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Finding the influence line for a bridge based on random traffic and field measurements on site

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Introduction

• Influence line
  • Response at a given a point under moving unit load
    • E.g. can be bending moment, strain, deflection, shear force, etc.
  • The influence line(s) of a structure reflects its behaviour
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• Influence line
  • Response at a given a point under moving unit load
    • E.g. can be bending moment, strain, deflection, shear force, etc.
  • The influence line(s) of a structure reflects its behaviour
  • Change in the influence line suggests change in its
    • Support conditions;
    • Connections;
    • Material or
    • Geometrical properties.
Introduction

• Bridge Weigh-in-Motion (WIM)
  • Known influence line (IL) of the structure + measurement under a truck passing
    → calculating the weight of the truck (forward problem)
  • A calibration truck and an IL estimate (based on FE model e.g.) is needed
Introduction

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• In this work:
  • Without an estimated IL and a calibration truck:
    • How to obtain information on truck weights in statistical terms?
    • Can we use this for damage detection?
Scope

- Introduction
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- Forward problem (Moses’s algorithm)
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• Inverse problem (Quilligan’s algorithm)
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- Proposed approach
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- Results
Forward problem (Moses’s algorithm)

• Basis of Bridge WIM
• To calculate the axle weights and so the gross vehicle weight (GVW) of a truck based on the IL and the measured signal

\[
\{Q\} = \frac{[IL]^T\{\varepsilon\}}{[IL]^T[IL]}
\]

where \(\{Q\}\) is the vector of the axle weights

[IL] is a matrix based on the influence line and the axle spacings

\(\{\varepsilon_m\}\) is the vector of the measured signal
Inverse problem (Quilligan’s algorithm)

• To calculate the influence line ordinates of a structure based on the measurement response and the axle weights and spacings of a truck

\[ \{IL\} = [A]^{-1}\{M\} \]

where

- \{IL\} is a vector containing the IL ordinates
- [A] is a symmetric matrix containing the information of the axle weights
- \{M\} is a vector based on the axle weights and the measured signal
Proposed approach

- An iterative approach combining Moses’ and Quilligan’s algorithm
- To obtain both the relative IL and axle weights of the passing trucks
Proposed approach

• An iterative approach combining Moses’ and Quilligan’s algorithm
• To obtain both the relative IL and axle weights of the passing trucks
• What information/data is needed?
  • Response signal
  • (Speed of the truck)
  • Number of axles and the axle spacings of the truck
  • Length of IL
  • An approximate initial IL shape

Forward Problem
Inverse Problem
Proposed approach

• Steps of the analysis
  1. Using an approximate IL shape and Moses’ algorithm to calculate the relative axle weights
  2. Using these axle weights and Quilligan’s algorithm to calculate the IL
  3. Repeating step 1 and step 2 until convergence is reached
Proposed approach

• Steps of the analysis
  1. Using an approximate IL shape and Moses’ algorithm to calculate the relative axle weights
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  3. Repeating step 1 and step 2 until convergence is reached

• How to use it for damage detection
  • Assuming that the statistical weight of trucks do not change (in a given time period) or assuming that it changes within some limits
  • If we find a greater change we can assume that it is caused by some changes in the structure (i.e. in the IL) and not in the weight of the trucks
Case study

• Culvert bridge in Slovenia
• Strain measured in midspan at the bottom of the slab
• Temperature data (recorded simultaneously) is collected as well
• Temperature change introduces change in the moduli of elasticity of concrete, and so it effects the bridge’s structural response, i.e. the IL
Results

- Convergence of the IL (from green to blue)
- Starting from a triangle IL (dashed line)
Results

• 5-axle trucks’ measured response compared to the ‘calculated’ response using the results of the proposed approach

\[ r^2 = 0.9989 \]

\[ r^2 = 0.9997 \]
Results and conclusions

• Results
  • Average GVW calculated by the proposed approach plotted against temperature
  • For a general truck population (blue line) and for 5-axle trucks only (green line)
Results and conclusions

• Results
  • Average GVW calculated by the proposed approach plotted against temperature
  • For a general truck population (blue line) and for 5-axle trucks only (green line)

• Conclusions
  • Calculated GVW correlates with temperature
  • Temperature can be used as ‘proxy’ for damage
  → Being able to track temperature change, suggests that we can track damage as well
Thank you for your attention

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