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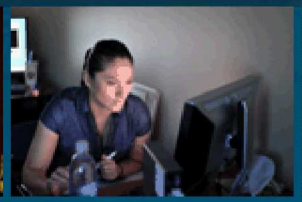
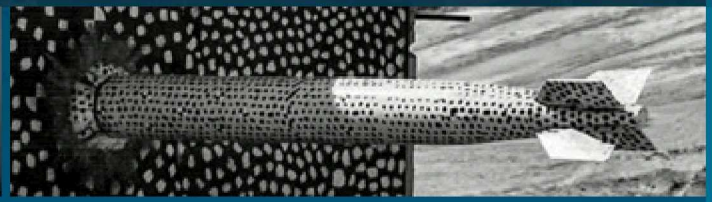
VideoSwarm: Analyzing Video Ensembles





PRESENTED BY

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Ensemble Data

Ensemble data is obtained by varying input to a numerical simulation and keeping track of outputs.

- Examples of simulations: climate, fluid dynamics, mechanics, materials.
- Examples of inputs: initial conditions, fluid/material properties, design changes.
- Examples of outputs: pressure, velocity, temperature, stress (at every grid point).

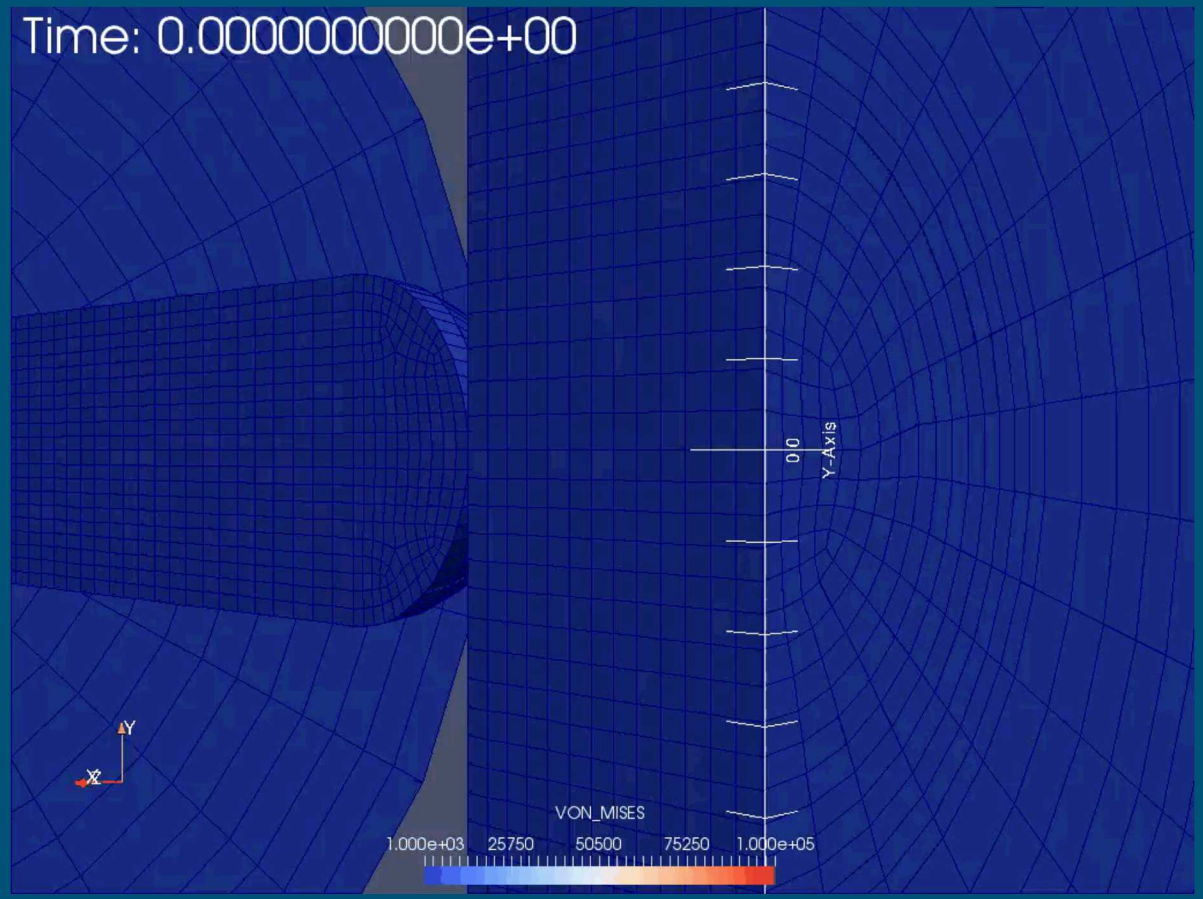
Scientists/Engineers want to understand effects of inputs on outputs by looking at the results of numerous simulations.

