PRODUCTION DATA ANALYSIS FOR PROCESS REFINEMENT IN HOT ROLLING

PROJECT DATAFLOW
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VINNOVA / OUTOKUMPU

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INDUSTRIAL DATA CASE

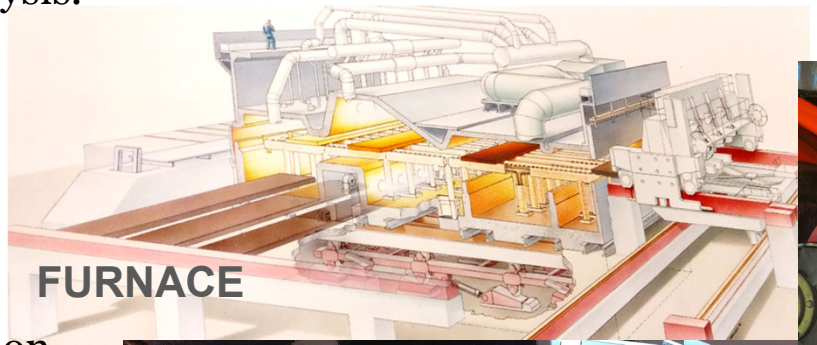
Show the value of the data + analysis.
Large data set, decades of production.
All production parameters included in analysis.

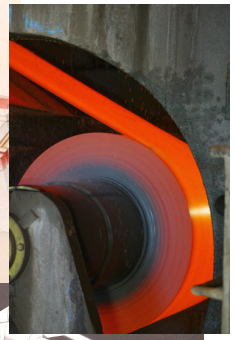
Avoid “telescoping” (~10% flaws).
Causes are partly unknown.
Manual evaluation is costly and inefficient.

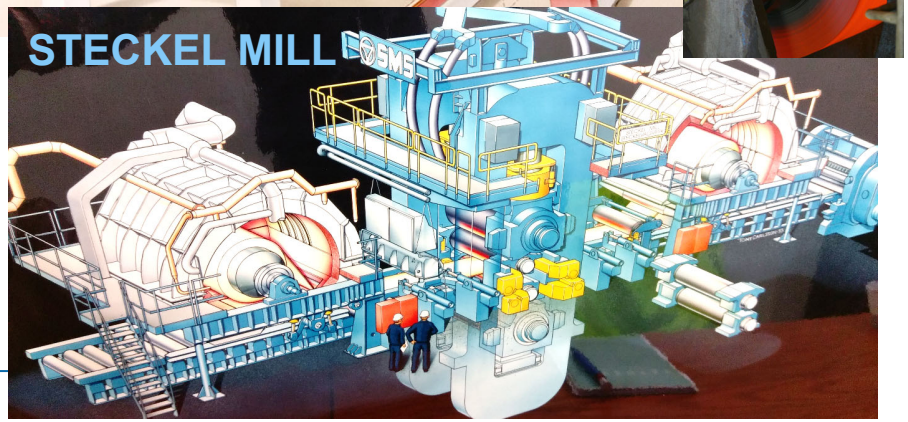
Combine machine learning and
expert analysis. Production line segmentation
approach.

