Neural network algorithms for generalised online tool control in medium size semiconductor fabs

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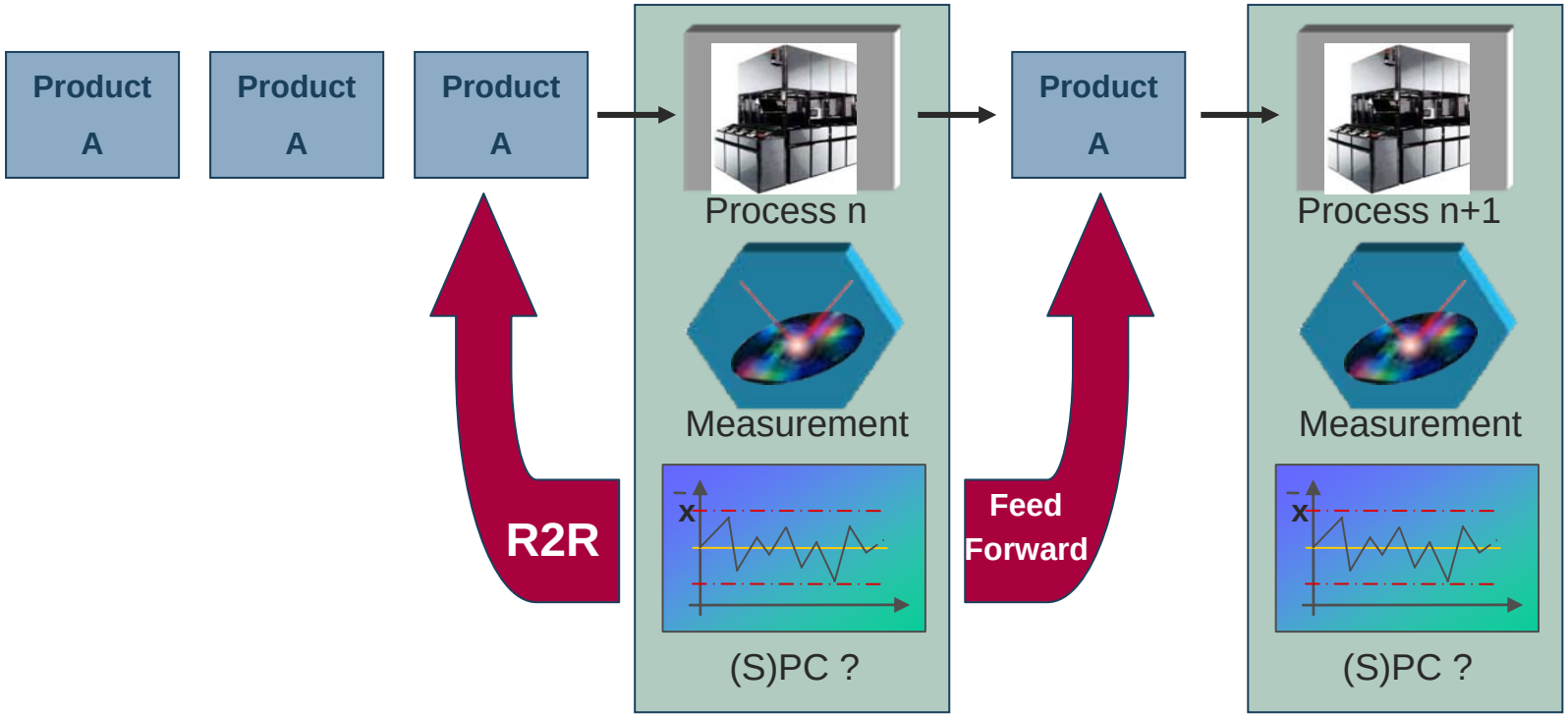
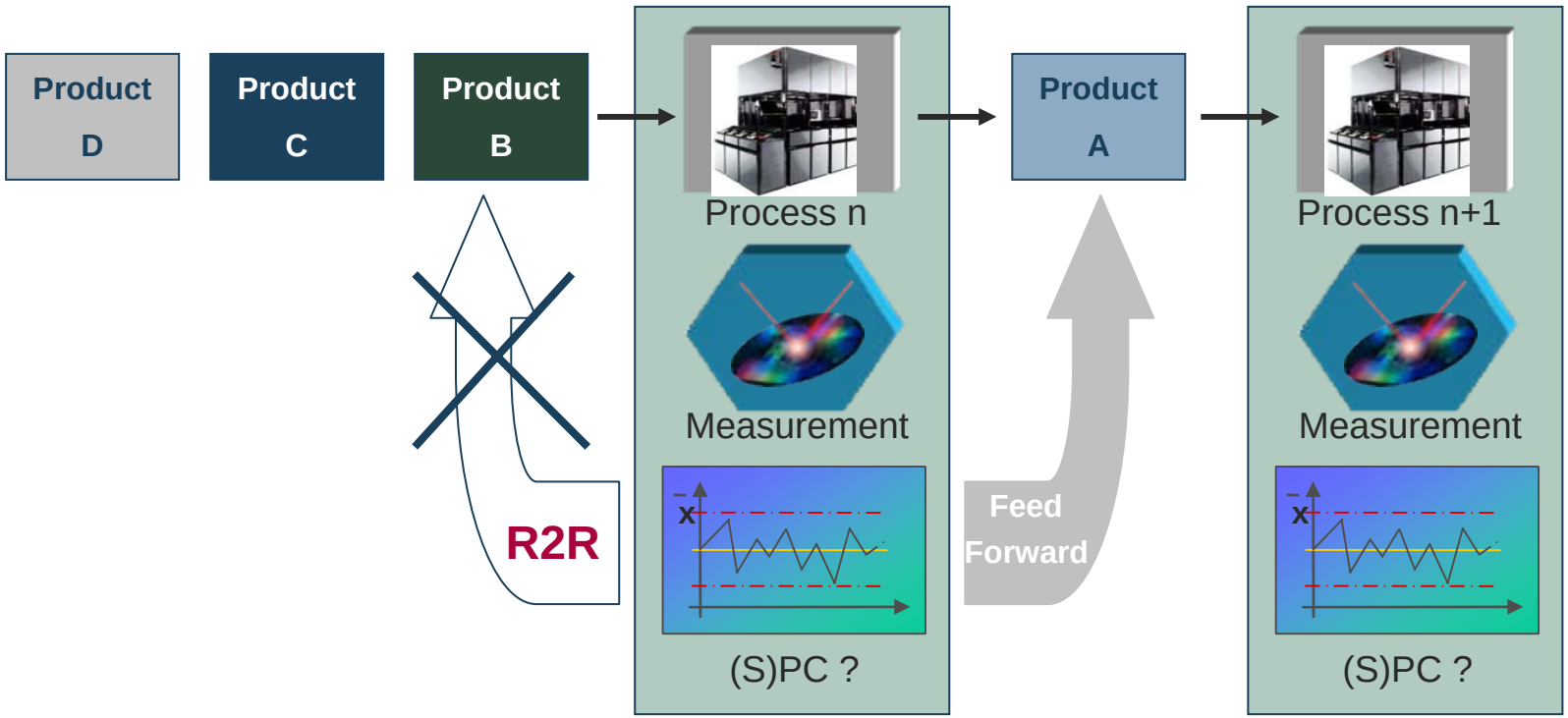
Motivation

