District Heating Model Parameter Estimation

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Goal

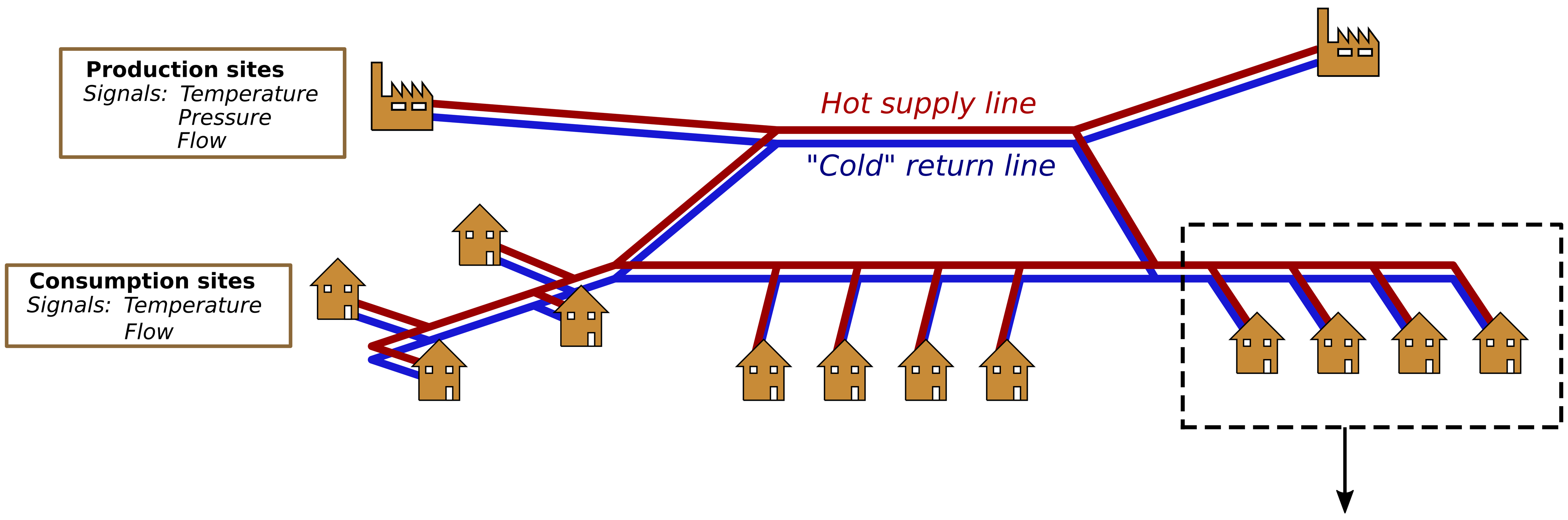
We want to use available operational measurements of **flows**, **pressures** and **temperatures** to estimate model parameters that describe the operation of a district heating system.

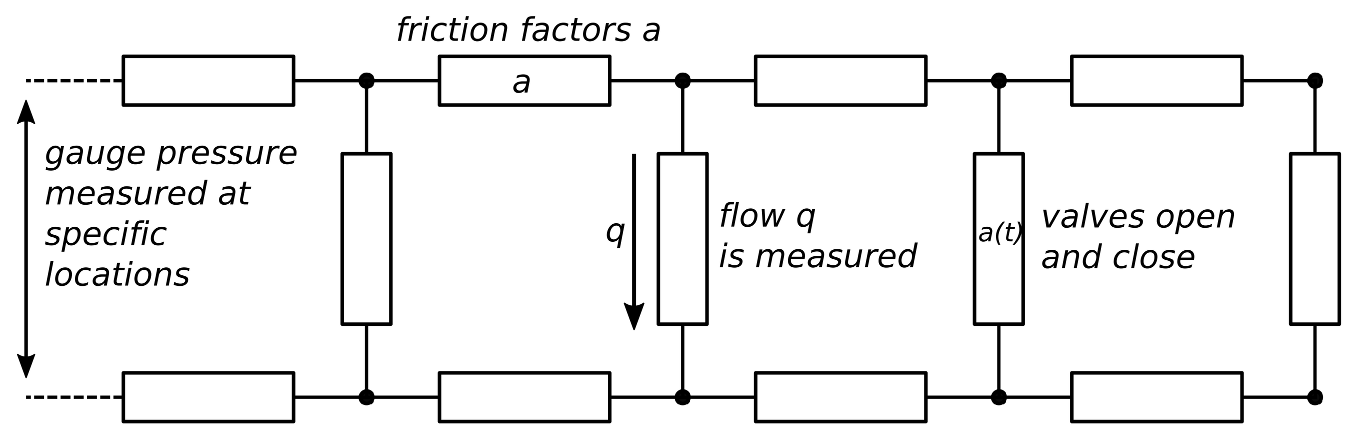
Project steps:

- Generate operational data from a high fidelity Modelica model
- Use model output data to estimate model parameters

Motivation

District heating is moving towards the so called **4th generation** of district heating, characterized by lower temperatures, more renewable energy, more measurements and smarter controllers. Accurate system models will be integral in this transition. Parameter-dependent models are used for simulation, operational optimization, long term planning, advanced control, and more. Data-driven methods will make these models cheaper to establish and easier to maintain.

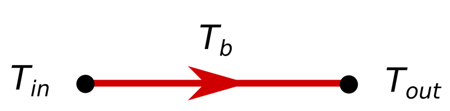




Thermodynamics

There are several ways to model the thermodynamics of the district heating pipes. Regardless of the method chosen, some parameters will be important to estimate. The **length L** of the pipe will induce time delays. The **thermal resistance R** will dictate the rate of heat loss to boundary temperature, and the **heat capacity C** will decide the rate at which the temperature changes.

Node Method

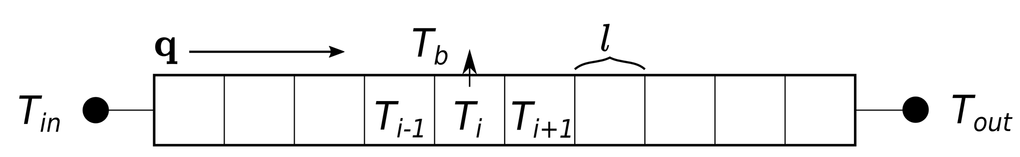


One can consider the input-and-output temperatures of eqch pipe.

$$T_{\text{out}} = T_b + (T_{\text{in}} - T_b)e^{-(t_{\text{out}}-t_{\text{in}})/RC} \tag{1}$$

Here the relation is modeled through a delay which depends on the flow rate, as well as a decay related to the parameters RC.

Finite Volume Method



To avoid modeling delays, we can also view each pipe as a set of finite volumes. The temperature of each volume i is then described by

$$lC\dot{T}_i(t) = -Cq(t)(T_i(t) - T_{i-1}(t)) - \frac{l}{R}(T_i(t) - T_b(t)) \tag{2}$$

This makes the temperature a high-dimensional but sparsely structured linear time dependent (due to time-varying flows) system.

Hydraulics

Hydraulics dictate the relationship between flows and pressure heads in the network. An edge between nodes i and j in the network experience the flow q_{ij}. The difference in nodal head p_i - p_j is then decided by the Darcy-Weisbach equation:

$$p_i - p_j = a_{ij}q_{ij}|q_{ij}| \tag{3}$$

where a_{ij} is a friction factor to be estimated by data. The parameter is slightly dependent on the flow rate, as it varies with the turbulence of the water.

The goal is to estimate the **friction factors** $\mathrm{a_{ij}}$. There are several complications.

- Nodal heads and flows are in general not measured everywhere.
- Measurements may be noisy where they are available at all.
- Friction factors corresponding to valves, such as in customer substations, are time dependent.
- Many parameters may be lumped (resistors in series).

Other Work

See how hydraulic parameters can be used to reduce unfair heat distribution due to bottlenecks in district heating systems.

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