Domain Adaptation

The problem

Neural networks require data to train on. But what if such data is unavailable?

Need to use simulations, similar data, and rely on generalization.

Very common problem:

- Physics: MC simulations of detectors response, space telescopes images
- Medicine: measurements by different instruments
- Object recognition: photos taken by different cameras

Solution: Domain adaptation

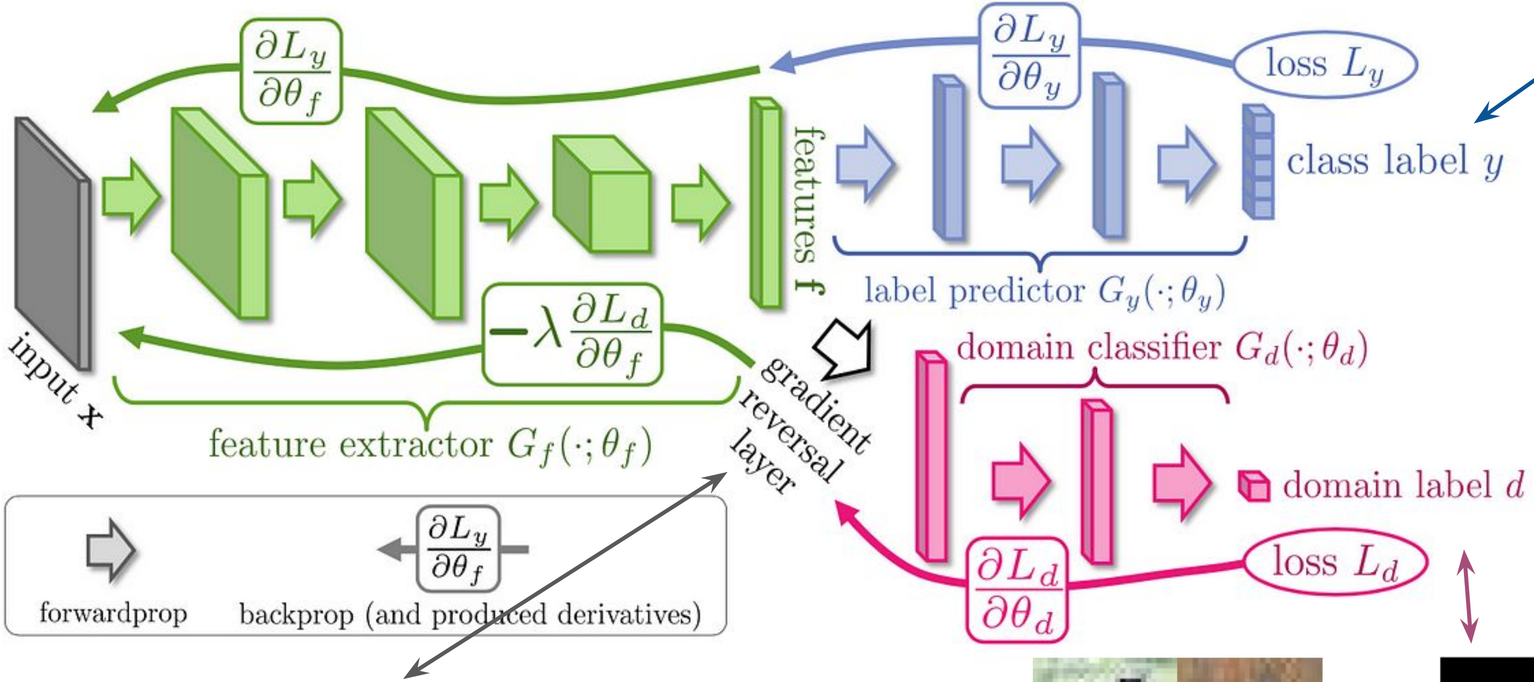
Identify and learn domain-invariant features

Available data for training (source domain)

Data of interest (target domain)

Domain adaptation technique

Train to recognize digits



Exclude domain-specific features

vs

Widely used

- Physics:
    - CMS@LHC (2405.13778)
    - Cherenkov Telescope Array Large-Sized Telescope (2308.12732)
    - Photometric Classification of Supernovae (1810.06441)
    - Strong Gravitational Lens Analysis (2410.16347)

- Reduces systematic error due to MC-data mismatch
- Enforces common representation space

NNs are bad at extrapolating

We want to fit the function:

