PARSIMONIOUS NEURAL NETWORKS

ADAGOS

spinner
next generation spine experts

Bypassing numerical simulations: deep learning perspectives in vertebrae modeling

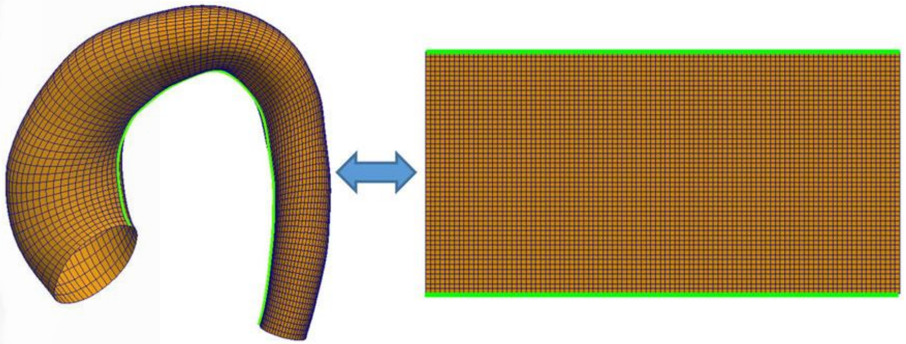
SPINNER

Deep Learning Methods and Reduced Order Modelling Techniques for Patient-Specific Spine Models

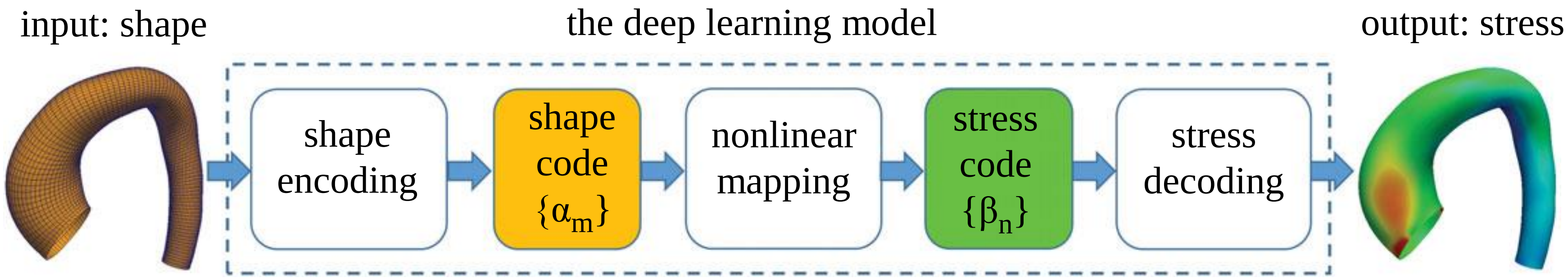
Project Aim

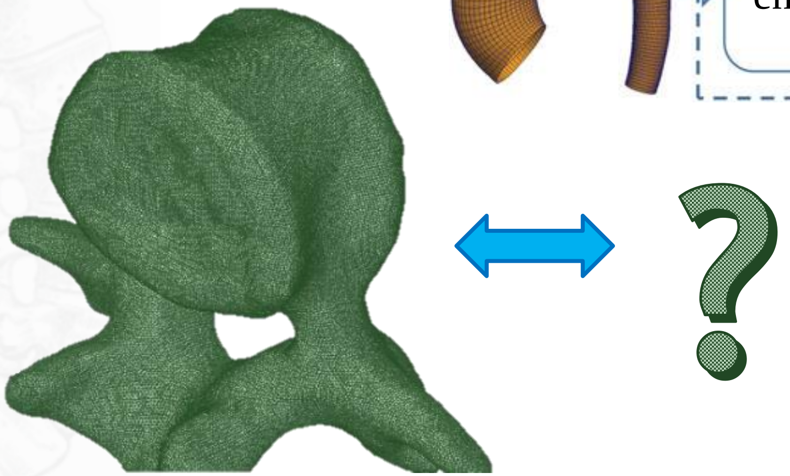
" To develop real-time biomechanical simulations of spinal surgical setups by integrating parsimonious deep learning approaches into the setup and execution of finite element simulations. "

Aorta example



Liang *et al.*, (2018)