- There are always „process control gaps“
- Process control for process management is installed within the manufacturing machines
- There are also partially product measurements made within the machines



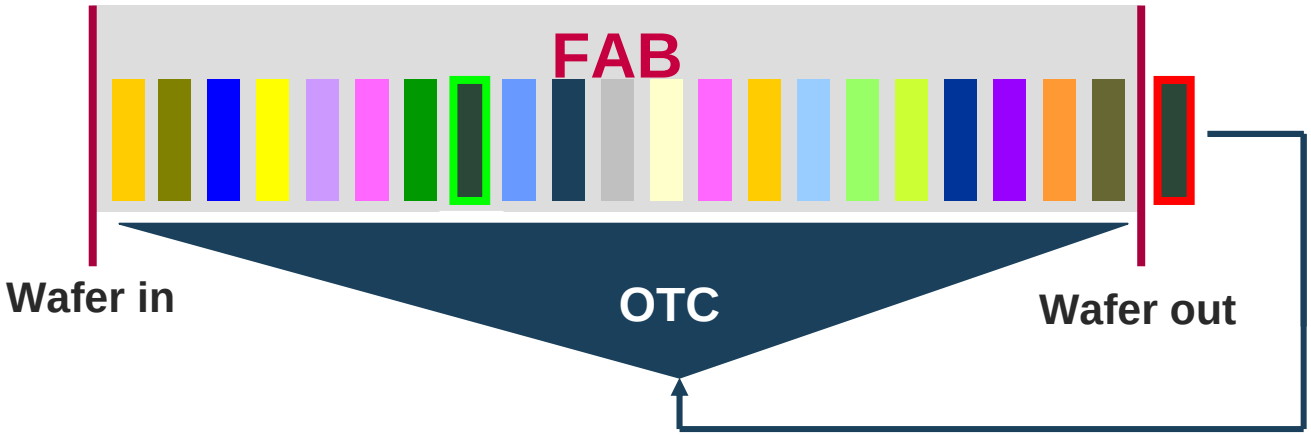
Motivation

- Connections between these and the MES are usually absent
- Product specific characteristics are not taken into consideration



Motivation

- In multi product factory few batches per product
- Numerous machine parameters are recorded.
- No automatic prediction of any problems about to occur with the machines based on this parameters



