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Better Resource Utilization in the 21st century

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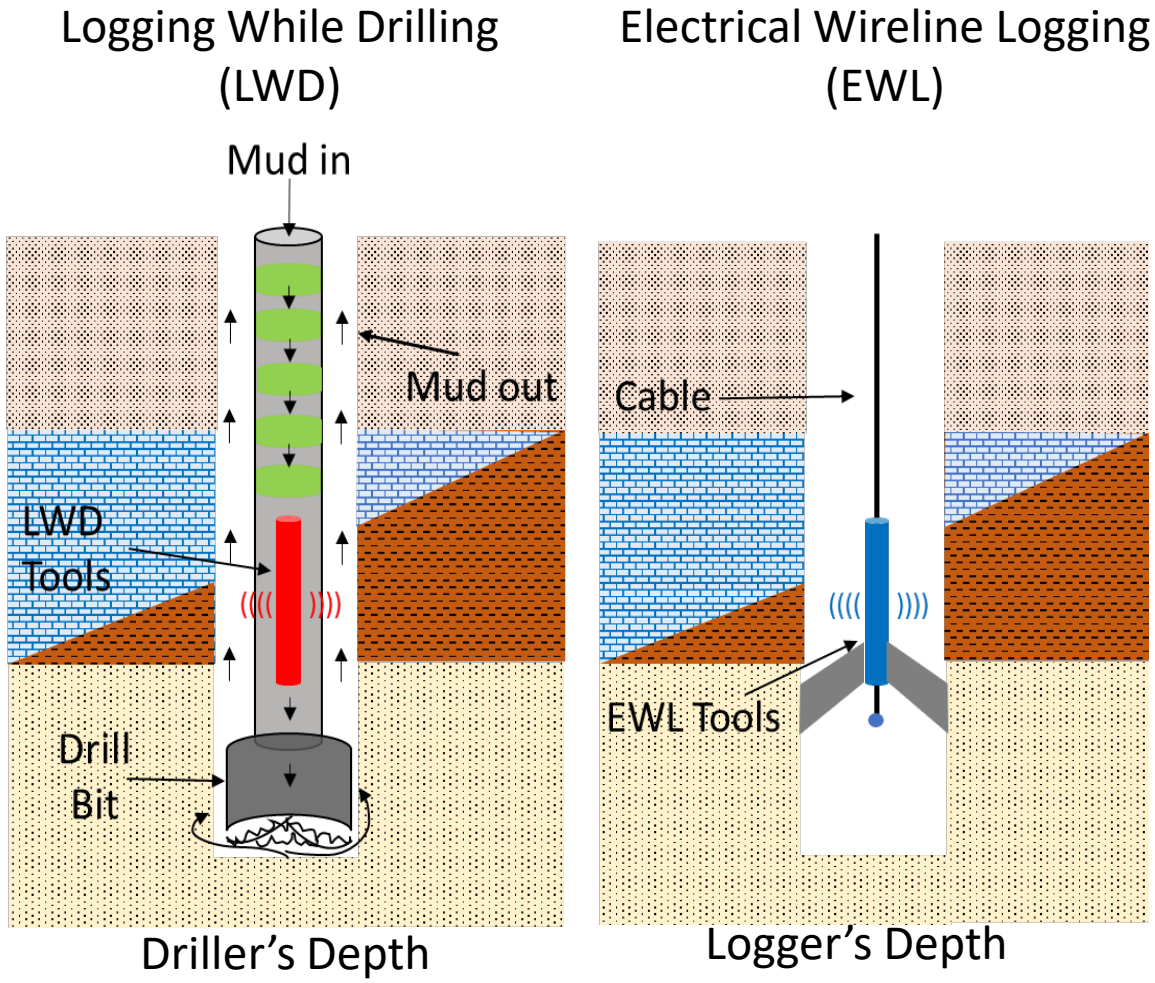
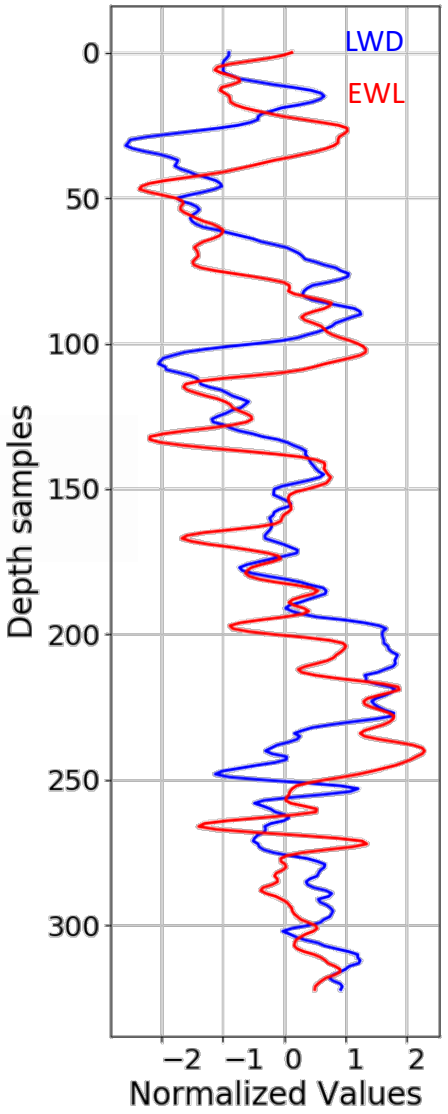
Automated Well Log Depth Matching with Machine Learning

Veronica A. Torres C.

