BRACE²: Bridge Rapid Assessment Center for Extreme Events

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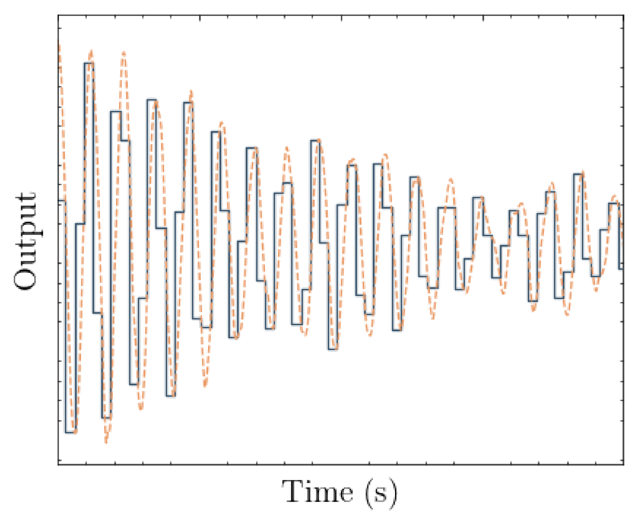
BRACE2

objective: invert the conventional analysis problem

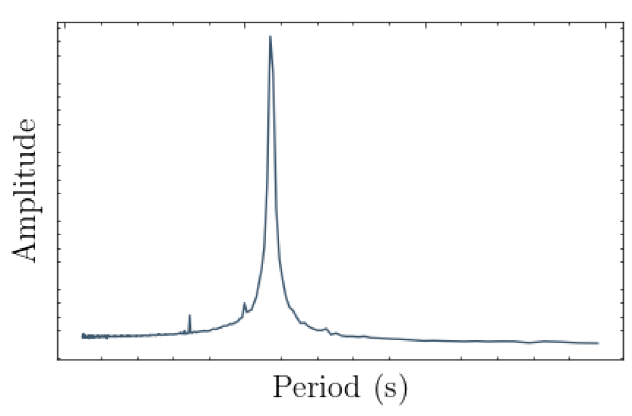
```
val, vec = eigid(inputs, outputs)
```

Two Approaches



Idea: Fit an ideal continuous system to the discrete response in the time domain.

- Ho-Kalman/Eigensystem Realization Algorithm
- Subspace Identification
- Least Squares Methods



Idea: Represent the system in the frequency domain.

- Fourier Spectrum
- Response Spectrum

Limitations

Identification methods must be scalable such that they can be applied to a growing and changing network of bridges.

$$A = U \Sigma V^H$$

High complexity systems

Frequency domain methods are ill-suited for identifying higher modes, and are limited to single-input, single-output, or **SISO** signals.

SVD

The singular value decomposition is heavily used in subspace and least squares methods. It is notoriously numerically intensive.

Solution

SRIM

State space system identification techniques such as System Realization with Information Matrix reveal the underlying fundamental dynamic system for a multi-input, multi-output, or **MIMO** signal.

$$\begin{aligned}
\dot{\mathbf{x}} &= \mathbf{A}_c\mathbf{x} + \mathbf{B}_c\mathbf{u} \\
\begin{bmatrix}\dot{\mathbf{u}}_f(t) \\ \ddot{\mathbf{u}}_f(t)\end{bmatrix} &= \begin{bmatrix} 0 & \mathbf{I} \\ -\mathbf{M}^{-1}\mathbf{K} & -\mathbf{M}^{-1}\mathbf{Z}\end{bmatrix}\begin{bmatrix}\mathbf{u}_f(t) \\ \dot{\mathbf{u}}_f(t)\end{bmatrix} + \begin{bmatrix} 0 \\ -\boldsymbol{\iota}\end{bmatrix}\ddot{\mathbf{u}}_g(t) \\
\mathbf{y} &= \mathbf{C}\mathbf{x} + \mathbf{D}\mathbf{u} \\
\ddot{\mathbf{u}}_f(t) &= \begin{bmatrix} -\mathbf{M}^{-1}\mathbf{K} & -\mathbf{M}^{-1}\mathbf{Z}\end{bmatrix}\begin{bmatrix}\mathbf{u}_f(t) \\ \dot{\mathbf{u}}_f(t)\end{bmatrix} + \begin{bmatrix}-\boldsymbol{\iota}\end{bmatrix}\ddot{\mathbf{u}}_g(t)
\end{aligned}$$