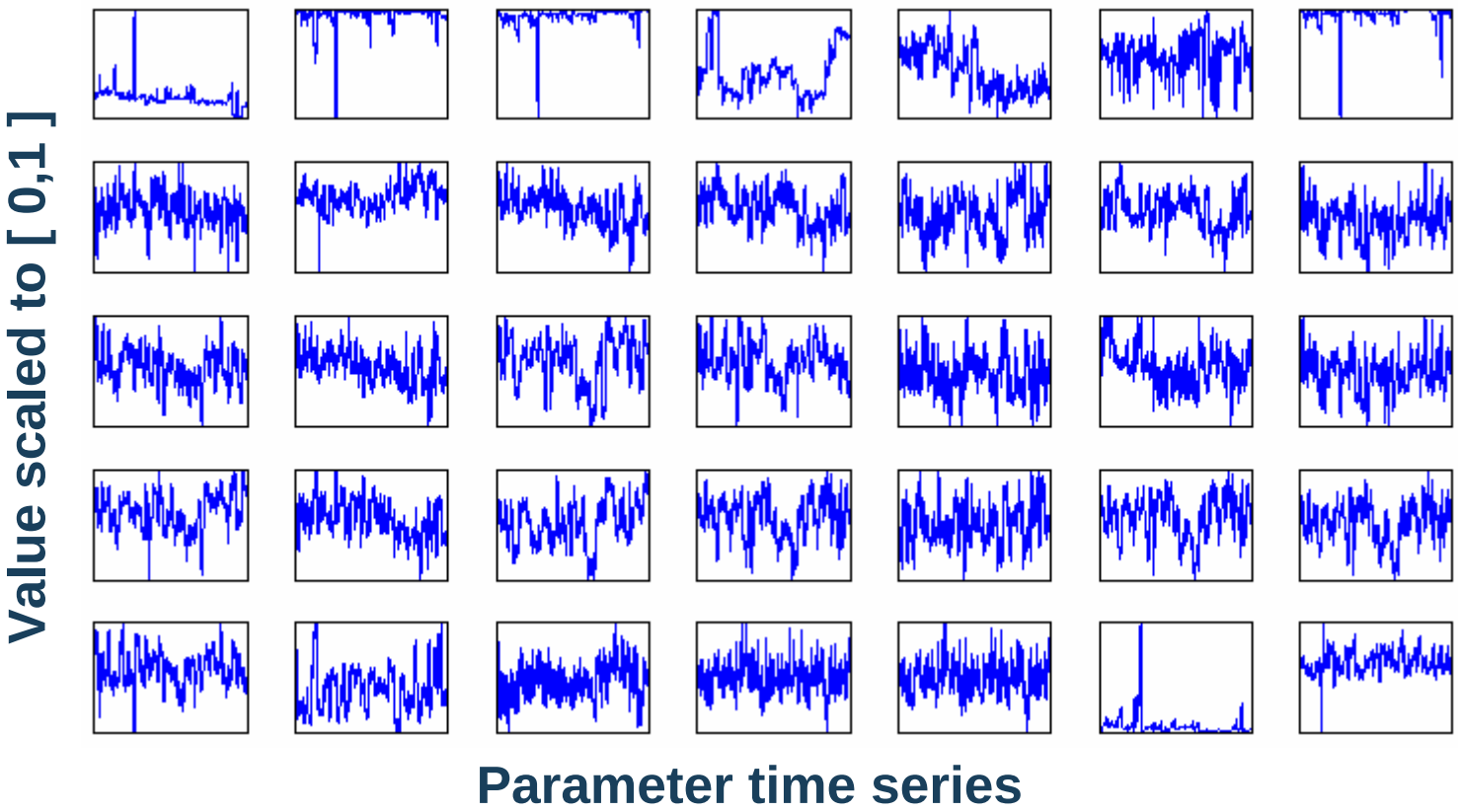
Work was done within the work package „Online Tool Controlling" (OTC) as a part of „Overall Equipment Effectiveness, a new plan for the improvement of efficiency in semiconductor production (OEE)". The OEE project was funded by the German ministry of education and research (BMBF).

Goal

- Generate a generalized automatic tool for all types of factory data which helps find correlations between this data and the occurrences.
- Prove the correlations found:
  - by yield prediction
  - by “out of order process” prediction
- Select relevant parameters
- Show the correlations found

Input Data Yield Prediction

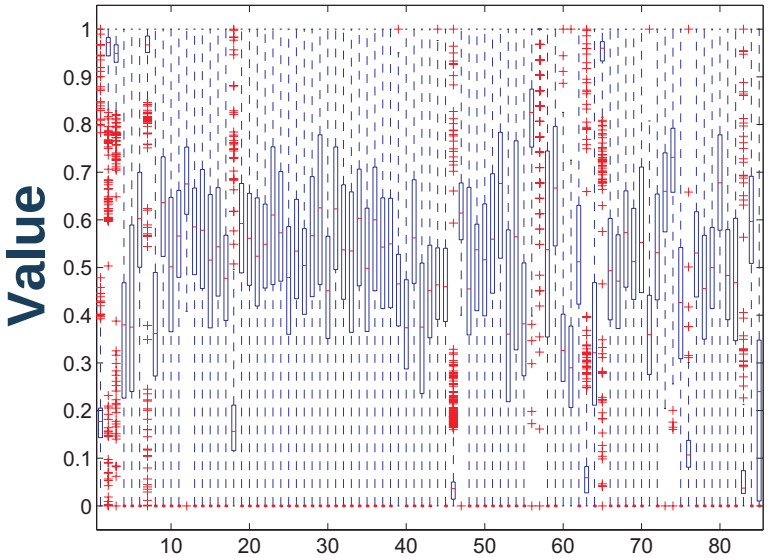
- Data for one product: 85 parameters
- 59 lots, 25 wafers per lot, 1300 data points