Well-log depth matching problem



Well logging sketch (modified from Schlumberger, 1989).

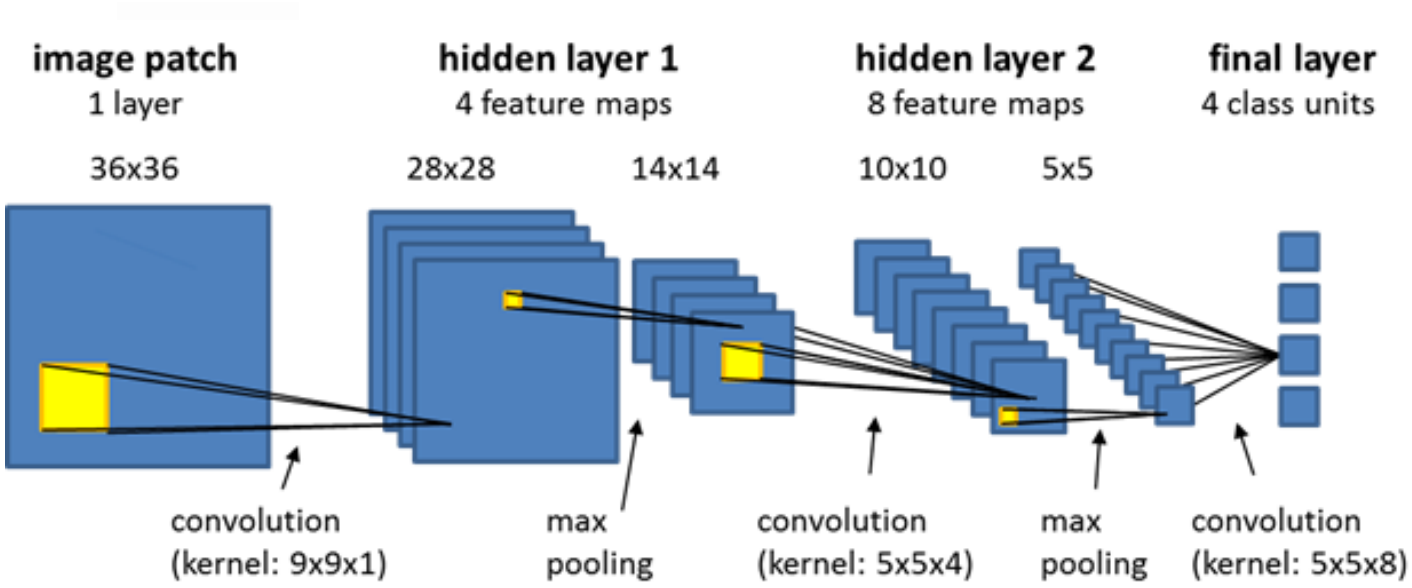


- Main detriment for interpretation purposes.
- Depth mismatch can range from 0.6 to 10 or 12 m.
- Tedious and time-consuming task → **bulk shift and manual matching of selected peaks** (stretch/squeeze).
- **Limited to EWL suite of logs.**

Developed solutions – Depth matching

- We have developed an automated well-log depth matching workflow:
  - Machine learning → 1D Convolutional Neural Networks (1D CNN)
  - Multimodal machine learning (1D CNN)