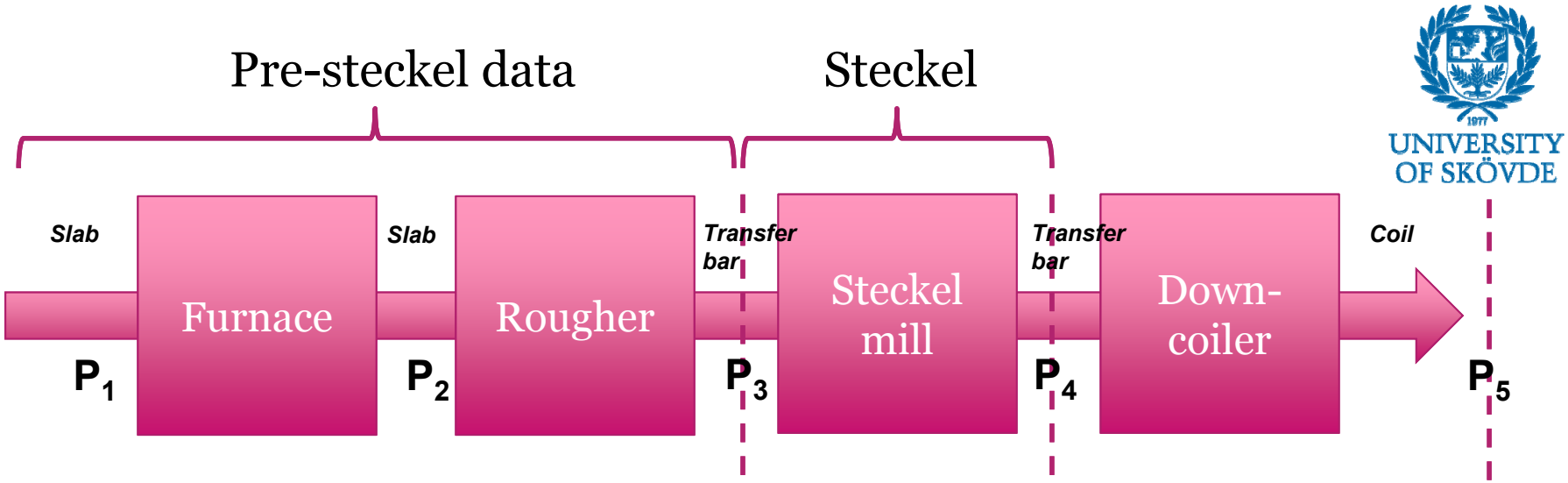
Predicting power: **84%** (AUC-ROC score).

Model **learns what product shapes** increases the risk of telescoping.









- 2600 production parameters.
- 50 GB of production data, 86 tables.
- 10-15 machine learning (ML) algorithms evaluated, adapted.
- Standard ML + Explorative ML.