Optimizations

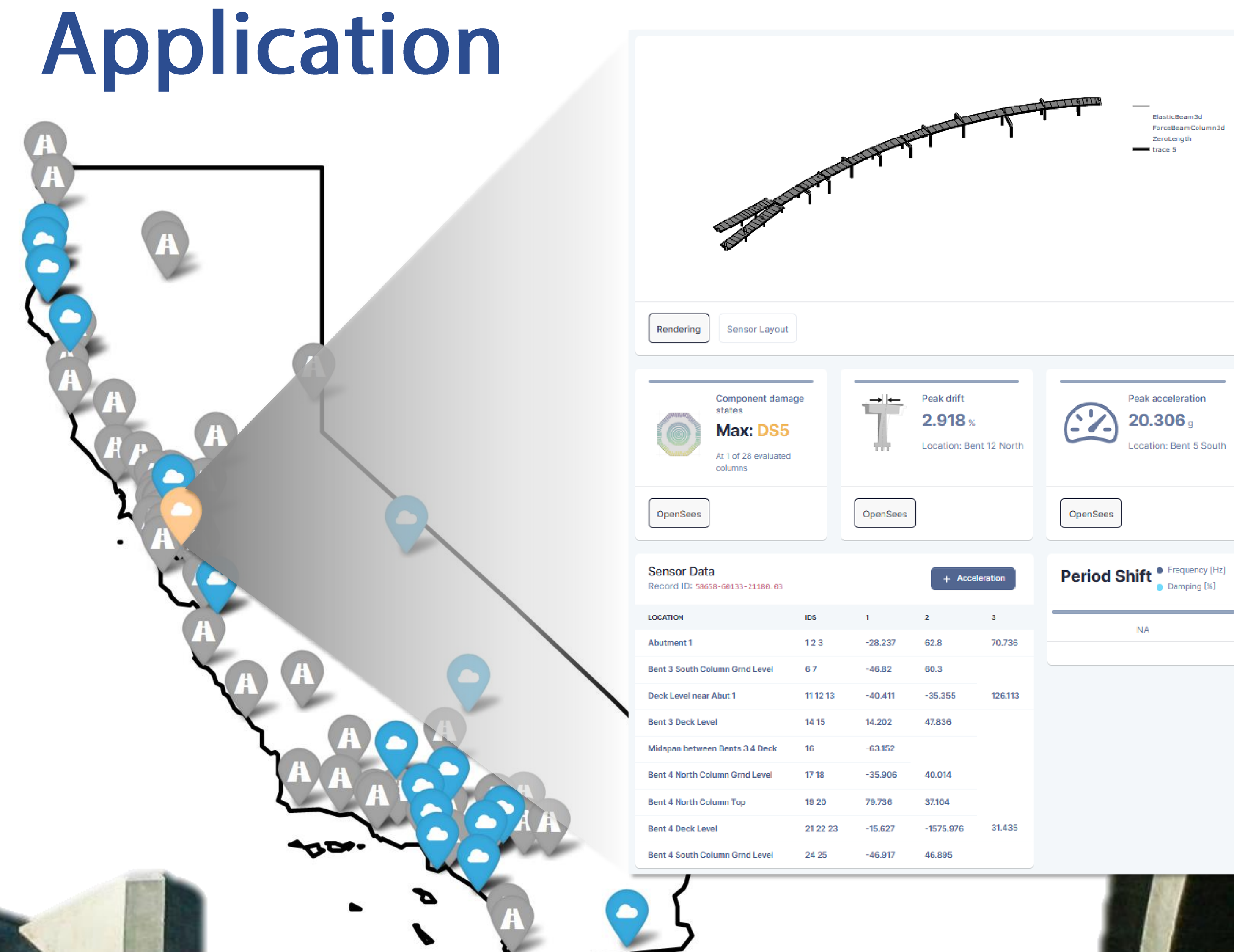
- A new, optimized algorithm has been developed that leverages **shared memory parallelism** to drastically reduce the computational demands of estimating a state space model.
- Memory use has been optimized to efficiently leverage caching.