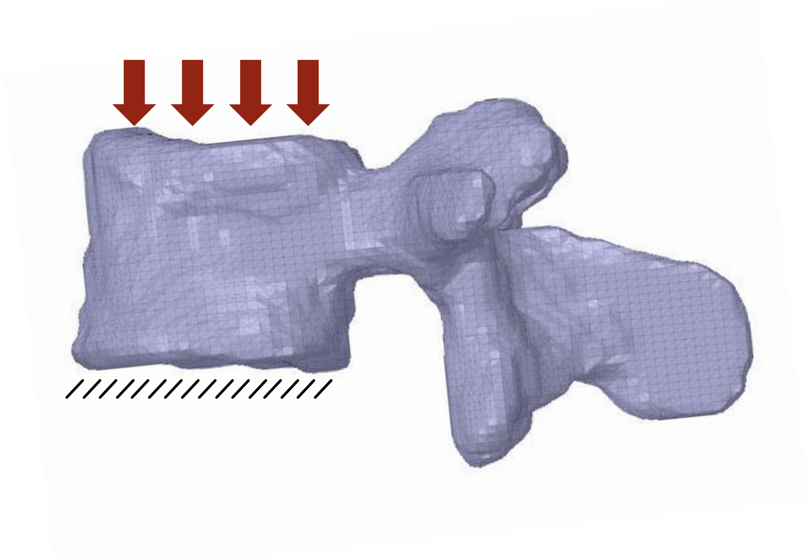
Objective: Mesh Morphing for Anatomical Shape Parameterisation

Objective : " By using a mesh morphing approach to parameterise the shape variations in a training set of lumbar vertebra, develop an artificial neural network to substitute the simulation of a lumbar vertebra under a compressive load. "

Dataset (Yao *et al*., 2012):

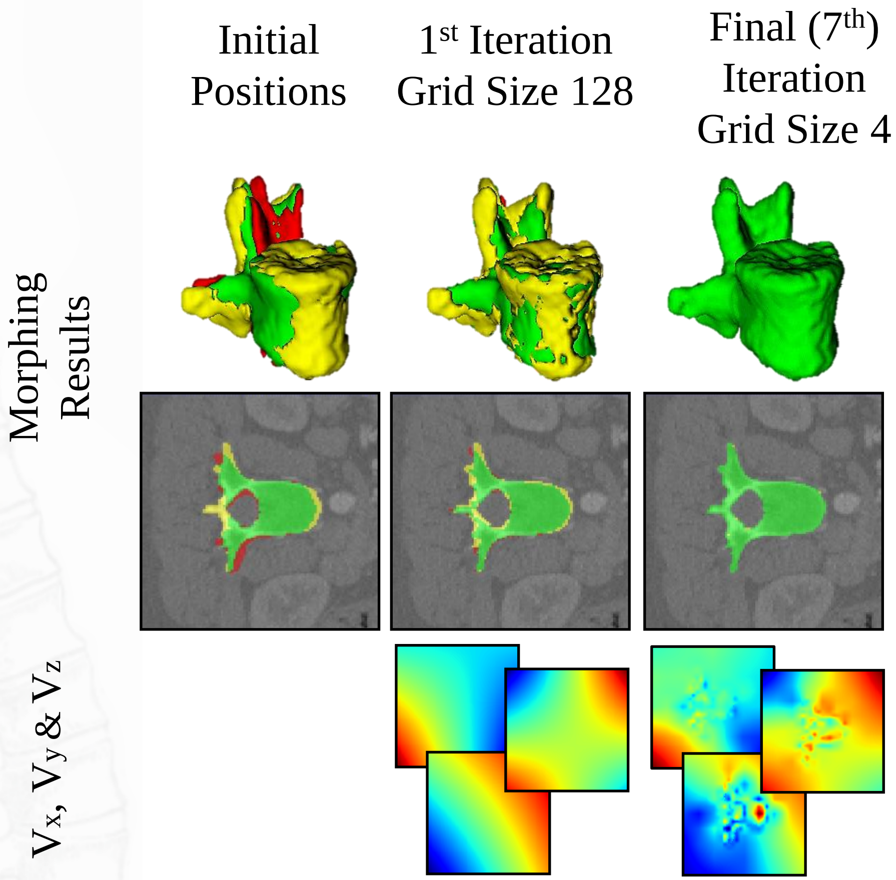
- CT scans with manual segmentations
- 10 spines (50 lumbar vertebrae)
- Fully anonymised and publicly available at:
  SpineWeb.DigitalImagingGroup.ca

The Simulation:



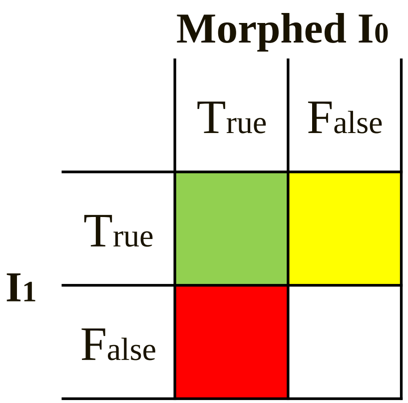
Yao, J., Burns, J., Muñoz, H. and Summers, R., (2012). Detection of Vertebral Body Fractures Based on Cortical Shell Unwrapping. *International Conference on Medical Image Computing and Computer Assisted Intervention, 7512, 509-516.*

