ETH zürich

Multi-horizon modeling

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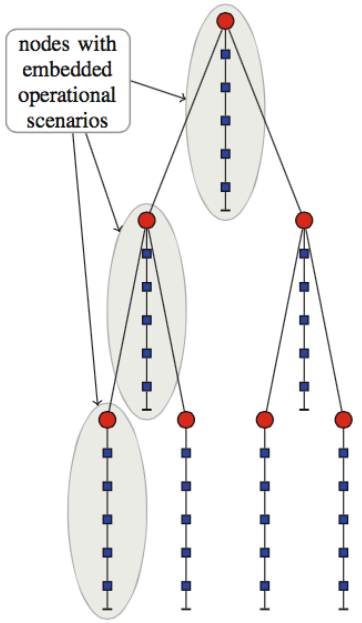
“Multi-horizon modeling”

- Multi-horizon decision trees:
  - Multi-horizon programming [1]
  - strategic / operational decisions
- Our previous works:
  - Inter- / intrastage decisions

-> same idea



[1] Kaut, M., Midthun, K., Werner, A., Tomasgard, A., Hellemo, L., Fodstad, M.. Multi-horizon stochastic programming. Computational Management Science 2013.

Outline of this talk

1. Idea of multi-horizon programming
2. Multi-horizon modeling for hydro scheduling
3. Alternative approaches
4. Comparison
5. Wrap up

1. Idea of multi-horizon programming

1. Idea of multi-horizon programming (1/2)

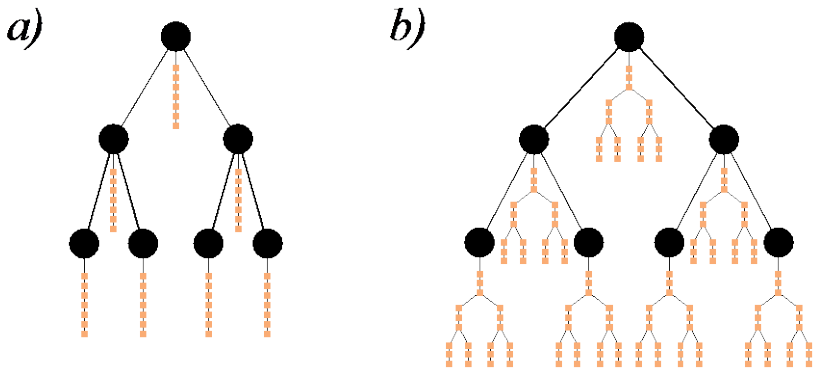
Multi-horizon decision trees

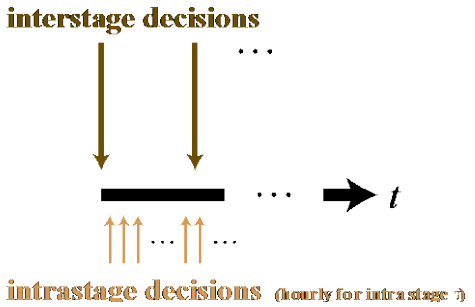
Two different types of decisions:

- different time scales
- subject to different uncertainties

Examples:

- investment / operational decisions
- medium-term / short-term scheduling decisions
- inter- / intrastage decisions





1. Idea of multi-horizon programming (2/2)

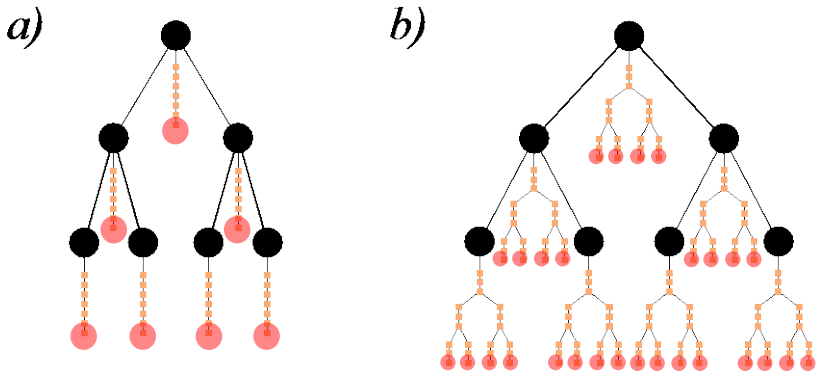
Pros / Cons

Purpose:

- reduce complexity of the tree

Costs:

- information about the state of the system at terminal intrastage is lost.