- Challenges: data are extremely large, heterogeneous, and time-valued.

Video Ensemble Data

Instead of trying to understand all of the output in an ensemble, we look at slices (videos) of the output.

- One video per simulation, same time span, same viewpoint.
- Reduces storage requirements.
- Often contains more interesting information than summary statistics.



Analyzing Video Ensemble Data

How can we compare videos in our ensemble?

Where are the videos similar, and where do they diverge?

Do the videos cluster?

Can we identify interesting behavior in the videos and where it occurs?

Without watching every video, how can we digest the full content of the ensemble?

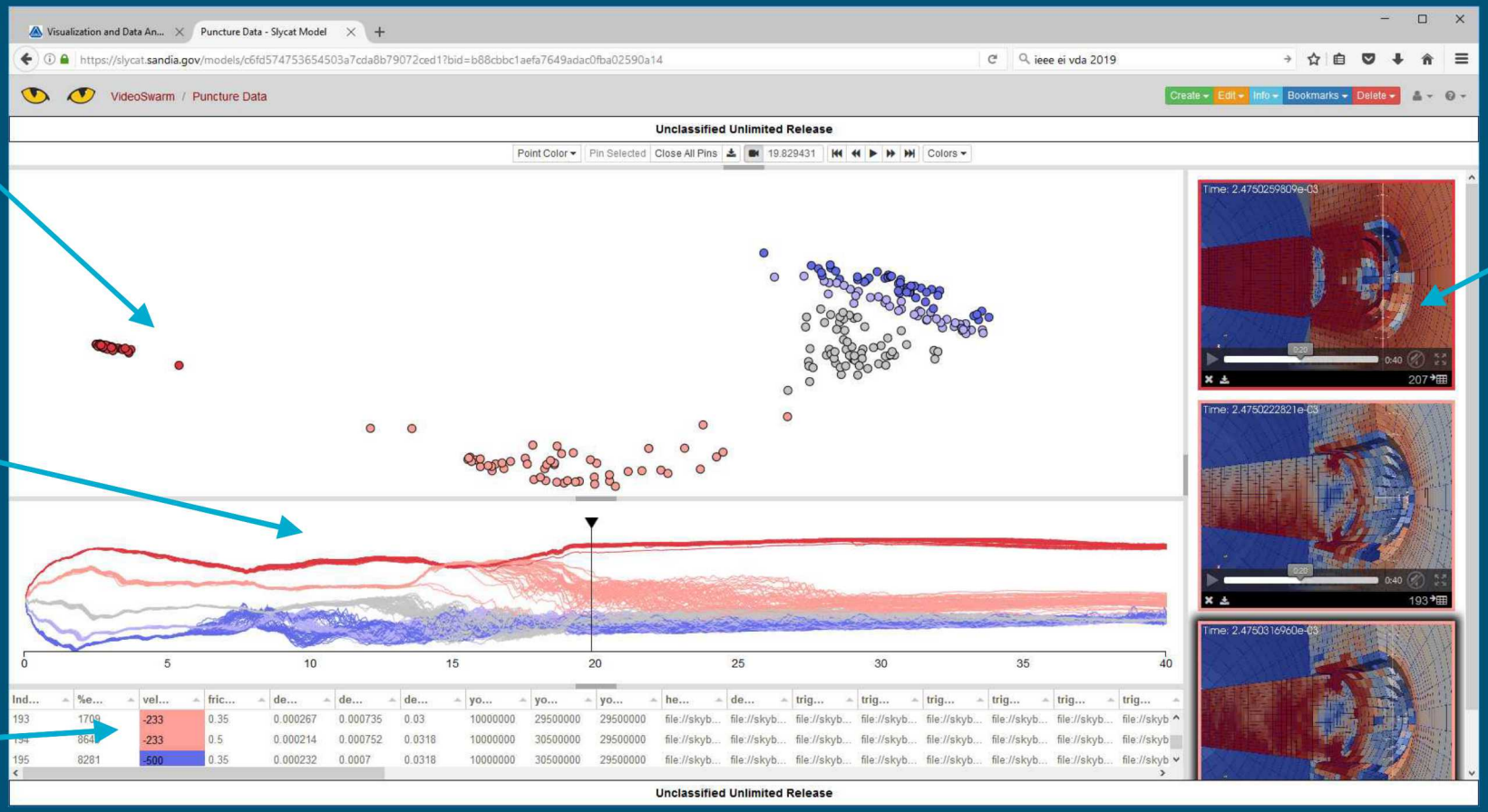
VideoSwarm

VideoSwarm is a web-based visualization UI which lets the scientist/engineer browse through the low dimensional coordinate representations of videos through time.

Each point is a video at a specific frame, where similar frames cluster.

Video similarity over time is shown using curves.

Simulation meta-data is shown in a table.



Videos can be played individually, or in sync.

All panes are interactive and coordinated.

Multidimensional Scaling

