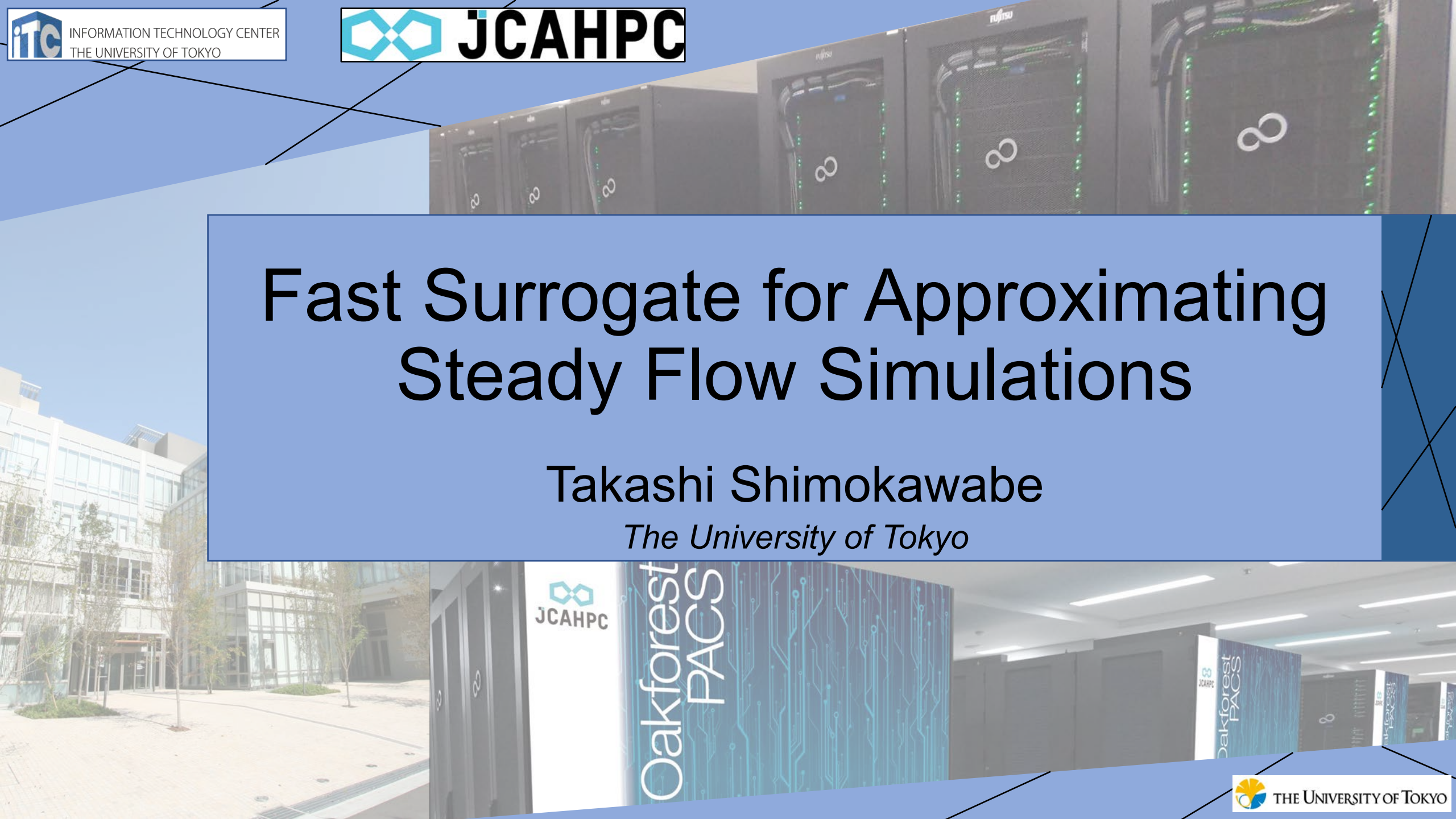

INFORMATION TECHNOLOGY CENTER
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JCAHPC

