Comparative study of two head effect modelling approaches for hydropower production planning

Hydropower scheduling converence

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Introductory part

- Outline
- Introduction
- Main contributions summarized

Outline

- Introduction
- Contributions summarized
- Brief description of the two models
  - Bilinear
  - Triangularization
  - Pros and cons
- The comparison – briefly
- Some results
- Conclusion

Formalities

- Presentation based upon Master’s thesis results
  - Modeling the Head Effect in Hydropower River Systems using MILP and BLP Approaches
  - https://www.diva-portal.org/smash/get/diva2:1685995/FULLTEXT01.pdf
- Intention: Modifications/improvements for the journal
- The students cannot attend – new jobs
- Lars and Jonas supervised

Background

- Need for head effect consideration identified
- Determine which model suited which needs
  - Medium-to-Long-term studies
    - Investment analyses
    - Outage planning
    - Environmental studies
- Begin with comparison of models
  - Proposed new and existing modeling approaches
  - The students chose two – one each
  - One existing (some adaptations), one new

Main contributions summarized

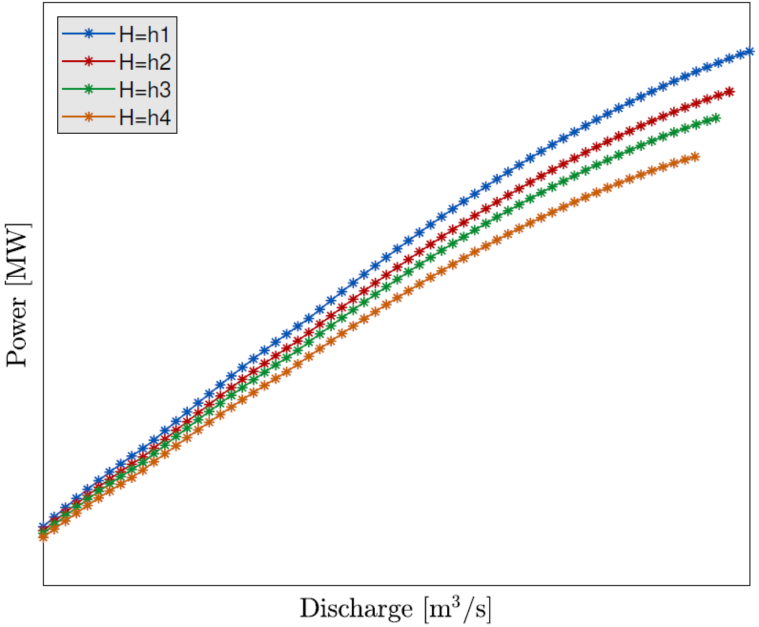
- Bilinear model development, including parameter estimation
- Comparing the triangulation and bilinear models
- Head effect importance of stations