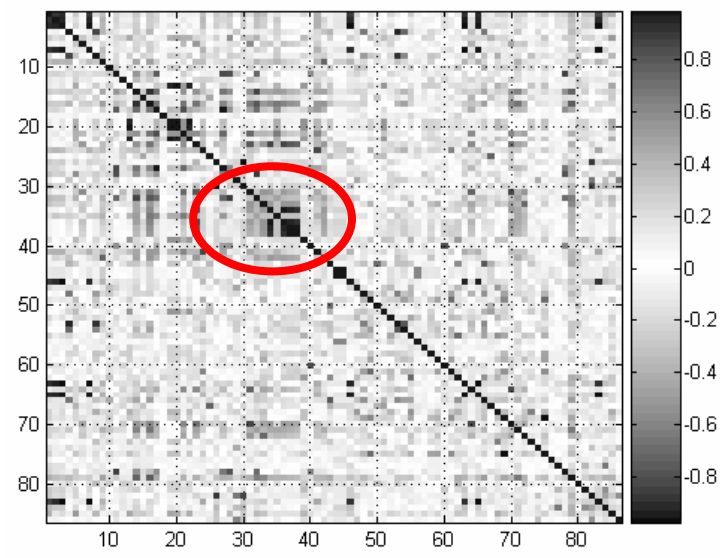
Input Data Yield Prediction

Visualization of all 85 parameters

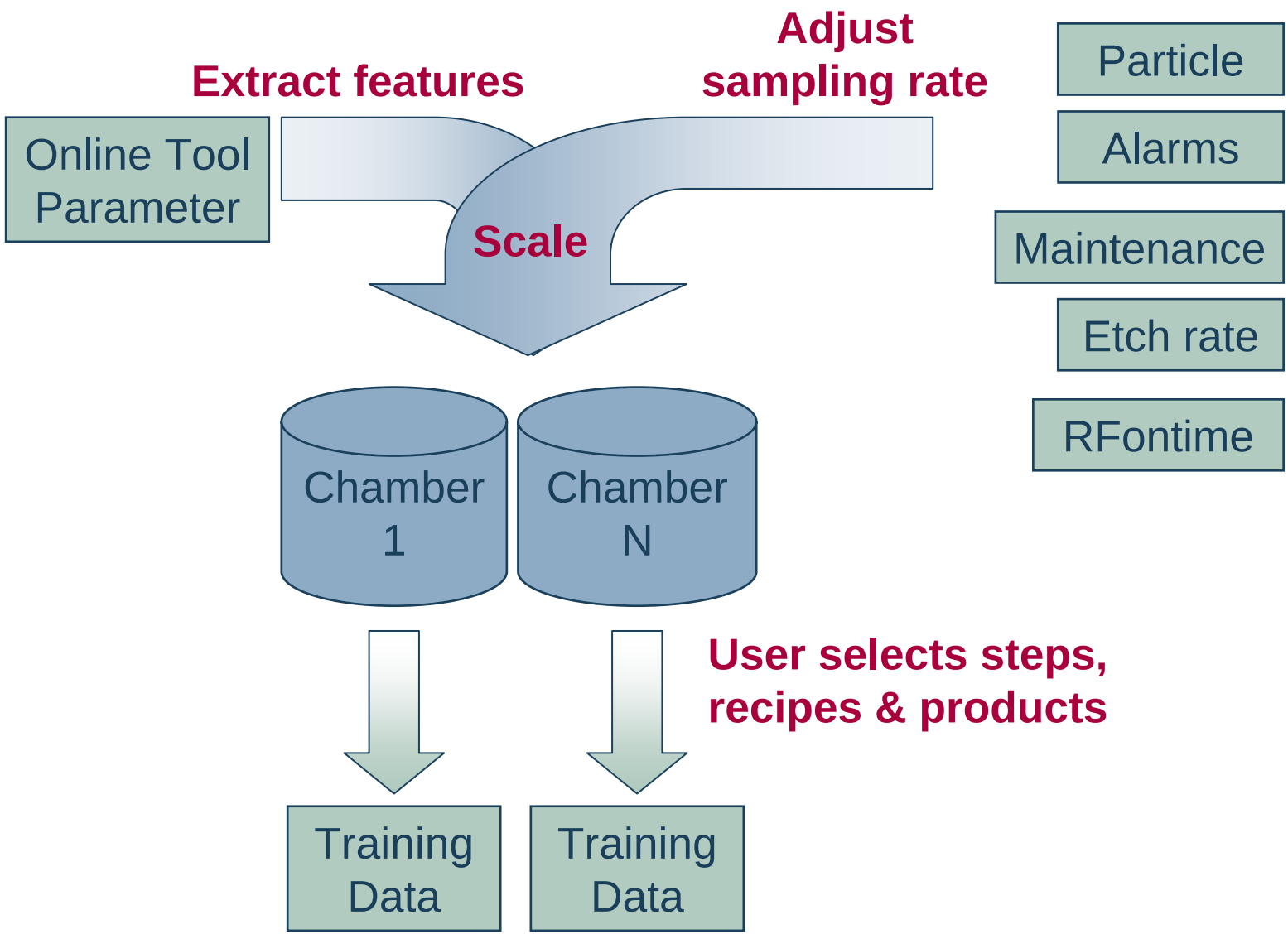
Distribution and Outliers of Parameters



Cross - Correlation of Parameters

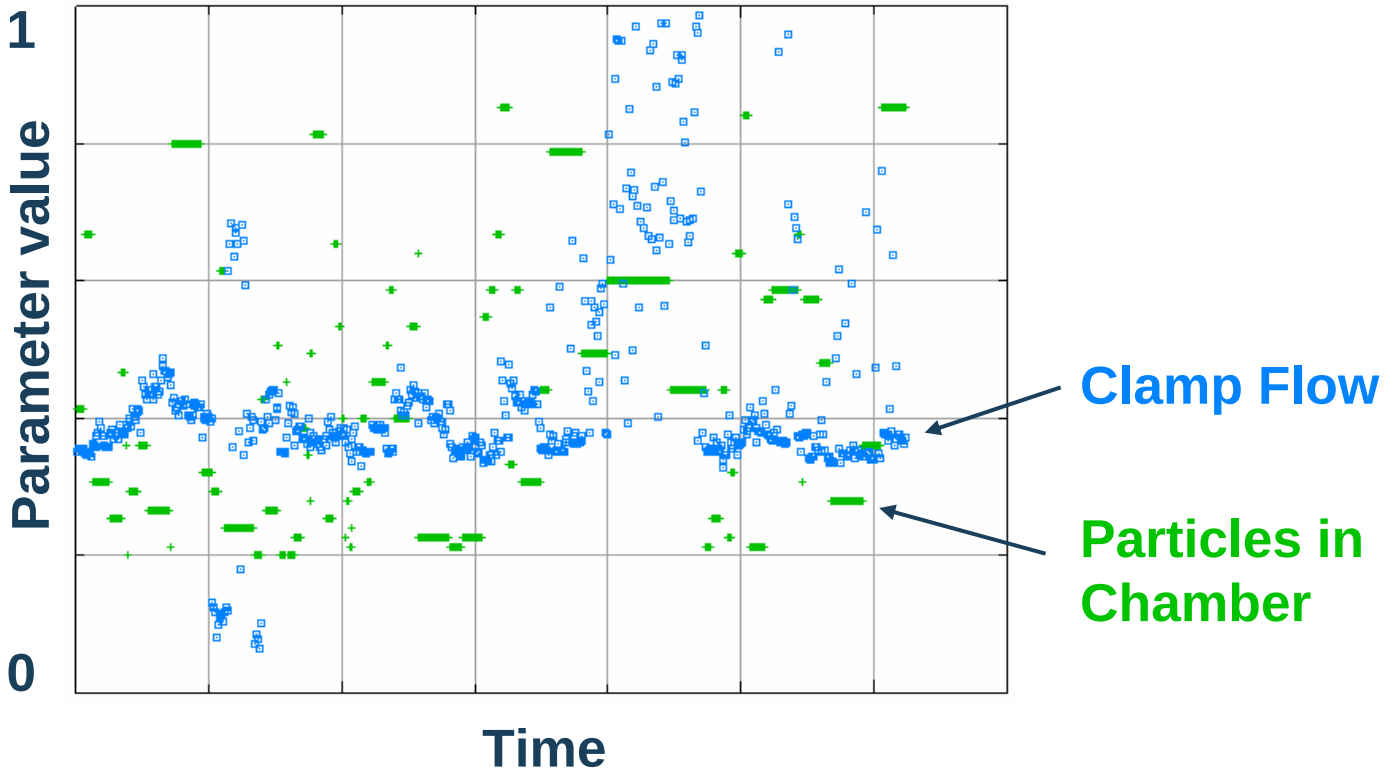


Input Data Online Prediction



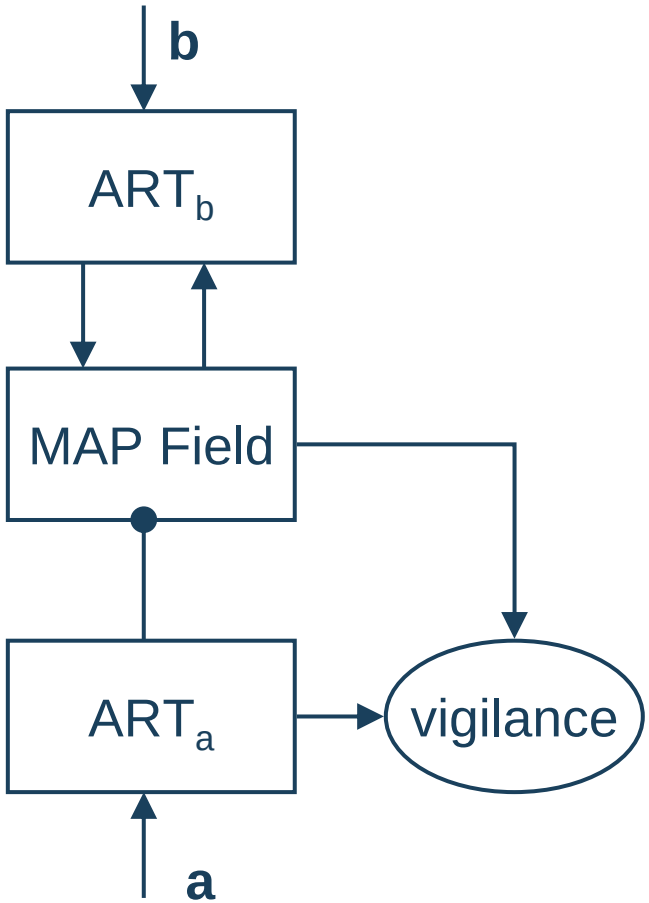
