Optimal Controller Synthesis with Application to Floor Heating

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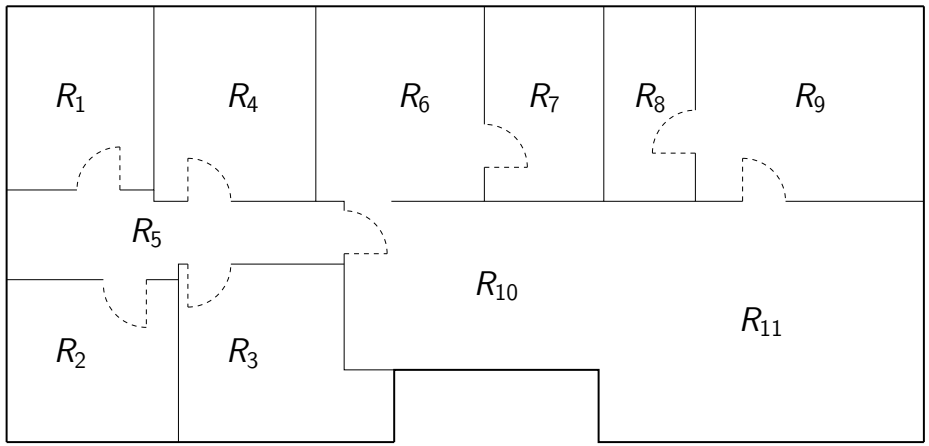
In collaboration with:

Introduction

- Automatic control of a floor heating system in a family house.
- Formulated as a game between the environment and the controller.
- From abstract game strategies to a concrete code running on real hardware.
- Experimental evaluation of the benefits.

The Floor Heating Scenario



- Each room has a hot water loop that can be opened/closed.
- Loops are controlled via activating/deactivating valves.
- Rooms equipped with wireless temperature sensors (report every 15 minutes).
- Each room has its user-defined target temperature.

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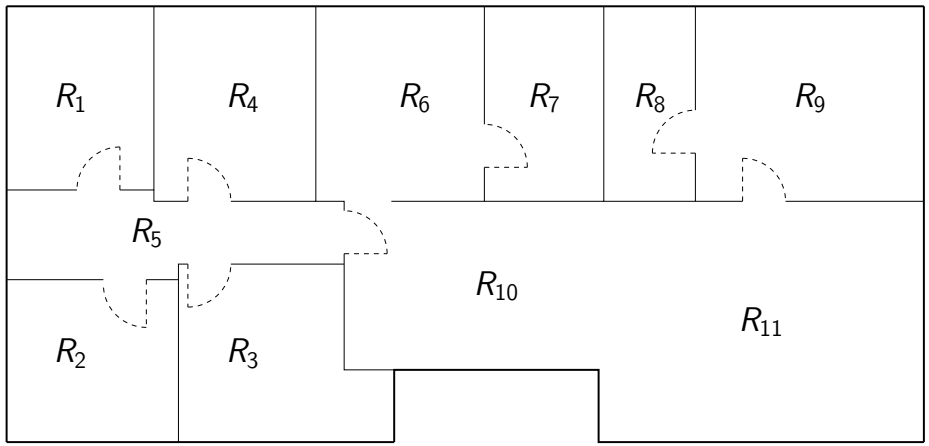

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Control Task

Maintain the room temperatures as close as possible to the target temperatures.

Additional Factors and Restrictions

- Heat exchange among the rooms (influenced by the door positions).
- Pipes are traversing under several rooms.
- Outside temperature and weather forecast.
- Capacity of the heating system.
- Temperature user-profiles for the different (group of) rooms.

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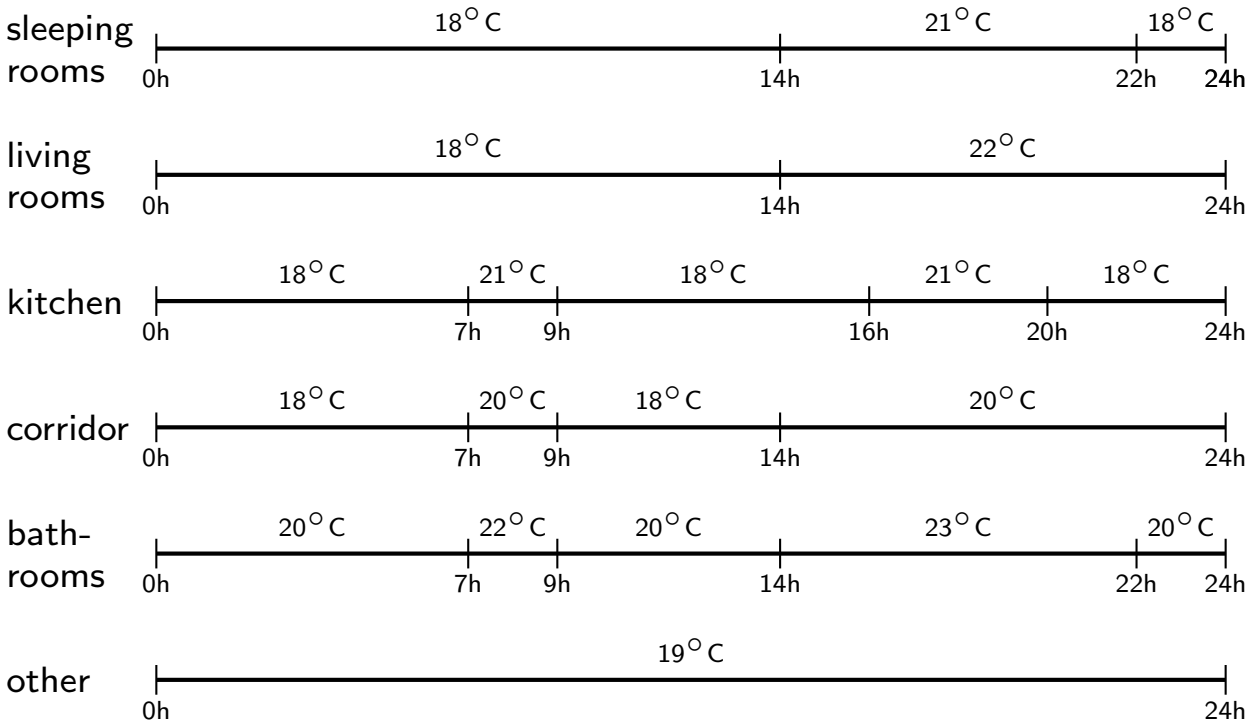

