Joint Pursuit: Detecting Weak Joints Using TSD Measurements by Basis Pursuit

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Outline

• Introduction
• Basis Pursuit
• Results
• Further Improvements
Introduction

• TSD has been extensively used for flexible pavement structural evaluation

• Rigid pavements have been harder to assess:
  • Low deflections are an issue relative to device accuracy
  • Joint evaluation requires higher data resolution (~1m)

• Limited research on joint evaluation:
  • SHRP2 R06(F)
  • United Kingdom
  • Wavelet analysis (Katicha et al. 2014, 2016)
Introduction – Joints LTE
Introduction – Joints LTE
Introduction – Typical TSD Measurements
Introduction – Repeated Measurements
Basis Pursuit - Overview

• Help identify weak joints
  • Fast
  • Statistical balance between wrong identifications and missed identifications
  • Standard procedure (more science, less art)

• Key idea
  • Decompose TSD measurements into sum of simple features
  • Weak joints have specific geometric feature
Basis Pursuit - Features

Wavelets

Joints
Basis Pursuit – Feature Selection

• How are features selected
  • Have twice as many features as measurements

• Best subset selection
  • Lowest number of features that works
  • Very hard (impossible) to solve

• Basis Pursuit selection
  • Lowest sum of absolute values of features coefficient
  • Very easy to solve (as easy as linear regression)
Basis Pursuit – Geometric Interpretation

- Fit feature to measurements by regression ($y$ are the measurements and $x$ are the features)
Results – Threshold Effect
Results – Threshold Selection

• Threshold
  • Need measurement accuracy of TSD $\sigma$
  • Upper limit $T=\sigma\sqrt{2\log(n)}\approx 4\sigma$ (universal threshold)
  • Optimal: minimize Stein’s Unbiased Risk Estimate (SURE)
    • Can go lower than $4\sigma$ depending on number of weak joints
  • Best fit
Results – Best Fit with SURE
Results – Detected Joints
Results – Universal Threshold
Results – Detected Joints
Results – Repeated Measurements
Multiresolution – Weak Joints Grouping
Multiresolution – Benefits

• Why?
• Detection depends on the number of weak joints in the group
  • \( \sigma \sqrt{2 \log(n)} \approx 4 \sigma \) order of detection limit for individual joints
  • If we have \( k \) joints in a group
    • \( \sigma \sqrt{\frac{2 \log(n)}{k}} \)
Multiresolution – Example
Multiresolution – Example Solution

Multiresolution

No multiresolution
SparseNet
SparseNet – Universal Threshold