UNBALANCED TRAINING DATA

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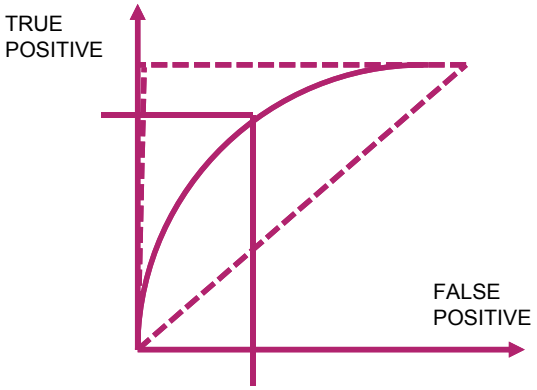
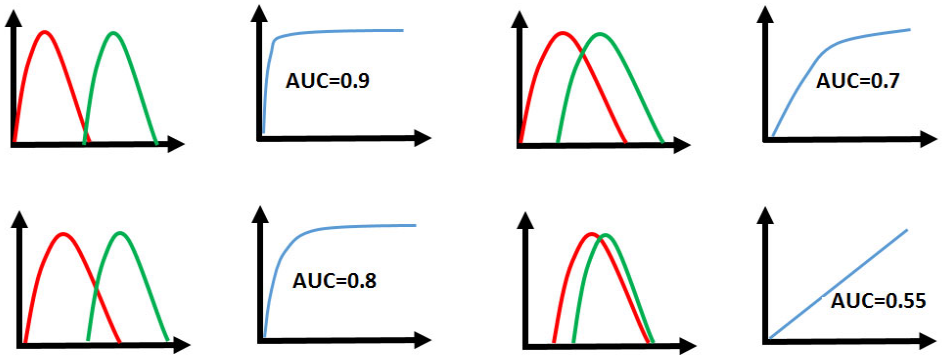
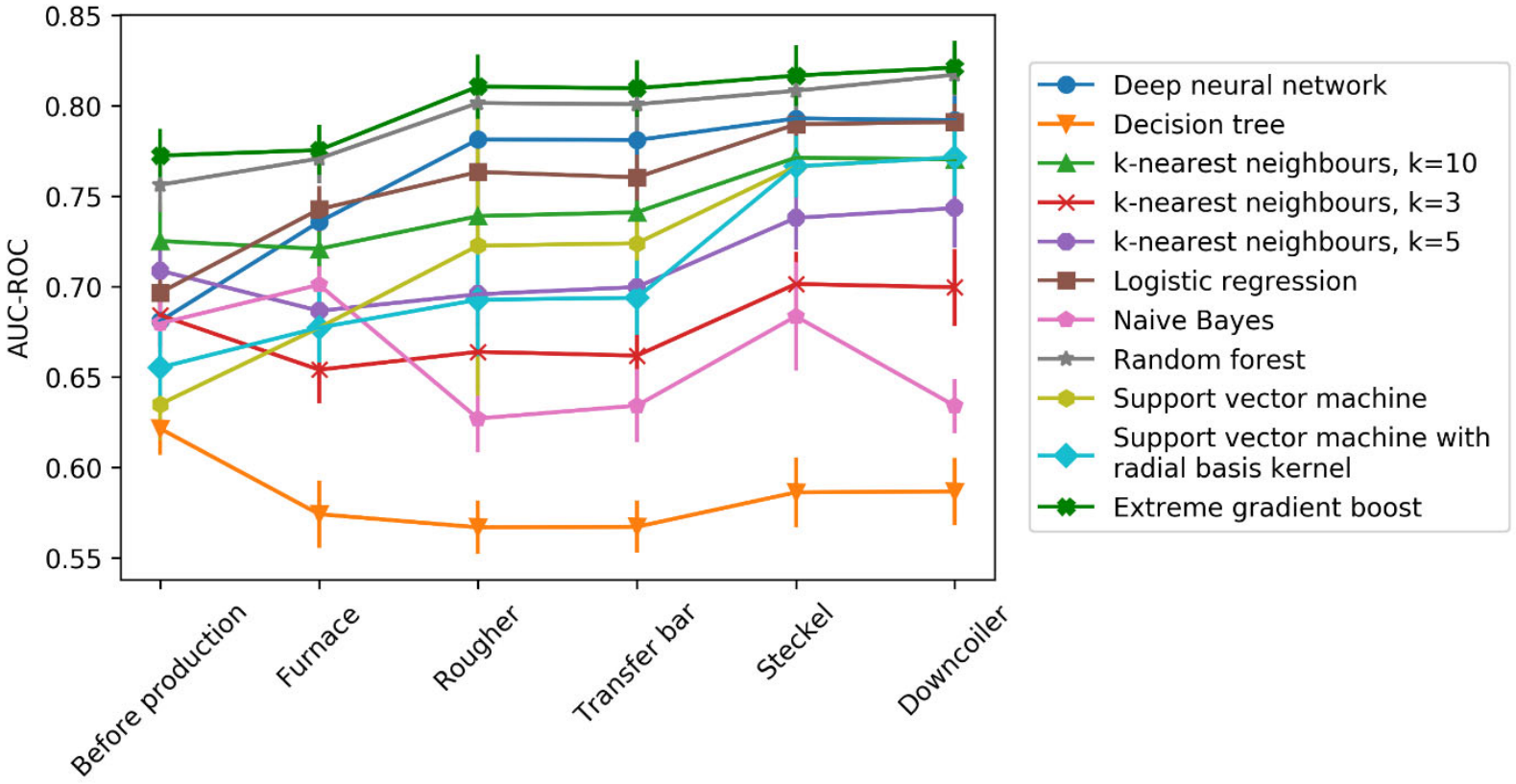
Percentage of correctly classified test examples - not enough for evaluation.