Input Data Online Prediction

- Sample data extracted from data base: Chamber 1, step 3, recipe A



Method 1: Fuzzy ARTMAP

- Fuzzy ARTMAP Neural Network



- Fuzzy Rules

IF

Parameter b0hn60 IN [0.0476;0.524]

AND … AND

Parameter beta_npn IN [0.00455;0.954]

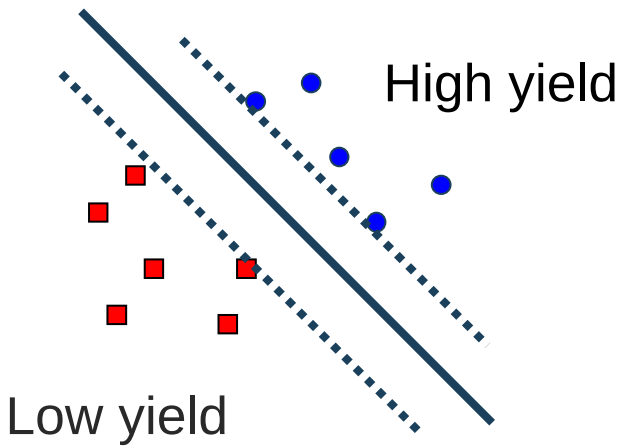
THEN "Low Yield"

