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Evaluating Structural Engineering Finite Element Analysis Data Using Multiway Analysis

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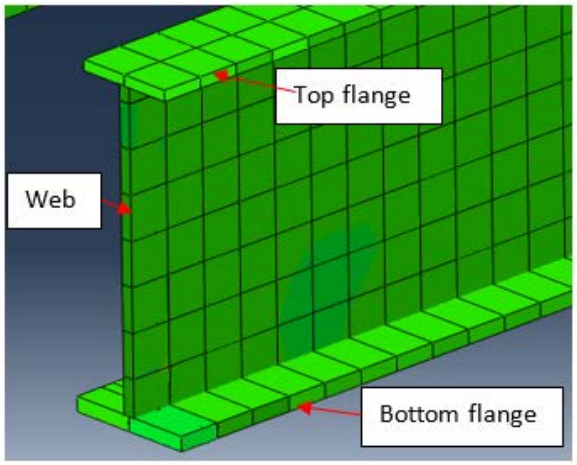
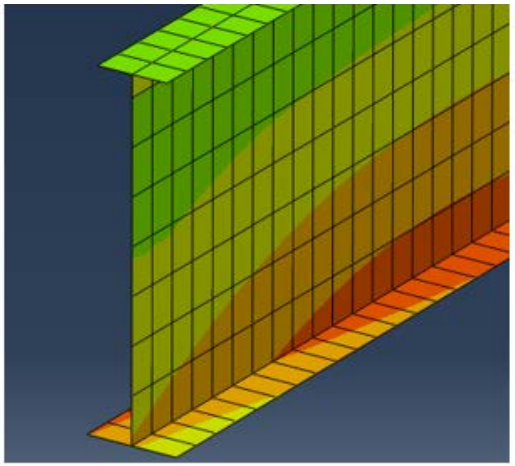
Finite Element Analysis (FEA)

- Common tool in structural engineering
- Predicts structural behavior
- Based on a discretization of structural parts into geometric shapes (elements)
- The number of elements in a typical model could vary anywhere from hundreds to millions





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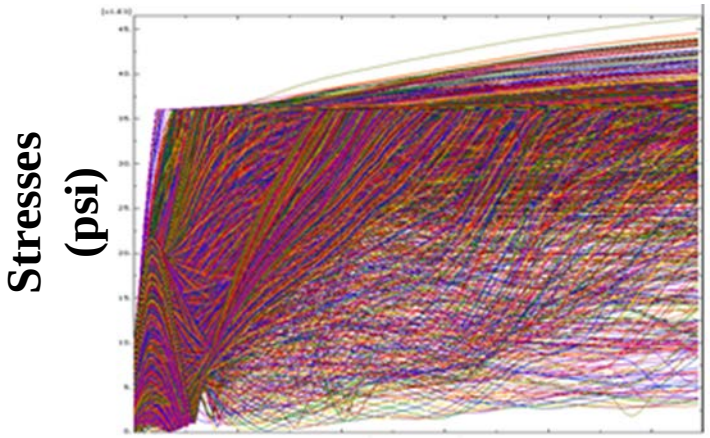
FEA in Current Practice

- Only a small fraction of this available data (such as min. and max. stresses) are quantitatively analyzed
- Big data techniques provide opportunity for more holistic analysis
- Likely to be advantageous for comparing differences in competing design options



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Goal:

- To explore the use of multiway data analysis techniques in analyzing structural engineering FEA output