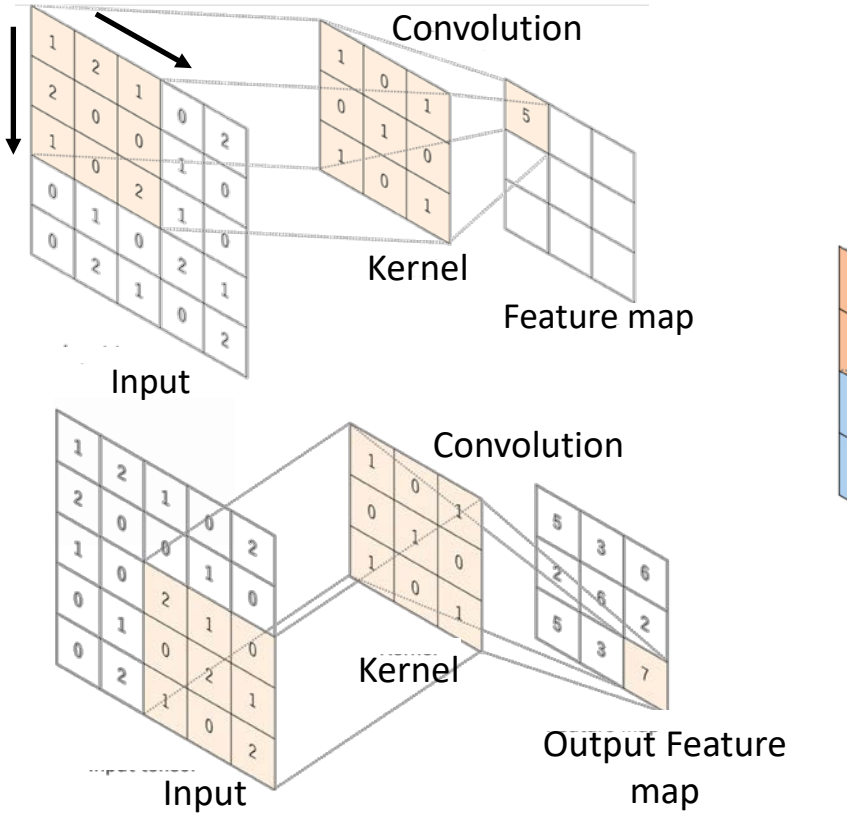
- Python-based implementations.



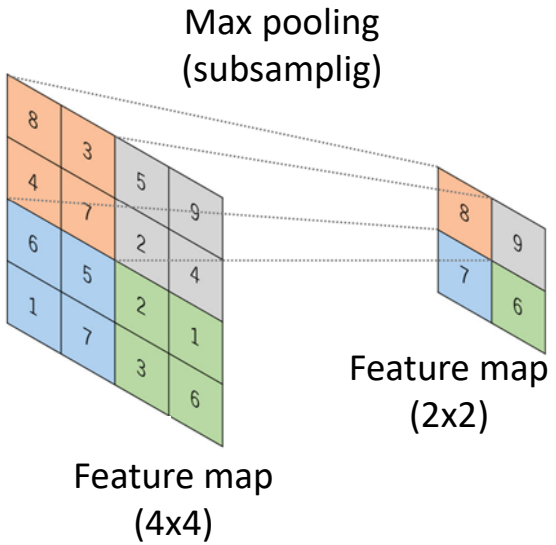
2D Convolutional Neural Network example (taken from https://docs.ecognition.com/eCognition_documentation/Reference%20Book/02%20Algorithms%20and%20Processes/9%20Deep%20Learning%20(CNN)%20Algorithms/Deep%20Learning%20(CNN)%20Algorithms.htm).

Machine learning – CNN

- Invariant feature extraction:
  - Local Receptive fields
  - Sharing weights
  - Subsampling



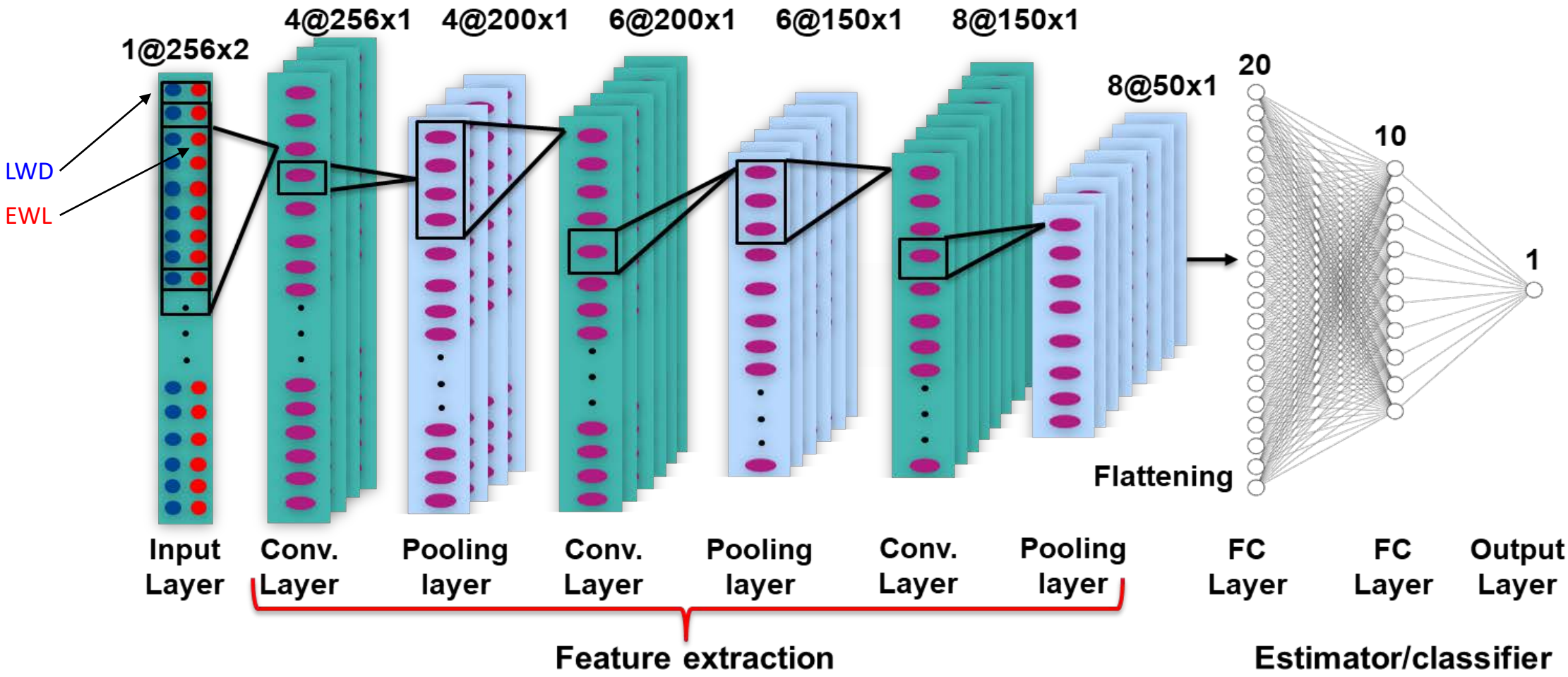
Convolutional process taken and modified from Yamashita et al. 2018