Few Rules — Many Rules

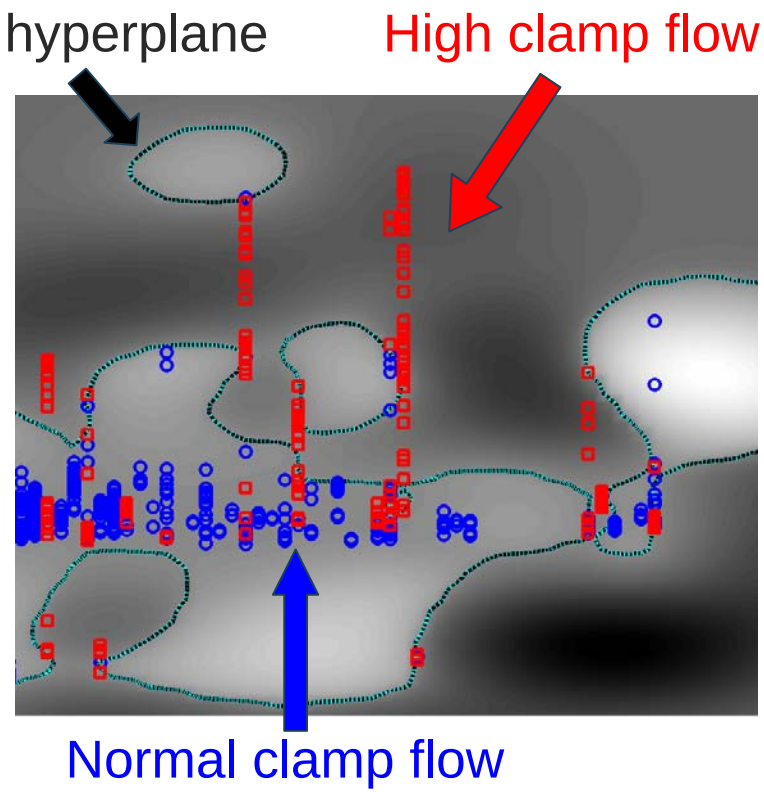
Easy Interpretation — High Accuracy

Method 2: Support Vector Machine

- Separation of classes by hyperplane
- works well for high-dimensional problems



- SVM trained on Clamp Flow and particles in chamber

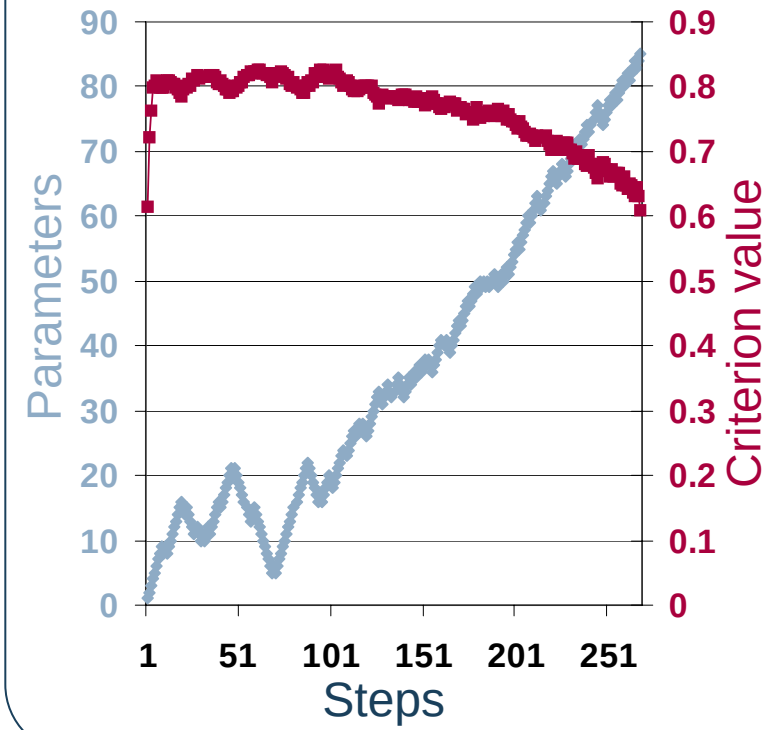


Method 3: Parameter Selection