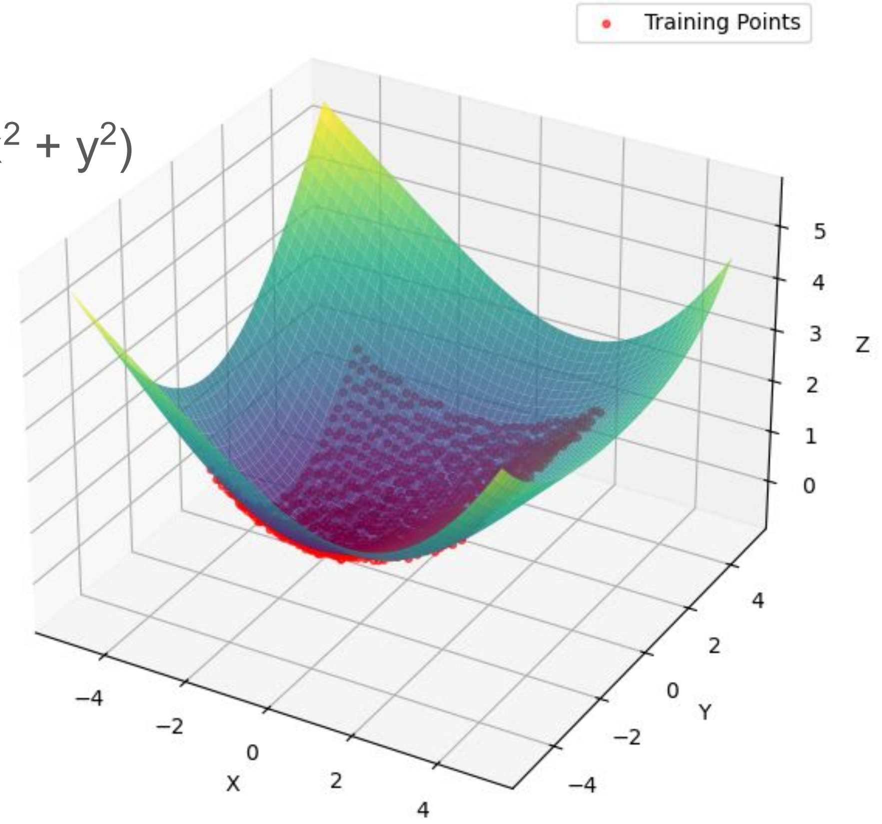
$f(x,y) = \sin(0.5 * x) * \cos(0.5 * y) + 0.1 * (x^2 + y^2)$