Mesh Morphing



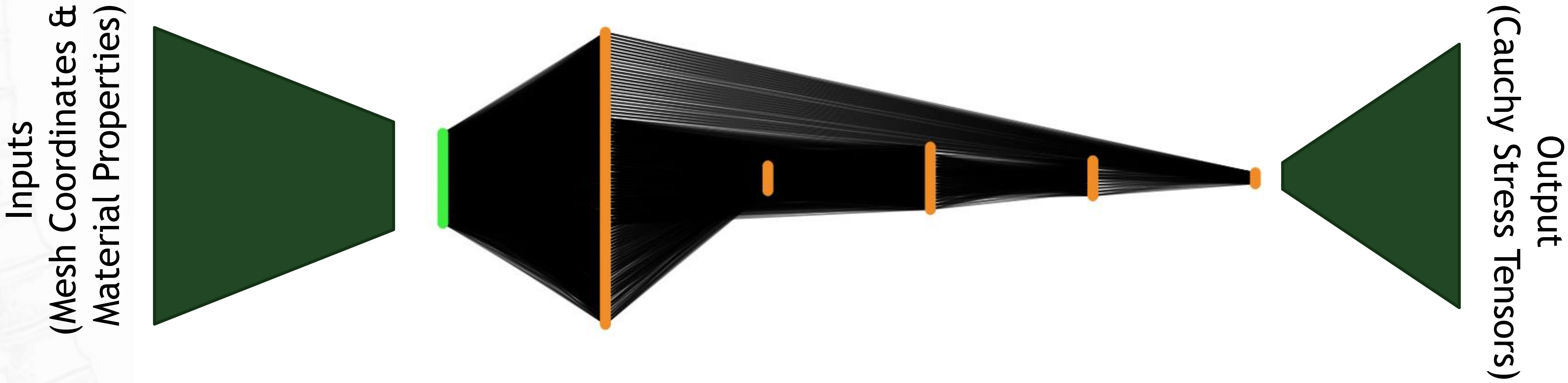
Images created using ITK-Snap

Morphing Results Key :



Fehrenbach, J. and Masmoudi, M., (2008). A fast algorithm for image registration. *Comptes Rendus Mathématique*, **346**(9-10), 593-598.

