AI for energy systems – what's different?

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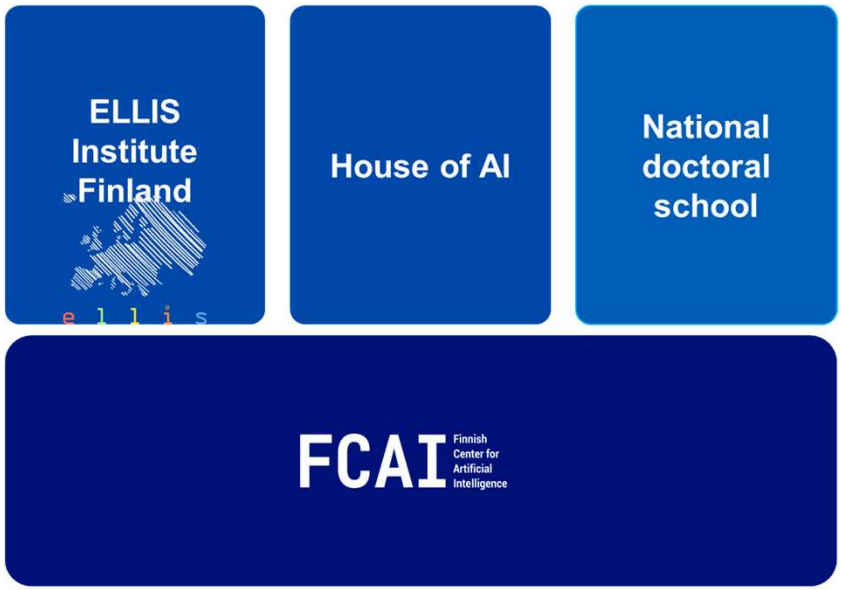
AI activities in Aalto

- About 45-50 professors in AI-related fields

- Flagship FCAI
- ELLIS Institute Finland
- National Doctoral School, coordinated by Aalto

- House of AI:
  - Multidisciplinary research for applying and developing AI
  - Industrial collaboration
  - Long-term projects and rapid piloting
  - Postdoctoral researchers
  - Continuous interaction with the companies
  - Main themes: **energy systems**; manufacturing industry; health



FCAI Flagship: Aalto, University of Helsinki, VTT

Energy systems

- Energy systems are a central part of our society
- Decreasing energy consumption, cutting emissions, achieving green transition
- Modern data analysis and AI as an important tool in this
- … and consuming energy …
- “Net positive or net negative”?

- Data-rich environments; quality

- Examples of energy systems
  - Electric energy systems of different sizes
  - Buildings (HVAC)
  - Transportation
- Areas of industry with similar properties
  - Water management
  - Process industry

- Different yet similar in some ways

AI in the energy systems vs. in generic LLMs

AI discussion focuses on by large language models
What properties are specific for AI in energy systems?

Similar

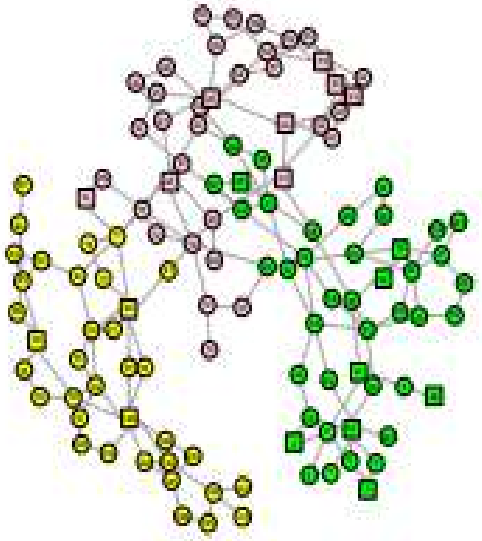
- **Very large potential**
- **Rapidly developing technology**
- **Guaranteeing safety, trusthworthiness, robustness, fairness, reliability are not easy**

Different for energy systems

- **Mostly numeric data**, not text
- **Different ways of using** the models than for LLMs
- **Physics is there**: properties of the real world
- **Restricted domain**: not all possible themes
- Generative techniques are less prevalent
- **Small and large** models can be useful
- Understandability, explainability are sometimes easier
- Out of distribution problems can be very severe

Mostly numeric data, not text

- A simplified model of energy system: nodes connected by lines
- Time series of different types (voltage, current etc.)
- Models for numeric data, not models for text
- **Very high-dimensional time series**
- Novel data, modeling, prediction, optimization questions
- Text data occurs in maintenance reports, user feedback etc.