- Binary classifier. How well are classes separated?
- Receiver Operating Characteristic (ROC), perceived classification.
- The curve expresses discrimination under varied threshold (cf. continuous input).
- Can reason about the threshold.
- Area under curve gives a value.



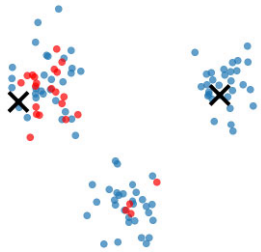


AUC-ROC SCORES FOR SEGMENTS

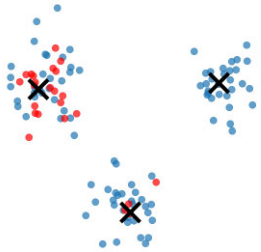


SOENN, APPROACH AND EVALUATION

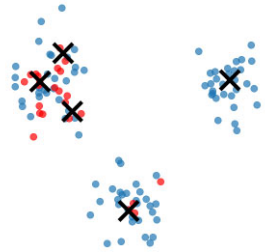
(a) Initial configuration.

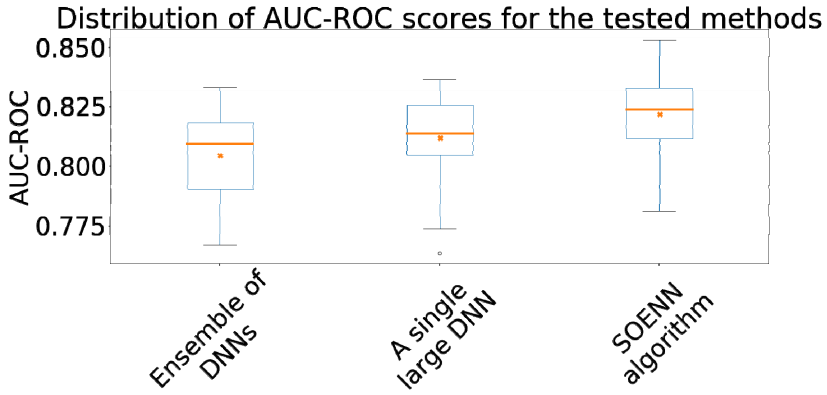


(b) Configuration after λ iterations.



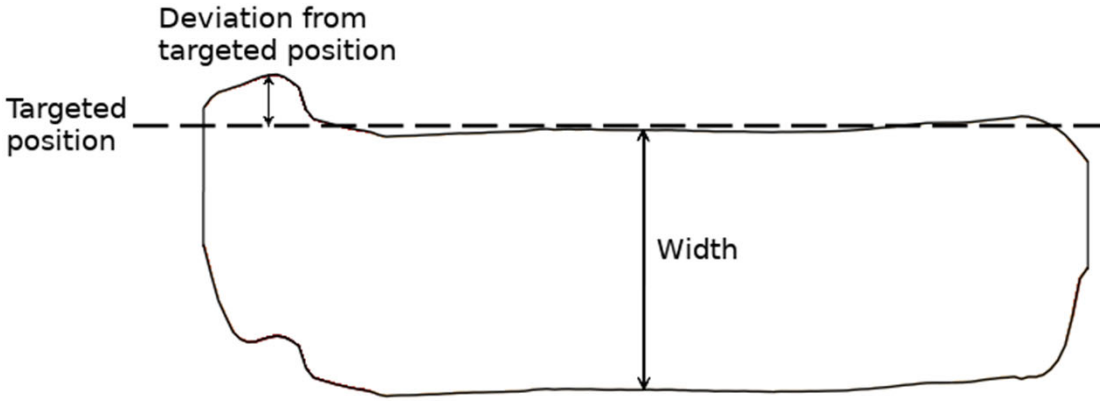
(c) Final configuration.





