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Smart Control with Embedded Weather Forecasting

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Introduction

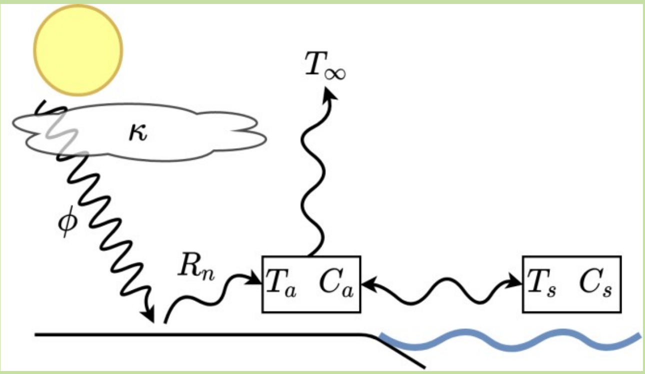
In a sustainable future, where fossile fuels do not belong, we need to harvest our energy from fluctuating and weather dependent sources. Reliable weather forecasts are thus critical for smart energy systems, e.g. smart- buildings or grid operators. Meteorological weather forecasts suffer from inaccuracies in their short-term predictions. These inaccuracies become critical for fast-changing "components" such as the solar radiation, which can fluctuate greatly during short time windows. For example to predict the amount of eletricity generated during the next hour, the accuracy depends one-to-one with the quality of the solar radiation forecasts.

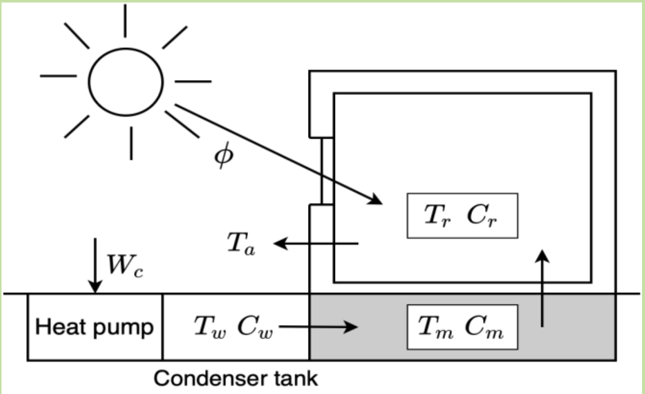
To predict short term weather conditions for smart control, we propose an embedded forecasting model based on non-linear grey-box models.

Methods

For control of smart buildings (e.g. with a heat pump and PV cells for electricity generation), the most important external disturbances from the weather are the **outdoor air temperature** and the **solar radiation**. The picture to the right illustrates the main components in the weather model to predict these important factors: the cloud cover, solar radiation, net radiation and outdoor air temperature.

In order to enable the computations of such forecasts, the only requirements are equipment to observe the outdoor air temprature and solar radiation. Such equipment is rather cheap and easy to install, which significantly reduces the barrier to entry.





Case study

To show the benefits of an embedded forecasting model, we carry out a simulation study:

- We apply a grey-box model describing the heat dynamics of a residential building. The building is equipped with a heat pump that provides floor based heating.
- Besides the floor heating, we investigate scenarios where the building also uses faster heating sources such as electrical heaters/coolers.
- For the actual weather, we apply hourly data for a period of 7 months.
- We compare the forecasts to persistent forecasts, which are current standards due to the simplicity.

Results

The main take-away from the results of the simulation study is that the embedded forecasts for control performs **almost as good as perfect forecasts**.

In terms of electricity savings, the results suggest between 5 – 15 % reduction compared to current standards. The constraint violations (visible in the table in the bottom of this page) says something about how comfortable the indoor climate is (lower is better). Not only do the embedded forecasts reduce the electricity consumption; the results also suggest significant improvements in the indoor climate. Also to a level that is close to perfect forecasts.

The conclusion is that great improvements may be available from using embedded forecasts for control.

Discussion

One of the main goals of this study was to show the significant impact short-term forecasts may have on smart control of buildings.

Meteorological forecasts deliver poor local short-term forecasts of the current weather, compared to the proposed short-term forecasts. This originates from the large local differences in the weather, which are hard to predict by large-scale models. For this reason, it is believed that the short-term weather forecasts may improve current forecasting standards for smart energy systems by including local weather observations and predictions.

The embedded forecasts may also be applied for other smart energy- related devices that require future weather predictions., e.g. batteries for electricity storage.

Constraint violation of the control simulations

Heating strategy	Persistent	Advanced forecasts	Perfect
Electrical heaters, u_1	48.5	39.6	25.1
Heat pump, u_2	157.9	12.3	1.7
Heat pump plus electrical heaters, $\boldsymbol{u}_3$	48.0	6.7	1.2
Heat pump plus electrical heaters and coolers, $\boldsymbol{u}_4$	4.4	2.4	0

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