(a)

Source: Influence ...

Different ways of using AI in energy systems

- **Analysis**
- **Modeling**

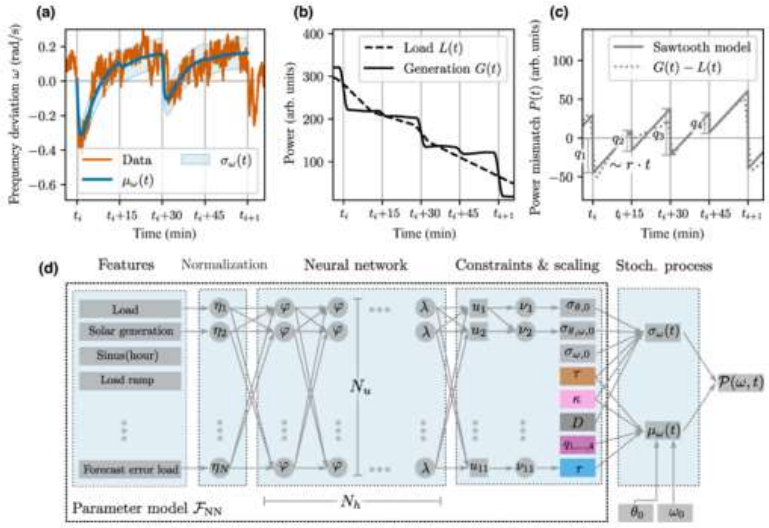
- **Prediction**
- **Simulation**
- **Control**
- **Optimization**
- **Design**

How to learn predictive models?

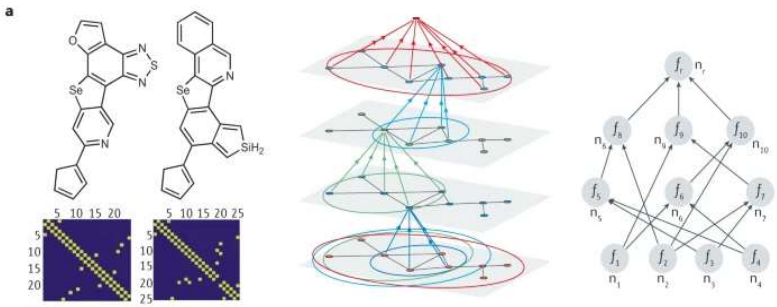
- Learn to predict the next value(s) in a time series
- Similar to “predict the next word” in learning LLMs
- Long tradition in regression methods for numeric data
- Only data from the system itself
- The models can still be large: multiple subsystems
- Autoregressive methods vs. transformers
- *Coefficients of even the large models are can be understandable*

Physics is there

- The energy systems satisfy physical laws
- It would be good if the predictions would also satisfy those (to put it mildly)
- Physics-informed machine learning integrating physical models and data
- *Physics-informed; physics-inspired; physics-based*



Kruse et al, PRX Energy, 2023



Source: Karniadakis et al, Nature 2021

Restricted domain

- A single system (and subsystems) **Even small models can be useful**
- Not the whole textual information available on the internet
- A very different task
- Easier in some ways

Even small models can be useful

- Text: one needs huge models
- In energy systems even small models can be quite accurate
- Robustness and explainability are easier than for huge models
- Even a larger model for numeric data can be understandable
- (Small models consume less energy)

Understanding variation

- Where are the errors?
- E.g., asymmetric costs of prediction errors
- For LLMs the notion of variation is not at all clear

- Models for numeric data can be easier to understand and explain

Controlling equipment

- Very different from using models to produce text
- Safety is crucial
- Different subsystems
- Human in the loop at some point!

Robustness, safety

- Robustness and safety are crucial
- Models on numeric data are sometimes easier to understand than textual models
- But there are still possible problems

Example

- Example: out of distribution situations
- In energy systems errors are typically rare
- Most of the data is from situations where thing go well
- What happens if the data is something we haven’t seen before?
- Human in the loop at some point

Summary: AI in LLMs vs. in energy

Similar

- **Very large potential**
- Rapidly developing technology

- **Guaranteeing safety, trusthworthiness, robustness, fairness, reliability are not easy**

Different in energy systems

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Thanks !

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