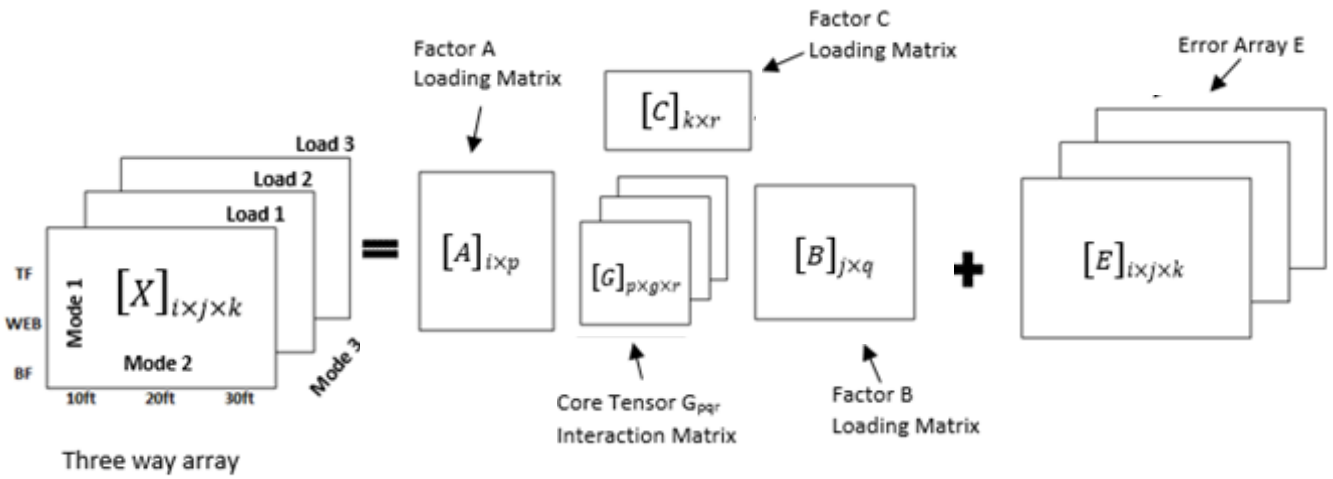
Scope:

- Propose a new procedure for interpreting FEA data in structural engineering
- Propose using multiway method (Tucker3 tensor decomposition) in evaluation of FEA data
- Make recommendations for future use of multiway tools in structural engineering FEA

Tucker3 Tensor Decomposition

- Type of higher order singular value decomposition
- Decomposes 3D array into sets of scores that describe the data in a more condensed form

$$[X]_{i\times j\times k} = [G]_{p\times q\times r} \times [A]_{i\times p} \times [B]_{j\times q} \times [C]_{k\times r} + [E]_{i\times j\times k}$$



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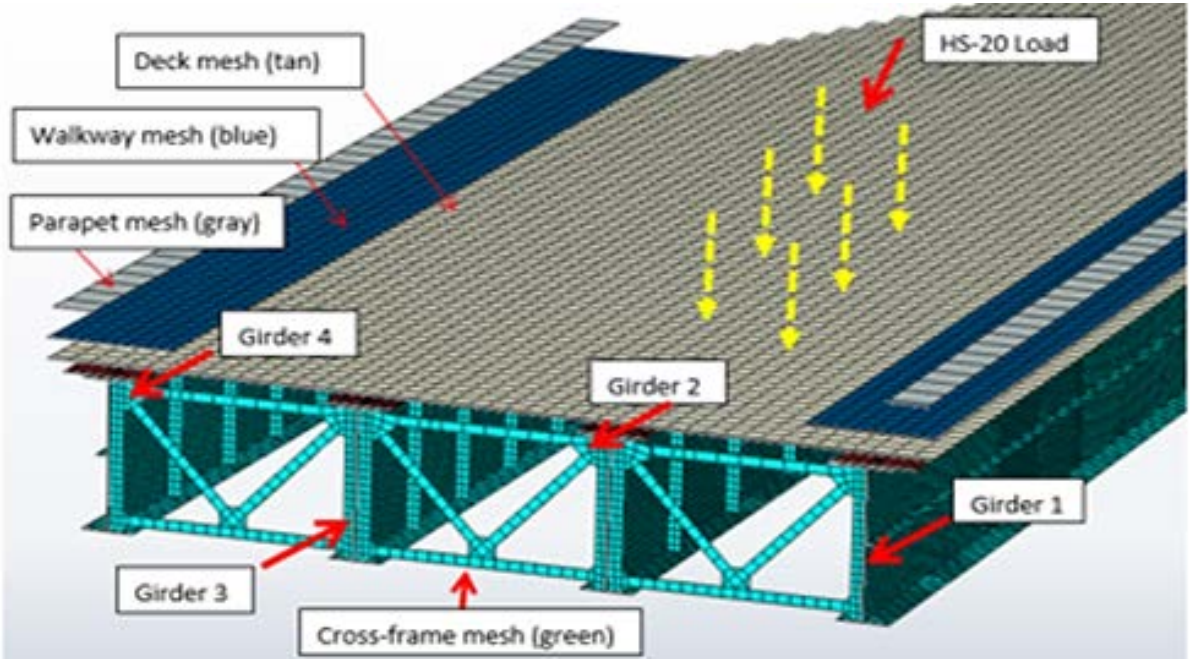
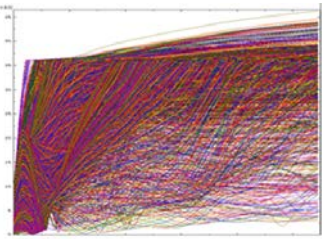
FEA Subject Bridge



Data Preprocessing for Tensor Decomposition, cont.



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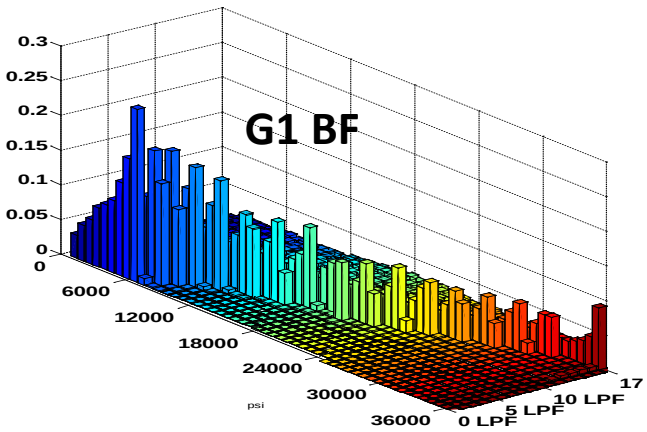
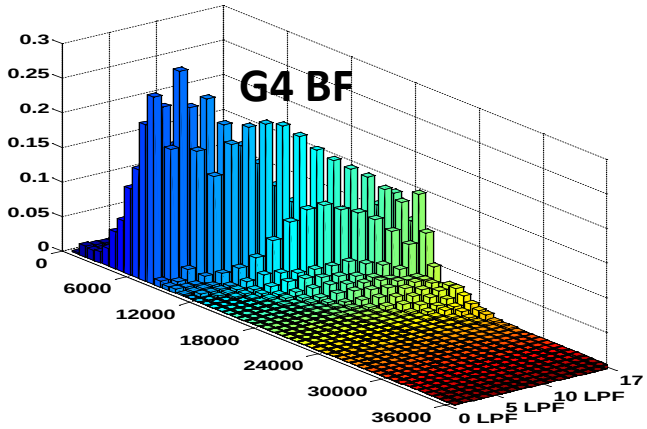
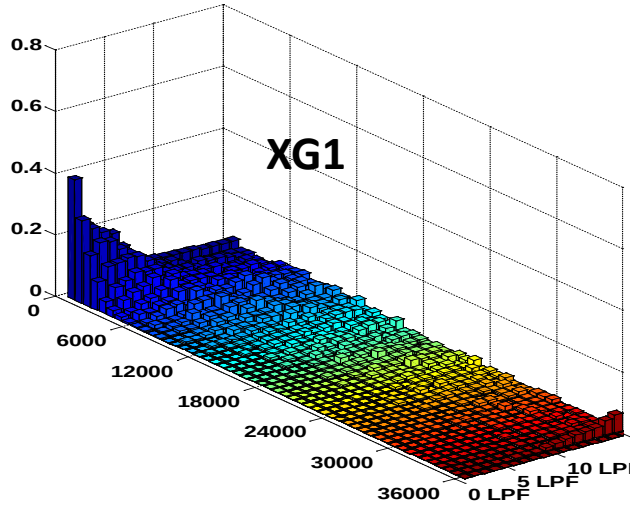
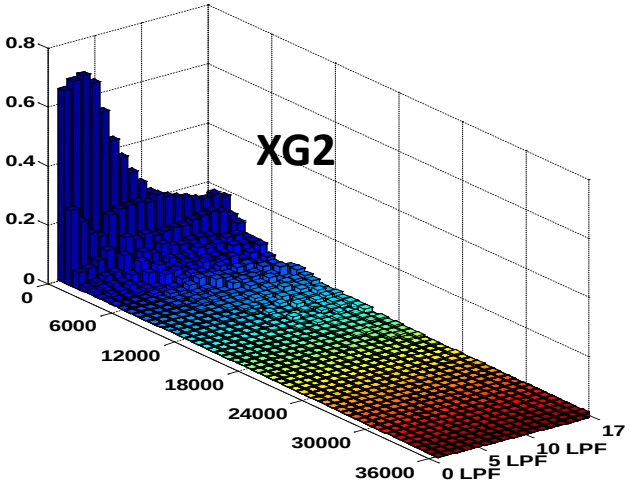








