Hochschule Düsseldorf
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Zentrum für Innovative Energiesysteme
Centre of Innovative Energy Systems

Prior-Approximation of Rule-Based Energy System Simulation for Fast Design Optimization

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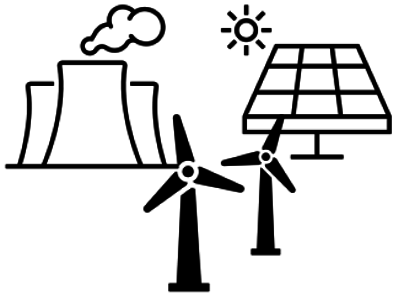
BACKGROUND & MOTIVATION

Bringing complex analysis to the non-scientific audience

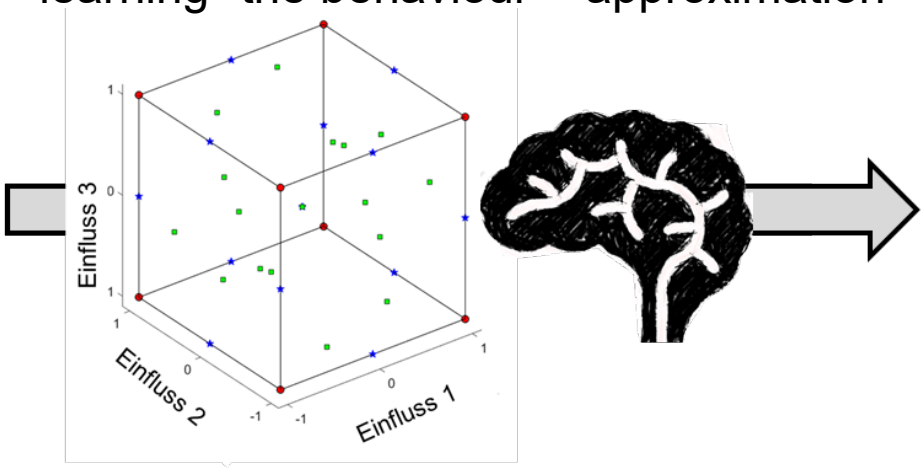
- Diverse systems for energy coverage possible, complexity of choice increases with RE
- Simple system comparison does not lead to the desired result