Fast Surrogate for Approximating Steady Flow Simulations

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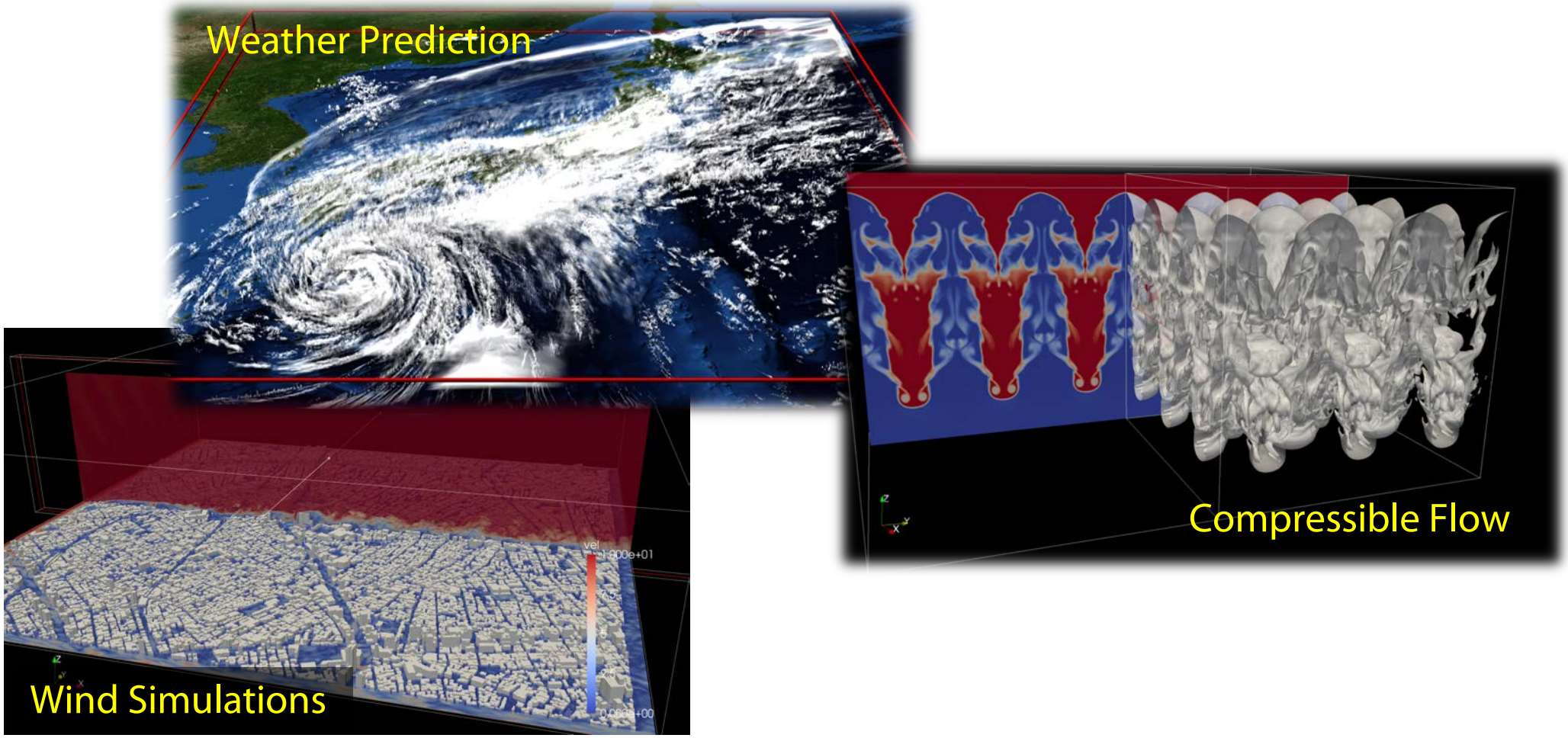
Computational Fluid Dynamics