Max pooling process representation taken and modified from Yamashita et al. 2018

Feature maps are inputs in a nonlinear function e.g., ReLU.

1D Convolutional Neural Networks



Machine learning implementation - Depth matching workflow

GR , Rt, Vp, Vs, Density, Neutron, PEF

Entire data set (synthetically shifted data) 100%

Training Set ≈70%

Validation Set ≈18%

Test Set ≈12%

Unseen

Training/Model Selection

Hyperparameter Tuning

Random Search Model

HYPERBAND Model

Bayesian Opt. Model

Model Assessment

Best Model = Lowest MSE

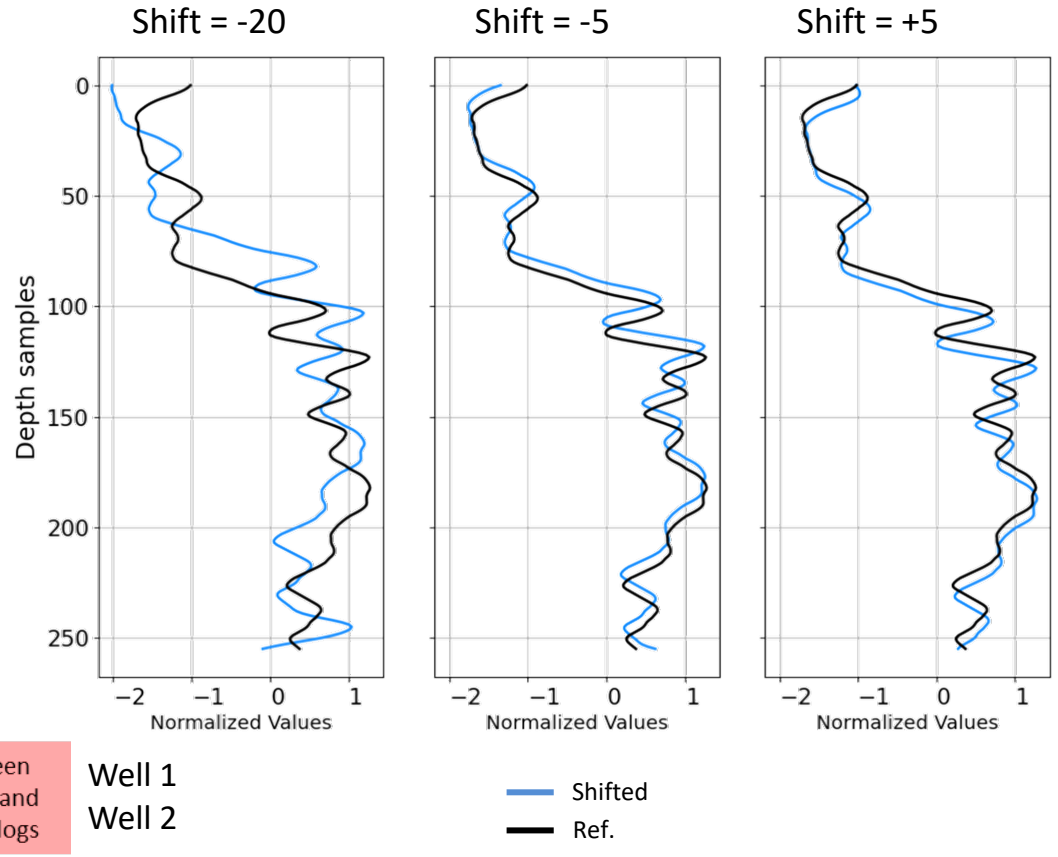
Retrain Best Model

Depth shift inference

Unseen LWD and EWL logs

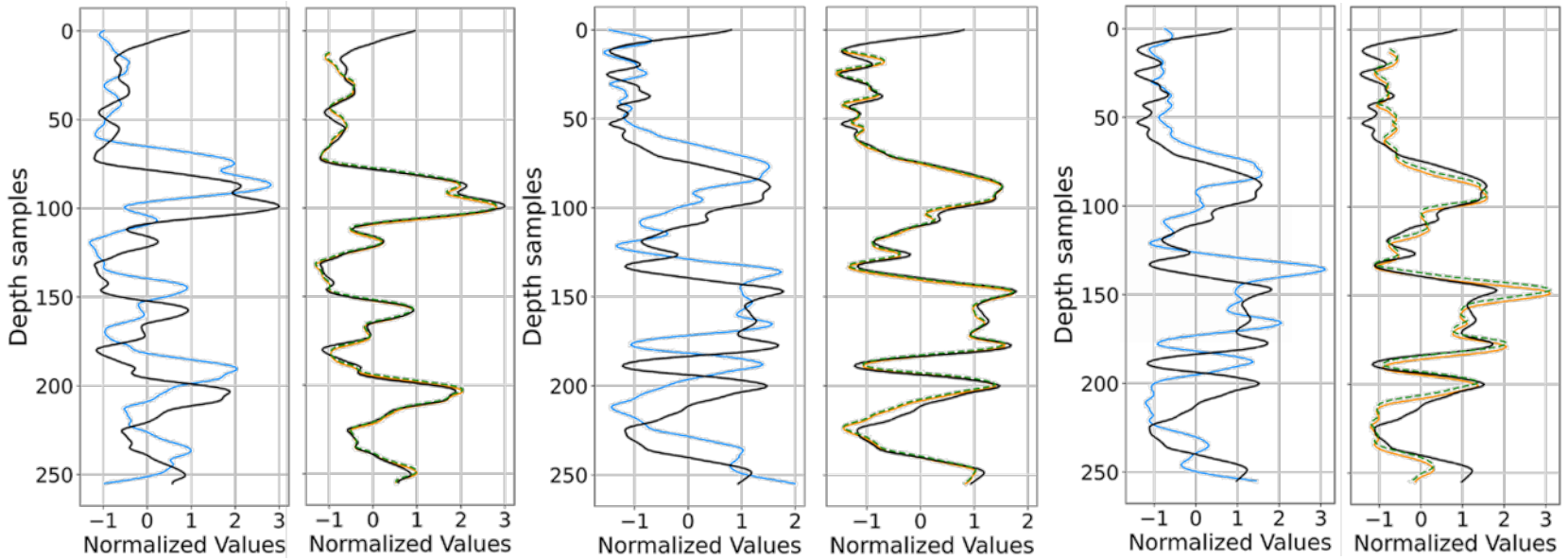
Well 1
Well 2

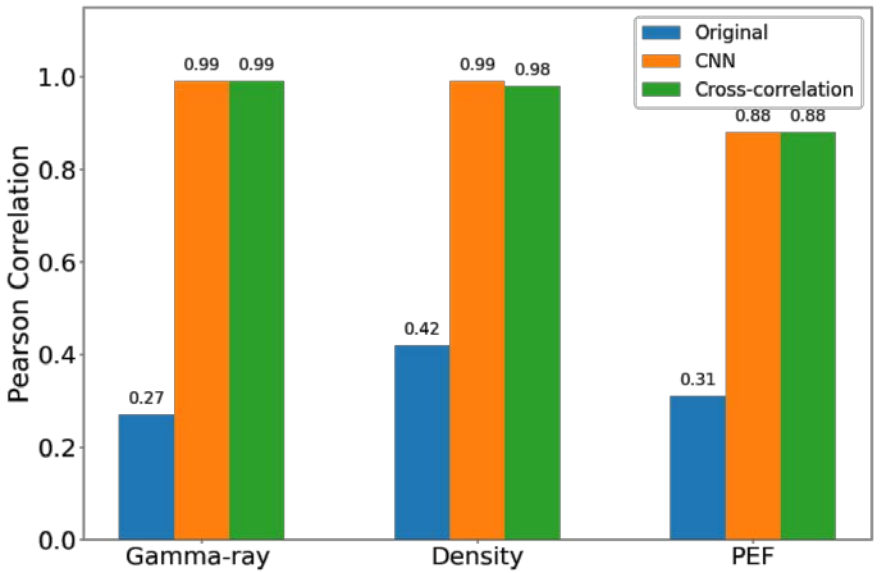
Depth Shift range (-20 to +20)



