Supervised convolutional networks for volumetric data enrichment from limited sectional data with adaptive super resolution

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Introduction

Spatio-temporal fluid big data

- Exponential development of computing power
- Expensive numerical simulations (DNS, LES)
- CFD data with an immense number of spatio-temporal discretized points [1]
- Efficient data handling methods are eagerly desired [2]


Neural-network-based state estimation

- Neural network can reconstruct flow fields from limited data
  - Estimation from sensors to a whole field [3]
  - Super-resolution analysis [2,4]
- Next challenge: 3D reconstruction from 2D sectional data towards efficient data compression
- Example: a flow around the square cylinder at Reₚ=300


Methods

2D-3D Convolutional Neural Network [5]

Input: Velocity field of several x-y sectional fields (qₓᵧ)
Output: Velocity field of the whole domain (q₃D)
Data: a flow around the square cylinder obtained by DNS

\[ w = \arg \min_w \| q_{3D} - F(q_{2D}; w) \|_2 \]

Results

1. 3D reconstruction from 2D high-resolution cross sections

- Reconstructed fields (L₂ = -0.001)
- The use of more input sections provides a wake reconstruction with the higher accuracy
- Estimated cross-sectional velocity fields

2. 3D reconstruction from 2D low-resolution cross sections

- Super-resolution reconstruction from adaptive-sampled low-resolution data
- The estimation accuracy with adaptive sampling is superior to that of conventional average pooling in the v and w components
- Efficient data compression can be achieved with appropriate pooling methods for each component

Conclusion

- 2D-3D CNN was constructed and applied to a flow around a square cylinder
- Reconstructed fields were in agreement with the reference
- Compressed data by 1/4600 of the original with adaptive-sampled super-resolution assistance

Reference


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