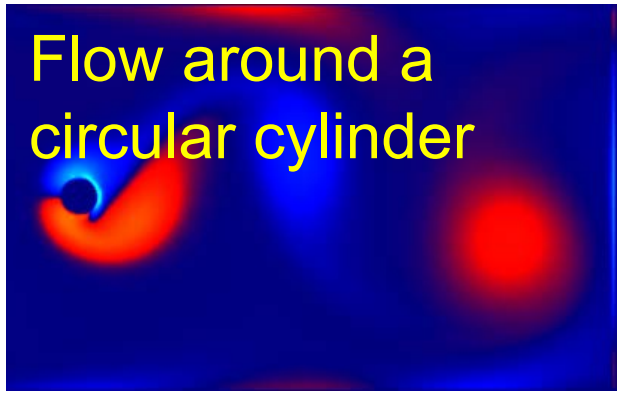


- Computational cost of computational fluid dynamics is relatively high.

  ➡ **Fast surrogate based on deep neural networks (DNNs) for approximating steady flow simulations**

Fast prediction of CFD simulation results by DNN

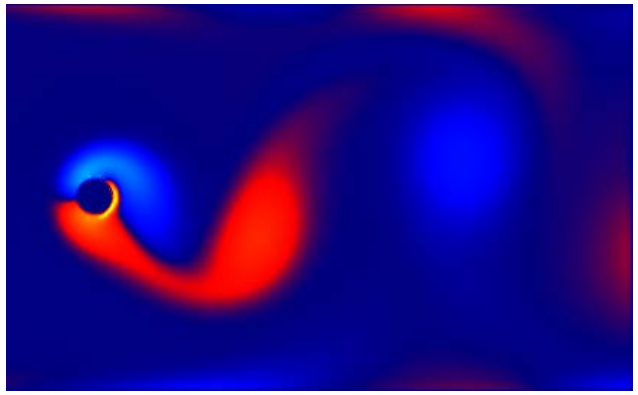
Dataset



CFD simulation
(Lattice Boltzmann
methods)

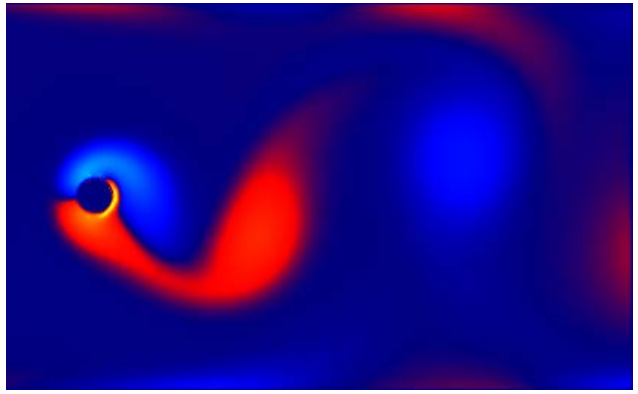
$$f_i(x + c_i\Delta t, t + \Delta t) = f_i(x, t) + \Omega_i(x, t)$$

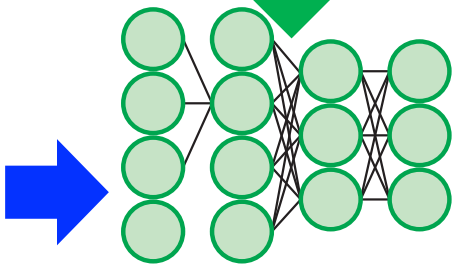
$$\Omega_i(x, t) = -\frac{1}{\tau}(f_i(x, t) - f_i^{eq}(x, t))$$