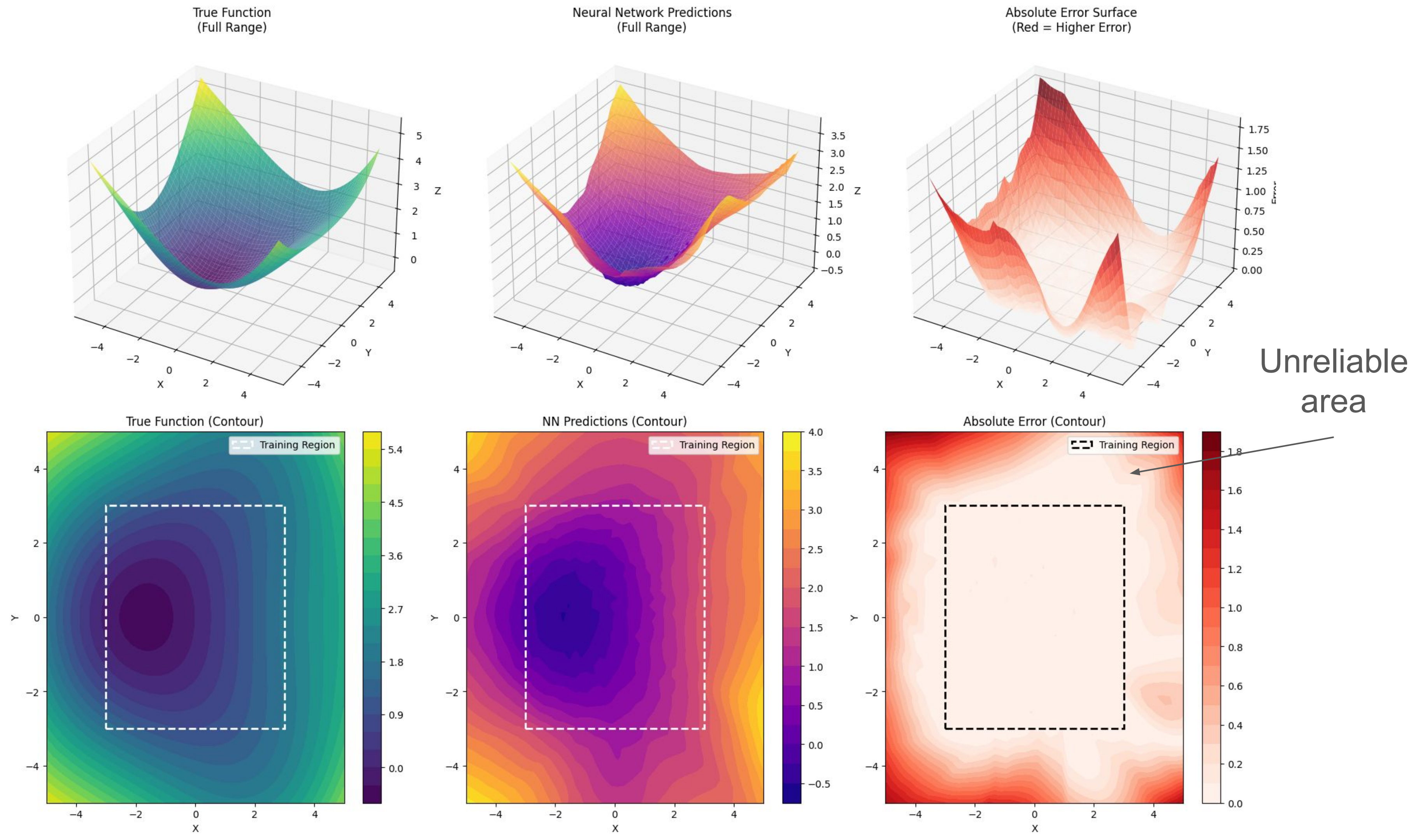
with MLP: 4 hidden layers,

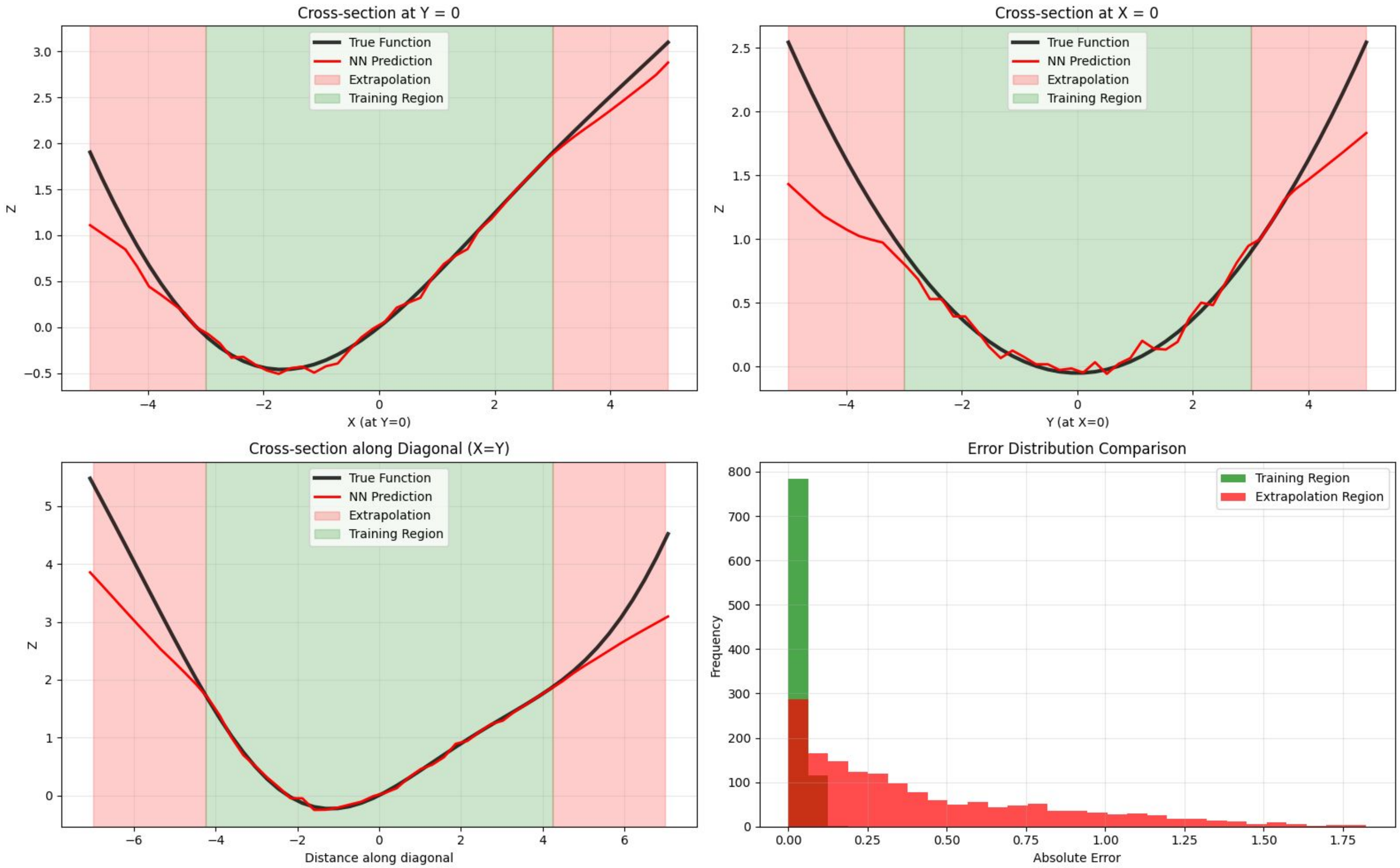
128 neurons per layer.