➢ Optimisation must be carried out, e.g. through **DoE + Machine Learning**

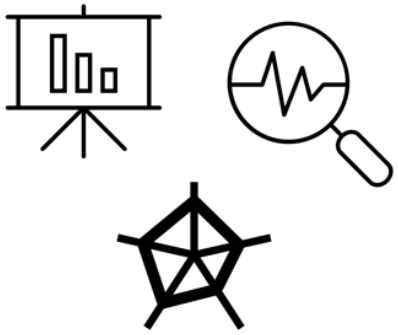
1: Choice of system boundaries



2: Sampling in system boundaries + "learning" the behaviour = approximation

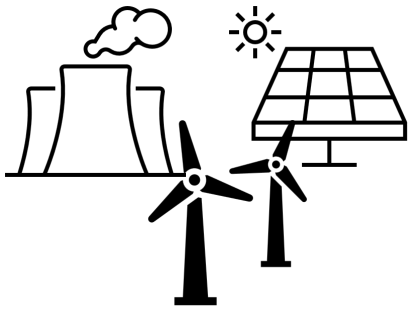


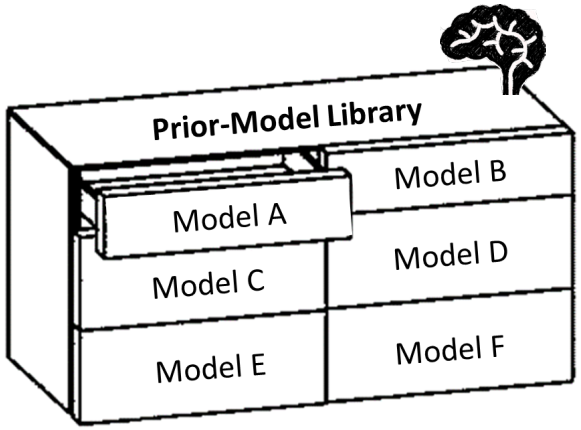
3: Performing analysis

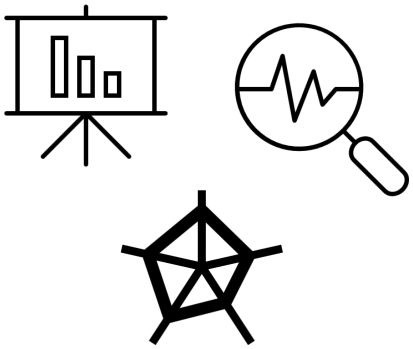


- Disadvantages: "Curse of Dimensionality", convergence, time requirement

BACKGROUND & MOTIVATION







User input:
- System selection
- Parameters
- Boundary conditions

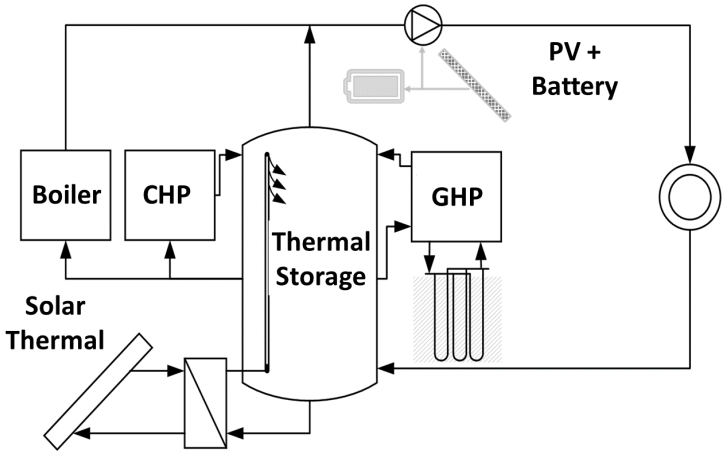
Assignment of the user to prior models

Possible analysis:
- Optimisations
-sensitivity analysis
- visualisations
- and much more.

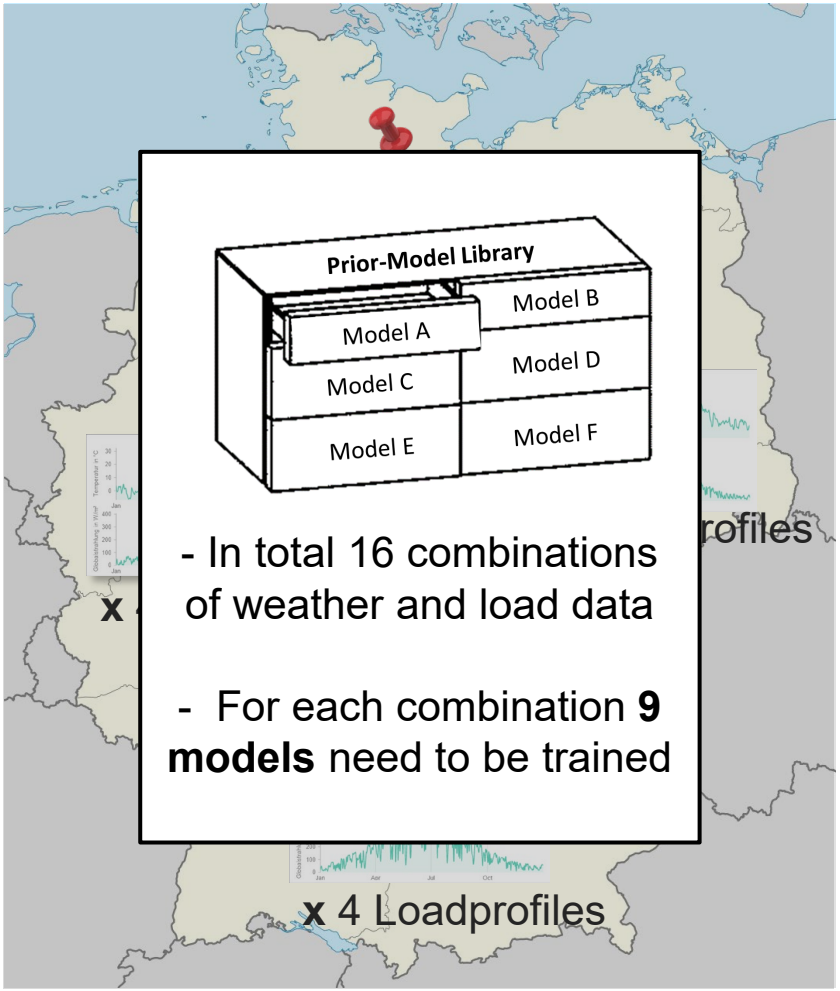
EVALUATION OF PRIOR MODELLING

1. Creating a prior model library

- For fixed superstructure:



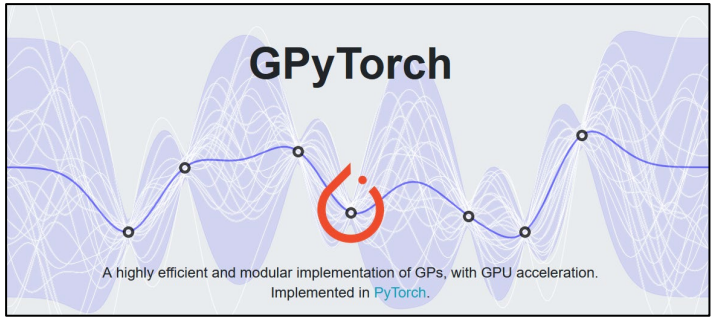
- Combination of weather data...
  - Location in western, northern, eastern and southern Germany
- ... and typical load curves
  - Single and multi-family house, business, bakery