Training

Prediction





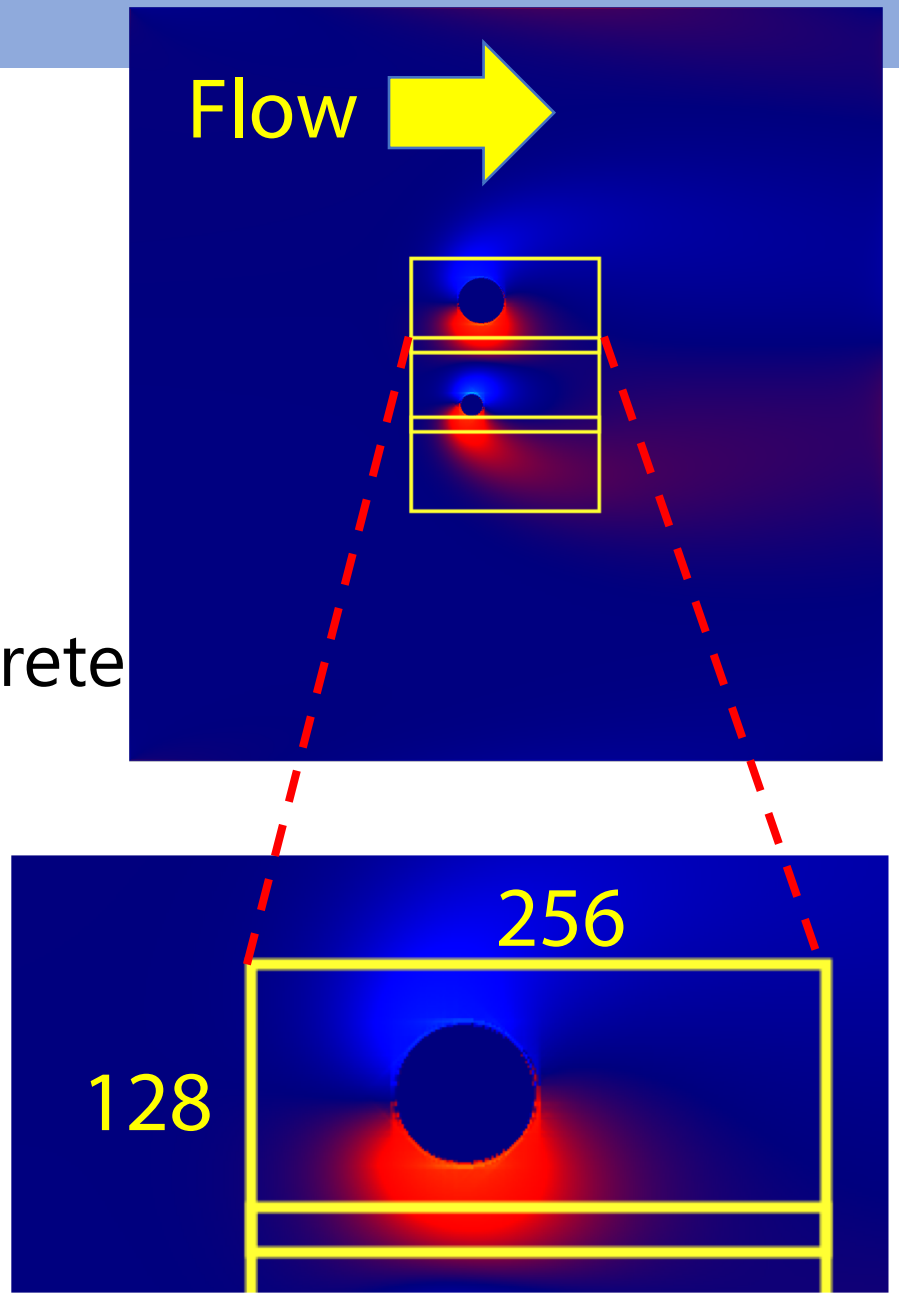
Prediction of flow

Convolutional neural networks (CNNs)
