

Concise Metamodels of Simulated Systems

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Preliminaries

- Simulation model — a mathematical model that is solved by means of experimentation [1]
- Metamodel (a.k.a. surrogate model) — an approximation of the input/output function that is defined by the underlying simulation model [1]

Purposes of metamodels [2]:

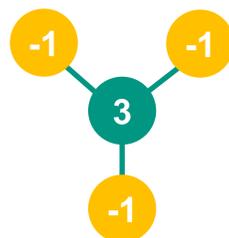
- Simulation model approximation (reduce costs)
- *Design space exploration* (“what if?”)
- Problem formulation (inputs’ significance)
- Optimization support

The Experimental System [3]

- The electrical grid frequency ω is connected to the electricity price
- Electrical grid connects n electricity consumers and producers
- Participant i measure frequency ω_i at his place, averages it over time T_i , calculates price and adapts his/her consumption after time τ_i

$$p_\omega = p_\Omega + c(\Omega - \omega)$$

One uses simulations to ensure the system stability given specific values of inputs (τ_i , T_i , and others)



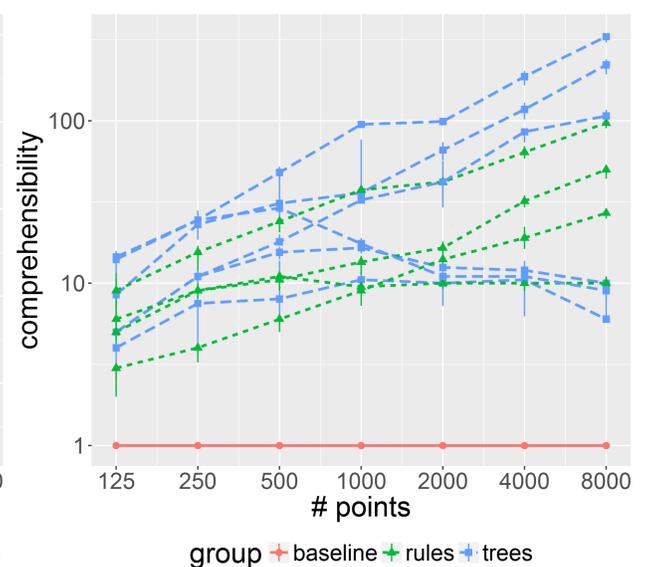
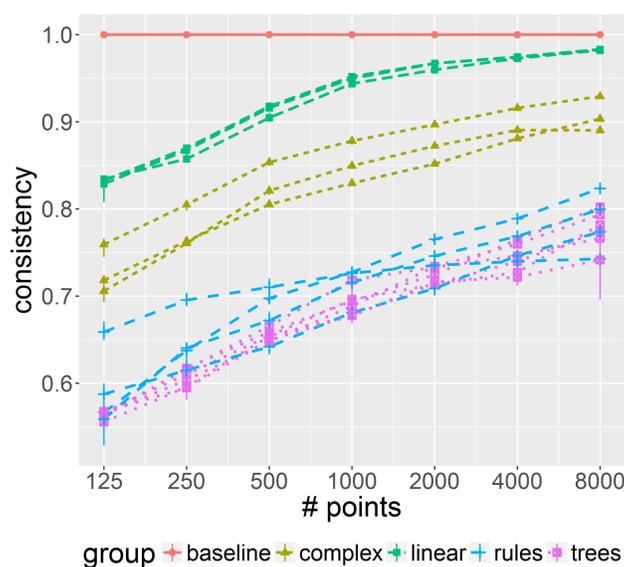
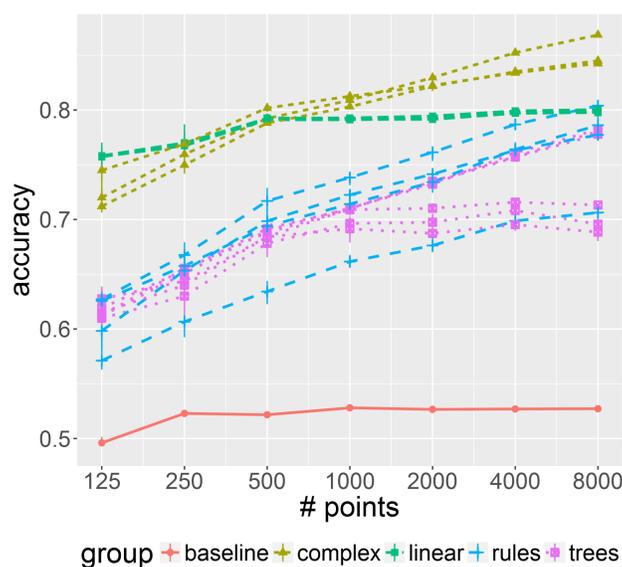
Methodology

- Run many simulations (4-node system)
- Estimate different metamodels
- Compare metamodels according to various criteria

Group	Models
Baseline	Most frequent class
Linear	Logistic, LDA, SVC
Tree	CART, C5.0, C4.5
Rules	PRIM, PART, Ripper, C5.0 rules
Complex	RF, SVM, Boosted trees

Some Results

Quality measures: (1) Accuracy (2) Consistency — the similarity of the models produced on different training sets generated by the same phenomenon (3) Comprehensibility — the number of leaves in decision trees or rules



Future Work

- For which input values to run the simulations?
- How many simulations to run?
- How to minimize the number of simulations, still obtaining good metamodel?

References

- [1] J. P. C. Kleijnen, Design and analysis of simulation experiments, 2015.
- [2] G. G. Wang and S. Shan, “Review of Metamodeling Techniques in Support of Engineering Design Optimization,” Journal of Mechanical Design, vol. 129, no. 4, p. 370, 2007.
- [3] B. Schäfer, C. Grabow, S. Auer, J. Kurths, D. Withaut, and M. Timme, “Taming instabilities in power grid networks by decentralized control,” European Physical Journal: Special Topics, vol. 225, no. 3, pp. 569–582, 2016.