[N. Ståhl, G. Falkman, G. Mathiason, and A. Karlsson, "A Self-Organizing Ensemble of Deep Neural Networks for the Classification of Data from Complex Processes," Information Processing and Management of Uncertainty in Knowledge-Based Systems. Applications, pp. 248–259, Jun. 2018.]

SEQUENTIAL DATA

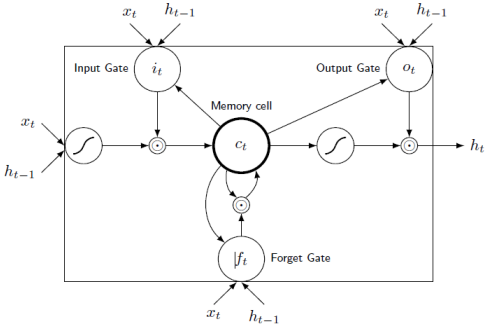


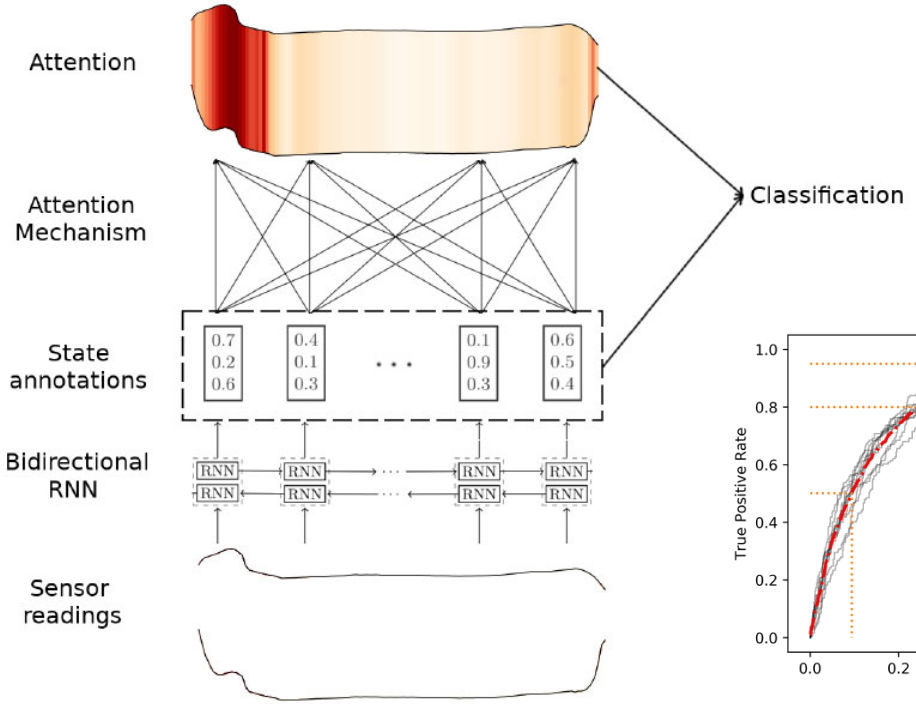
The recurrent network is jointly trained on two objectives:

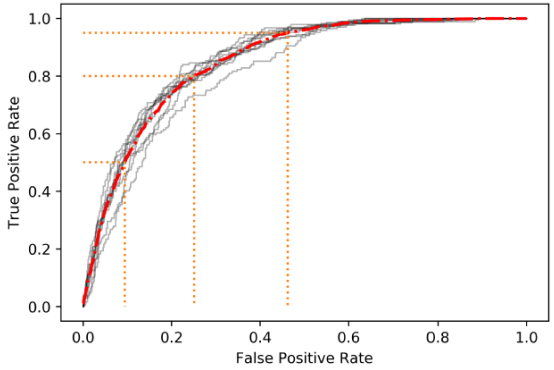
1) When the network is trained it either has to find better points to focus its attention on, or

2) be better at classifying if the slab would be telescoped or not from the points it focused on.