to predict simulation results

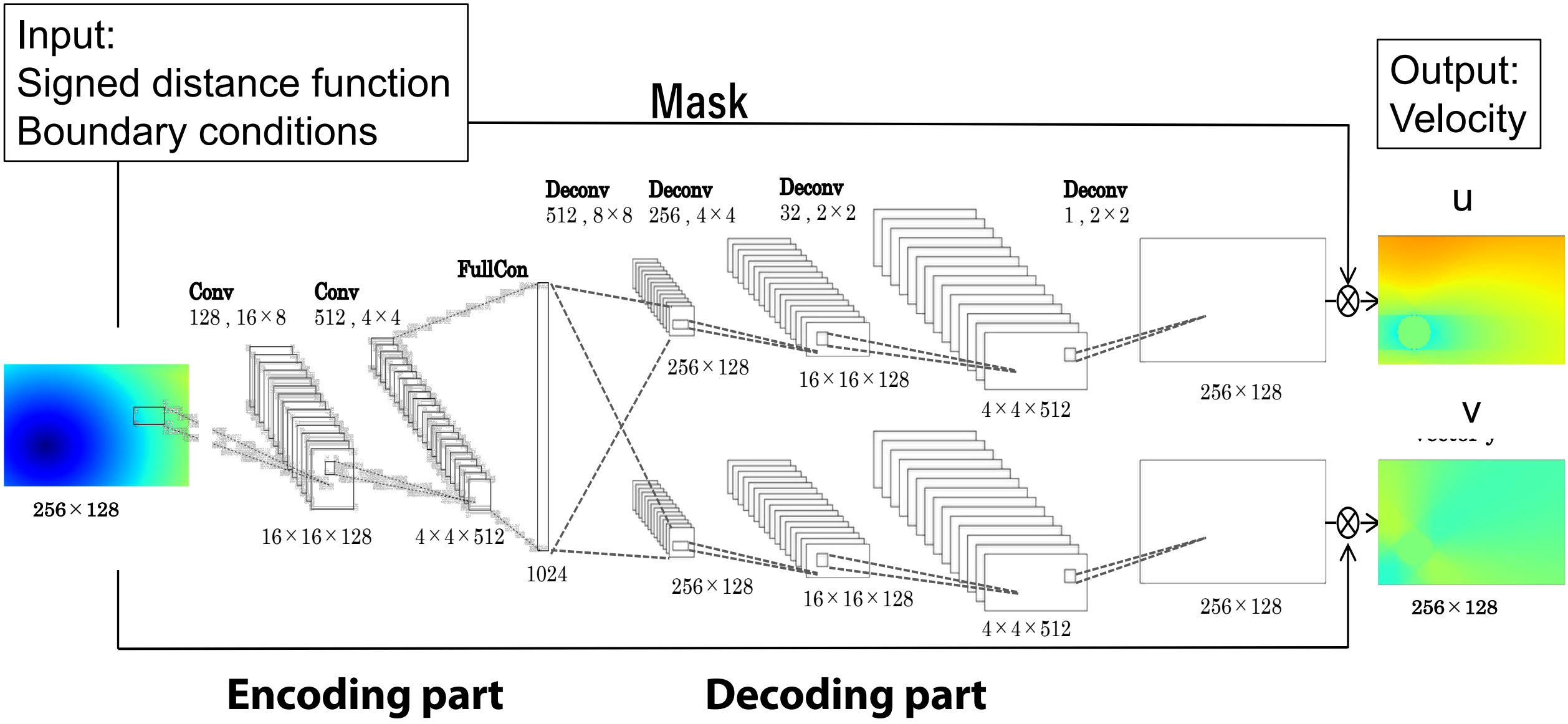
CNNs may become “faster simulator”