Selection

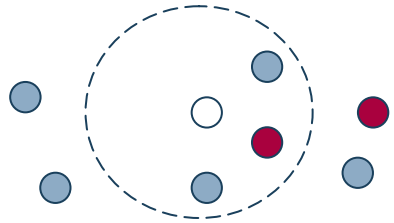
- Sequential Forward Selection (SFS)
- Sequential Forward Floating Selection (SFFS)

Example: SFFS

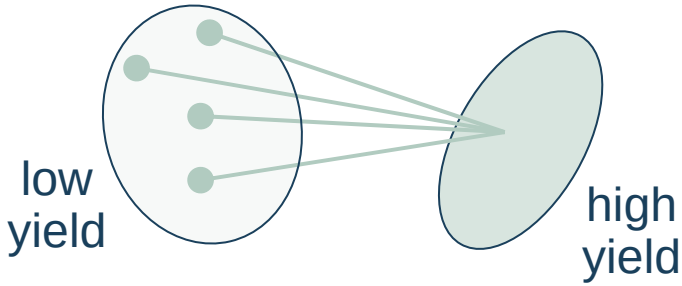


Criterion

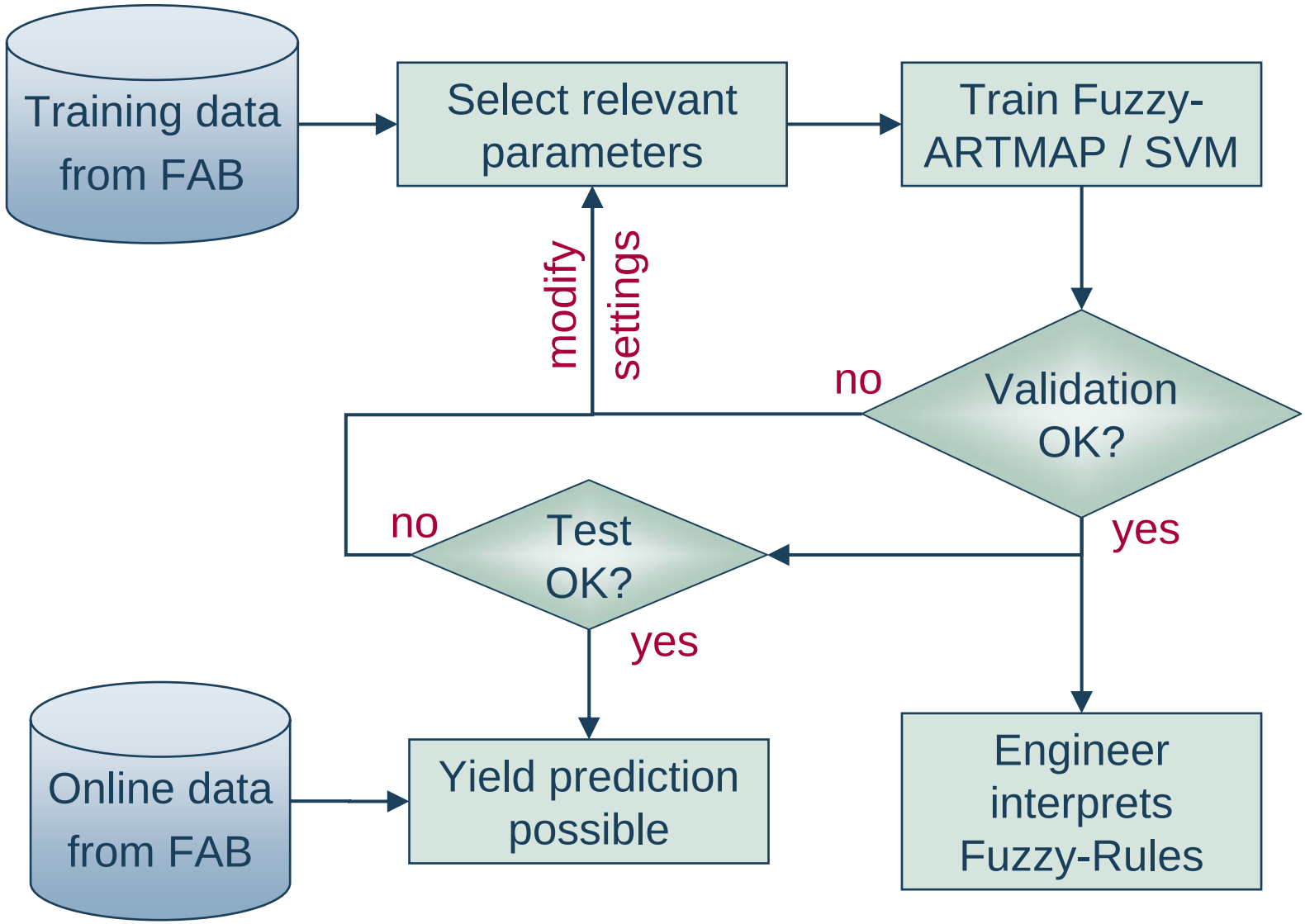
- FAM: Fuzzy-ARTMAP neural network
- k-NN: Nearest Neighbours classifier