Machine learning implementation - Depth matching results

Gamma-ray Density PEF





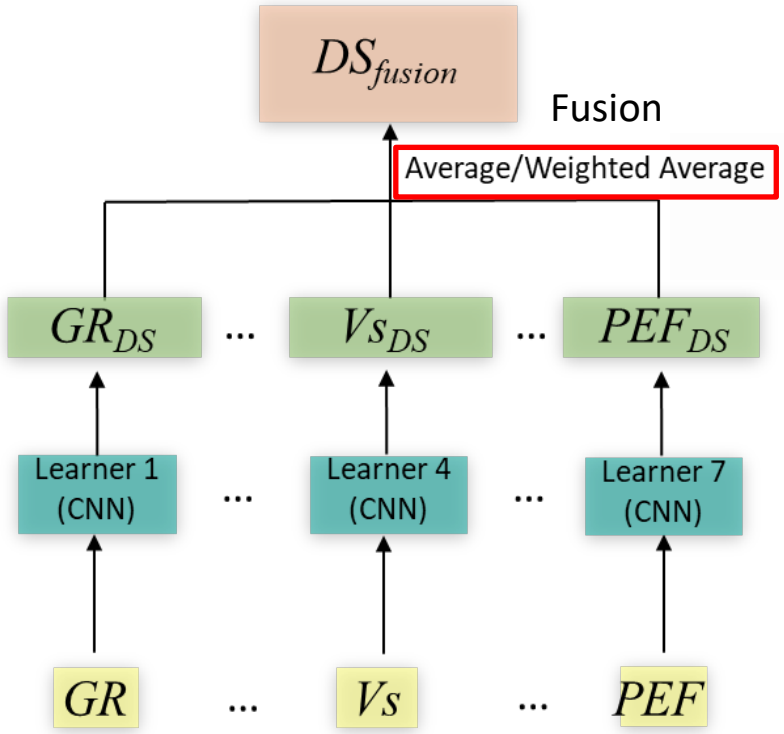
Orig. LWD
Ref. EWL
CNN LWD
Cross-correlation LWD

Multimodal Machine Learning - Depth matching

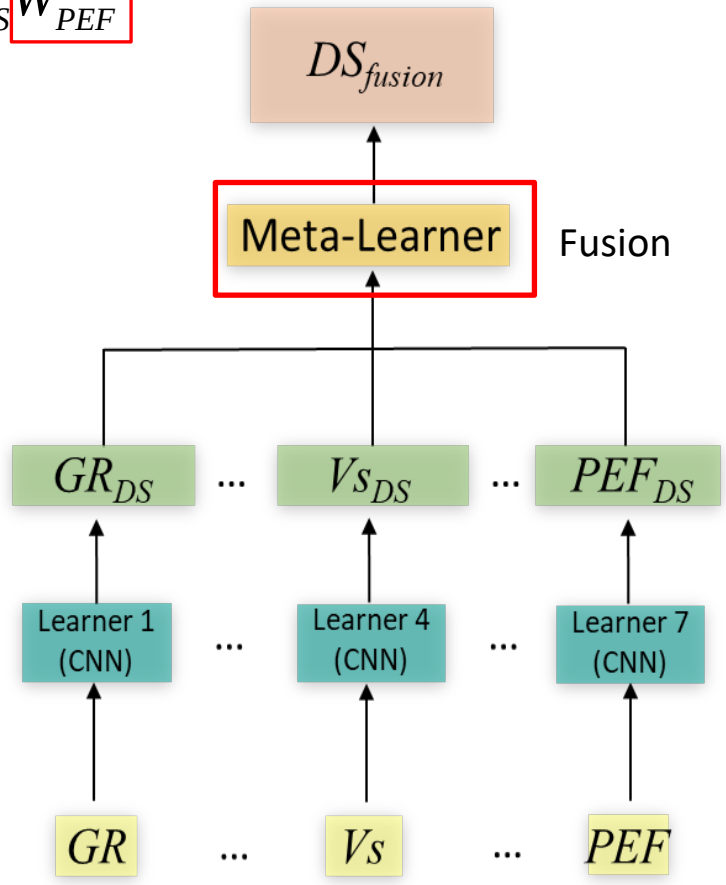
- Aggregation of modalities (sensors)

$$DS_{fusion} = GR_{DS}W_{GR} + Rt_{DS}W_{Rt} + \ldots + PEF_{DS}W_{PEF}$$

- Fusion strategies



Late fusion
(Average/Weighted Average)