Datasets

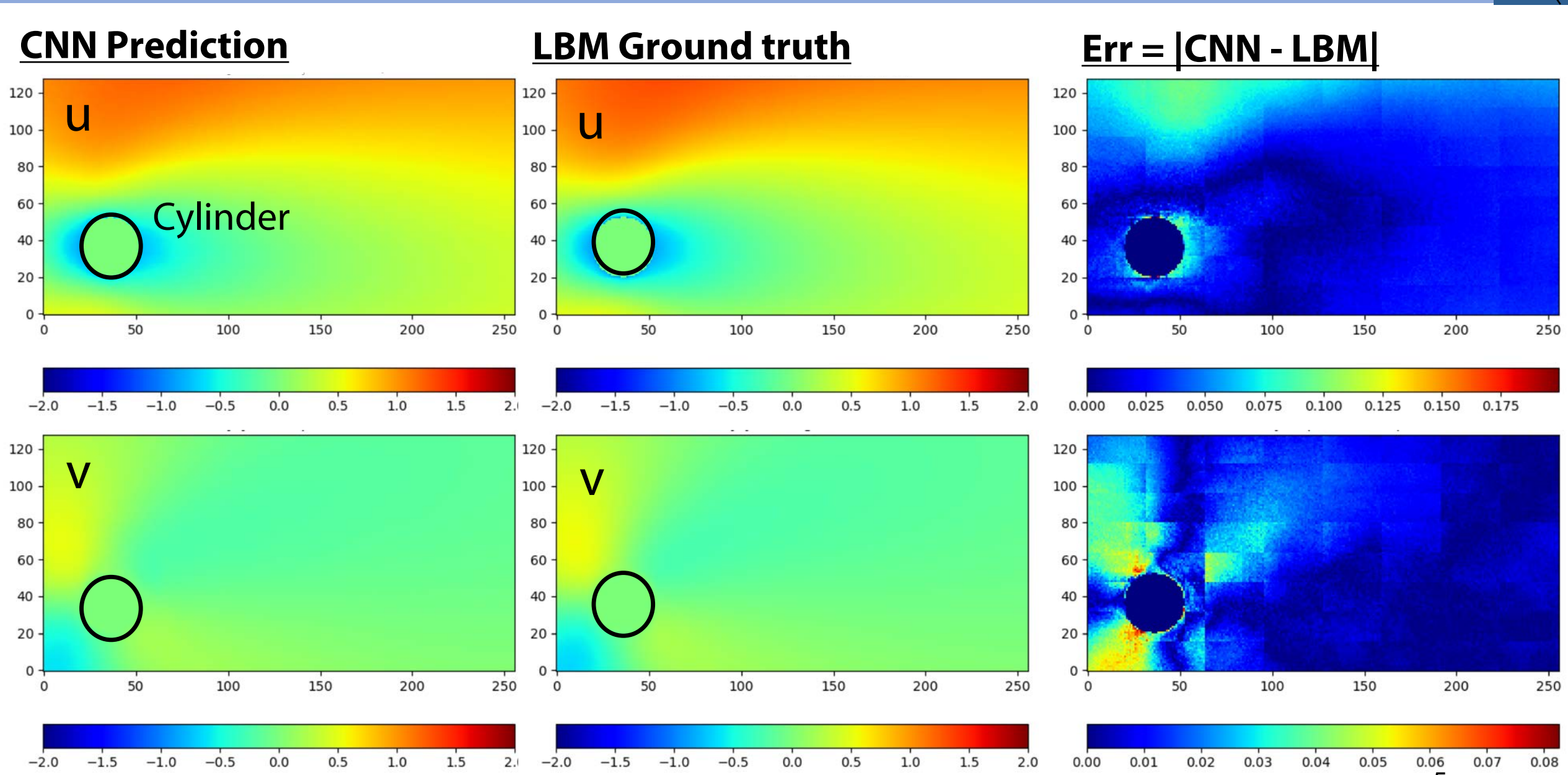
- Steady flow
  - The fluid flows along the x axis around objects.
- LBM simulation results
  - D2Q9 model (9 variables is used for discrete velocity)
  - Re = 100, Domain size:1024 x 1024
  - Random sized cylinders
- Input data: 256 x 128 (clipped)
  - Training: 4608
  - Validation: 1536



