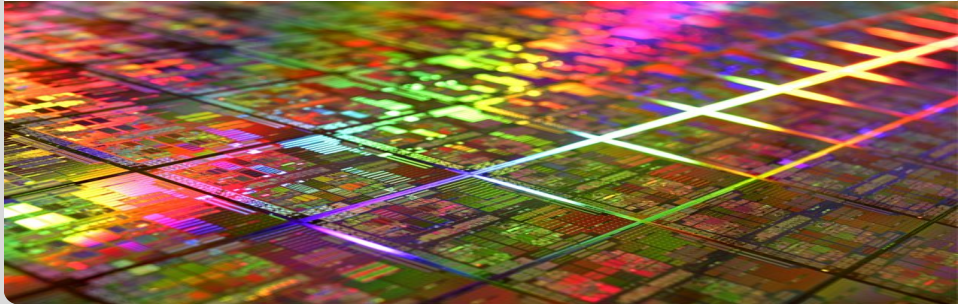


Towards Bringing Together Numerical Methods for Partial Differential Equation and Deep Neural Networks

Progress Update, Supervisor - Markus Hoffmann

Stanislav Arnaudov | September 26, 2019

CHAIR FOR COMPUTER ARCHITECTURE AND PARALLEL PROCESSING



Basic idea: Perform numerical simulation with ML-models

Basic idea: Perform numerical simulation with ML-models

- Concrete problem: Flow around an object according to the Navier–Stokes equations.

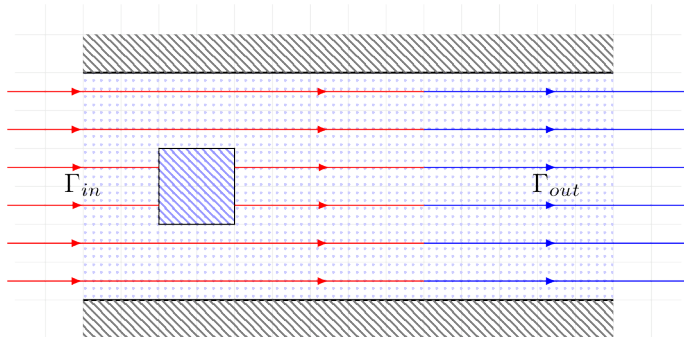


Figure: Simulation Setup

Basic idea: Perform numerical simulation with ML-models

- Solutions of the simulation can be represented as images.

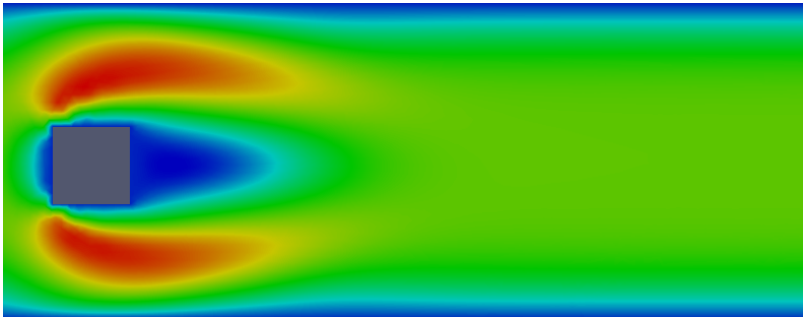
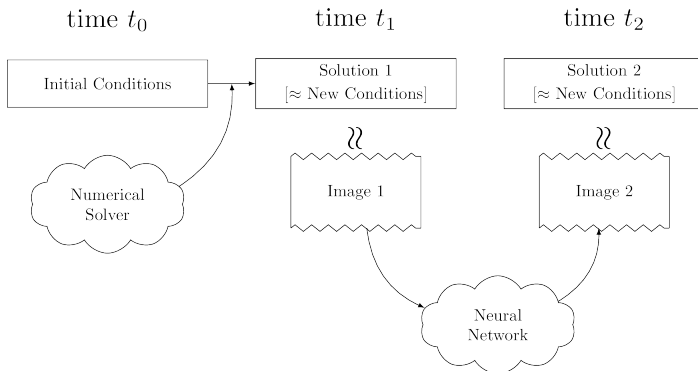


Figure: Simulation Image

Basic idea: Perform numerical simulation with ML-models

- Or ML-model primarily use images as input and output.



