Improving Model Abstraction by Active Learning*

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***Abstract*—Organizational structures such as hierarchies provide an effective means to deal with the increasing complexity found in large-scale energy systems that results from uncertainties in nature as well as computational efforts in scheduling. Abstraction-based methods provide a way to calculate a simpler behavior model to be used in optimization in lieu a combination of a set of behavior models. In particular, functional dependencies over the combinatorial domain are approximated by repeatedly sampling input-output pairs and substituting the actual function by piecewise linear functions. However, if the selected input-output pairs are selected in a weakly informative way, the resulting abstracted optimization problem introduces severe errors in quality as well as bad runtime performance. We therefore propose to apply methods from active learning based on decision trees for regression to search for informative input candidates to sample and present preliminary results that motivate further research.**

I. Hierarchical Distributed Energy Management

Future energy systems move from systems of relatively few centrally organized units providing most of the power demanded by consumers to many highly distributed units. To deal with the resulting complexity in scheduling and controlling power plants in the face of uncertainties introduced by nature and technical deficiencies, hierarchical organizations that form autonomously can be employed. To achieve a reduction of complexity in the optimization problem to be solved by the overall system, techniques are borrowed from abstraction. In particular, functional dependencies over a combinatorial input domain stemming from the aggregate of underlying agents are approximated by repeatedly sampling input-output pairs and substituting the actual function by piecewise linear functions. However, if the selected input-output pairs are selected in a weakly informative way, the resulting abstracted optimization problem introduces severe errors in quality as well as bad runtime performance. We therefore propose the use of methods from active learning to search for informative input candidates to sample and present preliminary results that motivate further research.

In general, the problem to be solved is a hierarchical resource allocation problem [1].

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$$
\begin{aligned}
\underset{S_a[t]}{\text{minimize}} \quad & \alpha_\Delta \cdot \Delta + \alpha_\Gamma \cdot \Gamma && (1)\\
\text{subject to} \quad & \forall a \in \mathcal{A}_\lambda, \forall t \in \mathcal{W} : \exists [x,y] \in L_a^t : x \leq S_a[t] \leq y, \\
& \overrightarrow{A}_a^{\min}(S_a[t-1]) \leq S_a[t] \leq \overrightarrow{A}_a^{\max}(S_a[t-1]) \\
& \text{with } \Delta = \textstyle\sum_{t \in \mathcal{W}} \left| S_{\mathcal{A}_\lambda}[t] - S_\lambda[t] \right|, \\
& \text{and } \Gamma = \textstyle\sum_{a \in \mathcal{A}_\lambda,\ t \in \mathcal{W}} \kappa_a(S_a[t])
\end{aligned}
$$

We propose to solve it using an approach based on self-organization:

- A so-called "regio-central" approach: agents transfer models to their local supervisor who, at meso-level, centrally optimizes the allocation [2], [3]
- An auction-based decentralized approach [4]

We align the minimal set of constraints along the physical requirements that power plants impose: a minimal and maximal power boundary, discontinuity by the ability to be switched off as well as a function limiting the possible change in production over a certain period of time. The latter function might depend on the type of an agent as well as the current contribution.

II. Issues with Model Abstraction

III. Improving Sampling Point Selection

IV. Evaluation

We investigate the effects of selecting a particular set of sampling points for one group that could have emerged as part of a self-organization process.

References

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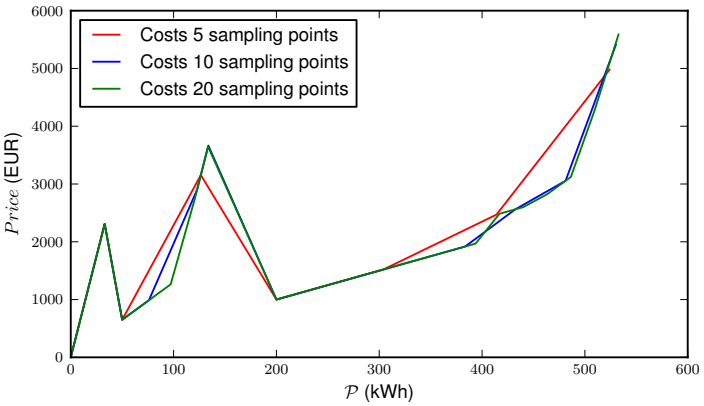
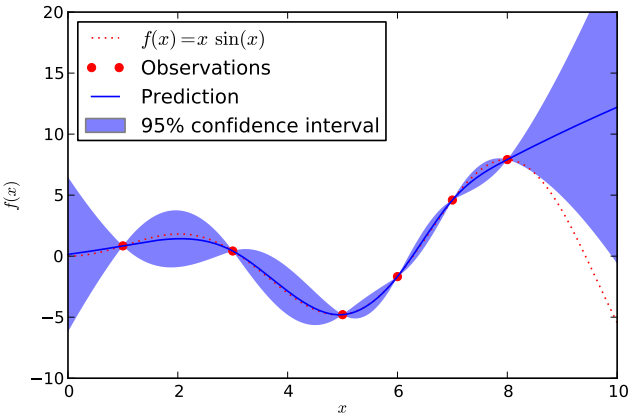


(a) Accuracy affected by the number of sampling points selected.



(b) A probabilistic regression model allows to quantify uncertainty at given points in the domain of a learnt function.

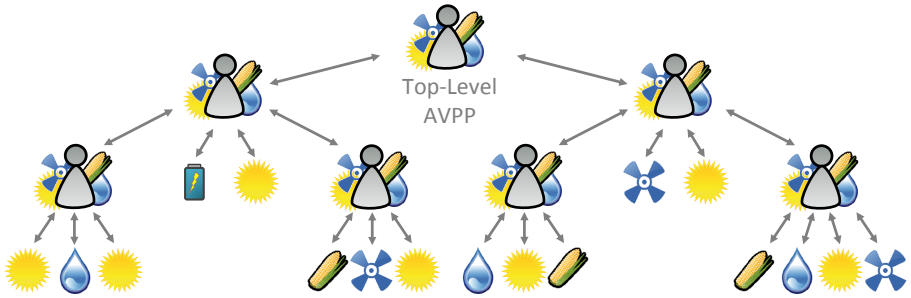


Fig. 2: Hierarchical system structure of a future autonomous power management system: Prosumers are structured into systems of systems represented by AVPPs acting as intermediaries, thereby decreasing the complexity of control and scheduling. AVPPs can be part of other AVPPs.