Network Architecture and Training

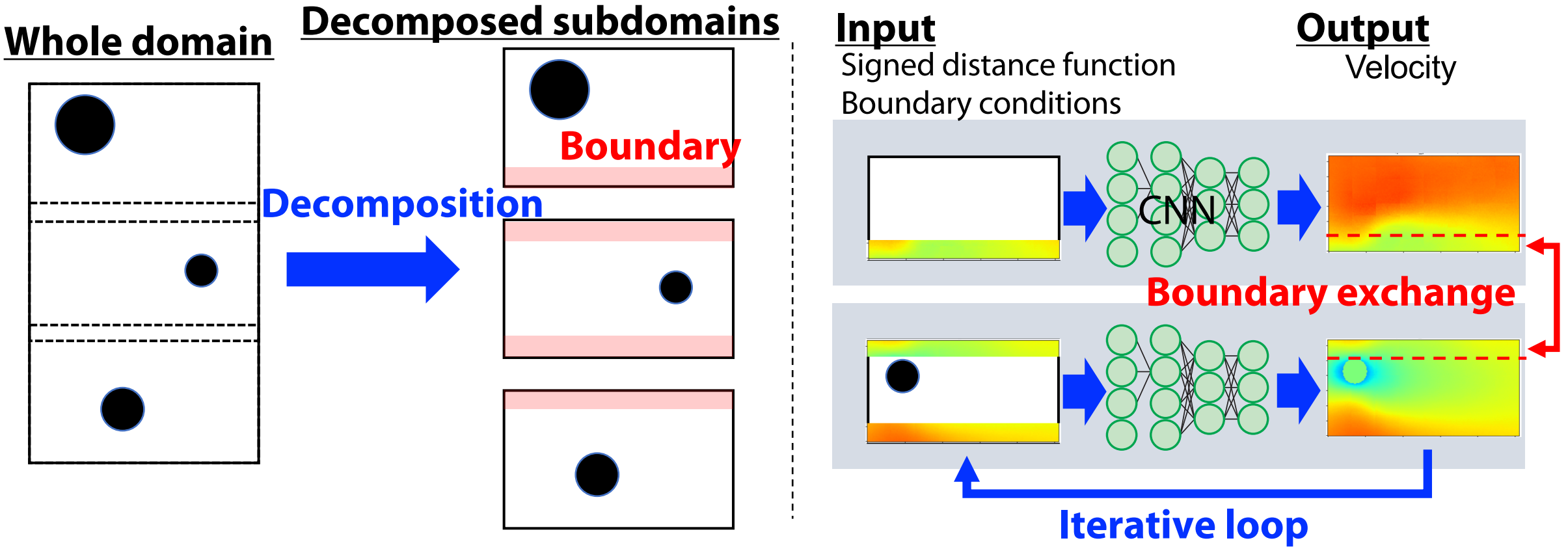


Prediction results for single domain



Prediction by CNN with boundary exchange

- The network model trained for a single domain is applied to the decomposed subdomains to predict the simulation results in each subdomain.
- In order to maintain consistency between values in the subdomains, boundary exchange between neighbor subdomains is performed.
- CNN and boundary exchange are performed iteratively until values converge.
- This method has no limitation for device (GPU) capacity.