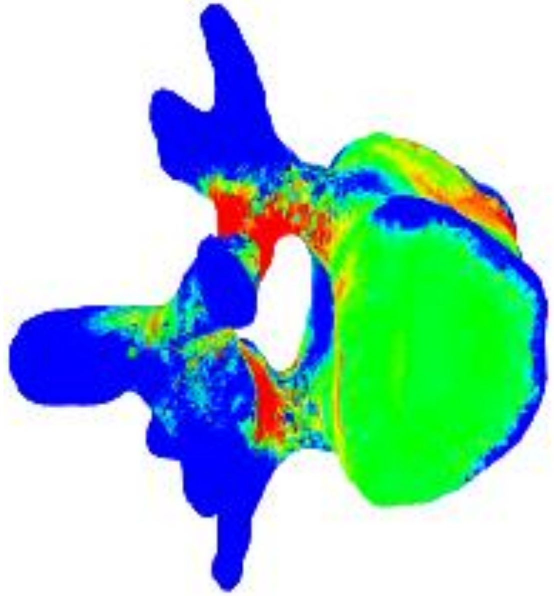
Compressions & Neural Network



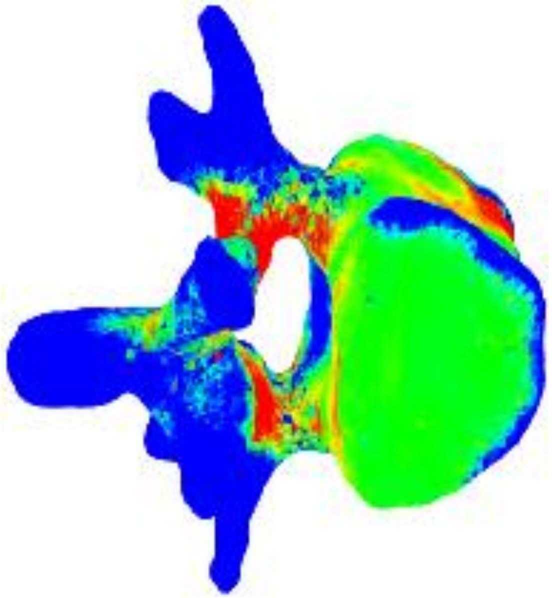
NeurEco Neural Network

Testing Set Results

Testing Sample Results for σ_{11} of the Cauchy stress tensor



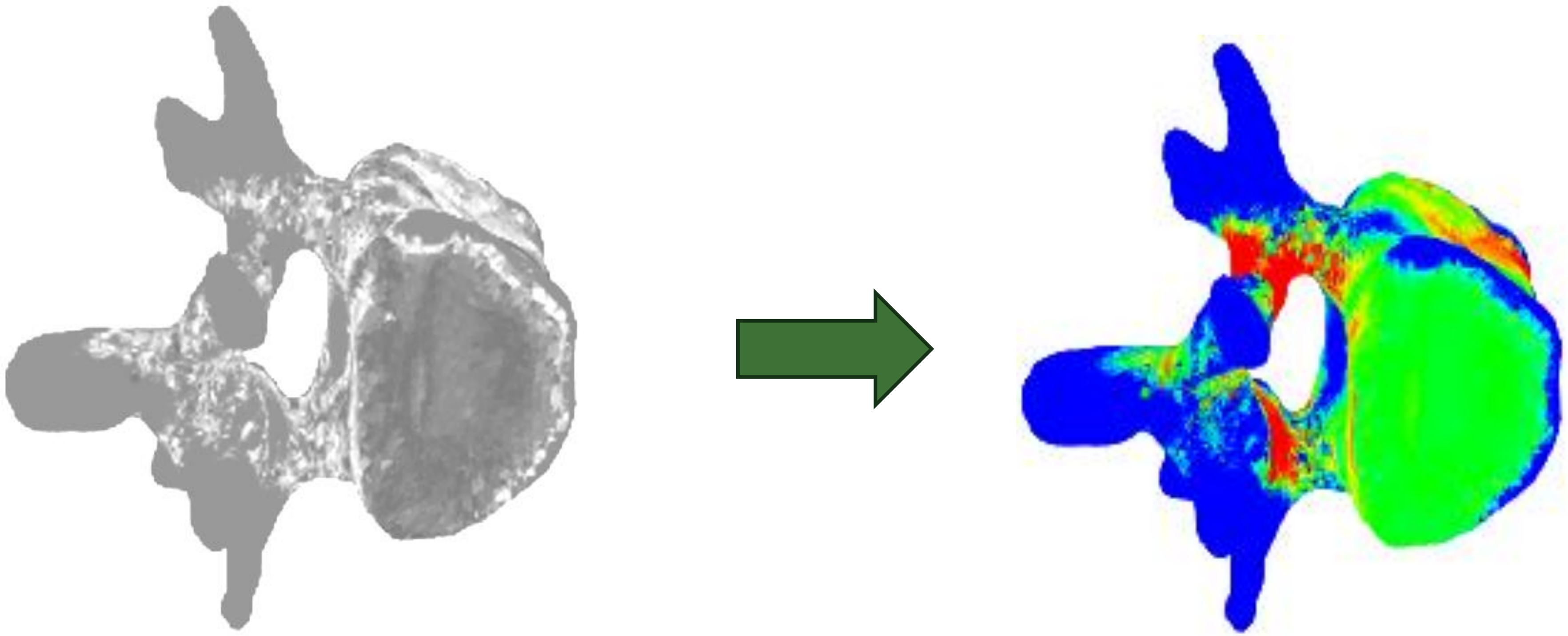
Finite Element Simulation



Neural Network

- Error 6.00% in the Euclidean norm of the output vector.
- Execution time of the ANN is around 1% of the execution time of the equivalent FEA simulation.

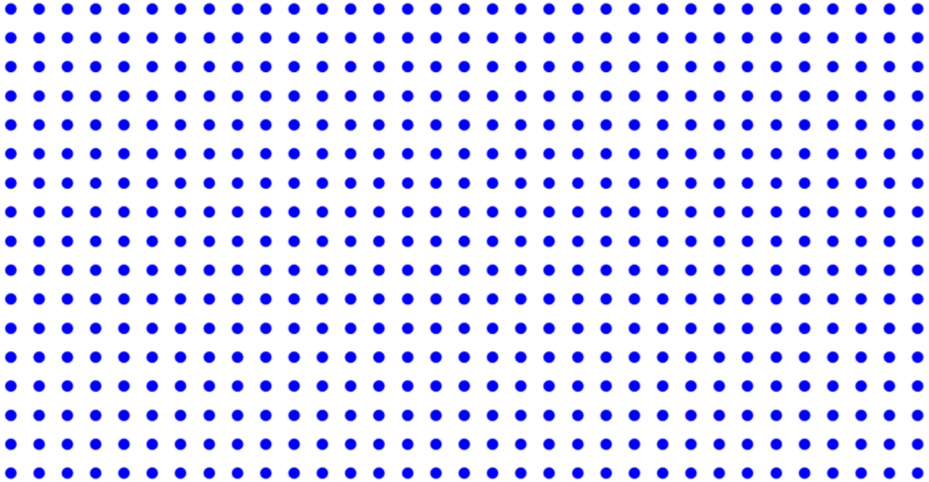
Perspective
Skip everything and learn directly



