Simulation based approach to calculate utilization limits in opto semiconductor frontends

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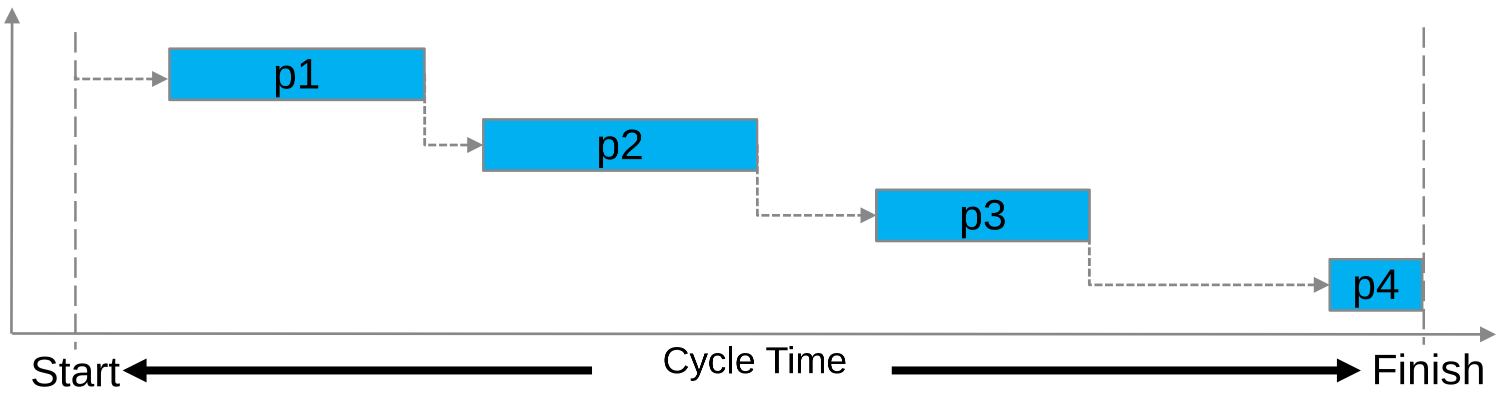
Agenda

1. **Project and motivation**
2. **Data farming based machine learning**
    1. System overview
    2. Factors
    3. Data farming
    4. Training
    5. Where are we today?
3. **Outlook**

Some introductions



$$Raw\ Processing\ Time = p1 + p2 + p3 + p4$$

$$\boldsymbol{Flow\ Factor = \frac{Cycle\ Time}{Raw\ Processing\ Time}}$$

Flow factor is a performance measure which reflects how much time material is spending waiting with regard to its actual processing time.