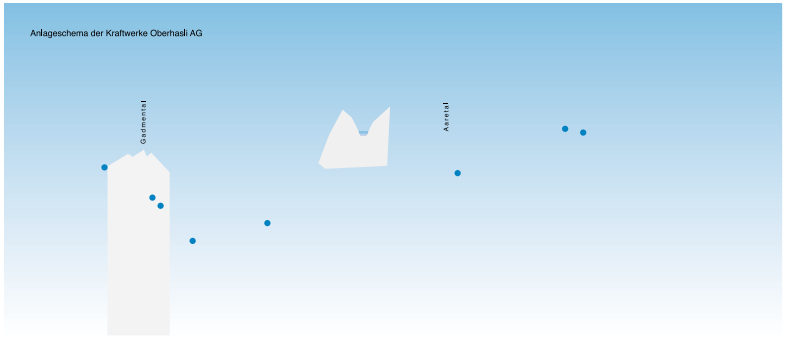


2. Multi-horizon modeling for hydro scheduling

2. Multi-horizon modeling (1/4)

Storage reservoirs:

- Store water inflows for dryer periods
- Seasonal operation



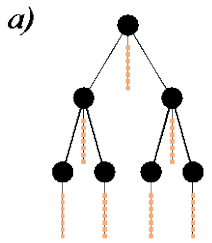
Balancing reservoirs:

- Gather / balance out water inflows
- Important in daily operation

2. Multi-horizon modeling (2/4)

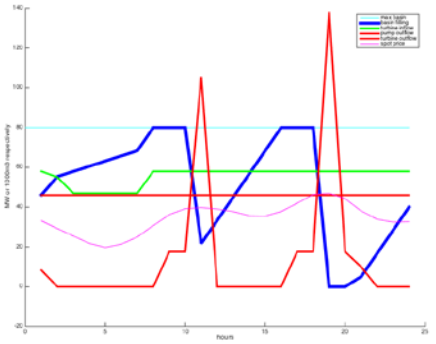
interstage problem:

- state: storage reservoirs
- decision: water discharge
- subject to uncertainty
- water value



intrastage subproblem:

- state: balancing reservoirs
- decision: hourly production
- deterministic problem

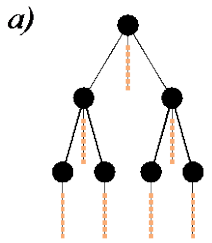


2. Multi-horizon modeling (3/4)

Remarks: modeling perspective

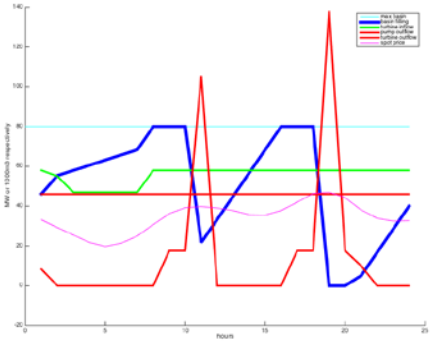
Advantages:

- mimics operators thinking
- usage of daily patterns



Disadvantages:

- „reset“ balancing filling each day
- more complex formulation

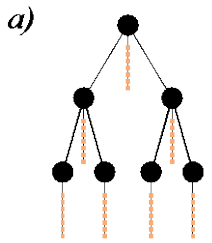


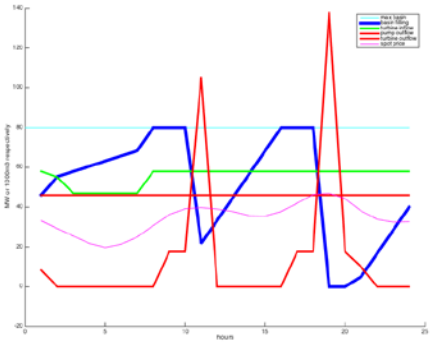
2. Multi-horizon modeling (4/4)