- Mahalanobis distance

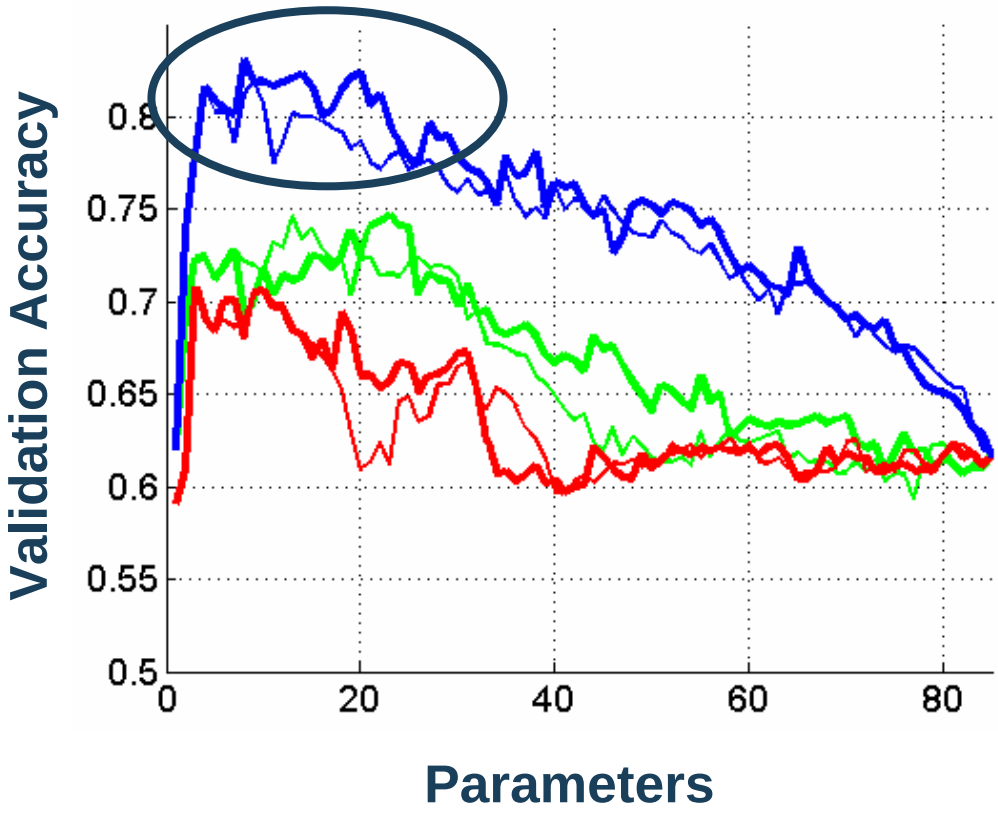


System Description



Validation

- Problem is modeled well with low number of parameters



Evaluation

- SFFS not better than SFS for yield prediction!
  - Use SFS (faster)
- Small parameter set can model production problem well
- Yield prediction improves when using selected parameter subset (5-20 parameters in our case)
- Comparison of Fuzzy ARTMAP results with engineer's problem solution competence brought back positive results.

Result

- Production problem
  - Automated method for knowledge extraction from Fuzzy-Rules necessary
  - Visualization would be helpful
- Yield prediction
  - More datasets (various operating conditions) must be tested to prove generality of solution
- System is useful to find unexpected root causes
- Experienced engineer still necessary to get results
- Real advantage of system is its absolute absence of engineering knowledge

Outlook

- Online prediction time must be improved for the precision needed in a factory environment
- The results gained make it appear promising to continue in the path taken
- Before starting on product development of a tool based on the said, considerable efforts are still necessary

Thank you !

? Questions ?