Motivation
Equipment utilization limits

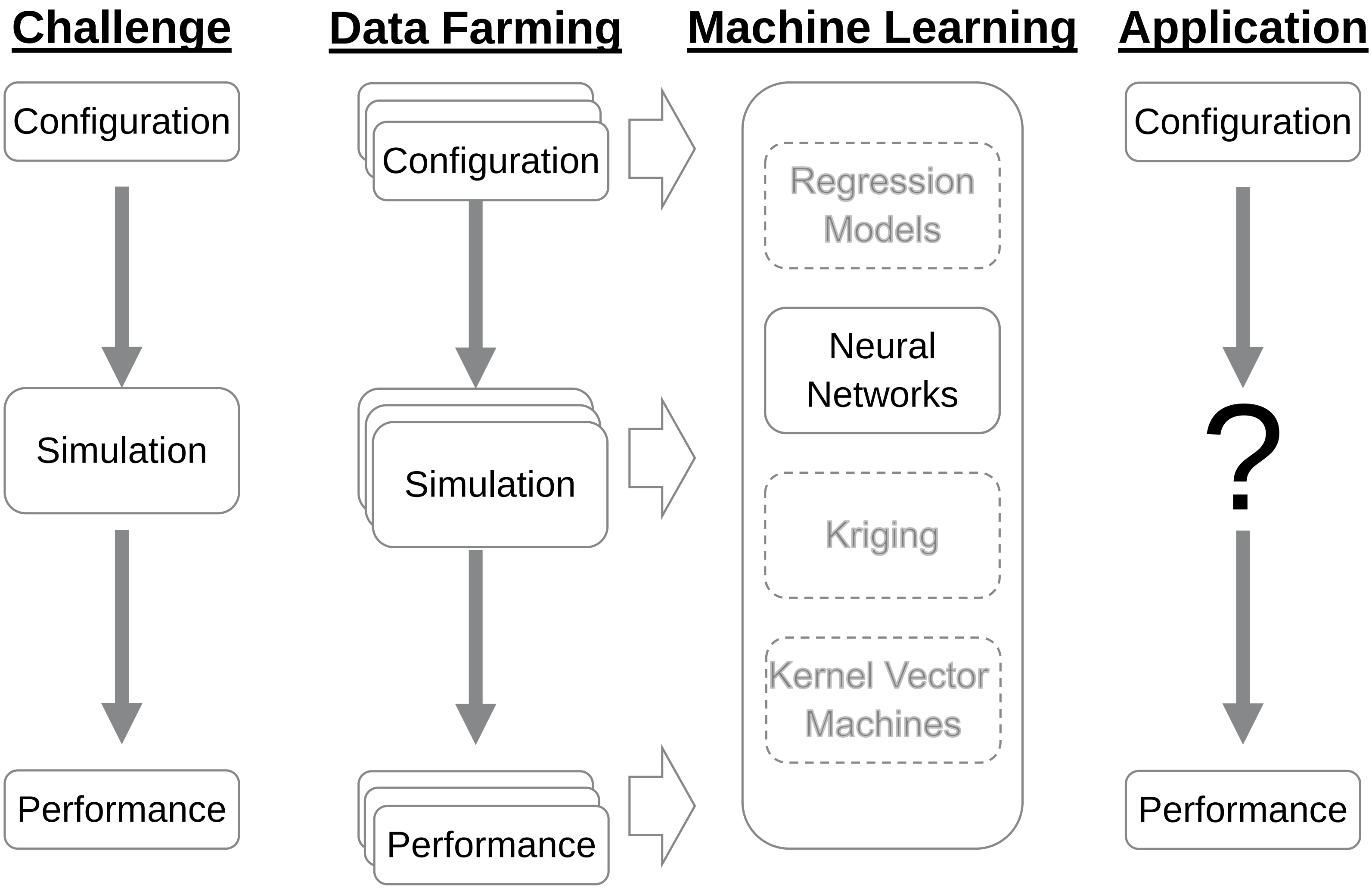
For static capacity planning it is necessary to know about maximal utilization limits for each equipment.

Estimating maximal „planned utilization limits“ to reach target flow factor.