To assign each video a 2D coordinate representation, we use a dimension reduction technique called Multi-Dimensional Scaling (MDS).

- Time trajectories are plotted as the first coordinate of MDS versus time for each video.
- For MDS, we first compute pair-wise distances between each frame of each video in the ensemble.

$$D_t = \begin{bmatrix} d(\mathbf{f}_{1t}, \mathbf{f}_{1t}) & d(\mathbf{f}_{1t}, \mathbf{f}_{2t}) & \cdots \\ d(\mathbf{f}_{2t}, \mathbf{f}_{1t}) & d(\mathbf{f}_{2t}, \mathbf{f}_{2t}) & \cdots \\ \vdots & \vdots & \ddots \end{bmatrix}$$

$$d(\mathbf{f}_{it}, \mathbf{f}_{jt}) = \sqrt{\sum_k (f_{itk} - f_{jtk})^2}$$

Multidimensional Scaling Continued

- Second, we "double-center" the distance matrix.

$$B = -\frac{1}{2} H D^2 H$$

$$H = I - 11^T/n$$

- Third, we compute the eigenvalue decomposition of B, keeping the two largest positive eigenvalues λ_1, λ_2 and corresponding eigenvectors $\boldsymbol{e_1}, \boldsymbol{e_2}$.

$$B = E \Lambda E^T$$

- The MDS coordinates are given by the first two columns of $E\Lambda^{1/2}$.
- (In fact, we keep k dimensions of each reduction for the purpose of aligning frames, described in the next slide.)

