Data-driven CFD

19.04.2025
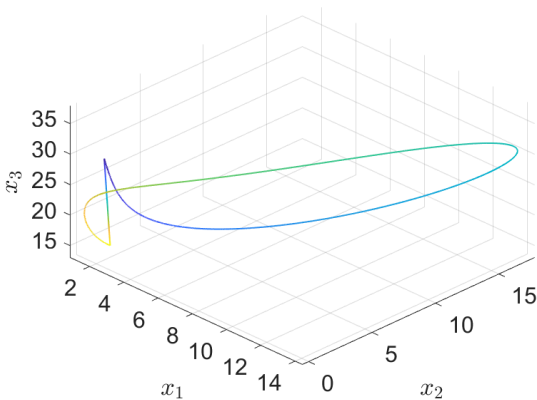
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SINDy:

The data plotted:

When we set the sparsity parameter to zero, we get the following function approximation:

```
Discovered model using SINDy(sparsity set to zero):

dx/dt = - -1.1405e-05 - -10x + 10y
dy/dt = + 28x - -0.999976y - -0.999999xz
dz/dt = - -0.000106264 - -4.64983e-05x + 4.0588e-05y - -2.66666z + 1xy
>>
```
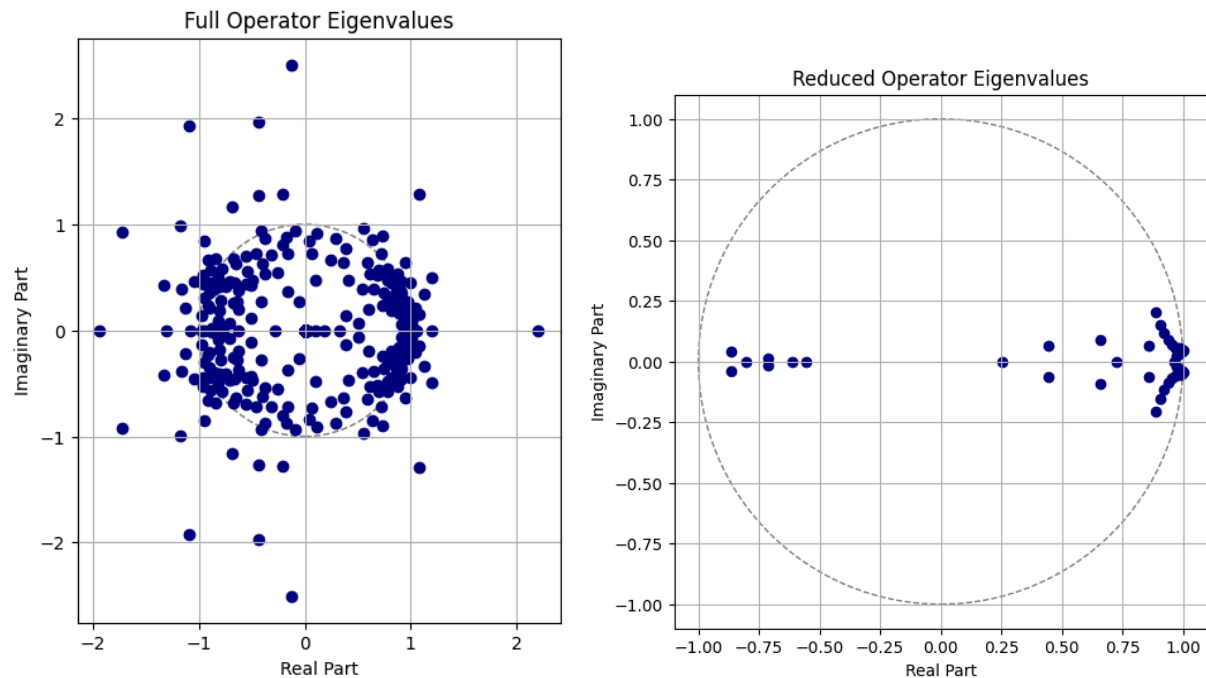
When we set sparsity parameter to 0.1, we get the following function:

```
Discovered model using SINDy:

dx/dt = - -10x + 10y
dy/dt = + 28x - -0.999997y - -1xz
dz/dt = - -2.66667z + 1xy
```