Prediction results over a large computational domain

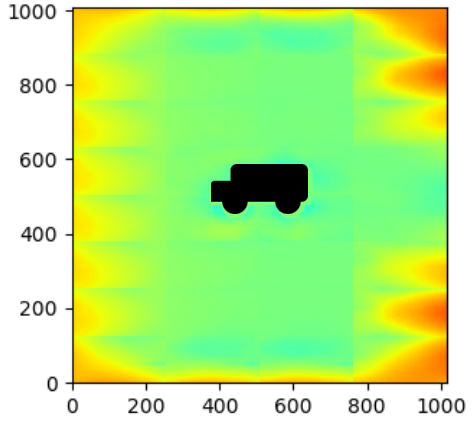
CNN Prediction

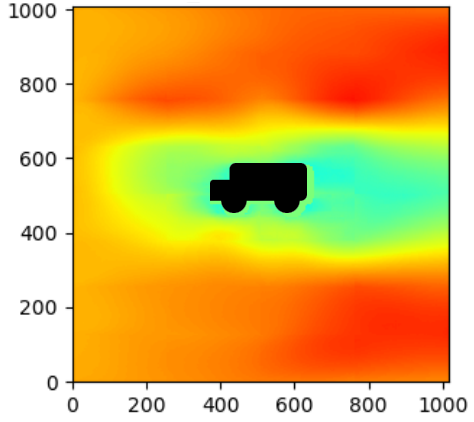
LBM Ground truth

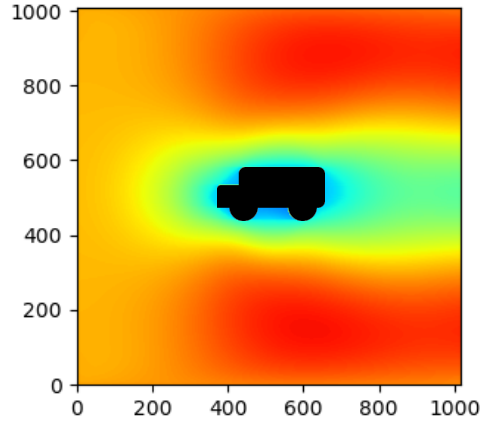
Initial Prediction

Final (converged)

Velocity x

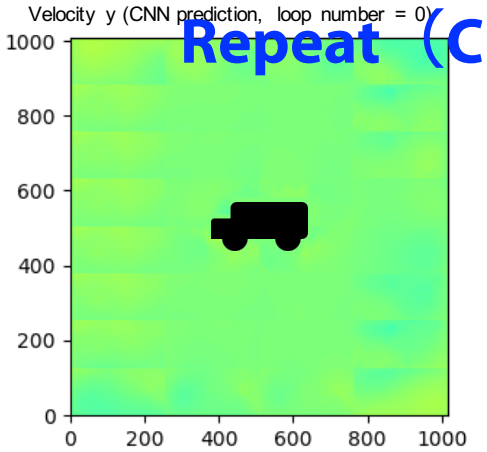


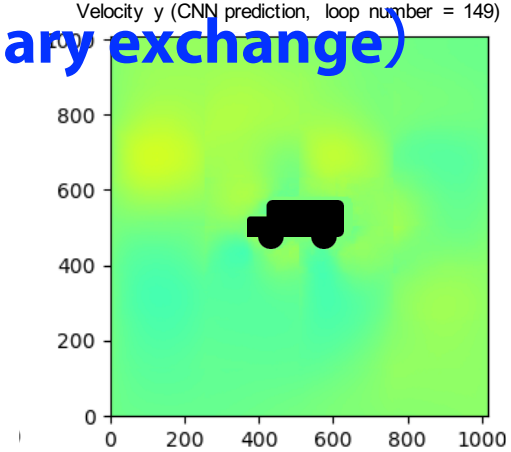


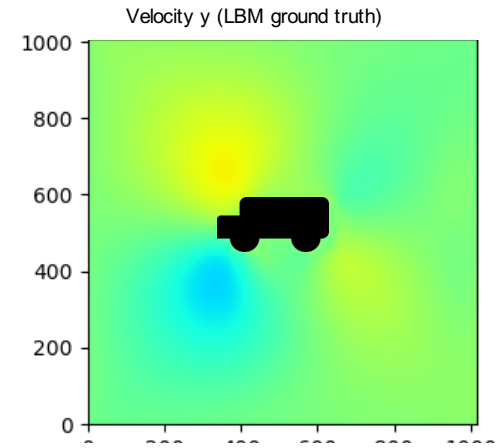


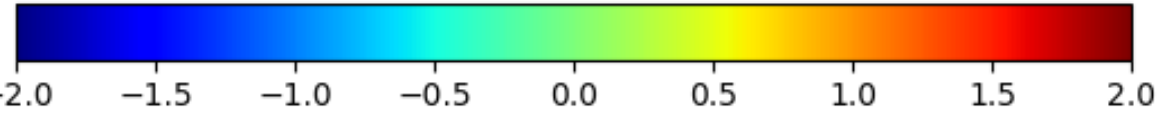
Repeat（CNN + boundary exchange）

Velocity y









4 x 8 subdomains

Conclusion

- We have developed deep learning fast surrogate for steady flow.
  - Predicting the LBM results by using convolutional neural networks (CNNs).
  - Predicting simulation results on large domain using CNNs with boundary exchange.
    - CNN and boundary exchange are performed iteratively until values converge.
    - The proposed method has no limitation for device (GPU) capacity.
    - The predicted results using 32 subdomains are shown.

- Future works
  - Extending the proposed methods to 3D CFD simulations.

Thank you for watching