Multidimensional Scaling Continued

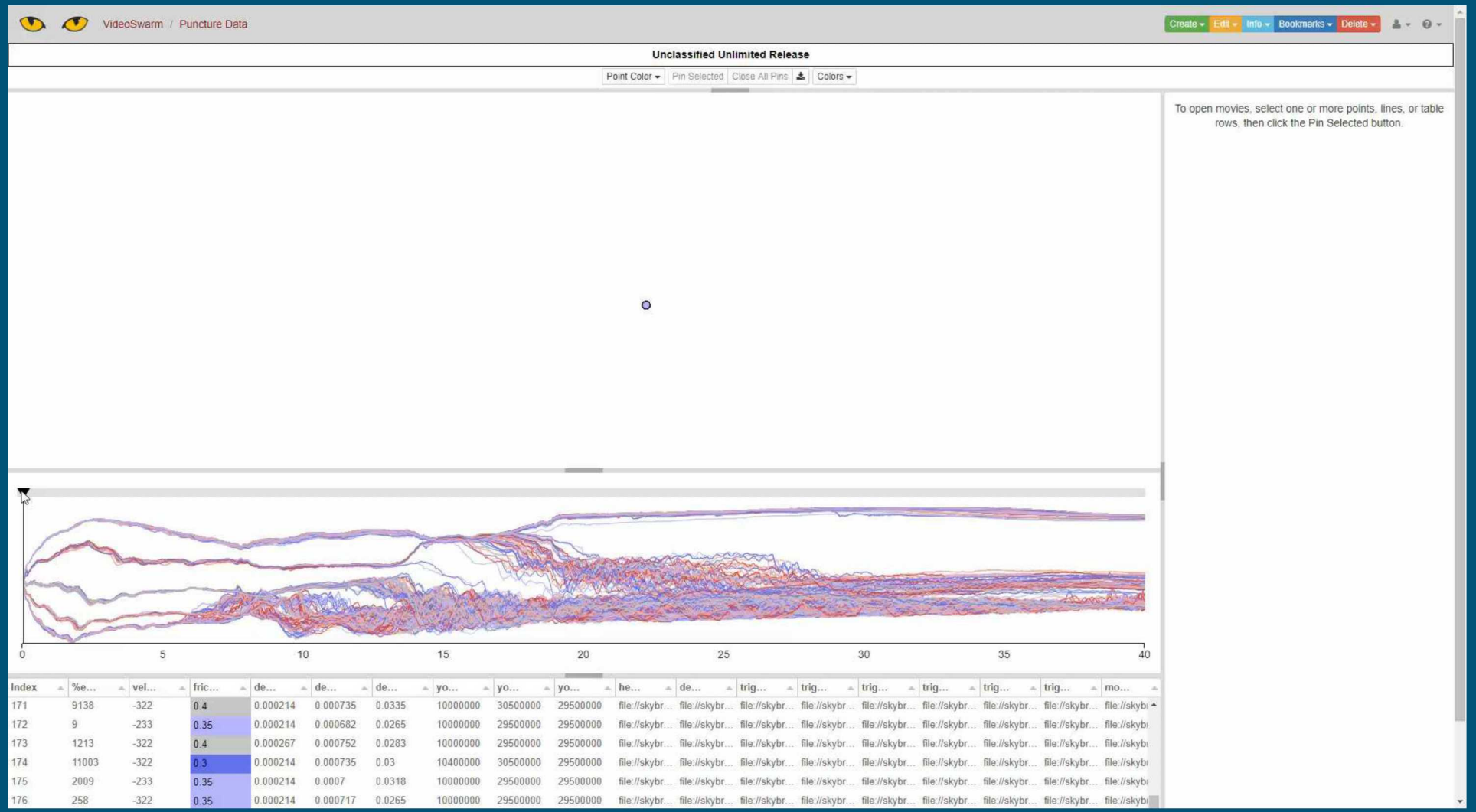
- Finally, we align the MDS visualizations per frame using an optimal orthogonal transformation.
  - If P and Q are matrices containing the MDS coordinates of two consecutive time steps, we compute (using the Singular Value Decomposition)

$$A = P^T Q \qquad R = V_k U_k^T$$

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

  - R gives an optimal transformation (rotation and/or reflection) matrix which best aligns P and Q using up to k dimensions.

VideoSwarm Demo



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Slycat

VideoSwarm is a plugin for Slycat, which is a web-based data science analysis and visualization platform:

https://github.com/sandialabs/slycat

https://slycat.readthedocs.io/en/latest/

VideoSwarm is not open-source, but will be soon.