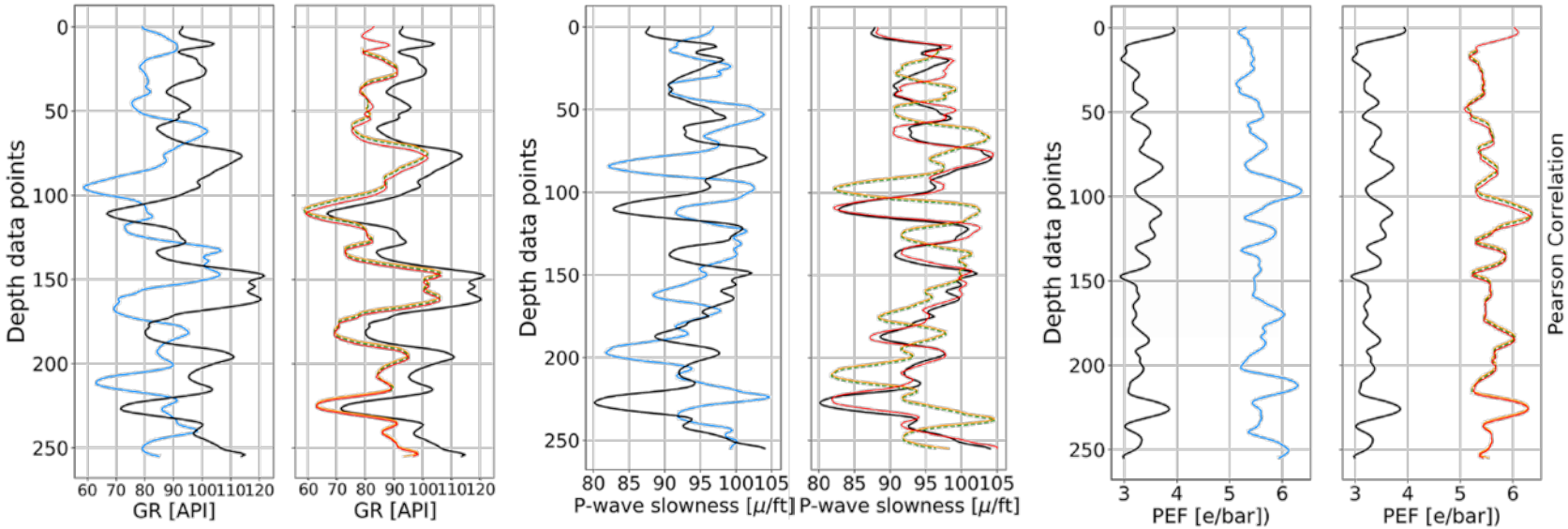
Late fusion
(Additional learner)

Multimodal Machine Learning - Depth matching results

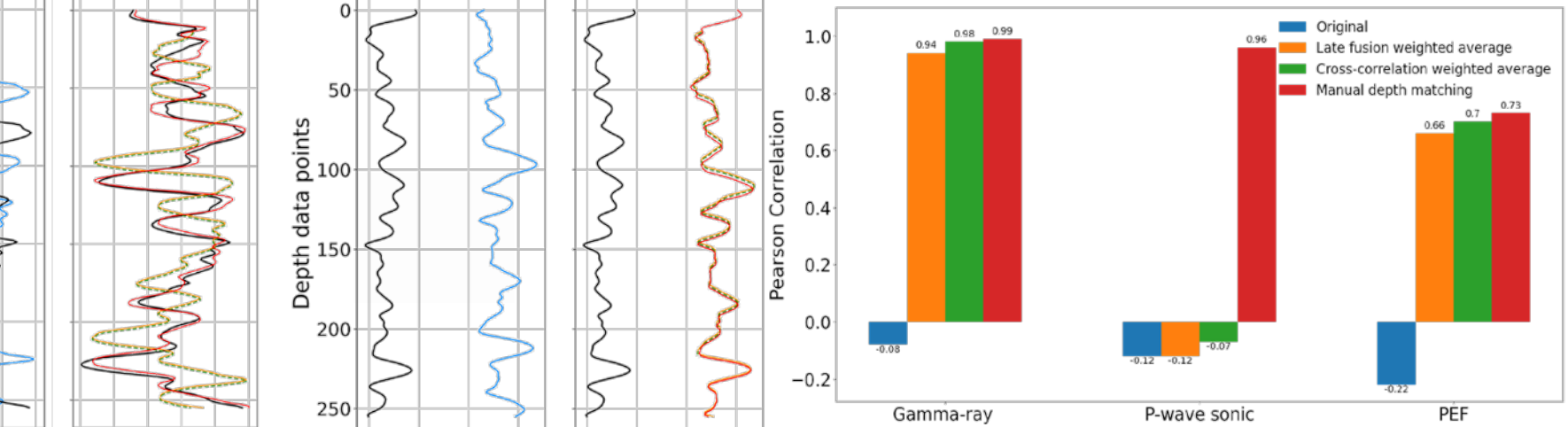
Gamma-ray

P-wave sonic

PEF



Before After Before After Before After



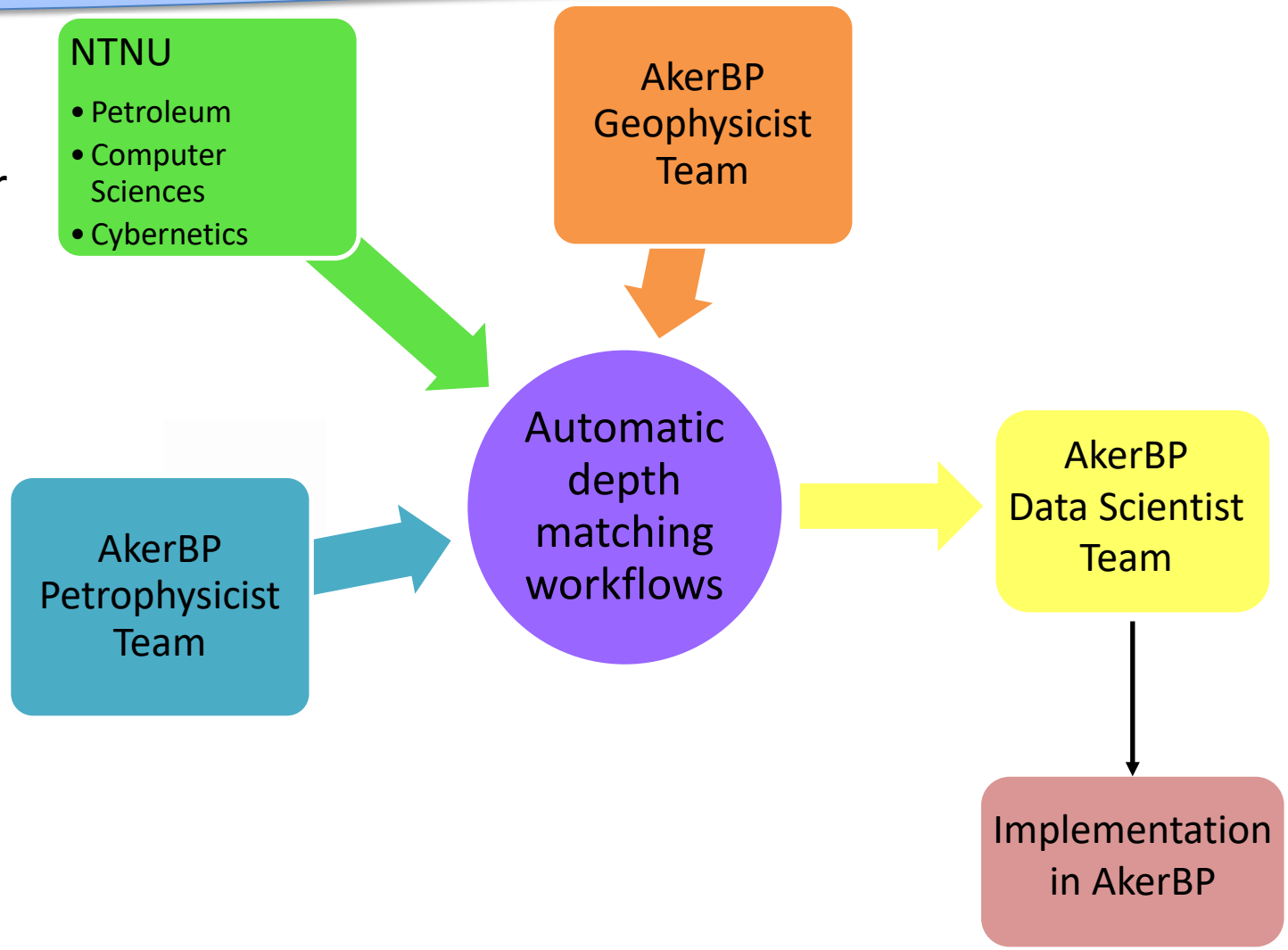
Orig. LWD
Ref. EWL
CNN LWD
Cross-correlation LWD
Manual depth matching

Advantages of our development

- Automatic workflows to tackle the well- log depth matching challenge for massive number of logs in short times, e.g., 20 well-logs in seconds vs. hours.
- Inclusion of LWD logs into the well-log depth matching.
- Possibility to implement our approach in a cloud-based database → open access to all available data.
- Demonstrated the applicability of Artificial Intelligence (AI) to automate well-log depth matching.

Implementation at the sponsor's work environment

- Knowledge transfer: regular meetings.
- Workflows implementation.



Publications

Automated well log depth matching – 1D convolutional neural networks vs. Classic cross-correlation.

Veronica A. Torres C., Kenneth Duffaut, Anis Yazidi, Frank O. Westad, and Yngve Bolstad Johansen.

Published in Petrophysics VOL. 63, No. 1 (February 2022); Pages 12-34

Automated well log depth matching – Late fusion multimodal deep learning.

Veronica A. Torres C, Kenneth Duffaut, Anis Yazidi, Frank O. Westad, and Yngve Bolstad Johansen.

Published in Geophysical Prospecting Special Issue on Machine Learning on April 29th, 2022.

BRU21 Exploration Efficiency

THANK YOU

Machine Learning in Exploration and Production - feedback!

Provide feedback and register your interest using the following QR code (scan with the camera of your mobile)

https://forms.office.com/r/WzsDzNRa9z