EVALUATION OF PRIOR MODELLING

1. Creating a prior model library

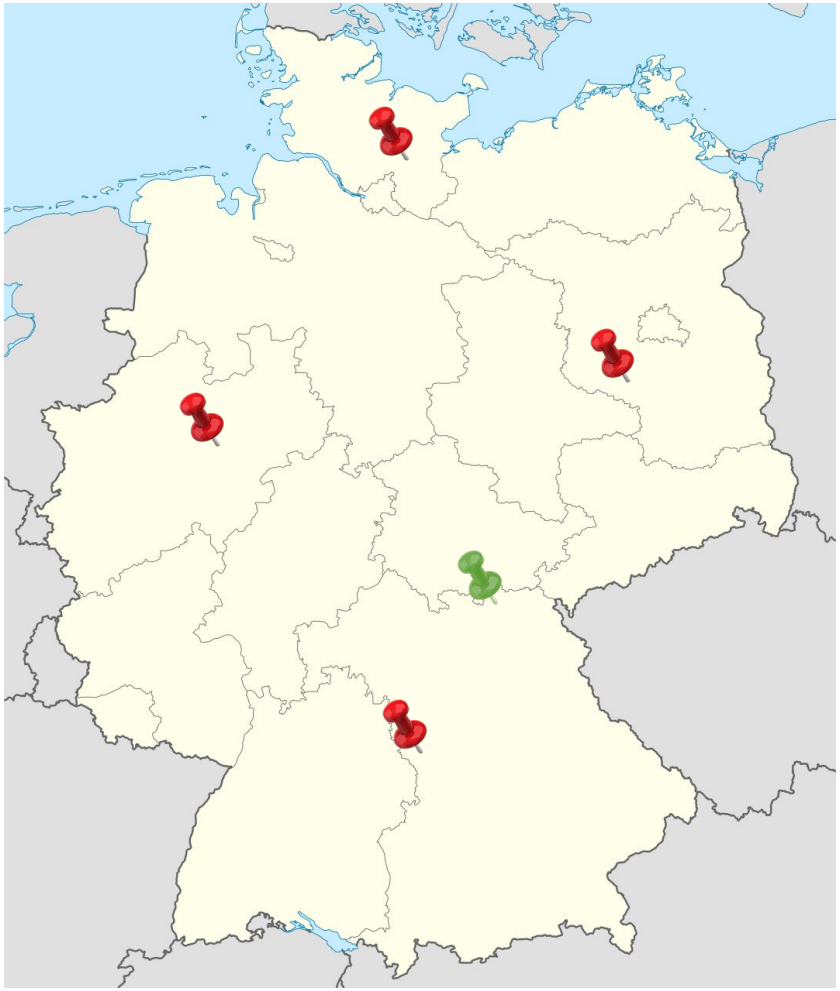
- Modelling using Gaussian process regressions
  - Use of the Python library *GPyTorch*
  - Utilizing an active query strategy for efficient learning:
    - Start with initial samples to simulate (in parallel)
    - Train models
    - Sample new setting with highest uncertainty over all targets to approximate
    - Abort when overall uncertainty is low enough
  - Time required to create the models: **approx. 4,600 seconds**



EVALUATION OF PRIOR MODELLING

2. Generation of randomised use cases + assignment

- Random choice of the boundaries of the influencing variables
  - For this evaluation in the boundaries of the superstructure = no extrapolation
- Random selection of weather data based on latitude and longitude
- Matching to prior models:
  - Evaluation of the normalised time series via distance measure



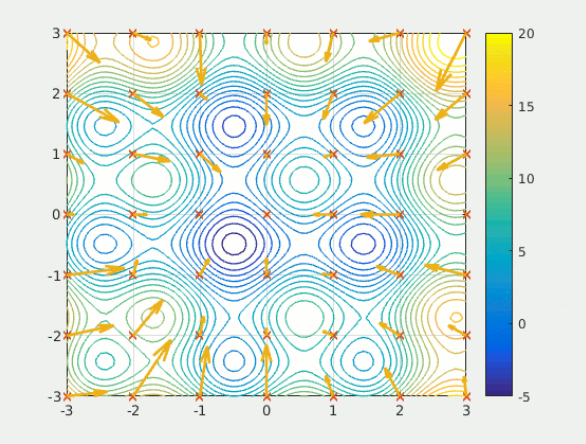
EVALUATION OF PRIOR MODELLING

3. Analysis: Finding a system configuration with minimal costs

- Optimization algorithm: particle swarm optimization
- Comparison: simulation with user-specific boundary conditions VS assigned prior model,
  both approaches for TAC determination:

$$TAC = OPEX + INV + Penality$$

Annualised total costs in €/a — Operating costs in €/a — Annualised investment costs in €/a



- Undercoverage: Penalty for cost function

$$Penality = \max\left(0, hl_{max} - \sum_{i=1}^{n_{gen}} \dot{Q}_{H,i}\right) \cdot M$$

- Boundary conditions and starting values of optimization are identical

EVALUATION OF PRIOR MODELLING

4. Comparison of the results

- Costs achieved and calculation times required for a total of 40 runs:
  - ∅- Time required, Simulation: 1120 seconds, Prior: 5 seconds (-99,6 %)
  - Costs: 50% of all runs the same optimal setting is found, the other 50 %:
  - Changing the settings for optimization when using the prior models: