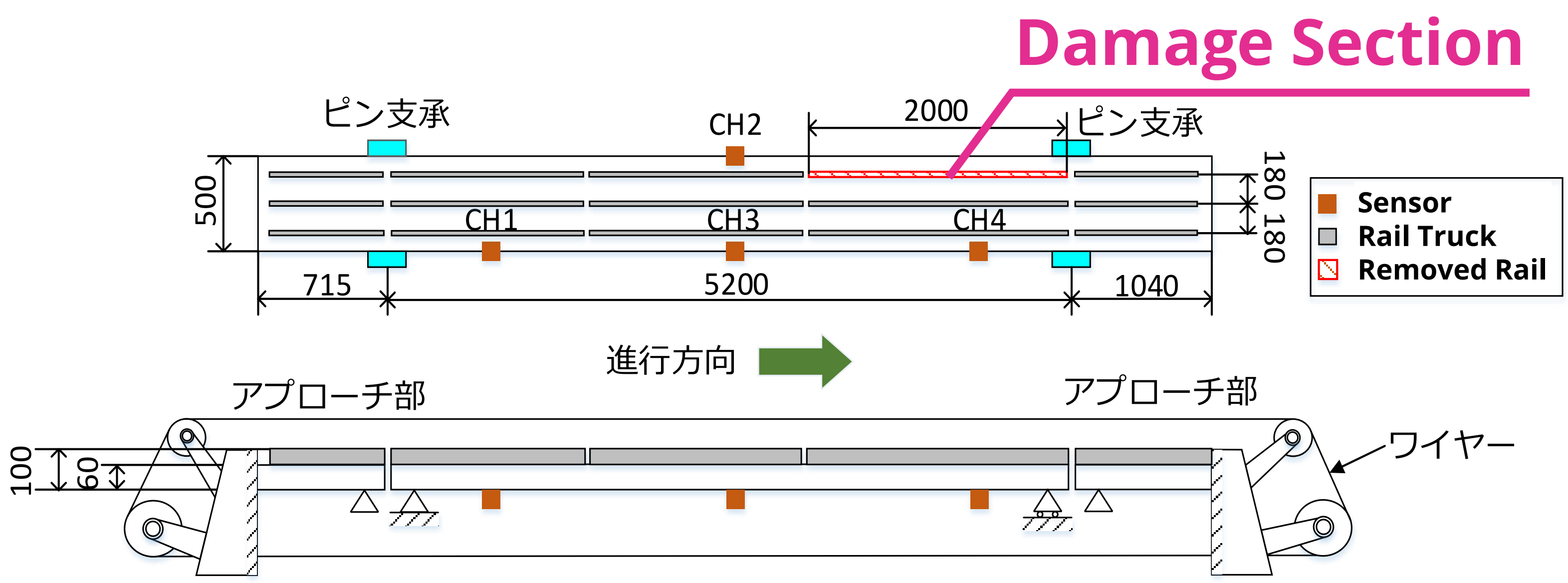
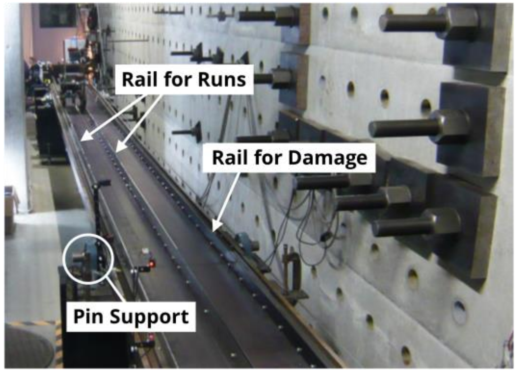
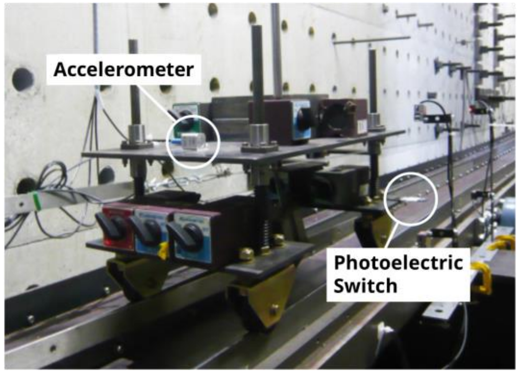
The Lab. Experiment:

Statistical Validity of SSMA should be examined for Engineering application







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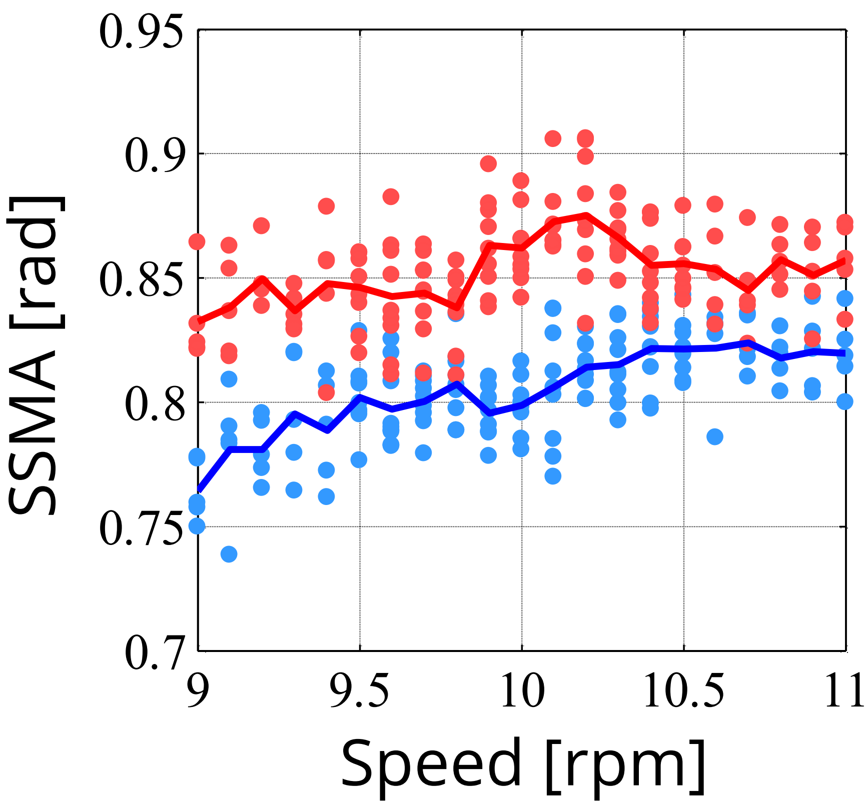
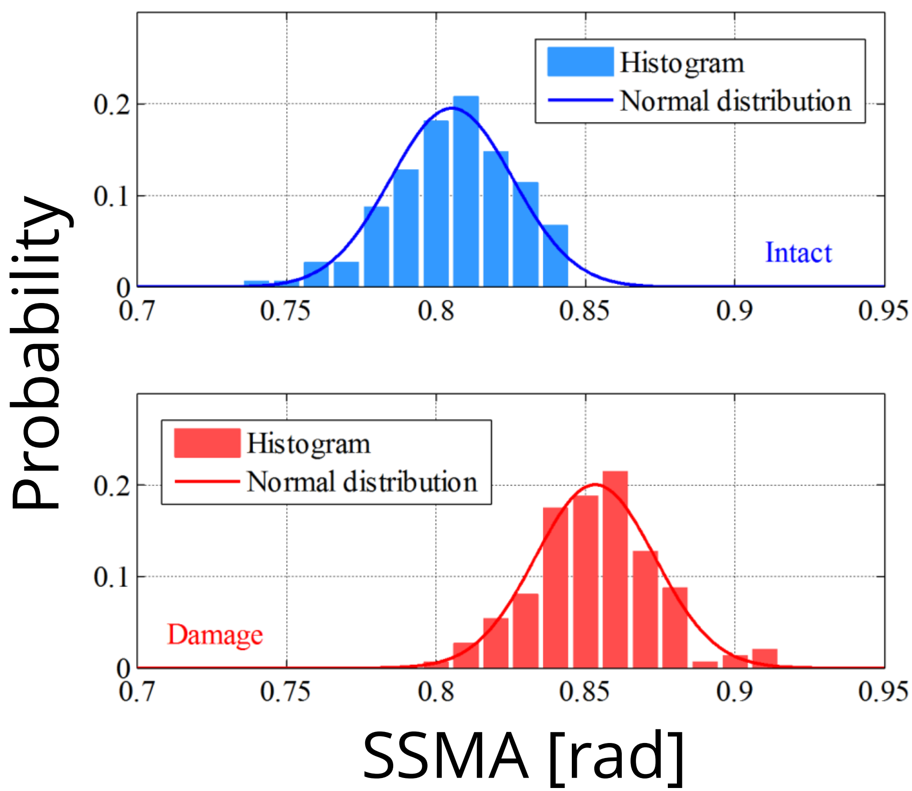
The result of the Lab. Experiment:

SSMA probability density distribution statistically changes after the bridge damage





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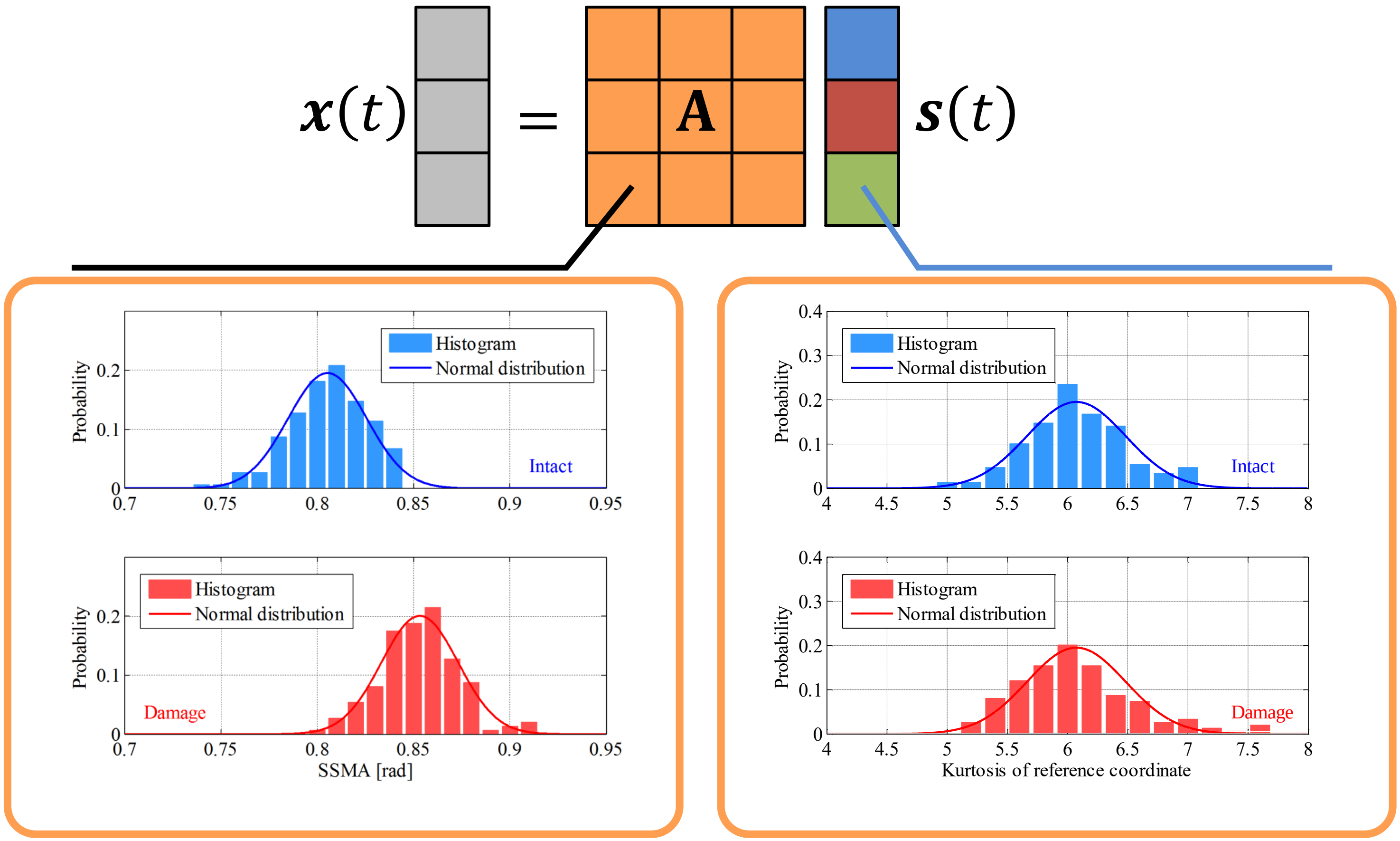
Discussion:

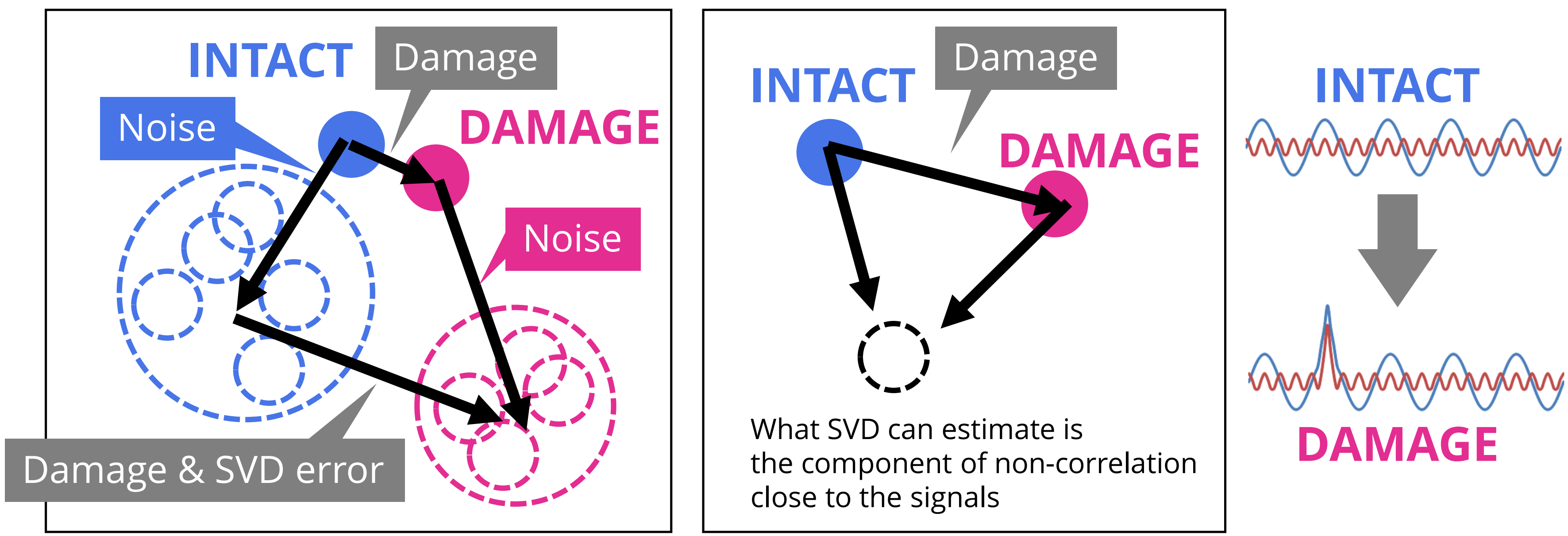
Why does **SSMA** shows the high sensitivity to the bridge damage?



Discussion:

Why does SSMA shows the high sensitivity to the bridge damage?

$$\boldsymbol{x}(t) = \boldsymbol{A}\,\boldsymbol{s}(t)$$



Mode Shape　　Basis Coordinate

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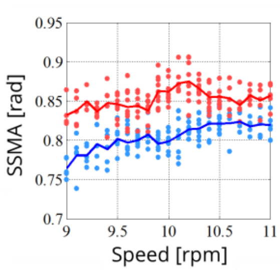
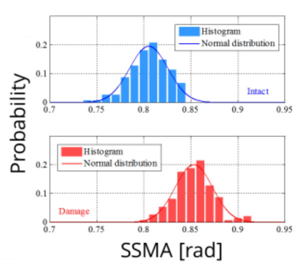
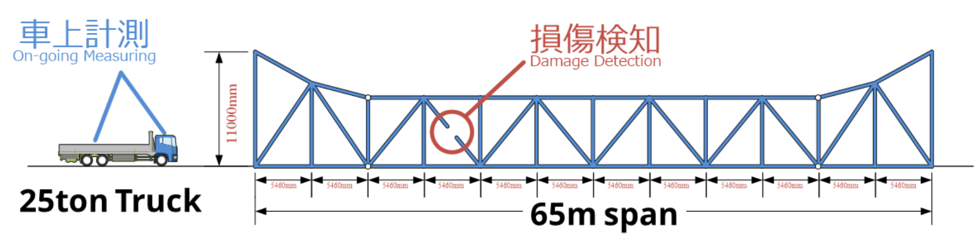
Conclusion:

1. SSMA is the **bridge mode shape estimated** only by using the vehicle data.
2. The applicability and statistical validity is verified **numerically** and **experimentally**.
3. It is applicable to the **damage detection** because of its high sensitivity.
4. It is still difficult to apply SSMA to the **damage identification**, because of its low estimation accuracy







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