Finite Element Analysis of USC Walking Bridges

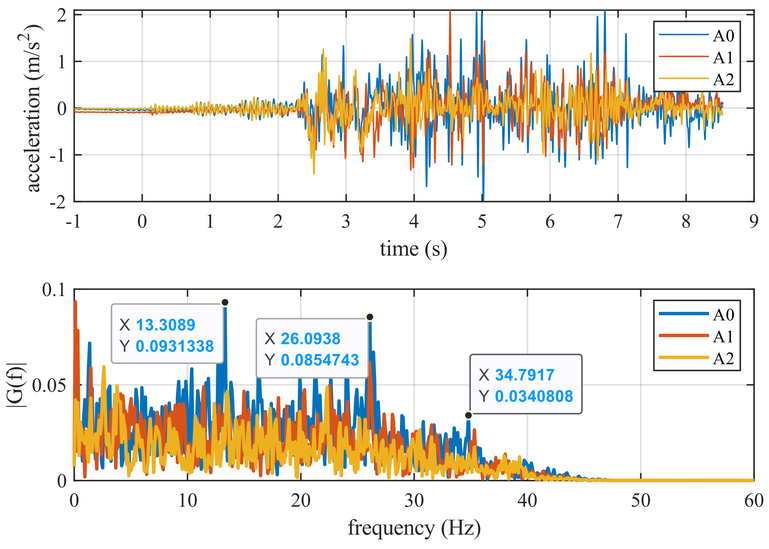
Samuel Roberts[1], Joud N. Satme[1], Gabriel Smith[2], Joseph Johnson[1],
Dr. Austin R.J. Downey[1]

1 Department of Mechanical Engineering, University of South Carolina Columbia
2 South Carolina Governor's School for Science and Mathematics

Introduction

- Analysis of walking bridges using drone deployed sensors
  - Tracking bridge health
- Finite Element Analysis (FEA) to determine:
  - Natural frequencies
  - Mode shapes
  - Node and antinode locations
- Using natural frequency information to determine material properties of the bridge

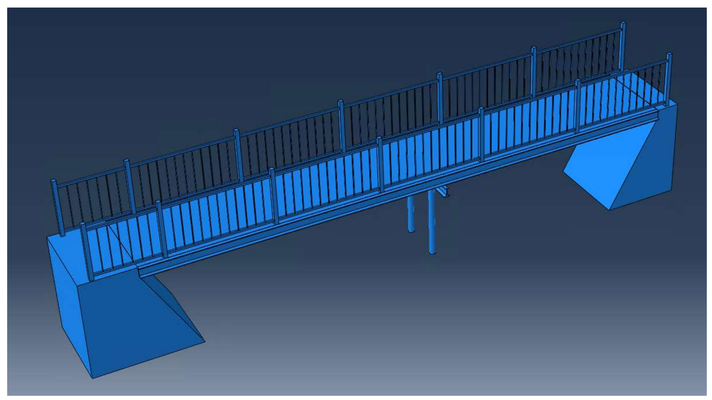
Walking bridge (A) used for FEA modeling



Sensor data collected from Bridge A

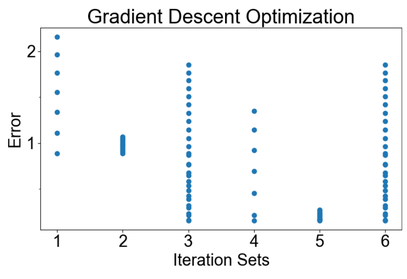
Methods

- Autodesk Inventor used to create CAD model of bridge
- Dassault Systems ABAQUS used to create FEA model of bridge
- High mesh density used for FEA, sacrificing simulation speed for simulation accuracy.
- Lower mesh density used for approximating material properties, sacrificing simulation accuracy for simulation speed

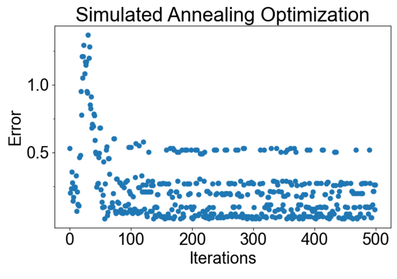


Bridge A model in ABAQUS

- Determining material properties of bridge concrete and steel using prior real-world testing data
  - Elastic modulus, density, and Poisson's ratio
- Python script used to automatically run ABAQUS simulations with different material properties.
- Simulation data was compared to known data by calculating and comparing weighted vector distances to the known data values
  - Higher weight was given to mode one error as we determined it to be most important.
- Gradient descent and simulated annealing optimization functions tested for homing in on known data values.

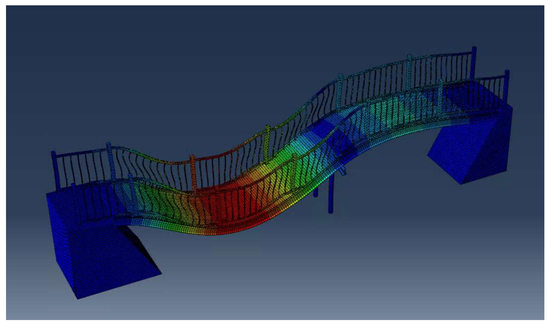


Min Error: 0.157



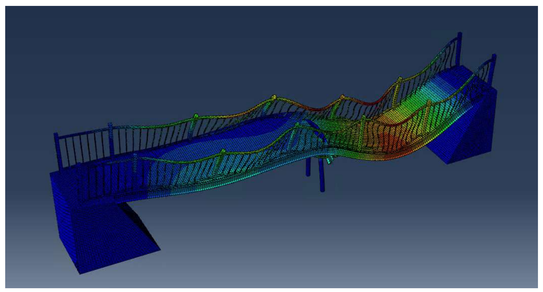
Min Error: 0.0125

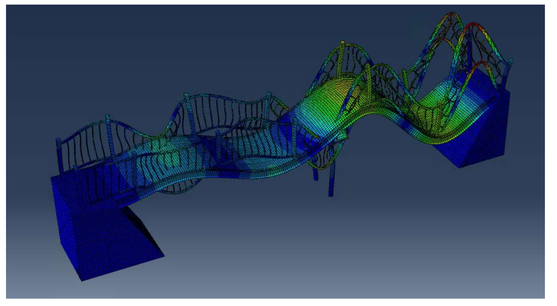
Results



Mode 1
15.39 Hz

Mode 2
22.84 Hz





Mode 3
55.24 Hz

Conclusions

1. Flexural modes returned from ABAQUS simulations are unusually shaped, suggesting a potential error in the simulation parameters.
2. Simulated annealing optimization provides significantly more consistent and more accurate results compared to gradient descent optimization.

This material is based upon work supported by the National Science Foundation through grant numbers 2237696 and 2344357, with additional support from the Air Force Office of Scientific Research (AFOSR) through award no. FA9550-21-1-0083. Funding for this project was also provided by the Molinaroli College of Engineering and Computing at the University of South Carolina through the McNair Junior Fellows Program. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation, the United States Air Force, or the University of South Carolina

Molinaroli College of Engineering and Computing
UNIVERSITY OF SOUTH CAROLINA