LSTM WITH ATTENTION



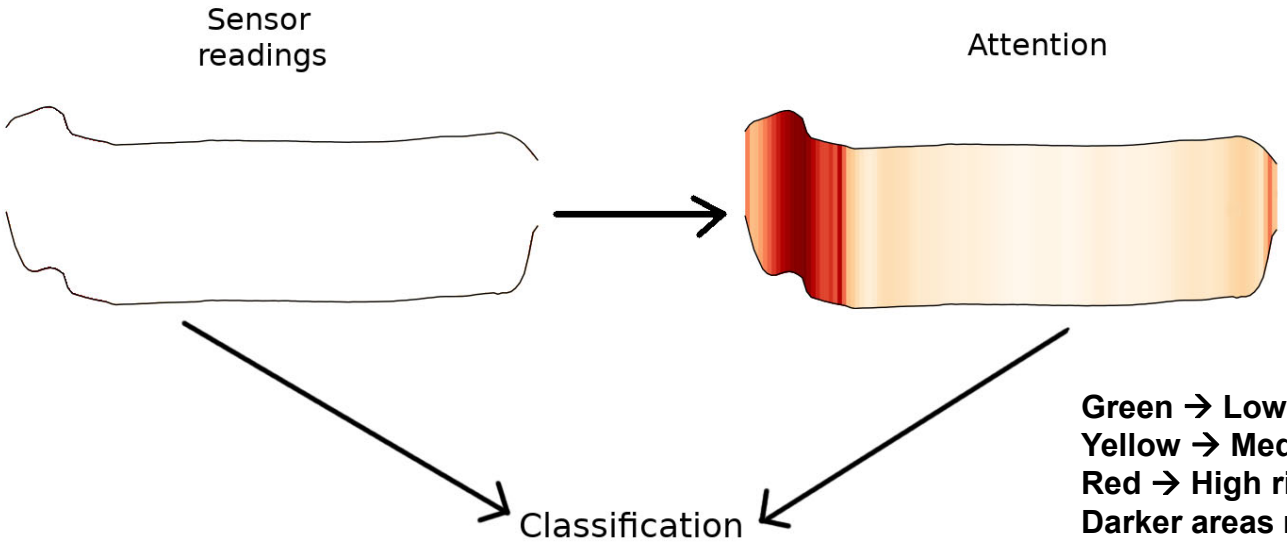




[N. Ståhl, G. Mathiason, G. Falkman, and A. Karlsson, "Using recurrent neural networks with attention for detecting problematic slab shapes in steel rolling," Applied Mathematical Modelling, 2018]