Changing approach from experience and guesswork to data based planning

 Picture from: Learntec Kalsruhe, Open Licence

System overview



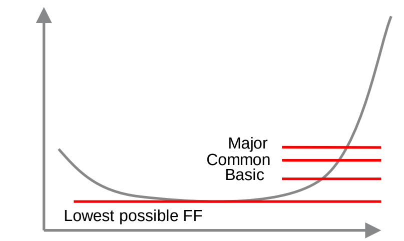
Data Farming: Configuration

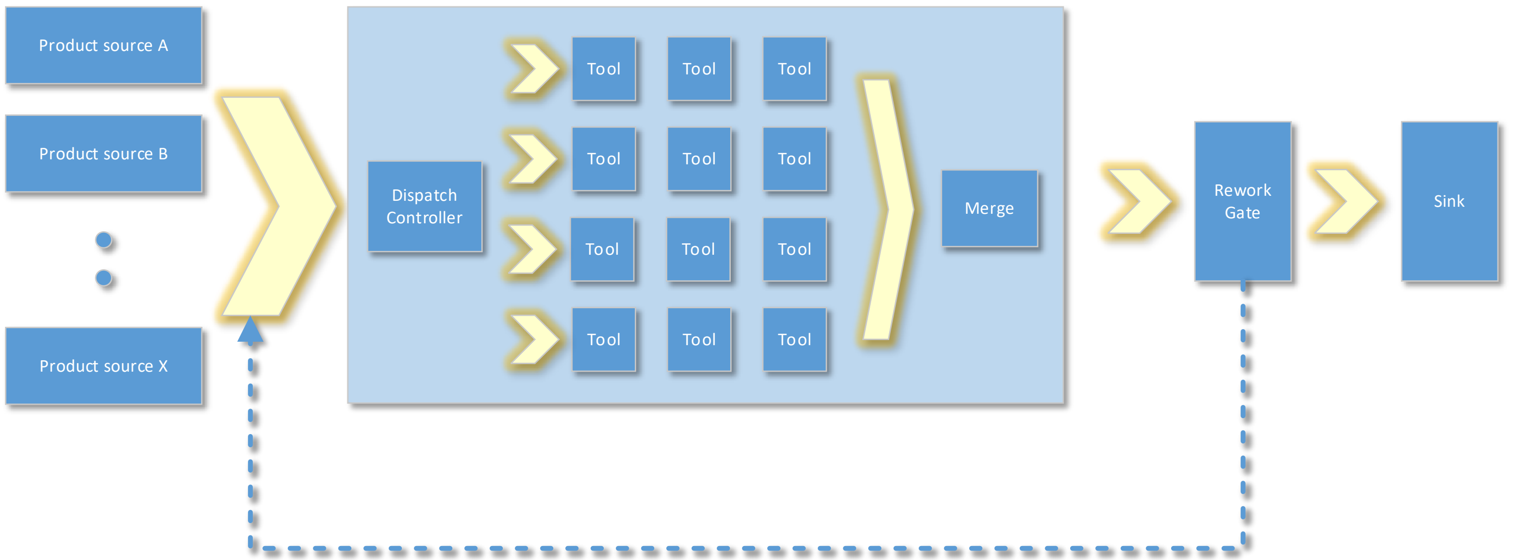
Factor	# Levels	Level Type
Number of Equipment	7	quantitative
Dedication	3	categorical
Batching	7	categorical
Product Mix	3	categorical
Breakdown	3	quantitative
Maintenance	3	quantitative
Processing Times	6	quantitative
Rework	3	quantitative
Setup	3	quantitative

All factors total in
214326 supporting points

Data Farming: Simulation

- Parameterized workcenters at different utilization levels
- Models for all scenarios automatically generated
- Determined 4 flow factor targets each
- Single run between few ms and a few hours
- 4 weeks of simulation time on high performance cluster





Data Farming: Validation

Queuing model with 5 servers: M/M/5

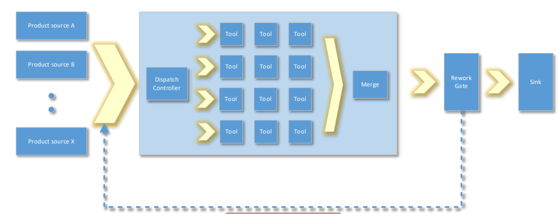
Service: $\mu = 80 \text{ wafer/day}$
Arrivals: $\lambda = 368 \text{ wafer/day}$
} UUM = 92%

Results:
9.28 wafers in queue
0.0125 days service time
0.0377 days average time spent in system
0.0252 days waiting time / wafer

$$FF_{Theory} = \frac{0.0252}{0.0125} = 2.01$$

Simulation

Tool count = 5
No breakdowns,…
UUM = 92%



$$UUM = 92\% \Rightarrow FF_{NN} = 2.0(*)$$

For all tested M/M/k models with k = {1,2,3,5,15}, the simulation returns nearly identical results compared to the multi server formula (Accuracy +/-1%)

* Simple model without batching, rework, breakdowns, dedication, maintenance, setup.

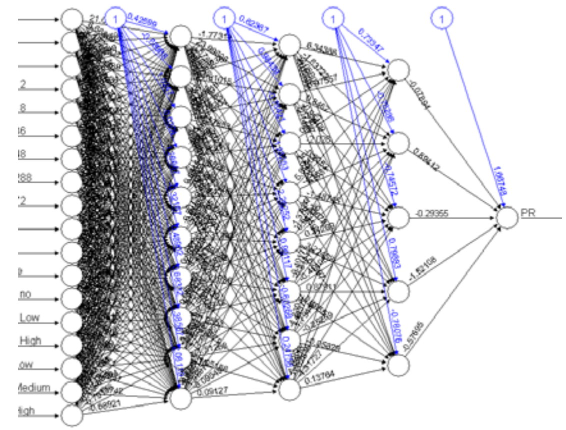
Machine Learning: Neural network

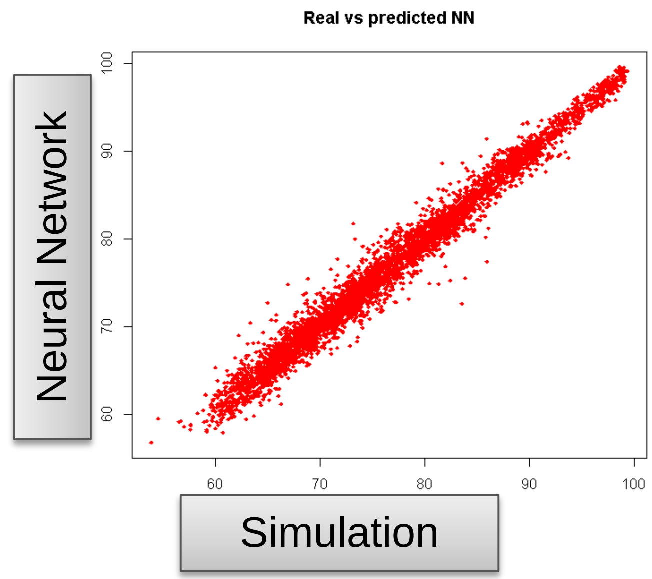
PROS

- Easy to implement
- Applicable for interpolation
- Measurable error during training