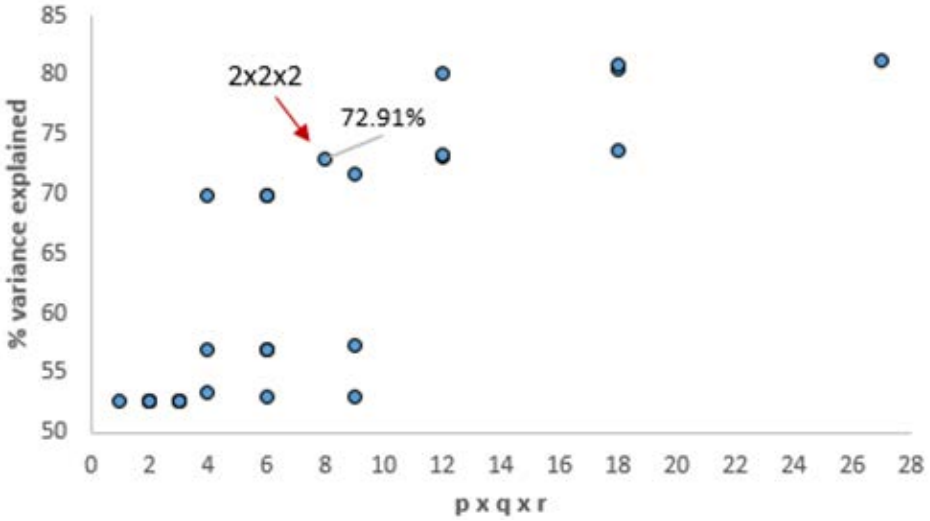
Data Preprocessing for Tensor Decomposition

- To carry out Tucker3 decomposition, the data must be organized in a 3-way (3-mode) format
- 1st mode- 7 element groups (4 girder groups and 3 cross-frame groups)
- 2nd mode - 51 stress ranges (51 stress histogram bins)
- 3rd mode -17 loading increments (LPFs).

Determining Appropriate Tucker3 Model

Fitting procedure based on:

- Percent variance explained
- Optimal model complexity



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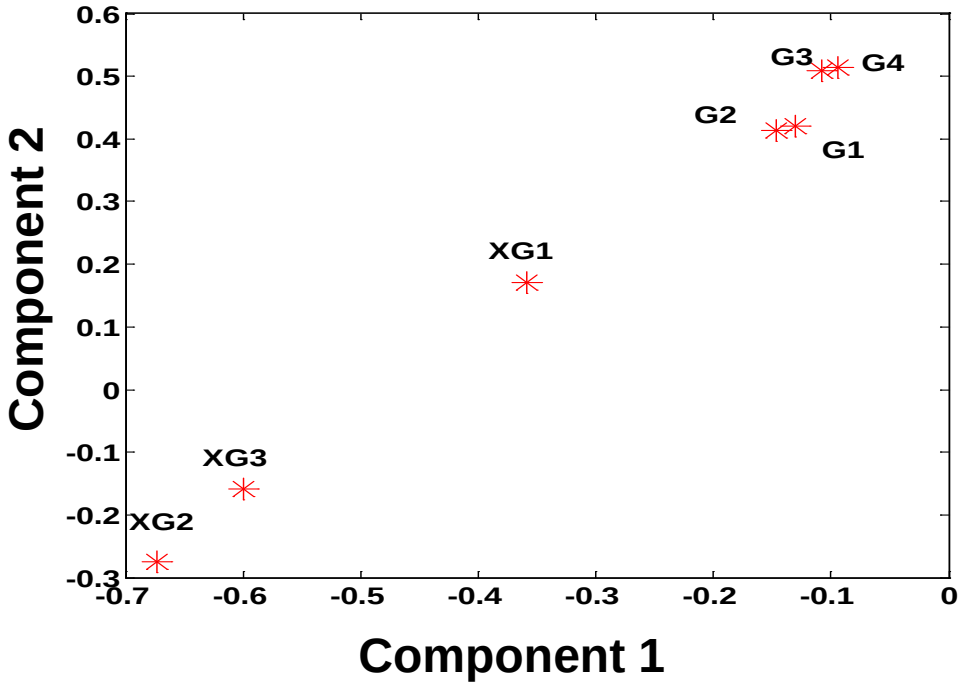
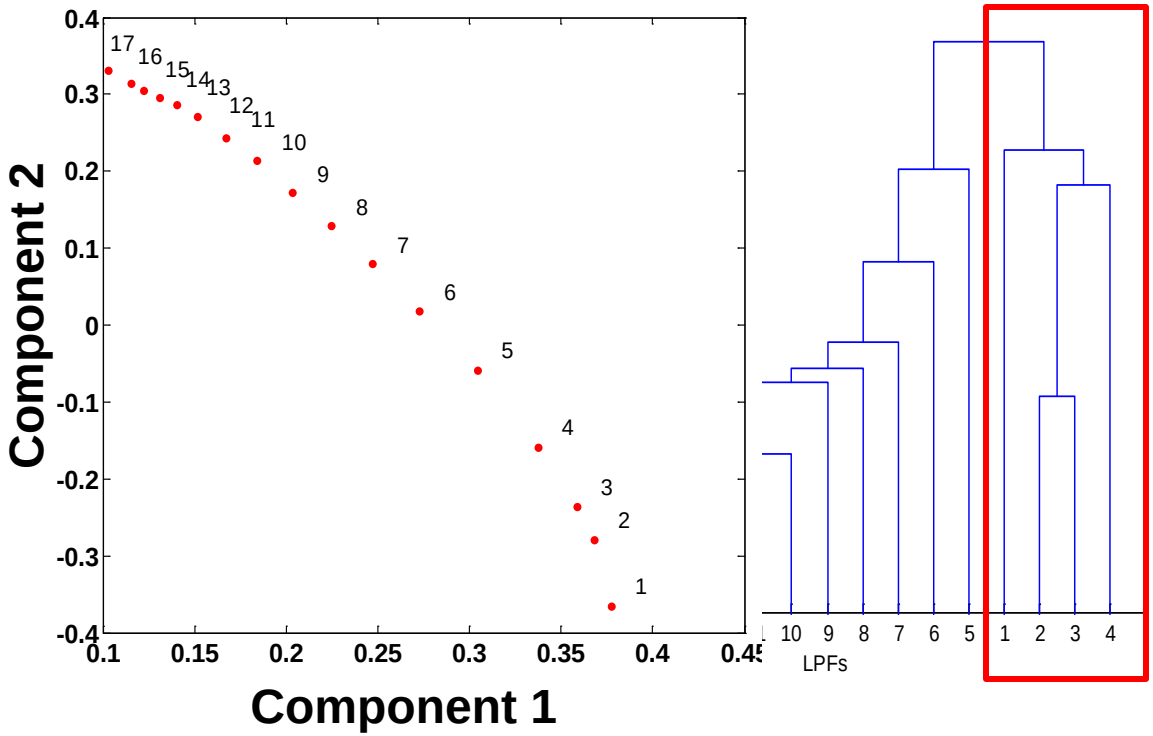
Results: Element Group Loading Scores