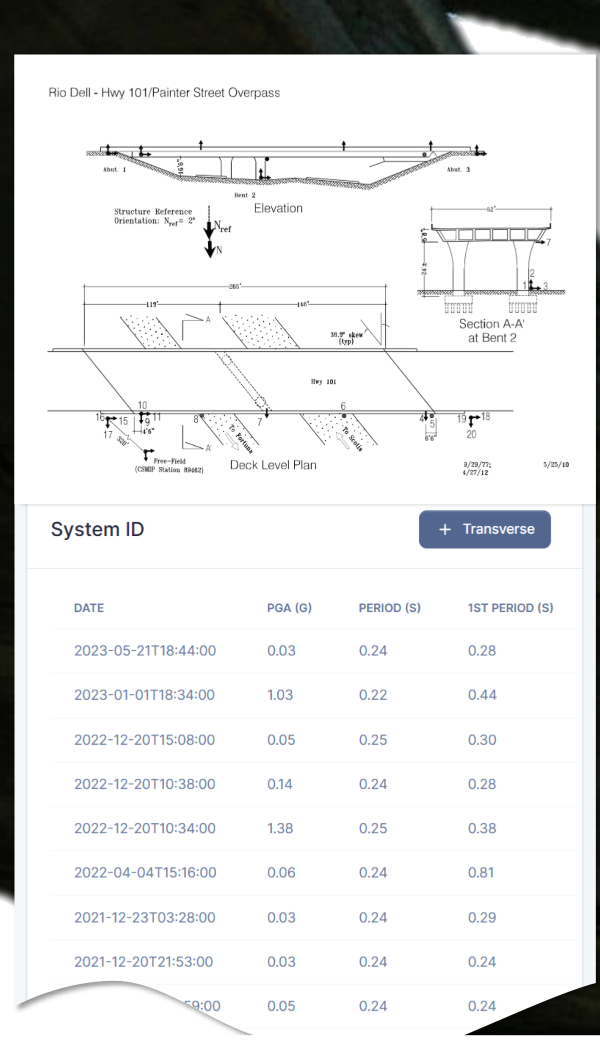
Package

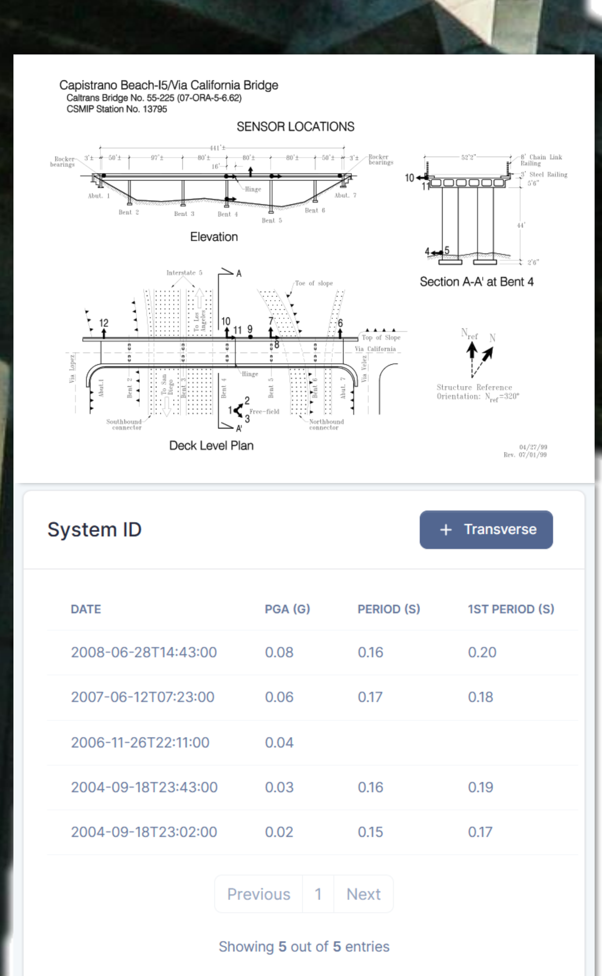
All methods are accessible through the python `lilo` package.