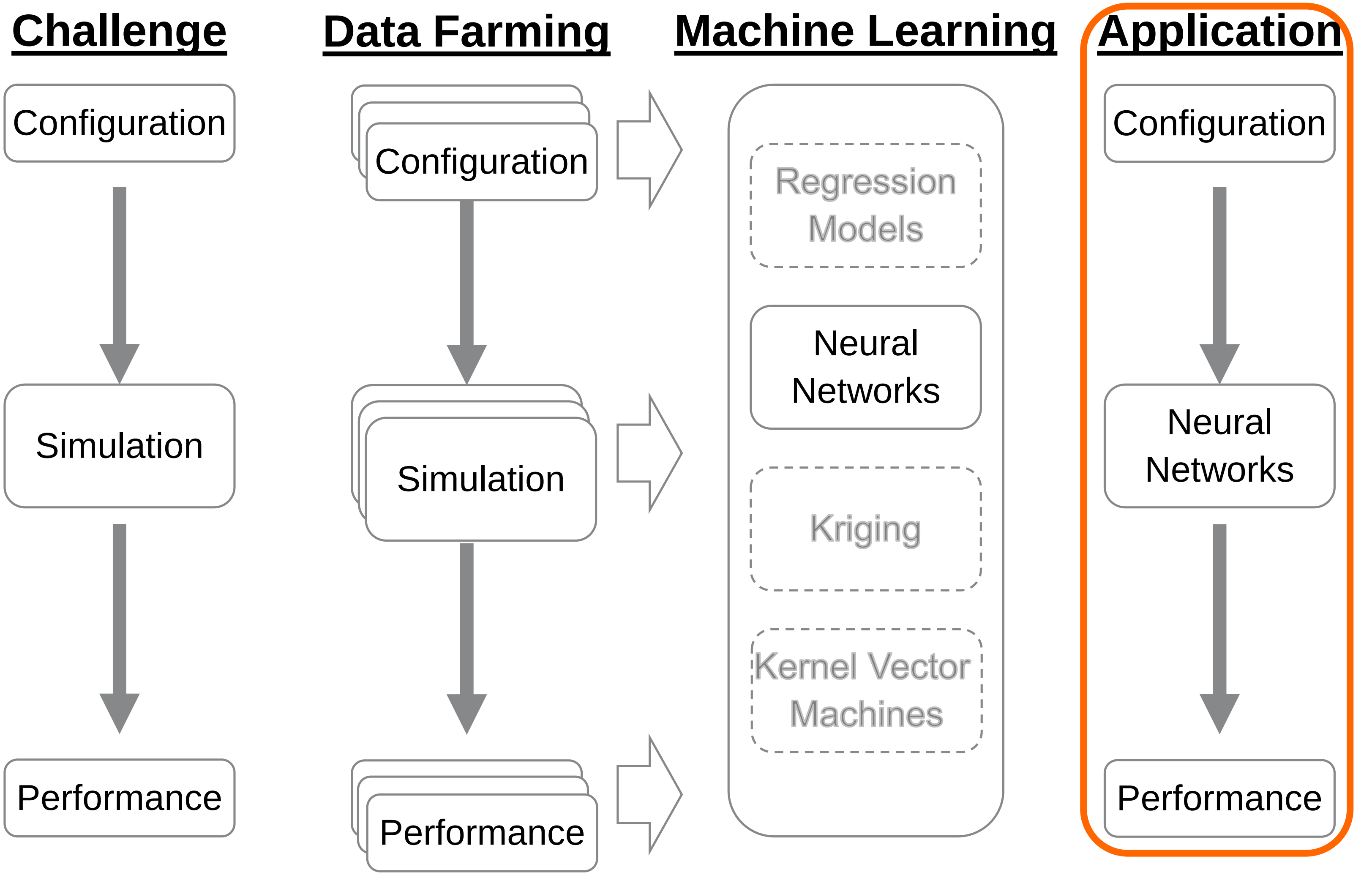
CONS

- Black box
- Long training phase





Where do we stand now?



Where do we stand now?

new	old
85.00%	84.00%
85.00%	84.00%
85.00%	75.00%
91.00%	80.00%
89.00%	82.00%
91.00%	82.00%
86.00%	80.00%
90.00%	85.00%
70.00%	85.00%
77.00%	80.00%
84.00%	81.00%
78.00%	78.00%
75.00%	70.00%
83.00%	84.00%
80.00%	78.00%
85.00%	84.00%

Is there actually this much capacity unused?

How could equipment perform much better than estimated?

Outlook

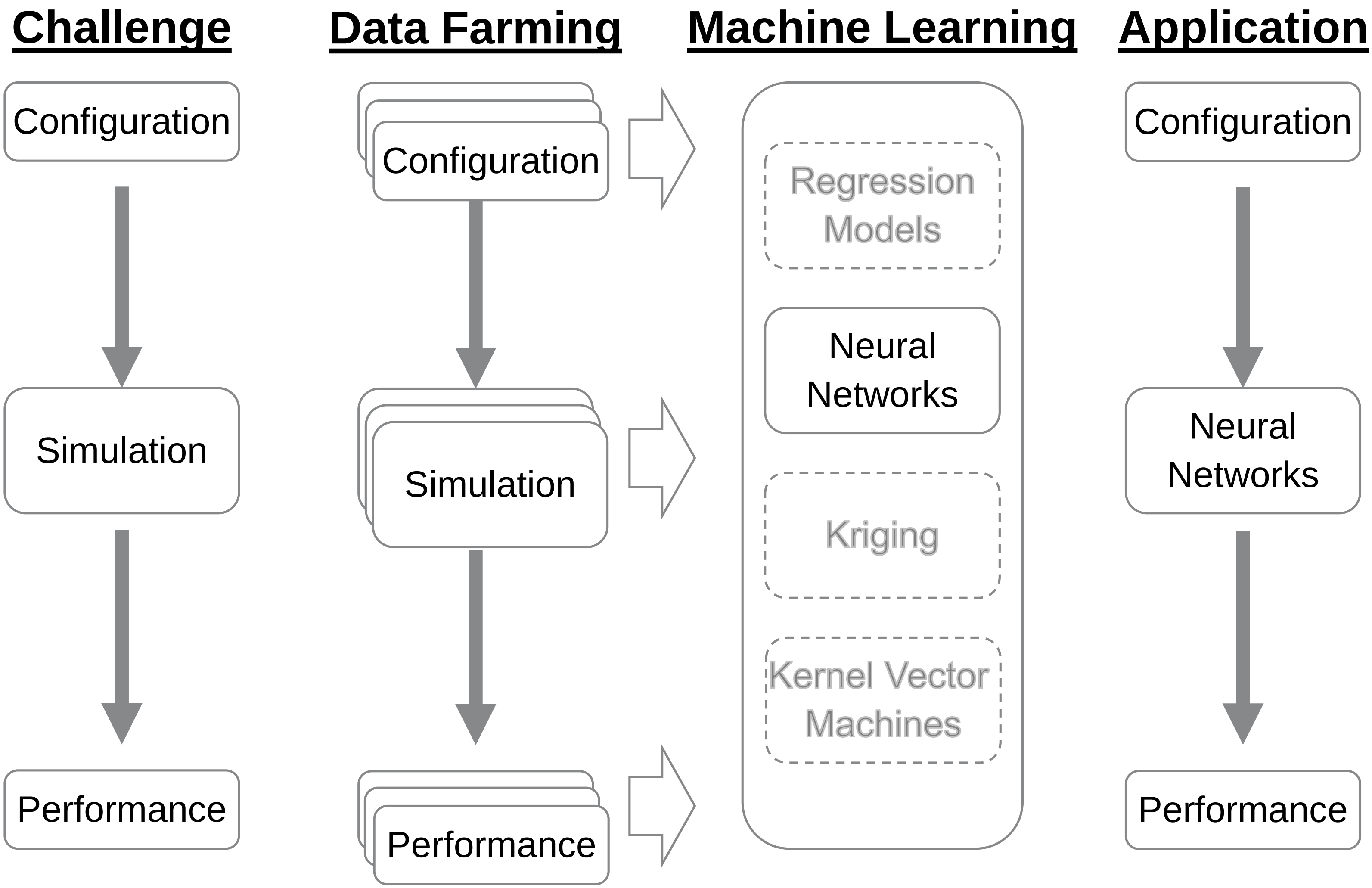
Current state and short term goals

- Planned max for equipment utilization
- Systematic basis for equipment evaluation
- Where are differences between model and real equipment coming from?
- Analyzing the effect of operators
- Analysis of potentials

Mid to long term goals

- Relevant worst case configurations
- Additional factors
- Ideal workcenter type assignment with regard to financial KPIs
- Fab wide flow factor planning based on flow factor limits

Questions?



Challenge
Data Farming
Machine Learning
Application
Configuration
Simulation
Performance
Configuration
Simulation
Performance
Regression Models
Neural Networks
Kriging
Kernel Vector Machines
Configuration
Neural Networks
Performance