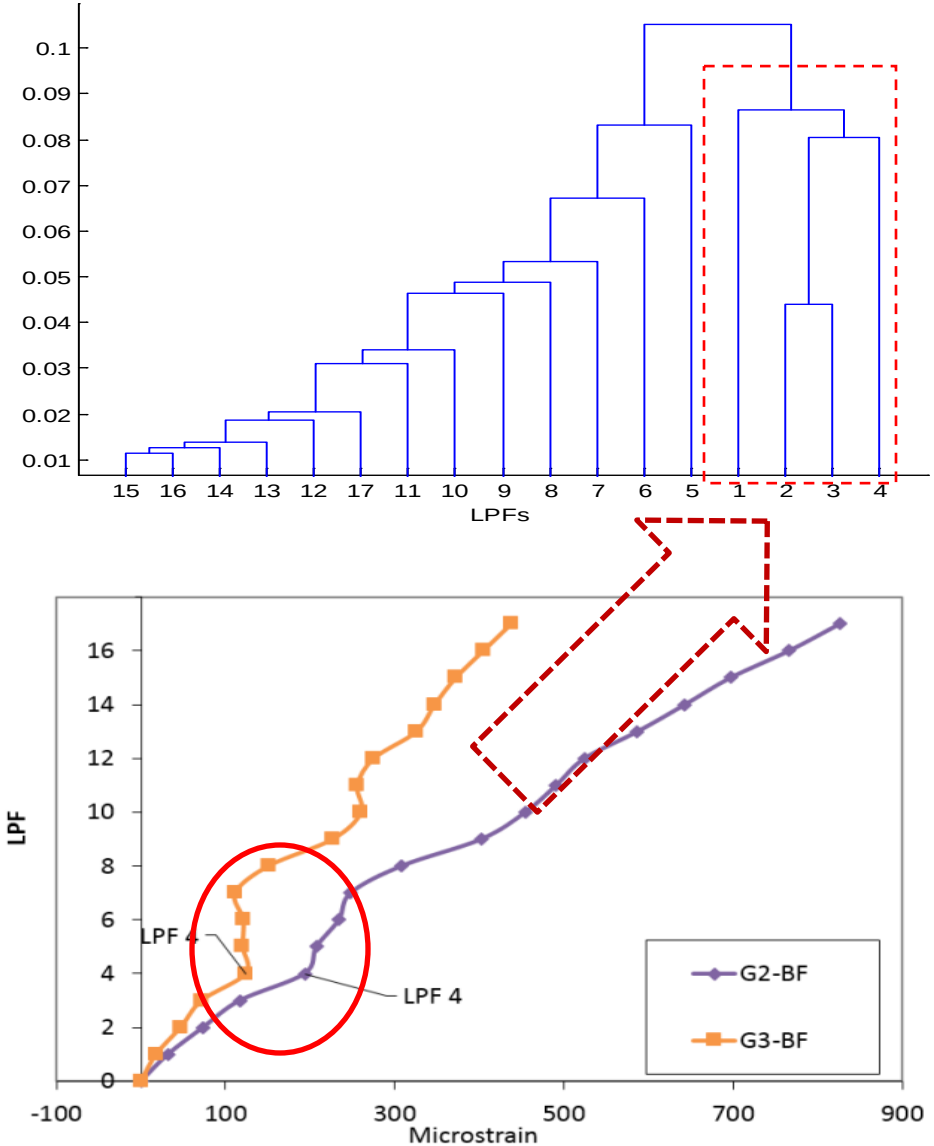
- High negative scores in Component 1 - narrowest spread in stress distribution
- High positive scores in Component 2 - widest spread in stress distribution

Results: LPF Loading Scores



- High positive scores in Component 1 and high negative scores in Component 2 → low LPFs
- High positive score in Component 2 → high LPFs.

Comparing Tucker3 Results to Experimental Results



Conclusions

- Innovative method of FEA data interpretation
- Possible ability to highlight latent behavior of bridge components subjected to increasing load
- Ability to quantify and differentiate the stress profiles of different bridge components