Drive-by Detection of Railway Track Settlement and Bridge Damage

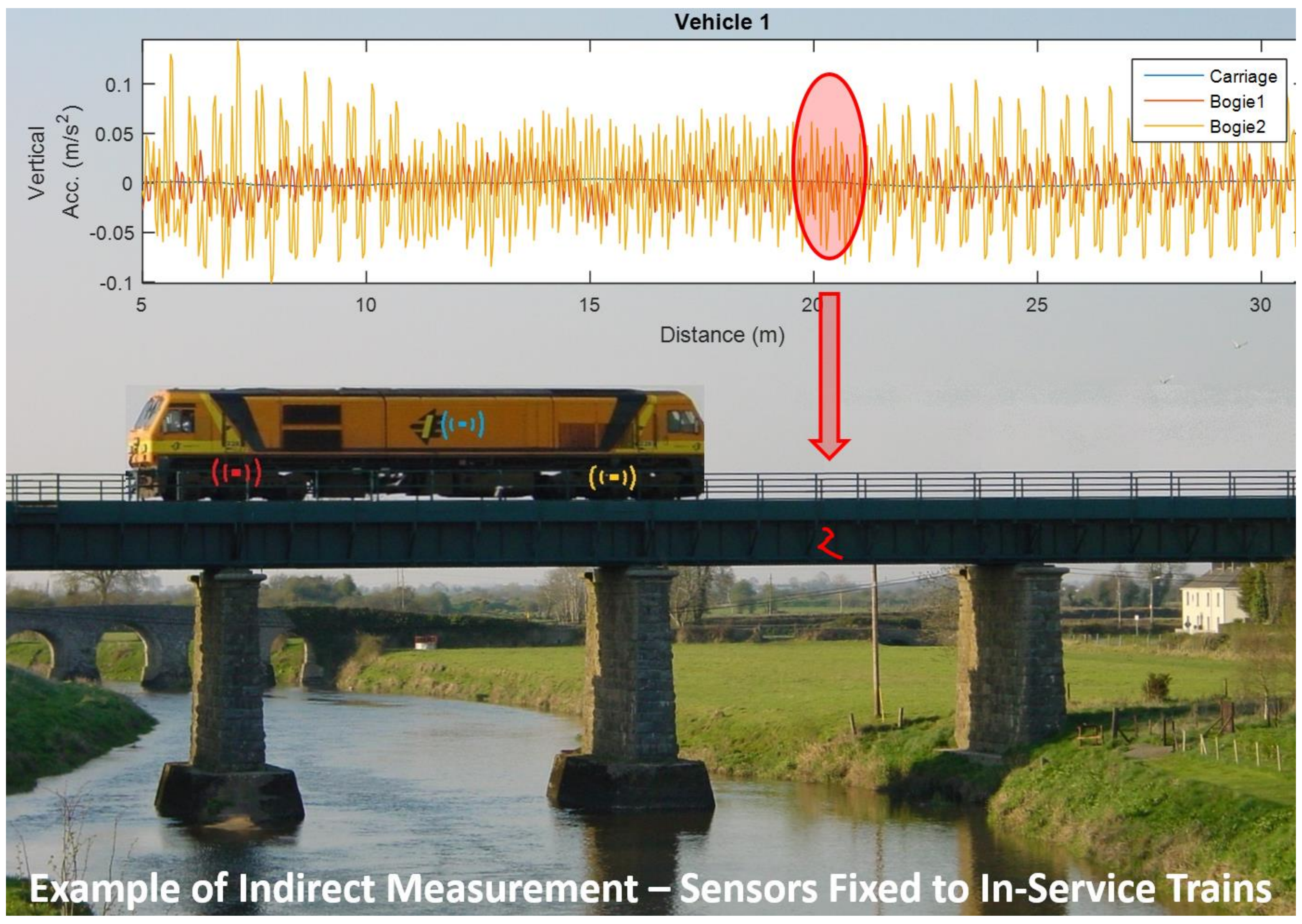
Paraic Quirke

SUPERR ITN
Sustainable Pavement & Railway Initial Training Network

www.superitn.eu
@superitn
@PQwitt
paraic.quirke@irishrail.ie

Introduction

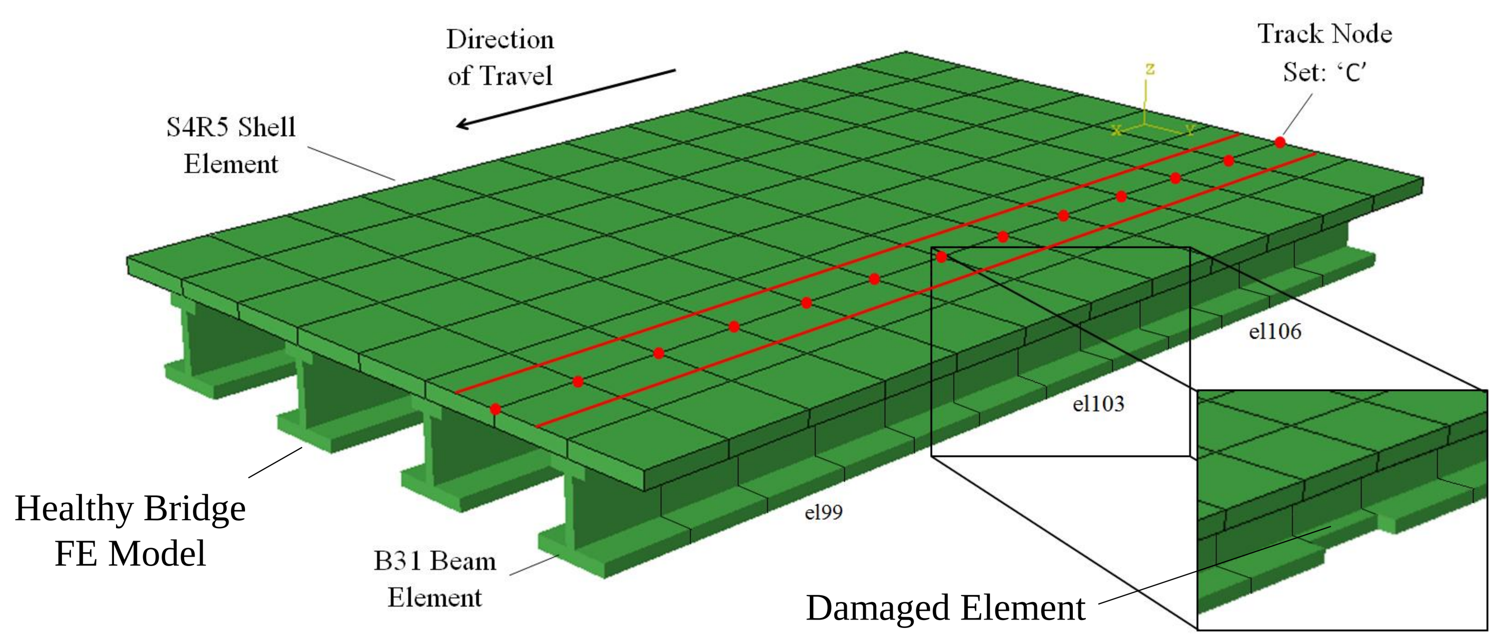
This project is concerned with the maintenance and sustainability of the railway network. Railway tracks settle over time which may result in safety issues. Bridges can also deteriorate due to corrosion or to impact from vehicles passing underneath. The purpose of this project is to develop and test methods whereby sensors in a train can be