Project description

Several cases to investigate

- Constant model
- Fluid speed model
- Fluid viscosity and density model
- Object in space model

- Use of numerical solver for real simulation data generation.
- The simulation has several adjustable parameters
 - inflow speed
 - fluid viscosity
 - fluid density
- Reynolds Number in the range of [90, 350]

- Use of numerical solver for real simulation data generation.
- The simulation has several adjustable parameters
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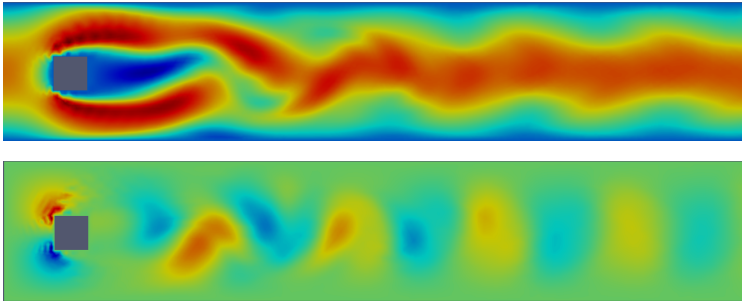
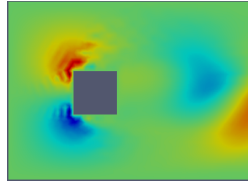
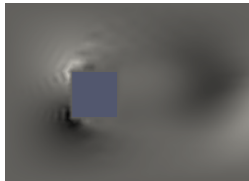
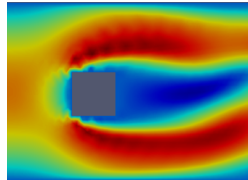
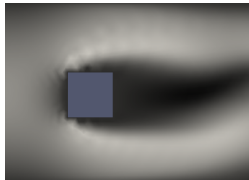


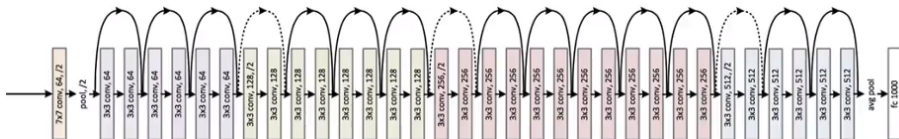
Figure: Karman vortex street

- Use of numerical solver for real simulation data generation.
- The simulation has several adjustable parameters
- Reynolds Number in the range of [90, 350]
- Choosing appropriate color space : Grayscale or RGB

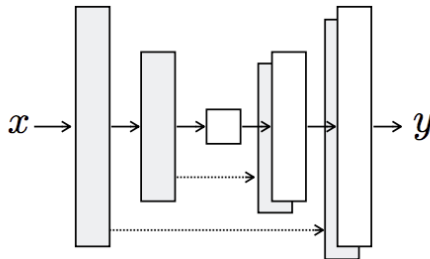


- Two types of architectures based on our preliminary research:

- Two types of architectures based on our preliminary research:
 - ResNet



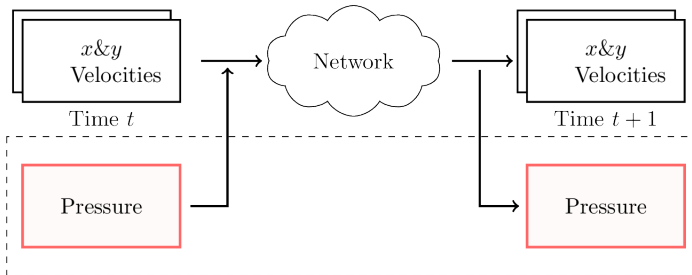
- Two types of architectures based on our preliminary research:
 - UNet



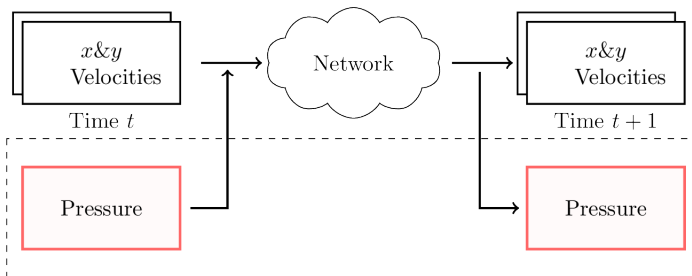
- Two types of architectures based on our preliminary research:
 - UNet turned out to perform better.

- Two types of architectures based on our preliminary research:
- Data being used by the network.

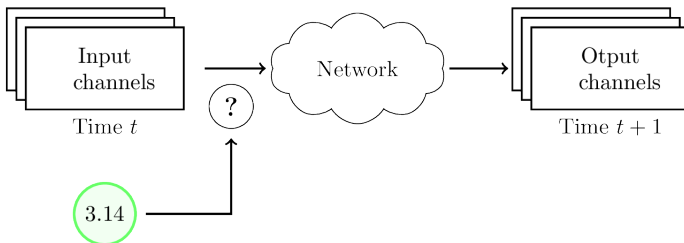
- Two types of architectures based on our preliminary research:
- Data being used by the network.
 - Usage of pressure field



