Fault Detection in Railway Suspensions under Varying Operating Conditions via MISO Transmittance Functions and Neural Networks

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The General Problem

Damage detection of minor faults in all railway vehicle's suspension component types under varying operational conditions (OCs) (vehicle's speed and the change in the geometry of the rails due to wear), based on vibration signals retrieved from the vehicle using the Simpack simulation program.

The Challenge

Minor faults don't cause distinct effects on the vibration signal's characteristics, while they are masked by the varying OCs.

The Study Goals

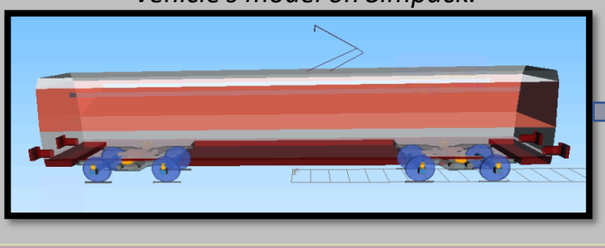
- Robust damage detection under two varying OCs (vehicle's speed, track's profile).
- Evaluation of Neural Networks using small training database.
- Early damage detection in all railway vehicle's suspension component types.

Used Methods

- **U-NN-MISO-TF-ARX:** Unsupervised Neural Network MISO Transmittance Function ARX.
- **U-MM-MISO-TF-ARX:** Unsupervised Multiple Models MISO Transmittance Function ARX.

Precise Problem Statement

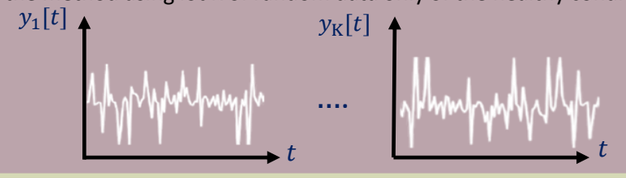
Vehicle's model on Simpack.



Data acquisition

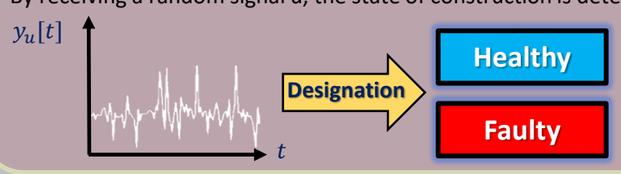
Baseline Phase

Training of the method using lot K of random data only of the healthy condition.



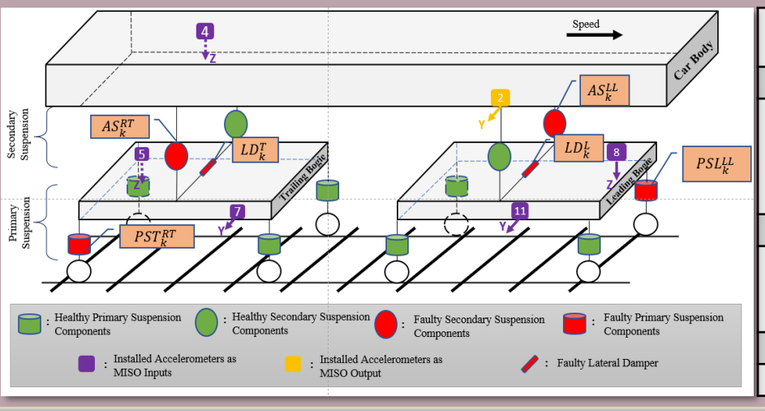
Inspection Phase

By receiving a random signal u, the state of construction is determined.