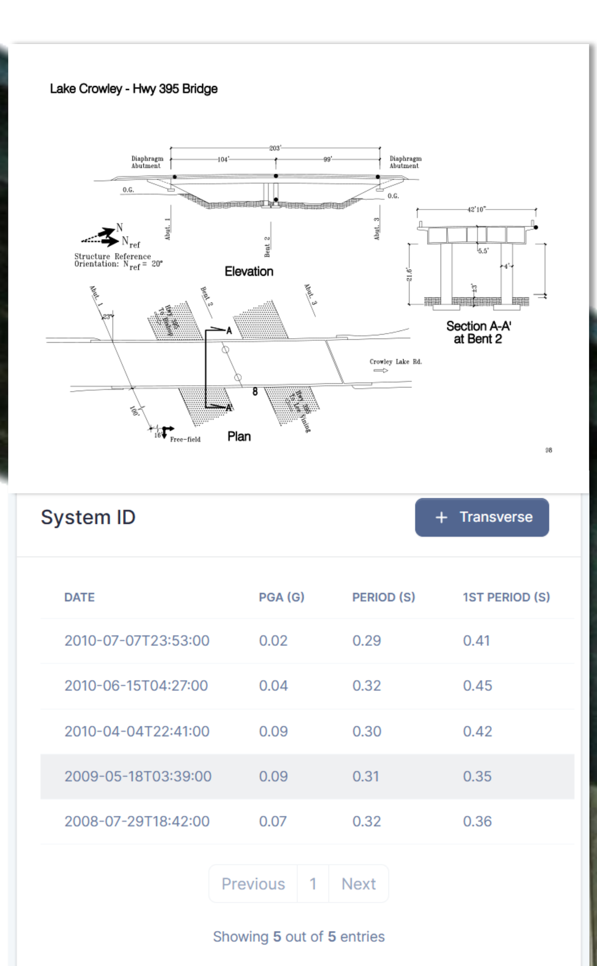
```
pip install peer-lilo
```

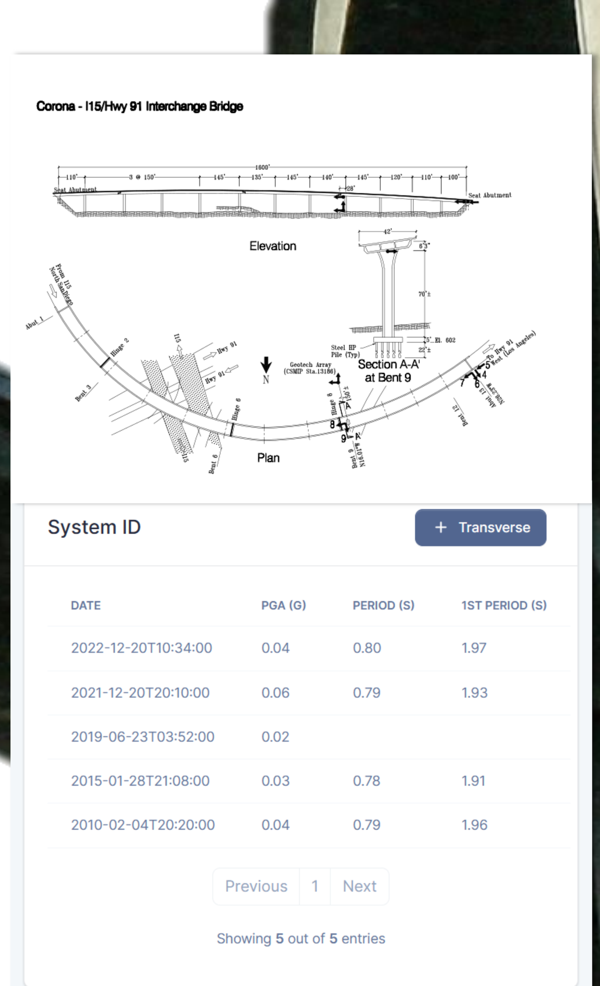
Application











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