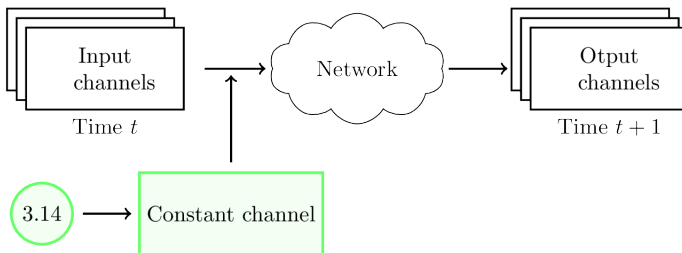
- Two types of architectures based on our preliminary research:
- Data being used by the network.
 - Usage of pressure field → the pressure field turned out to be useful



- Two types of architectures based on our preliminary research:
- Data being used by the network.
 - Processing of real values



- Two types of architectures based on our preliminary research:
- Data being used by the network.
 - Processing of real values \rightarrow extra image channel filled with the value



Evaluating the results

Two views of the results

Computer Vision

Numerical Simulation

Two views of the results

Computer Vision

- Perceived qualities of the image results
- Metrics:
 - Peak signal-to-noise ratio - PSNR
 - Correlation

Numerical Simulation

Two views of the results

Computer Vision

- Perceived qualities of the image results
- Metrics:
 - Peak signal-to-noise ratio - PSNR
 - Correlation

Numerical Simulation

- Real differences between the predicted and the actual values
- Metrics:
 - Average percentage difference
 - Max percentage difference

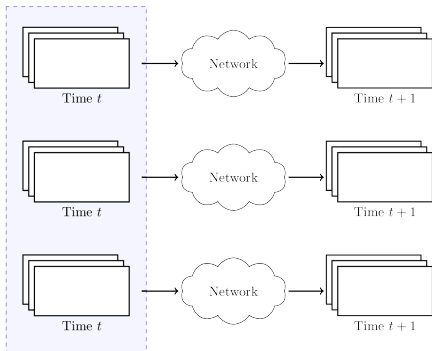
Two evaluation cases

Individual Images

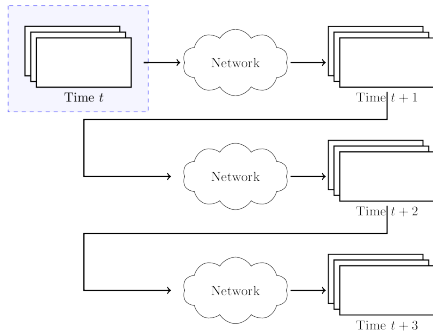
Recursive Application

Two evaluation cases

Individual Images



Recursive Application

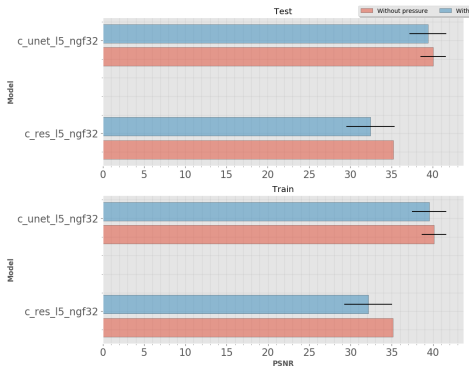


Results

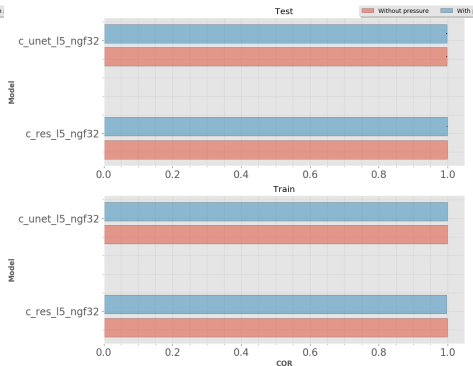
Individual Images – constant model

Cor. and PSNR:

Models comparison



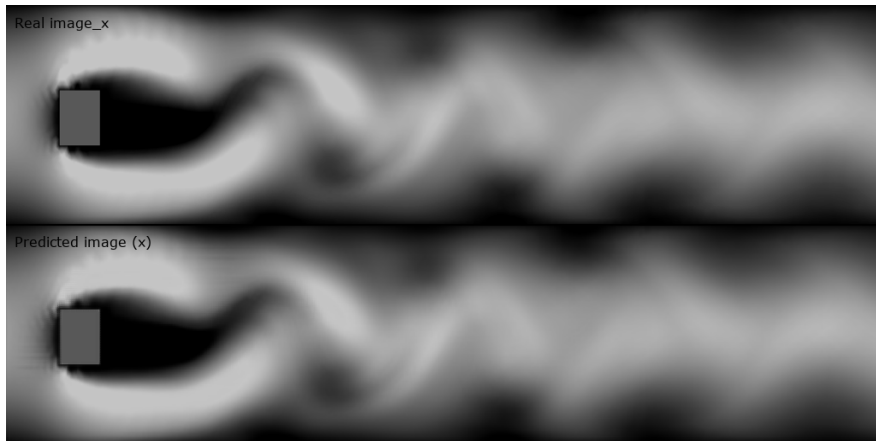
Models comparison



Results

Individual Images – constant model

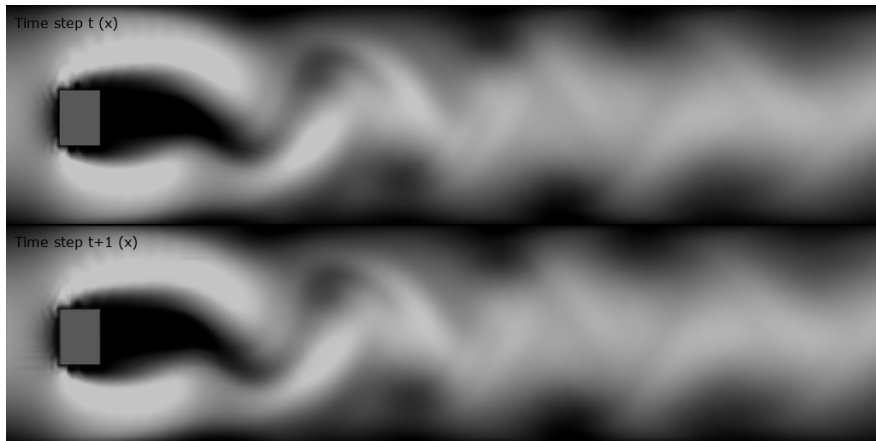
Prediction image:



Results

Individual Images – constant model

Timestep image:



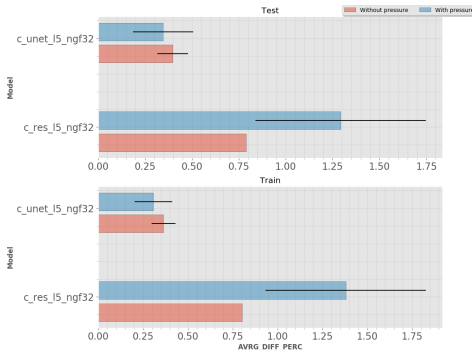
Results

Individual Images – constant model

Numerical view:

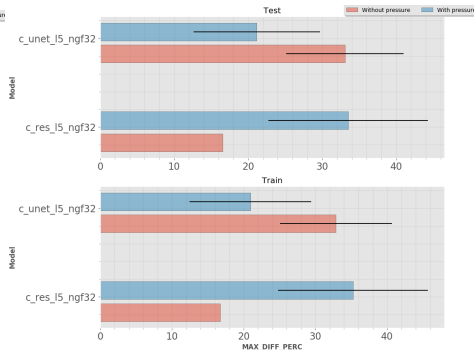
Avrg difference

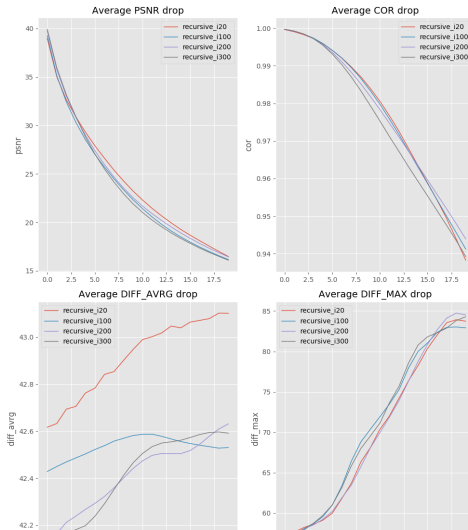
Models comparison



Max difference

Models comparison





Description

○○○○○

Data

○○○○

Models

○○○○○○○○○

Evaluation

○○○○○

Results

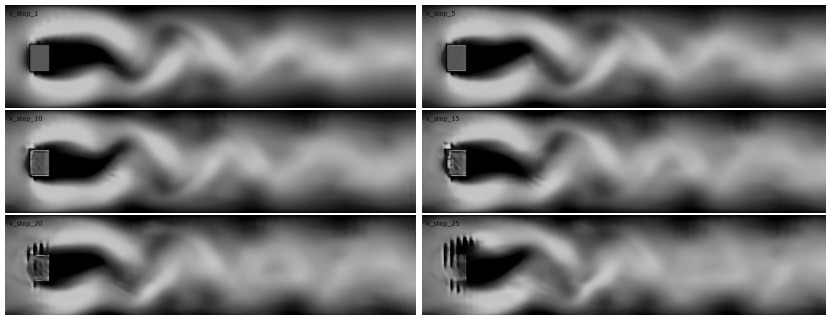
○○○○●○

End

○○

Results

Recursive application – constant model



Thank you for your attention.

Questions?