used to detect track settlement and bridge damage. The concept of indirect condition monitoring of railway infrastructure, using trains in revenue service, has the potential to provide inexpensive daily 'drive-by' track monitoring to complement and compare to data collected by less-frequent monitoring techniques. Simulations will be used to test the drive-by monitoring strategies. Field measurements on trains will be used to calibrate and test the concepts in real world conditions.



Example of Indirect Measurement – Sensors Fixed to In-Service Trains

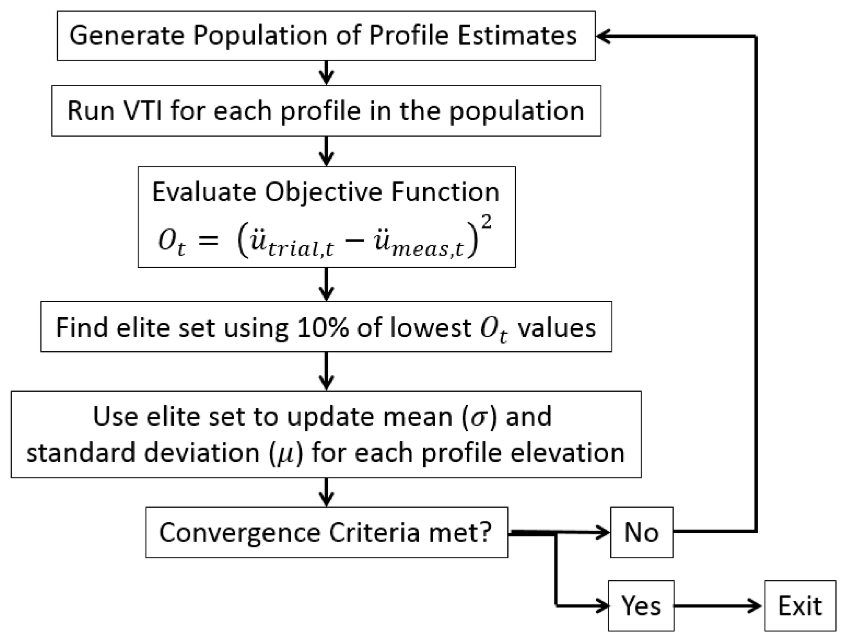
Bridge Damage Detection through Apparent Profile