The two head-effect-considering models

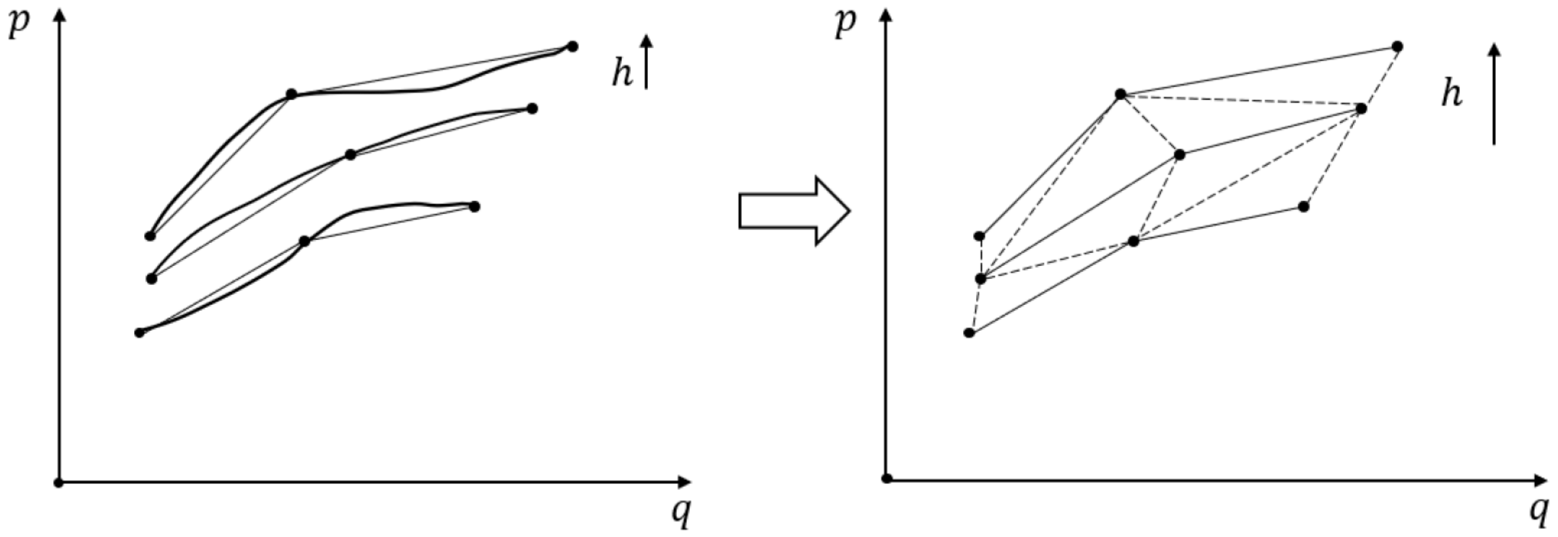
- Triangulation (MIP, existing)
- Bilinear (NLP/QP/QCQP, new)

Production functions background

- Head/Level/volume
- Production functions head dependency
  - Not only head
  - Level dependencies, e.g., river losses
- Levels and volumes
  - Reservoirs are irregular – not rectangular cuboids
    - Avoiding complicated constraints converting between levels/volumes
  - **Desire**: volumes production function independent variables
    - Upper & lower
    - Head effect including river losses