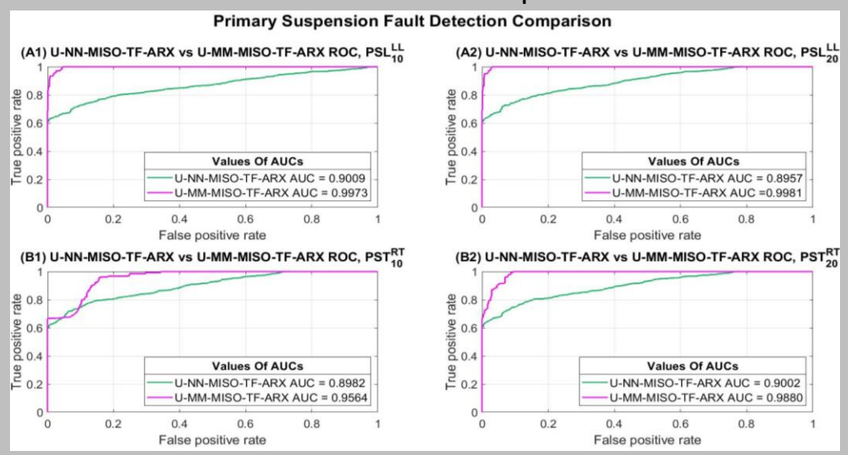
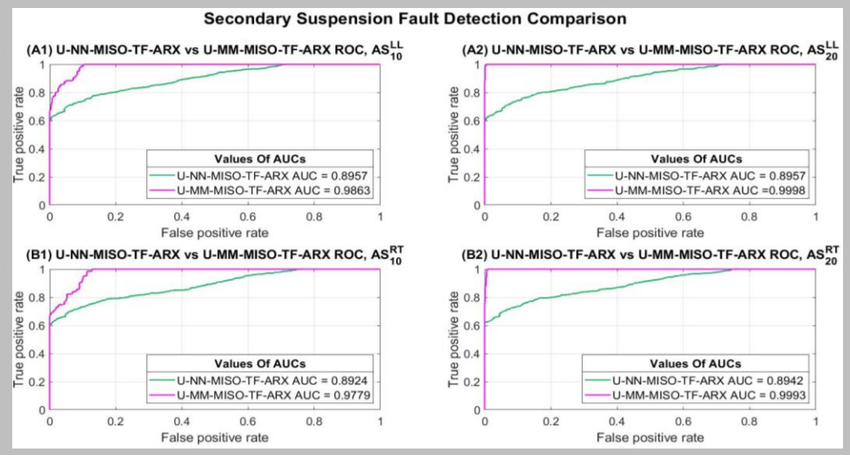
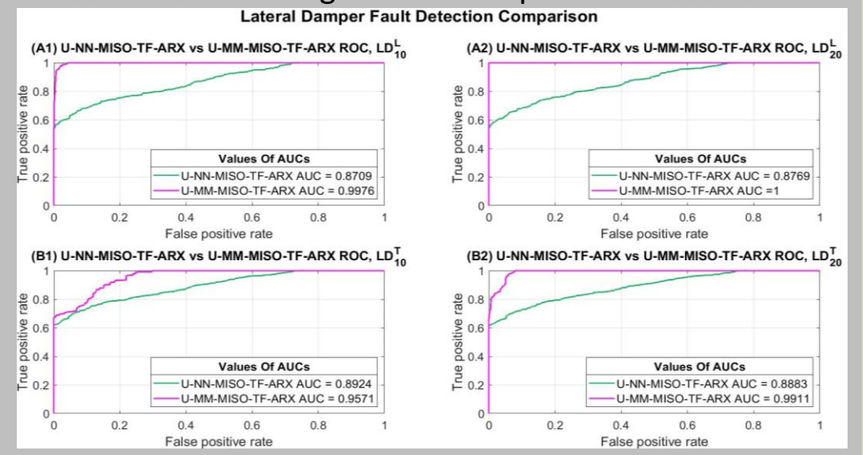
Simulation Characteristics

15 Rotations for Robustness



Fault Type	Fault Description	Fault range (k)
PSL_k^{LL} PST_k^{RT}	Reduction of all stiffness and damping constants in the directions (x, y, z) by the same percentage, due to fatigue of the material.	10%,20%
AS_k^{LL} AS_k^{RT}	Reduce all stiffness and damping constants in the directions (x, y, z) by the same percentage, due to air loss.	10%,20%
LD_k^{L} LD_k^{T}	Reduction of the damping factor due to loss of lubricant.	10%,20%

Vehicle's State	Speed – Track's Profile						Total signals per situation
	60 km/h		70 km/h		80 km/h		
	Low Profile	High Profile	Low Profile	High Profile	Low Profile	High Profile	
Healthy	20	20	20	20	20	20	120
Fault $LD_{10,20}^{L}$	10	10	10	10	10	10	60
Fault $LD_{10,20}^{T}$	10	10	10	10	10	10	60
Fault $AS_{10,20}^{RT}$	10	10	10	10	10	10	60
Fault $AS_{10,20}^{LL}$	10	10	10	10	10	10	60
Fault $PSL_{10,20}^{LL}$	10	10	10	10	10	10	60
Fault $PST_{10,20}^{RT}$	10	10	10	10	10	10	60
Total signals per combination of OCs.	140	140	140	140	140	140	

Detection Results

1. Only 1 Fault scenario (LD_{20}^{L}) is 100% successfully detected by U-MM-MISO-TF-ARX.
2. The U-MM-MISO-TF-ARX is Superior in All Cases.
3. Better Detection for the Leading Bogie.
4. The U-NN-MISO-TF-ARX needs more Training Data or Complex Architecture.