Remarks: computational perspective

Solution methodology:

- Interstage problem:
  - formulated dynamically: SDP or SDDP
  - storage reservoirs as state variables
- Intrastage subproblem:
  - formulated as deterministic equivalent
  - LP or MIP solver is used





Strengths of both dynamic programming and mathematical solvers are exploited:

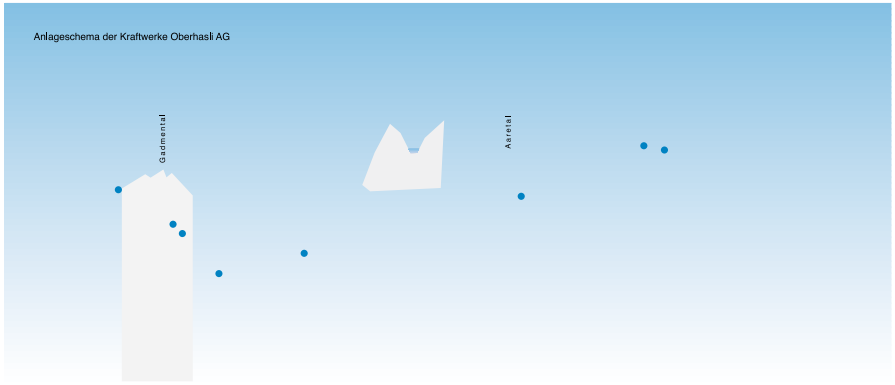
1. avoided curse of dimensionality in time
2. efficient solving of daily optimization problems

3. Alternative approaches

- hourly model
- daily model
- daily intrastage model

3. Alternative approaches (1/3)

How to model medium-term scheduling?



time step	states	SDP	SDDP	model	complexity
Traditional modeling:					
hourly	stor./bal.	+	−	+	−
hourly	storage	++	+	−−	+
daily	storage	++	++	−	++
Multi-horizon:					
daily/hourly	stor./bal.	++	++	++	+

how to model it ?

3. Alternative approaches (2/3)

Simple but powerful trick:

- balancing reservoirs not considered in value function but only in the constraints
  - -> less number and volatile states
  - -> no aggregation needed
  - -> but no water storage in balancing reservoirs

1. hourly model: hourly time steps
2. daily model: daily time steps

3. Alternative approaches (3/3)

3. Daily intrastage model (e.g. as in [2]):
   - inter/intrastage problems
   - physical differences of reservoirs not exploited

Pros:

-> balancing reservoirs: considered in value function

-> storage reservoirs: water balance in hourly resolution

-> simpler model and formulation

Cons:

-> only deterministic intrastage problems possible (because of comp. complexity)

-> more states

-> difficult to estimate daily balancing fillings

[2] Loehndorf, N., Wozabal, D., Minner, S.. Optimizing trading decisions for hydro storage systems using approximate dual dynamic programming. Operations Research 2013.

4. Comparison

- computational complexity
- modeling accuracy

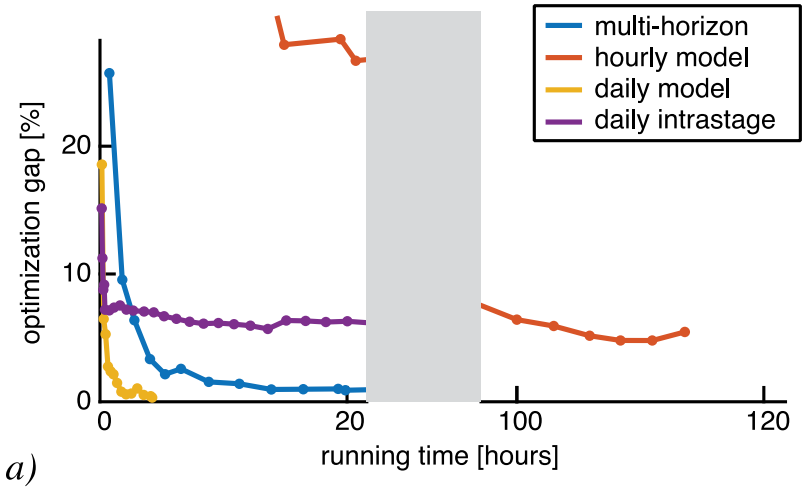
4. Comparison (1/2)