Convolutional approaches: Target applications

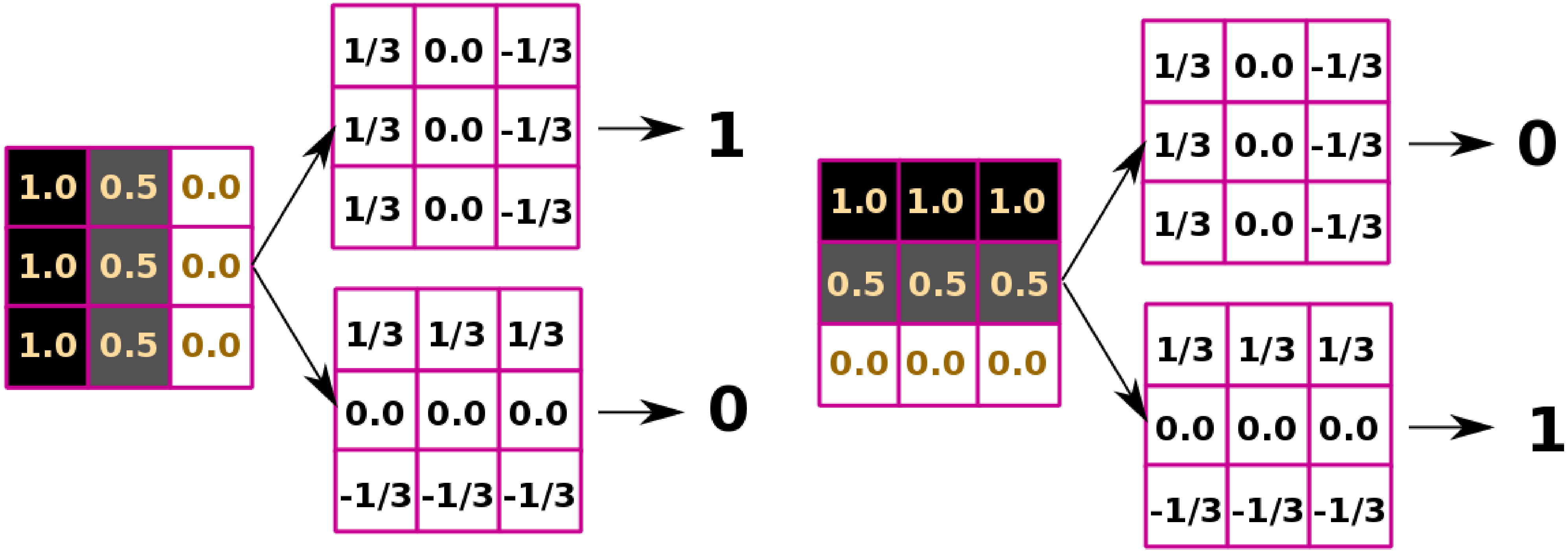
Work with structured data, for example

- The outputs of the solver

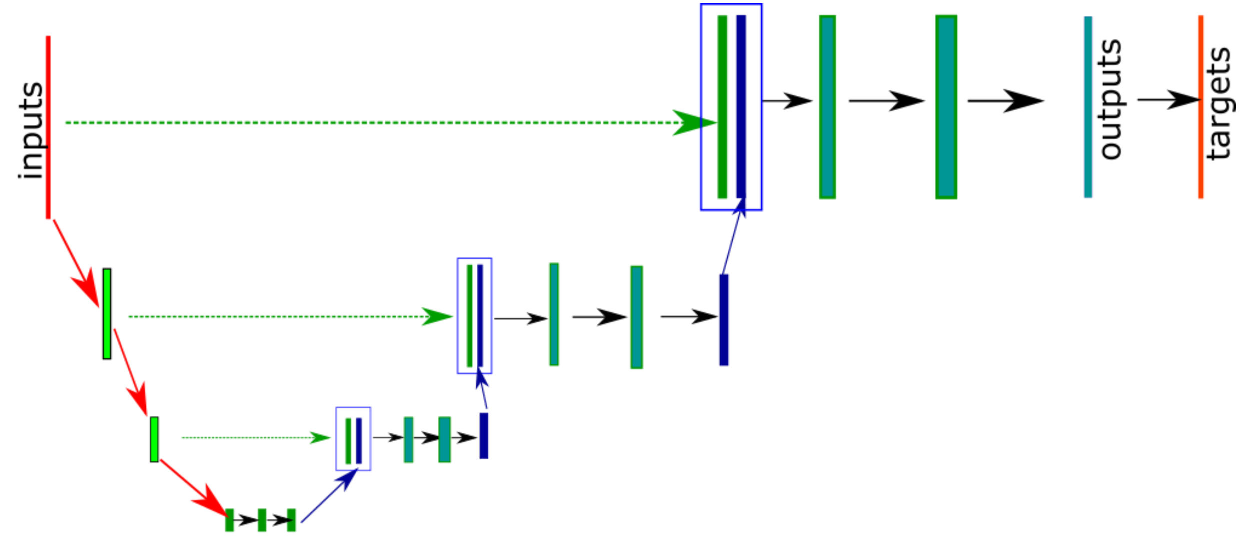


- Images

How convolution “sees” things?