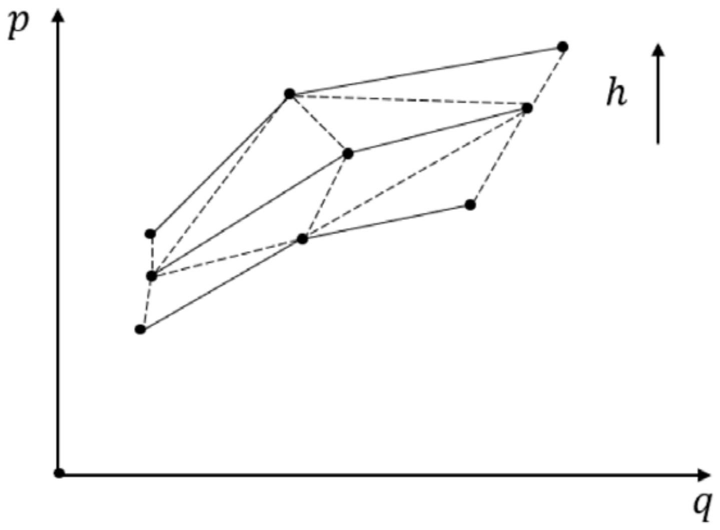


Graphical illustration of triangulation

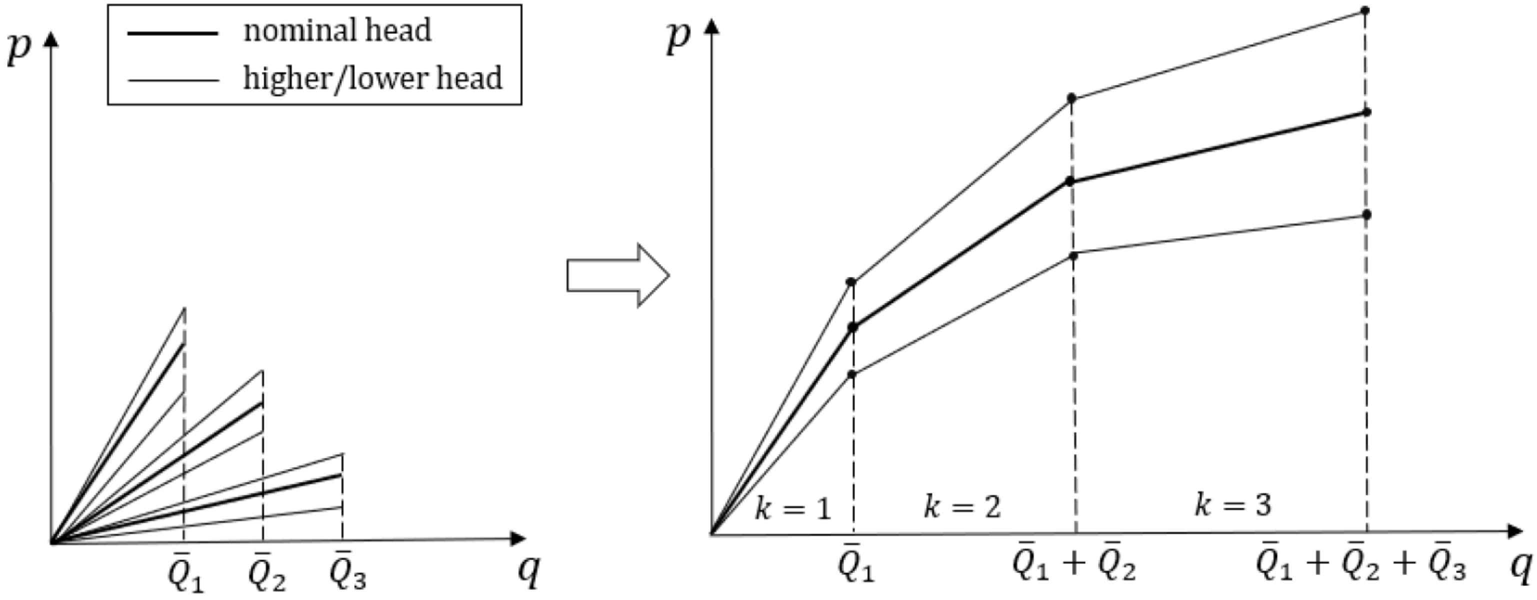


Triangulation

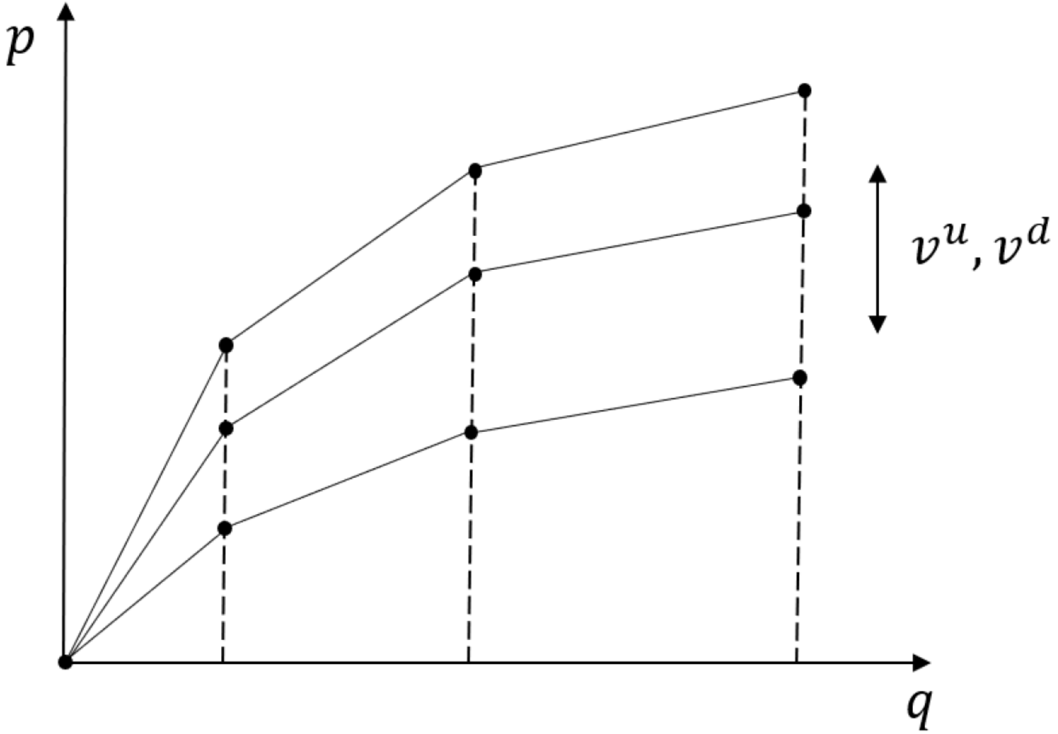
- Quadrangles / quadrilaterals / tetragons – no unique mapping
- Head linearly determined by volumes
  - Rectangular cuboid assumption
  - Tetrahedrons => more binaries => overcomplicated initial model