The striking of bridges by large vehicles is considered by Irish Rail to be 'the single most likely cause of a serious rail safety incident on the network' and there were 85 strikes recorded in 2015. The presence of damage in a railway bridge alters its stiffness and consequently, its static and dynamic response to loading. The dynamic response of a railway bridge to loading excites a dynamic response in the passing vehicle, potentially enabling detection of the damage through analysis of the vehicle response. As part of this project I have developed a method for the detection of bridge damage through comparison of apparent profiles sensed by the passing vehicle. The apparent profile is a virtual longitudinal profile which, when applied to a vehicle, invokes the same measured response to the crossing of a bridge.

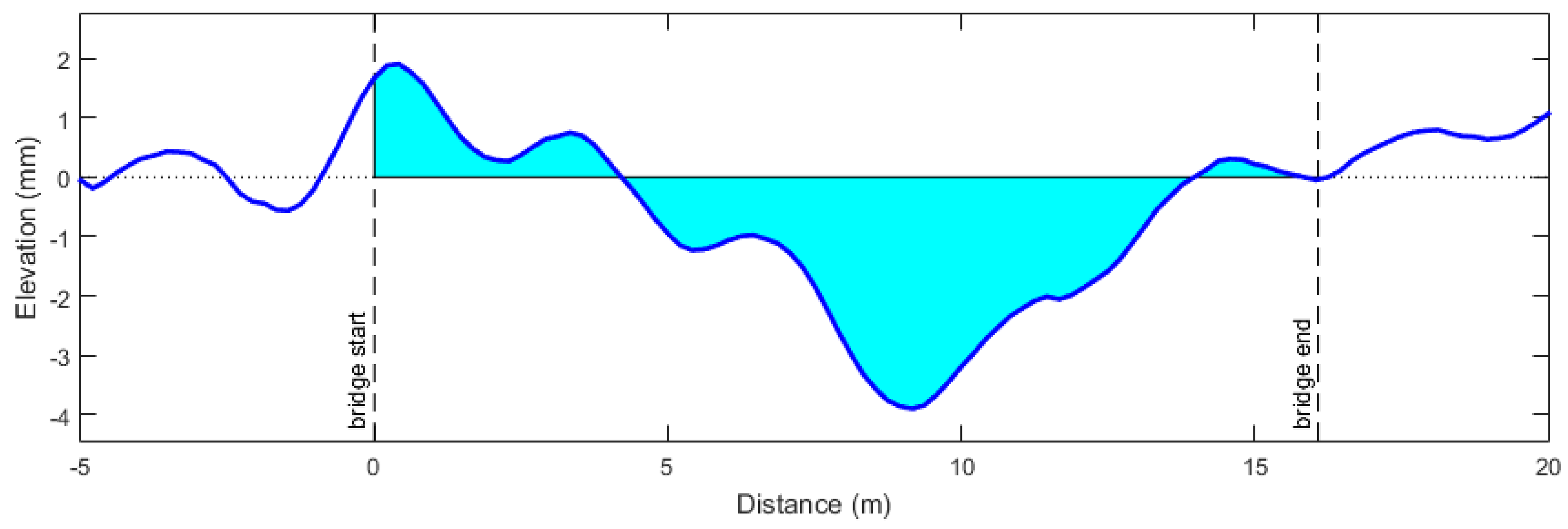


Apparent Profile

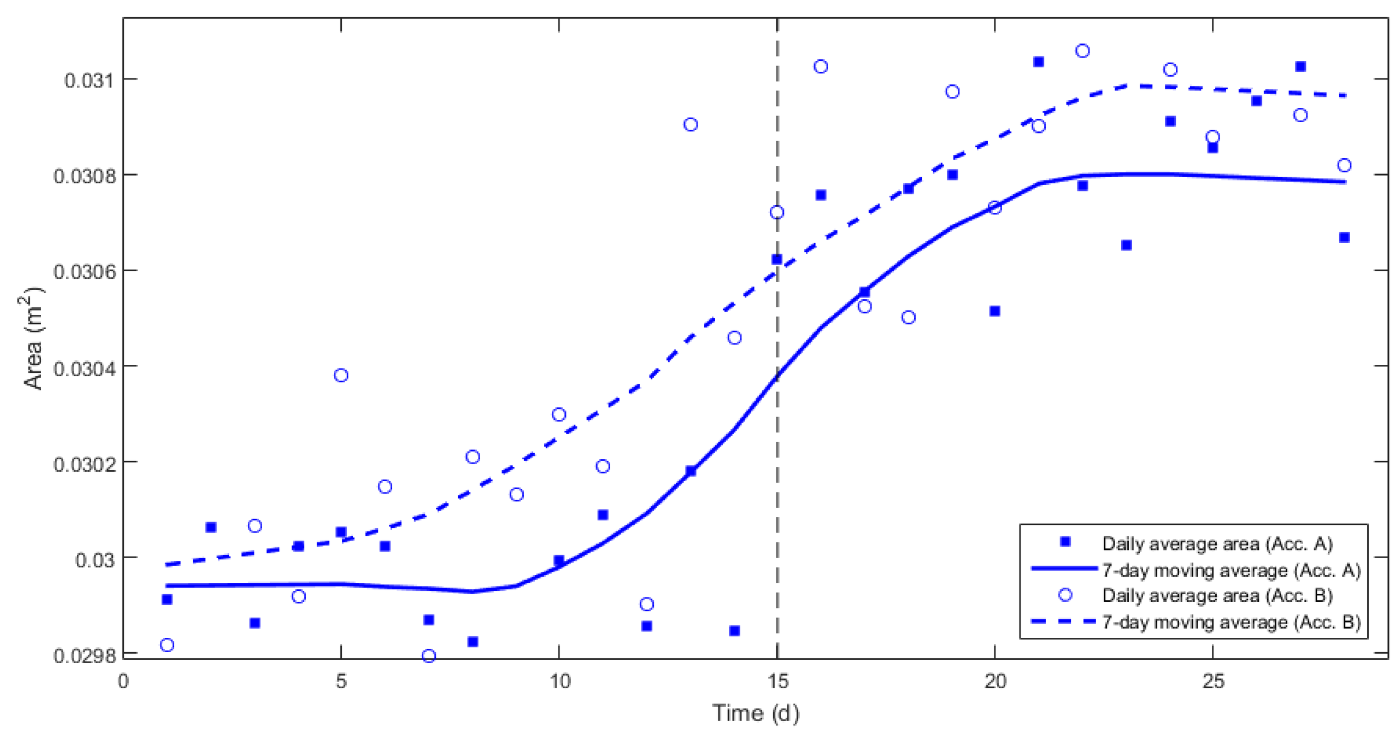
The computation of apparent profile is an inverse problem where a measured output (e.g. bogie vertical acceleration) is used as input to an optimisation algorithm. Populations of trial track profiles are randomly generated and vehicle-track-interactions are carried out for each. The cross-entropy optimisation method compares the response of the numerical model crossing the trial track profile to the measured response and updates the profile estimates through analysis of the best fitting responses. The method iterates until convergence to a track profile which generates a vehicle response most similar to the measured signal.



A change in the deflection of the bridge due to the presence of damage manifests itself as a change in the apparent profile associated with the measured vehicle response. It is found that using a comparison between profile elevations at one point in particular (e.g. at mid-span) is an unreliable indicator as the differences between profiles may be greater at other locations on the bridge. To account for differences between apparent profiles over the entire bridge span, an area between zero elevation and the apparent profile is computed and used as the damage indicator. A change in the value of this area will indicate that a change has occurred somewhere along the apparent profile.



An example of a daily monitoring application of the method is shown below. In the figure below, the points represent the daily average area computed from apparent profiles inferred from 5 train passes. The lines represent the weekly moving average of these areas. Two levels of sensor noise are shown, the higher quality sensor is 'Acc. A', shown by the solid blue line. The vertical dashed line indicates the day that damage was applied to the bridge. With both sensors there is a clear increase in the average area due to the presence of bridge damage.



Conclusion

Comparison of apparent profile for bridge crossing events can be used to detect damage in bridges. As a by-product of trains in regular service, this 'drive-by' monitoring technique can be used by railway infrastructure managers to assess the performance of their railway bridges on a regular basis.

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