Control Cycle

Each 15 minutes do:

1. Fetch readings of temperature sensors.
2. Gather weather information (outside temperature, weather forecast).
3. Receive the actual target temperatures request.
4. Set a new valve configuration (11-bit vector).
5. Use remaining time for computing a control strategy for the next slot.

Currently Employed Bang-Bang Controller

Each 15 minutes do:

1. Fetch readings of temperature sensors.
2. Receive the actual target temperatures request.
3. For each room do:
   - if actual-temperature $<$ target-temperature then open the corresponding valve,
   - otherwise close the valve.
4. Wait until the next time slot.

UPPAAL Stratego Controller

Each 15 minutes do:

1. Gather all relevant information.
2. Set the new valve configuration according to the computed strategy (in the previous time slot).
3. Compute an updated control strategy given the new information.

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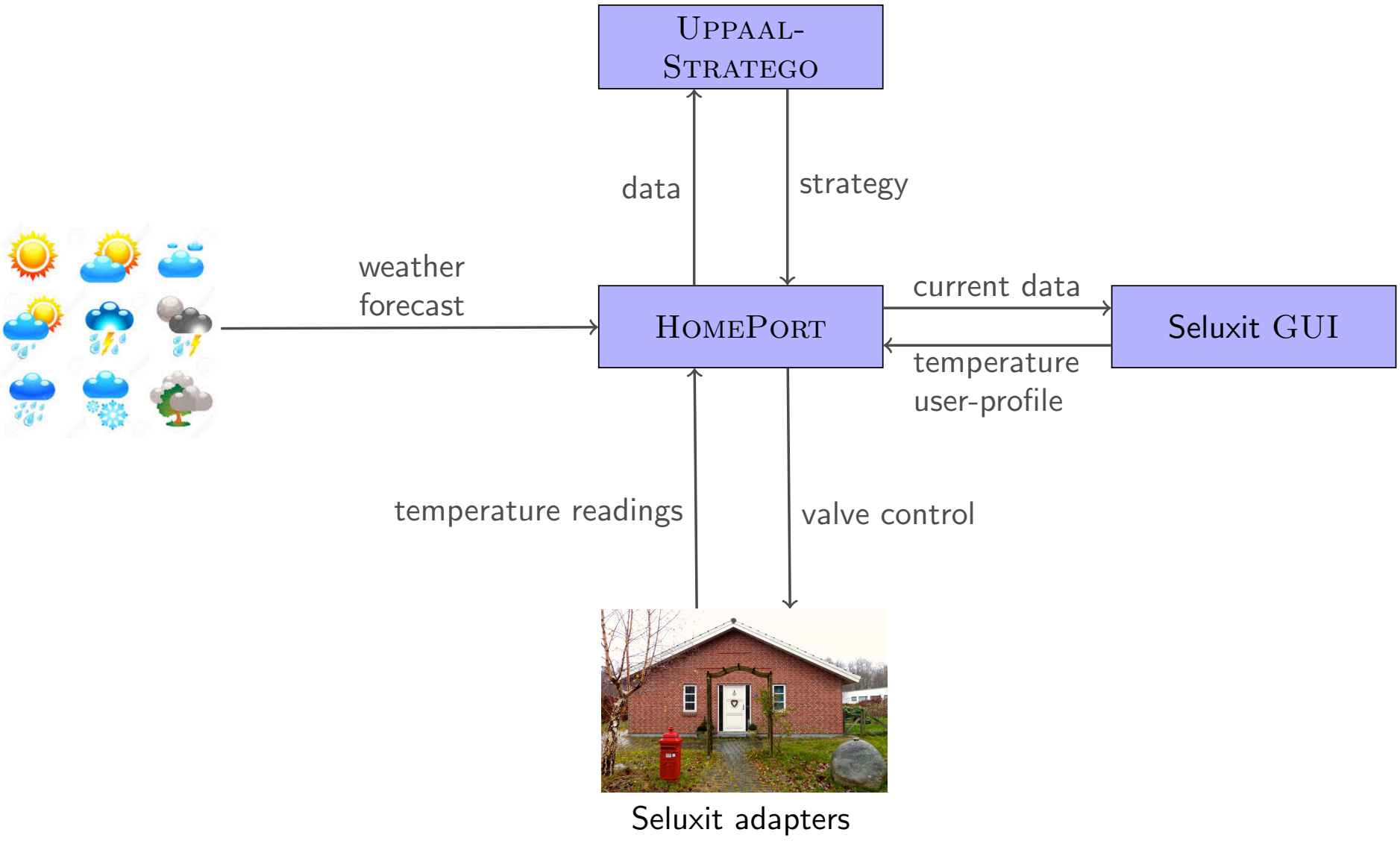
Aspects taken into account:

- House and room layout, pipe configuration.
- Stochastic information about the likehood of a door being open/closed.
- Actual outside temperature and weather forecast.
- User defined temperature profiles.

Tool Chain Architecture



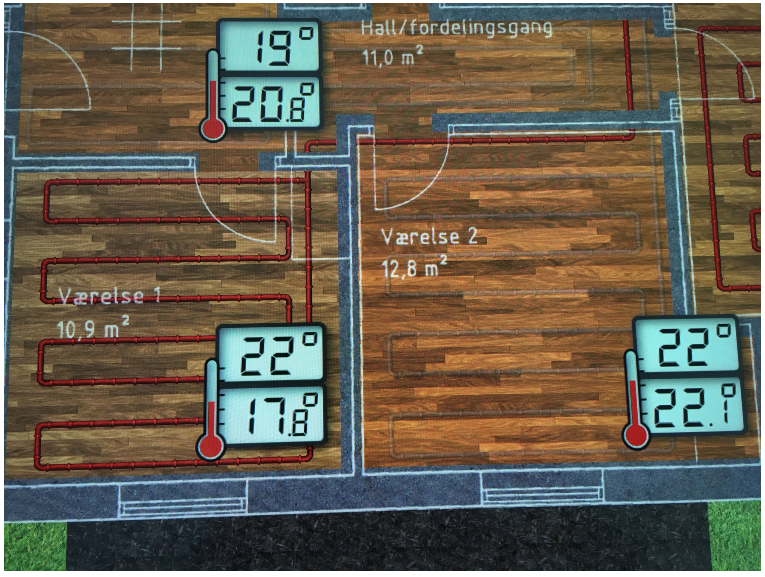
Tool Chain Architecture

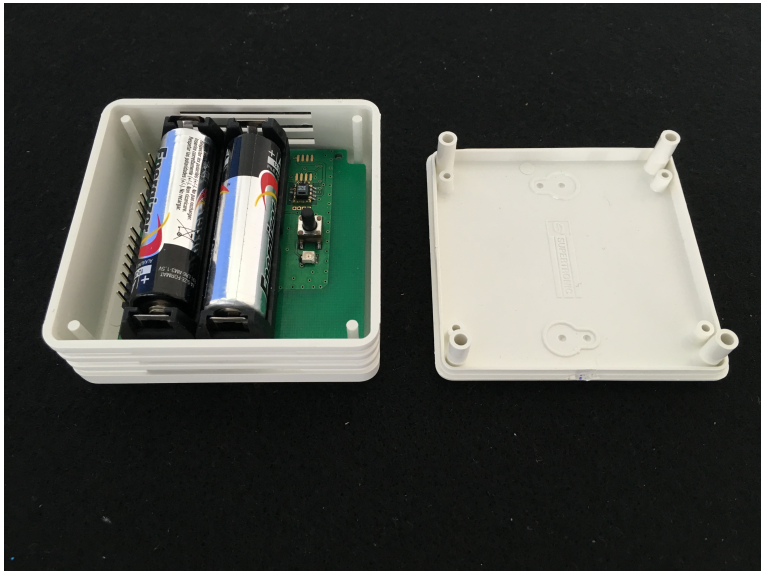
$$\frac{d}{dt} T_i(t) = \sum_{j=1}^{n} A^d_{i,j}(T_j(t) - T_i(t)) + B_i(T_{\text{env}}(t) - T_i(t)) + H^v_{j,i} \cdot v_j$$

Demonstrator

- Built using the real hardware, identical with the one in the house.
- Simulation running 60 times faster (1 second = 1 minute).

Hardware Details





Experimental Data - Three Day Scenarios

Weather	Comfort Penalty			Energy		
	Bang-Bang	Stratego	imp.	Bang-Bang	Stratego	imp.
Aalborg	14583	8342	**43**%	14180	12626	**10**%
Anadyr	2385515	1483272	**37**%	23040	22475	**2**%
Ankara	17985	10464	**41**%	17468	15684	**10**%
Minneapolis	22052	12175	**44**%	18165	15882	**12**%
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