Optimization gap: Difference upper / lower bound

- multi-horizon: 0.5% (30 hours)
- hourly model: 5% (100 hours)
- daily model: 0.5% (2 hours)
- daily intrastage: 7% (0.5 hour) / 6% (48 hours)

However:

- what gap is “ok”?
- what is a good model?



a)

4. Comparison (2/2)

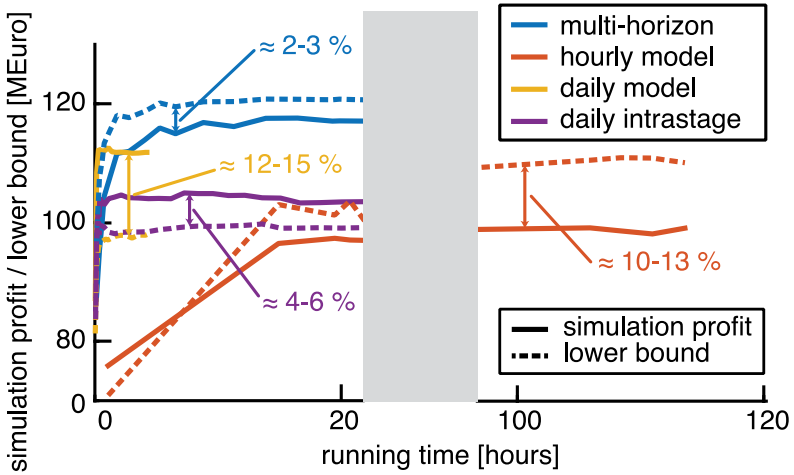
Goal: accurate model!

1. optimization gap <-> quality of policy:
   - indeed: lower gap <-> better policy

2. Simulation profit: simulated “reality”
   - multi-horizon: 115 MEuro
   - hourly model: 90 MEuro
   - daily model: 110 MEuro
   - daily intrastage: 105 MEuro

-> overfitting?

3. **Difference lower bound <-> simulation profit:**
   - **multi-horizon: 2-3%**
   - hourly model: 10-13%
   - daily model: 12-15%
   - daily intrastage: 4-6%



5. Conclusion

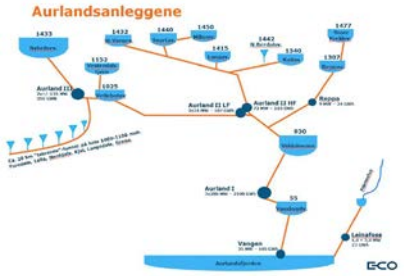
5. Conclusions

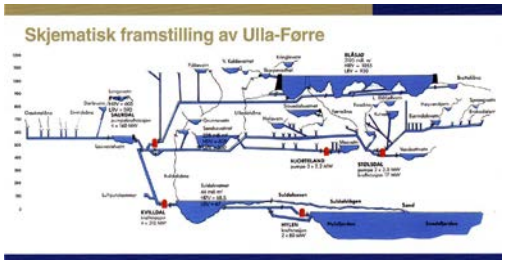
Multi-horizon modeling approach:

- flexible modeling approach (stochastic intrastage subproblems possible etc.)
- includes short-term flexibility in a medium-term optimization
- mimics the way operator think
- computational complexity is ok (DP and solvers)

Possible applications:

- for both SDP and SDDP (depending on power plant complexity)
- most valuable for power plants with different types of reservoirs





5. Conclusions

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- inclu
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Takk you for your attention!

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