

X-Tree –Transparent Energy Management

Rule Extraction and Interpretation from Symbolic Regression Trees



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MOTIVATION & GOALS

Residential energy management systems developed by Fronius use automated controllers based on **symbolic regression trees** to coordinate photovoltaic generation, battery storage, household consumption, and electricity tariffs. Although these controllers optimize energy costs and energy flows, their decisions are often difficult to **interpret**. This project aims to improve **transparency** by explaining battery actions, identifying influential inputs, exploring alternative operating conditions, simplifying controller models, and generating **natural-language explanations** of controller behavior.

Project FactBox

Project Name X-Tree
Project ID MFP II A.3-2
Duration 12 Months

Area 3
Area Analytics

Project Lead
DI Dr. Belgin Mutlu

APPROACH

- An **interactive visual analytics prototype** that combines historical data exploration with symbolic regression tree visualization and interactive **what-if analysis**.
- Users can inspect past controller decisions, manipulate input variables, **extract** and **simplify** rules from controllers, and observe the effect on the resulting battery action.
- LLM-generated** explanations complement the **visual analysis** with concise Natural-Language summaries and alternative outcome descriptions.

CONTRIBUTION

Scientific contribution

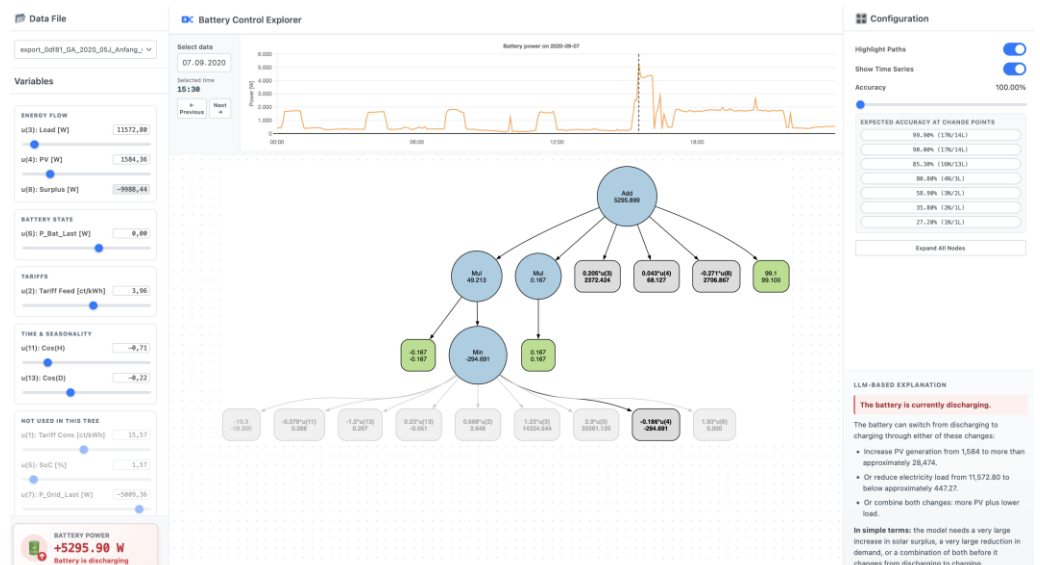
- Interactive visual exploration of symbolic regression controllers
- Model simplification with configurable accuracy
- Integration of what-if analysis for alternative operating conditions
- Combination of visual analytics with LLM-generated Natural-Language explanations

Economic contribution

- Reduced effort for troubleshooting and technical support
- Faster analysis of unexpected controller behavior
- Improved transparency of automated energy-management decisions
- Potential for clearer customer communication and support workflows

SYSTEM ARCHITECTURE

The prototype supports the analysis of historical energy data and **symbolic regression trees** through an interactive visual analytics interface. Controller calculations are evaluated, and symbolic regression expressions are **simplified** while preserving a user-defined level of accuracy. The visualization shows the resulting computation paths, relevant input variables, and battery action. Users can select and explore historical states and **what-if scenarios**. An **LLM** component complements the tool by generating concise **natural-language explanations** of controller actions and possible alternative outcomes.



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