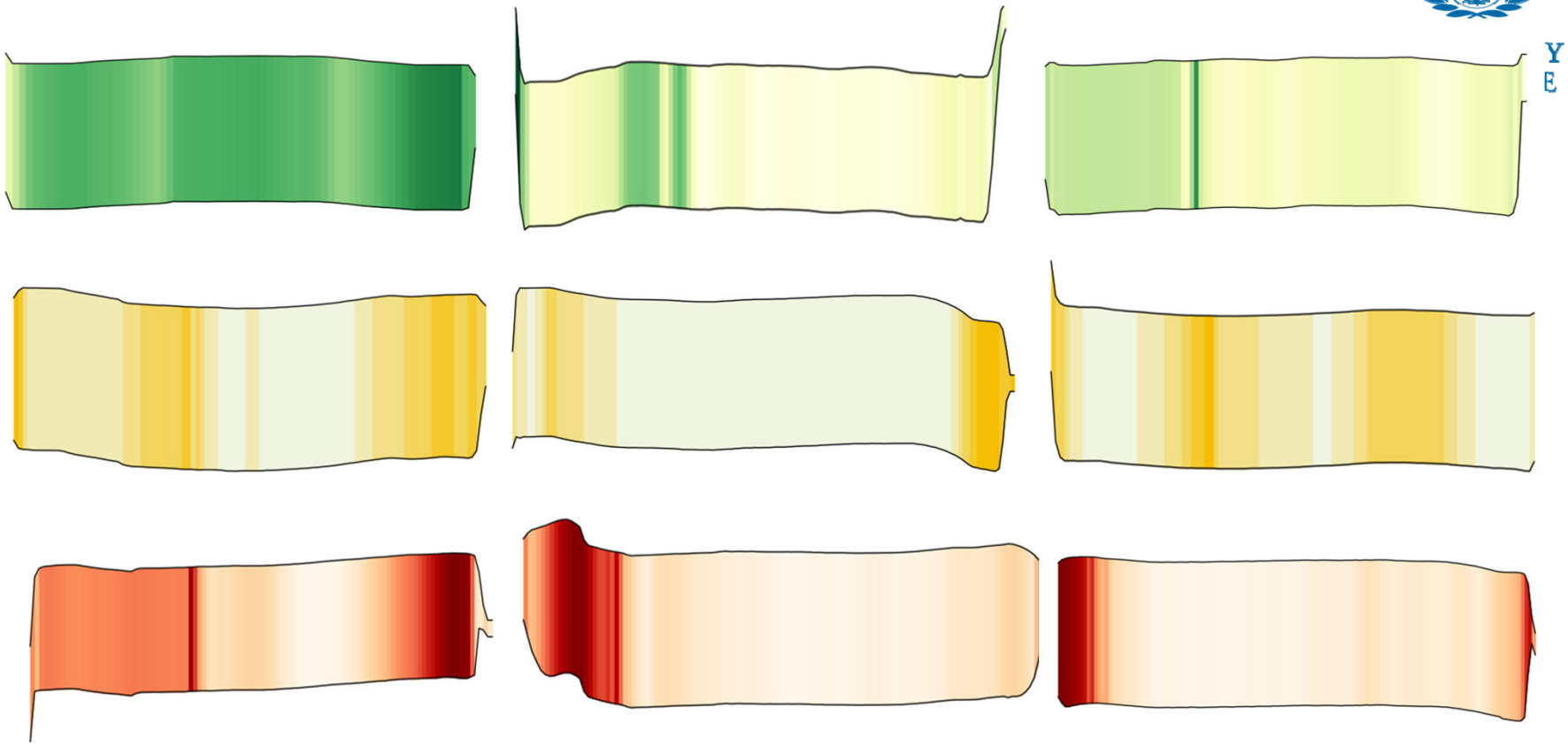
CLASSIFICATION

The network uses the points it focused its attention on to perform the classification of telescoping or not.

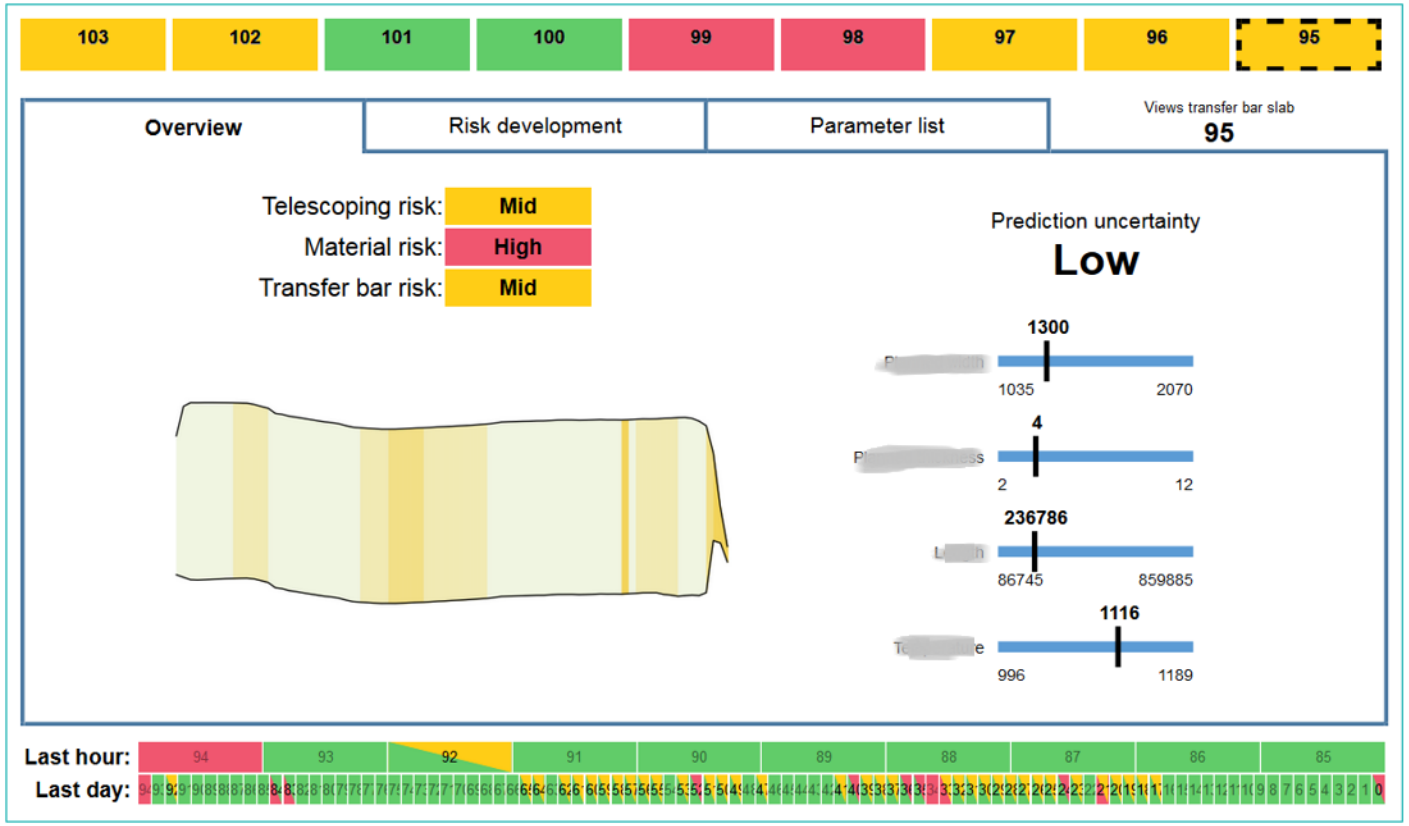


Green → Low risk of telescoping
Yellow → Medium risk of telescoping
Red → High risk of telescoping
Darker areas represent more attention.

SHAPES WITH RISK INDICATIONS



DEMONSTRATOR



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Transparency:

The model shows the **basis for** the risk classification.

The **operator can judge** about system decision quality and uncertainty.

GENERIC FINDINGS

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- Segmentation allows a **joint working group to localize** sources of improved classification accuracy.
- Correlation of input space with classification: Dominating parameters varies somewhat between classes of products, but a **few generic parameters dominate**.
- Up-stream prediction **better** than expected.
- ”Predicting power” of telescoping: 84% (AUC-ROC score) before Steckel.
- With attention cells we can **learn which parts** of the time series contribute to the classification prediction (the risk of telescoping).
- **Data confirms** that ”long bumps” (”sad face” heuristics) before Steckel correlates with telescoping.
- **Demonstrator** insights: Telescoping is dependent on the ability to compensate problems in the Steckel. Steckel operators benefit from **prediction visualisation**. **Offline analysis** is also very valuable.

EXECUTIVE TAKE HOME MESSAGE

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Recent machine learning offers:

- No need for manual feature extraction.
- System decisions becomes transparent by the expression of model knowledge.
- Model uncertainty can be learnt and expressed.
- Human analysis abstraction raised one level, for improved analysis capability.