Training data region: $x,y \in [-3, 3]$

Test data region: x,y out of [-3, 3]




True Function
(Full Range)
Neural Network Predictions
(Full Range)
Absolute Error Surface
(Red = Higher Error)
True Function (Contour)
NN Predictions (Contour)
Absolute Error (Contour)
Training Region
Training Region
Training Region
Unreliable
area
X
Y
Z
Error



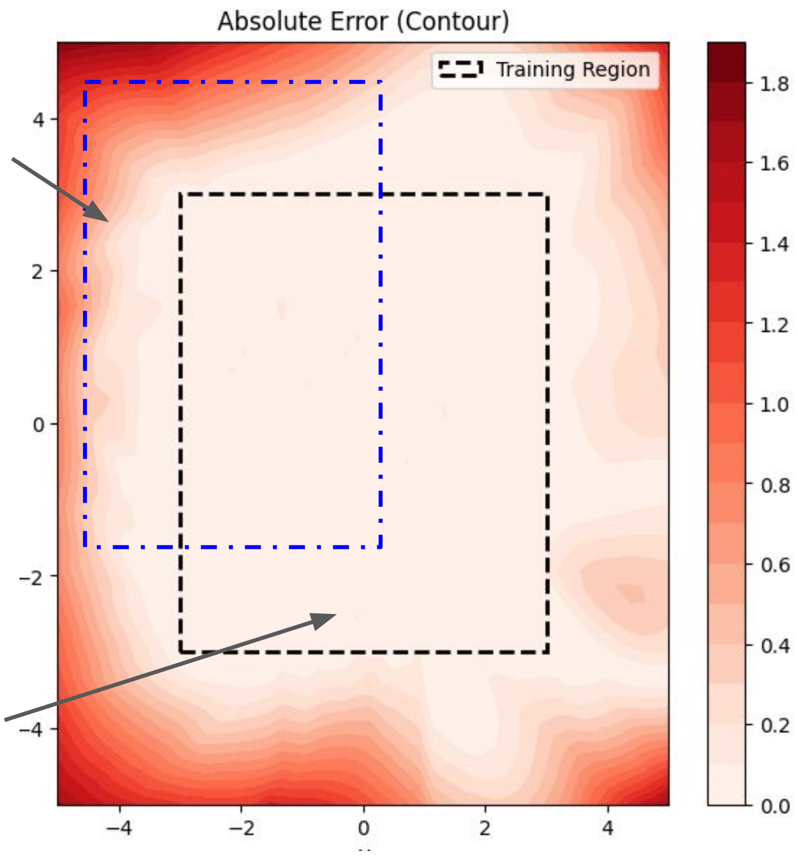
Cross-section at Y = 0
True Function
NN Prediction
Extrapolation
Training Region
Z
X (at Y=0)
Cross-section at X = 0
Y (at X=0)
Cross-section along Diagonal (X=Y)
Distance along diagonal
Error Distribution Comparison
Training Region
Extrapolation Region
Frequency
Absolute Error

Connection to cross-calibration

Actual UHECR phase space, $\mathbf{P_{real}}$

shift due to muons deficiency

MC UHECR phase space, $\mathbf{P_{MC}}$



NN: $f : P_{MC} \rightarrow E_{expected}$

Calibration (bias correction):
$g(f): P_{real} \rightarrow E_{expected}$

But:
$\Delta f(P_{real})$ is highly nonlinear, hence calibration must be nonlinear as well

Domain adaptation:
$P_{real}(z) = P_{MC}(z)$,
hence calibration might be simple (linear)