Graphical illustration of bilinear (1/2)

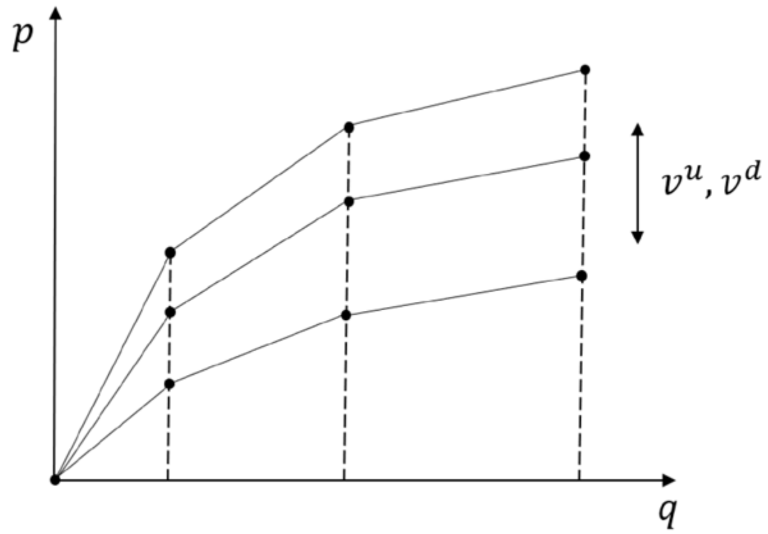


Graphical illustration of bilinear (2/2)



Bilinear

- Piecewise linearly concave in turbine discharge
- Gradient affine function of upper/lower volumes
- Parameters estimated – contribution in itself
  - Gradient
    - Nominal
    - Upper volume dependency
    - Lower volume dependency
  - $\bar{Q}$ volume dependency (not yet)



Pros and cons

- Triangulation
  - Unit commitment automatically included
  - Forbidden bands of operation easily implementable
- Bilinear
  - Nonconcave => global QCQP solvers exists (slower)
  - Faster, slightly lower accuracy

The comparison

- Very simplified explanation
- No detailed optimization to compare with
- Truth: detailed results from simulator
- Accuracy: power RMSE head effect reduction
  - Compared to a reference case