Adagos version of U-Net for PDEs



Convolutions with 3x3xd kernels, stride=1, preserves shape

Parallel propagation of information (no calculations)

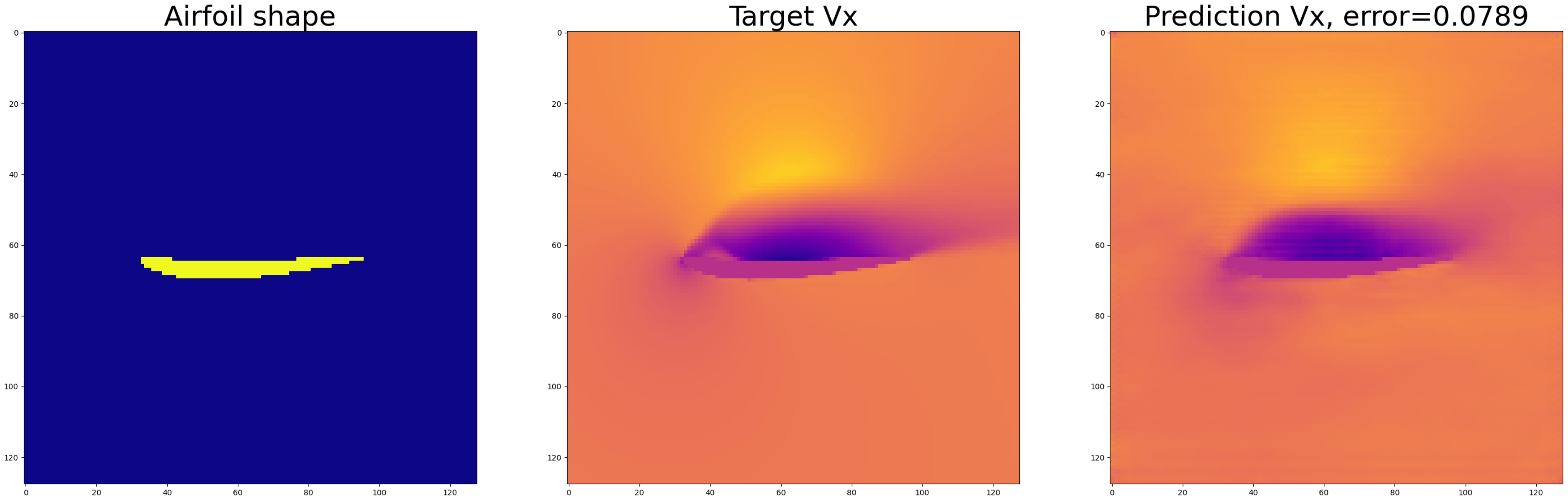
Concatenation

Compression. Wavelets constructions. For enrichment convolutions with 3x3xd kernels, stride=2, divides each spatial dimension size by two

Decompression, upconvolutions with 3x3xd kernels, stride=2, multiplies each spatial dimension size by two

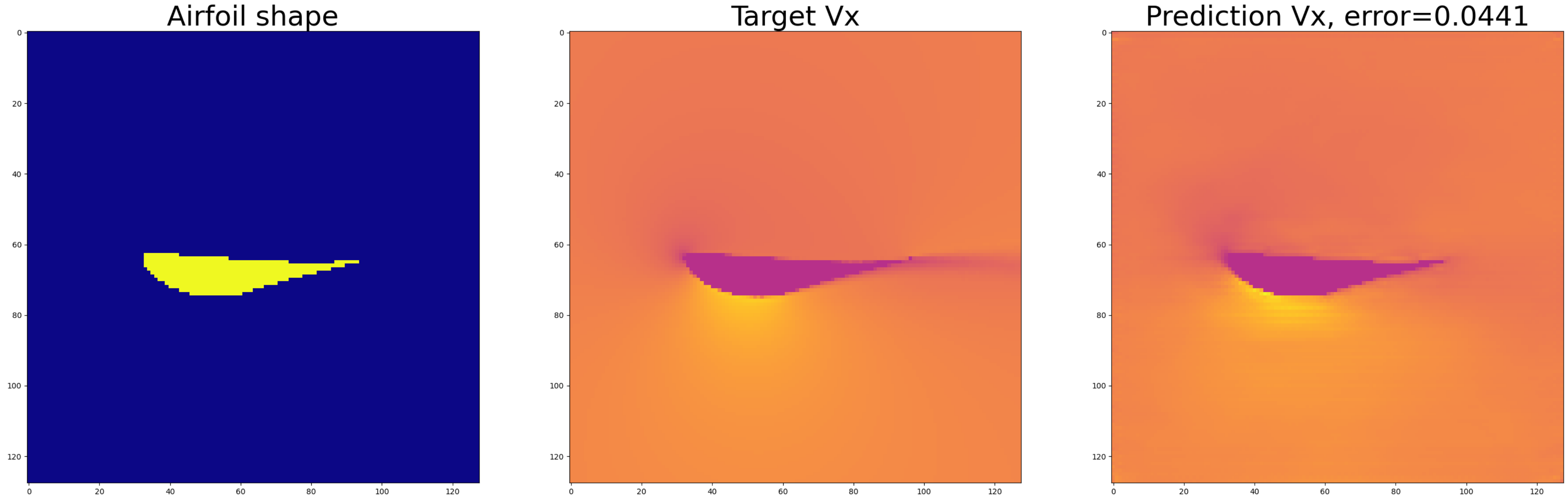
- Inspired by PDE theory and wavelets theory
- Deterministic initialization
- Automatically deduced architecture
- Small size