This function best approximates the given data and carries the significant terms.
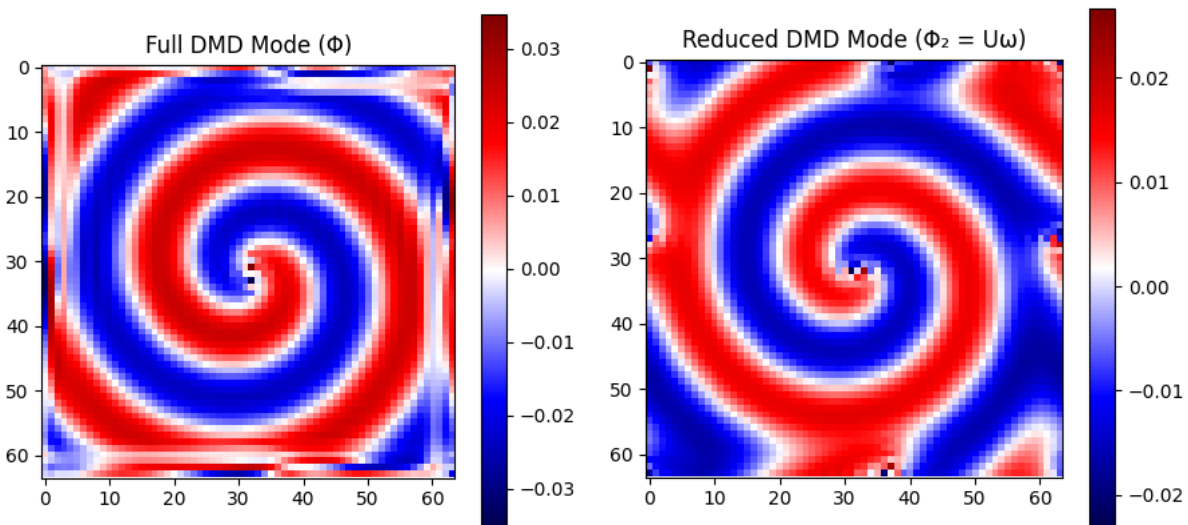
DMD:

Observations:

- The **full operator** produces many eigenvalues with magnitude $|\lambda|>1|$, indicating numerical instability due to noise and high-dimensional estimation.

- The **reduced operator** has eigenvalues mostly **inside or near the unit circle**, indicating a stable low-rank approximation.

- The reduced model filters noise and retains only dynamically relevant modes.

Conclusion:
The reduced operator captures the dominant coherent dynamics significantly better than the full operator, which is contaminated by noise and overfitting.
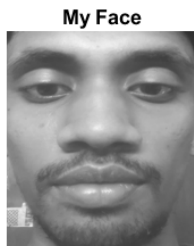
Observations:

- The **full DMD modes Φ** are noisy and contain high-frequency artifacts due to the ill-conditioning of AAA.

- The **reduced modes Φ_2** are much smoother and clearly capture the spatial patterns of the spiral waves.

- The reduced modes align with dominant low-rank structures, while the full modes contain unstable high-frequency components.
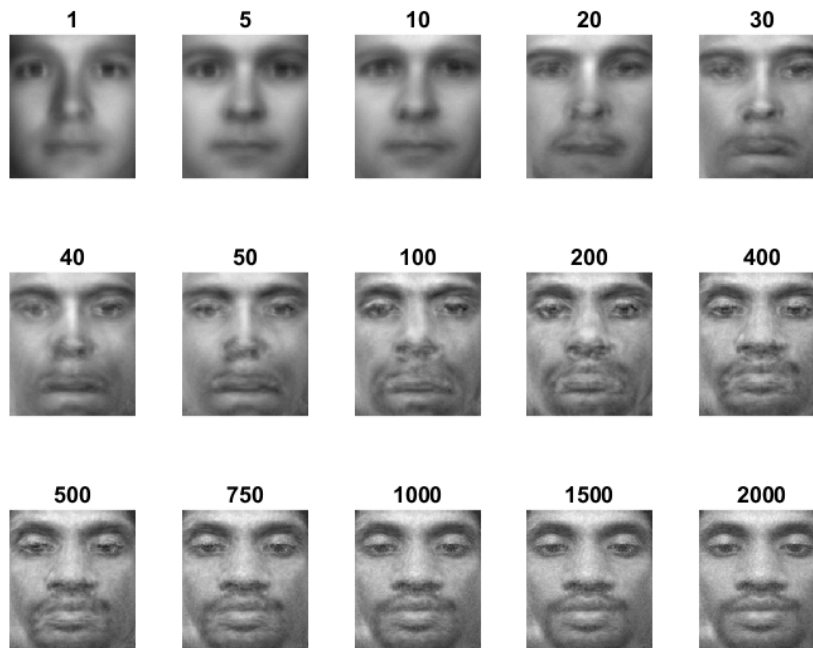
Conclusion:
The reduced DMD basis provides a more physically meaningful representation of the dynamics, while the full-space eigenvectors are dominated by noise and numerical errors.

POD:

Input image:

My Face

Reconstruction based on number of eigenvectors:

We observe that at approximately 400 basis vectors, the reconstructed image begins to recover the dominant features of the input image. As additional basis components are added, higher-frequency information is recovered, leading to reduced reconstruction error, and progressively clearer fidelity to the original image.