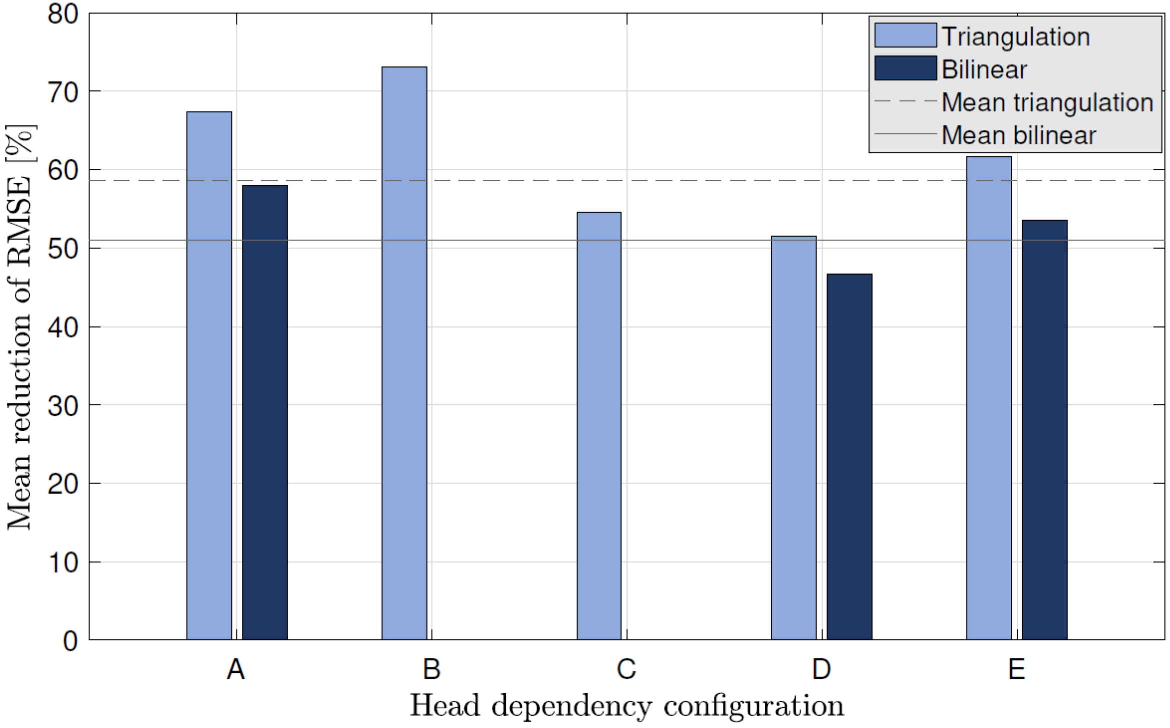
Results

- Head dependency comparison, accuracy/speed trade-off
- Brief visualization of conservativeness
- Summary