Example



Airfoil shape
Target Vx
Prediction Vx, error=0.0789
0
20
40
60
80
100
120

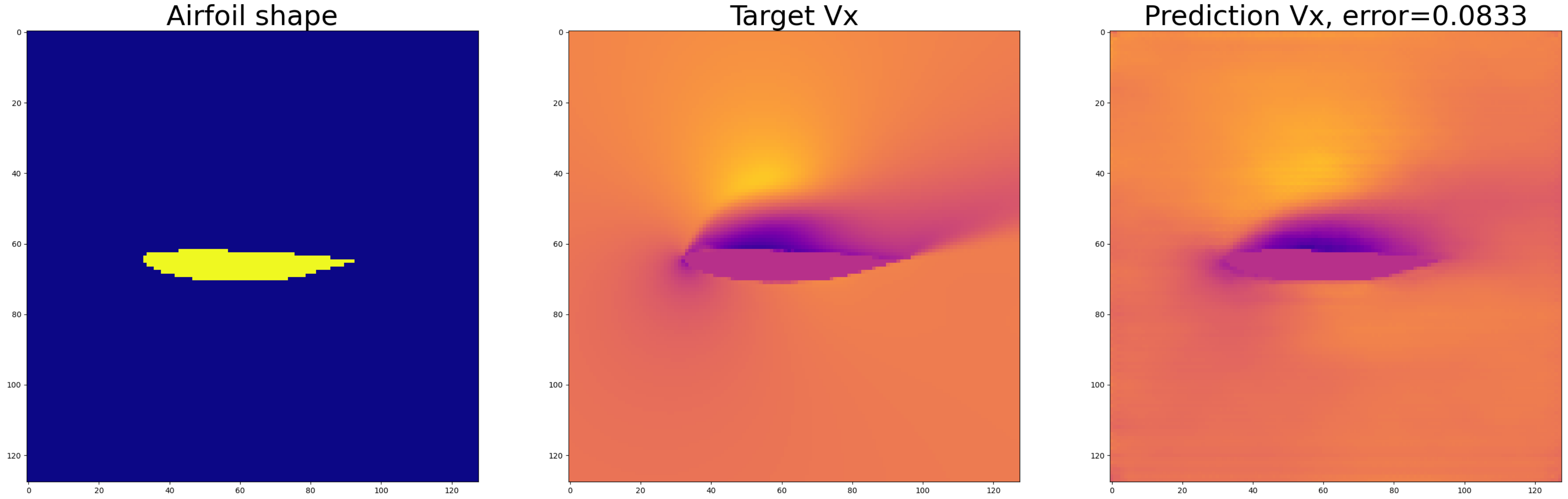
Example



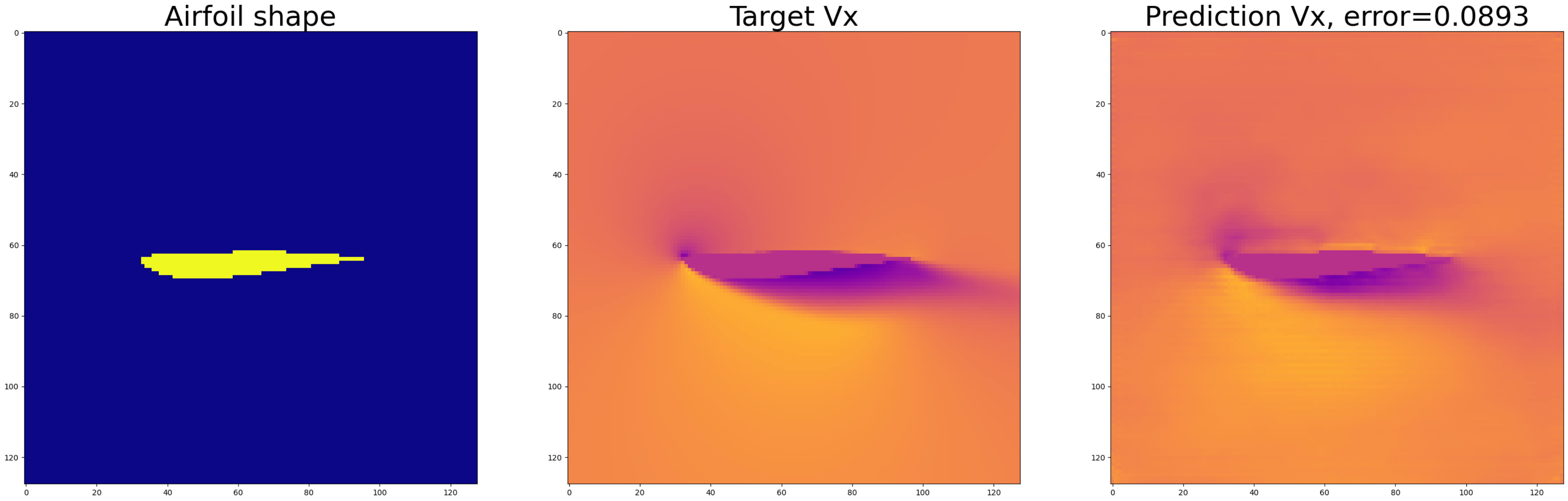
Airfoil shape
Target Vx
Prediction Vx, error=0.0441
0
20
40
60
80
100
120

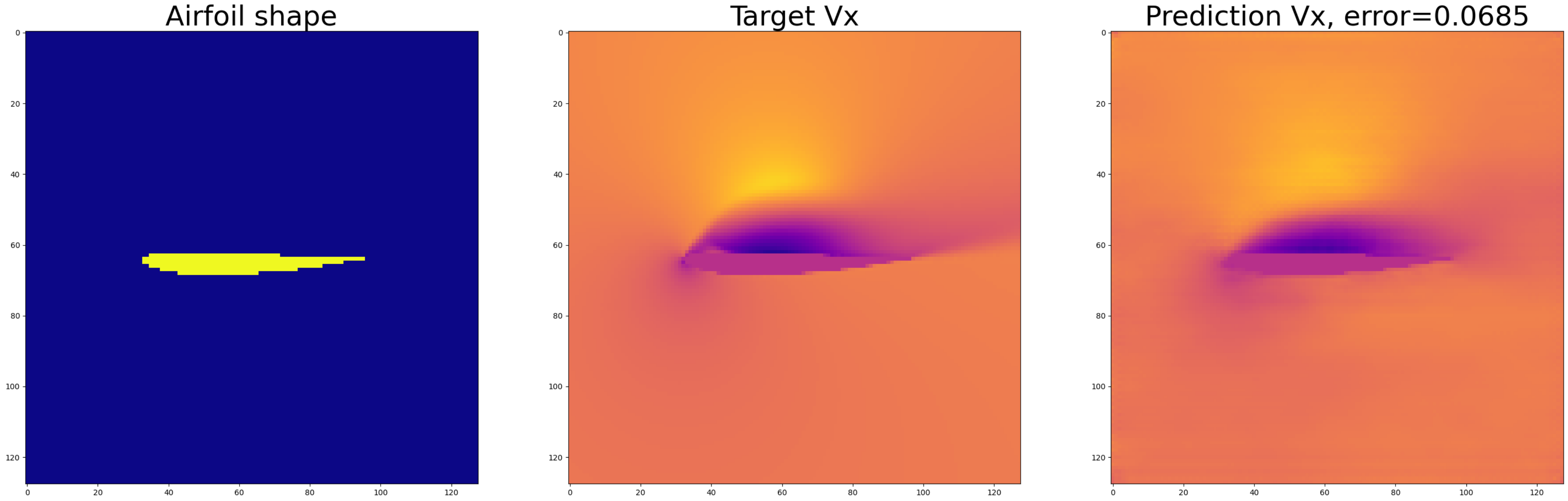
NEURECO


Airfoil shape
Target Vx
Prediction Vx, error=0.0555
0
20
40
60
80
100
120



Airfoil shape
Target Vx
Prediction Vx, error=0.0833


Airfoil shape
Target Vx
Prediction Vx, error=0.0893
0
20
40
60
80
100
120


Airfoil shape
Target Vx
Prediction Vx, error=0.0685

Thank You for your attention!
Q&A