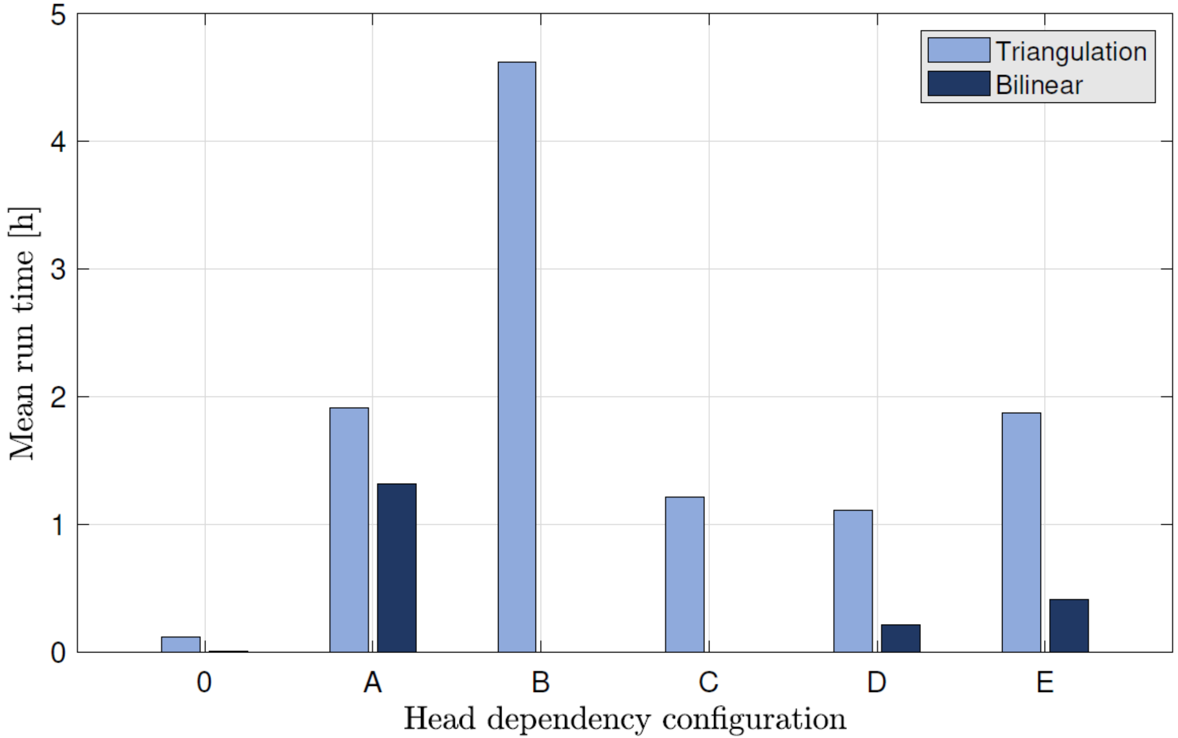
Head dependency

Head dependency name	Description	Triangulation	Bilinear
A	All stations ”normally” head dependent		
B	All stations very head dependent		
C	Distribution method 1: not, normal, very		
D	Distribution method 1: not, normal		
E	Distribution method 2: not, normal		

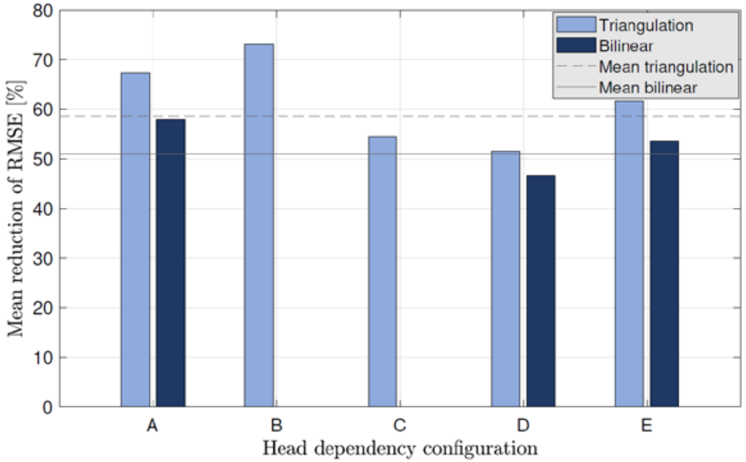
Head dependency: RMSE reduction

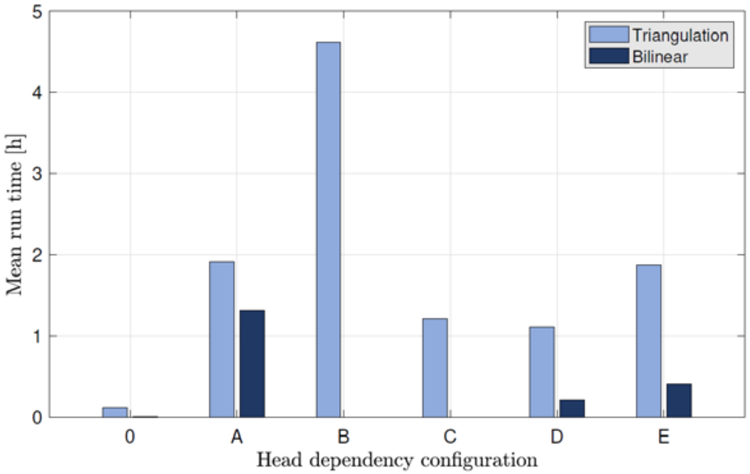


Head dependency: run time



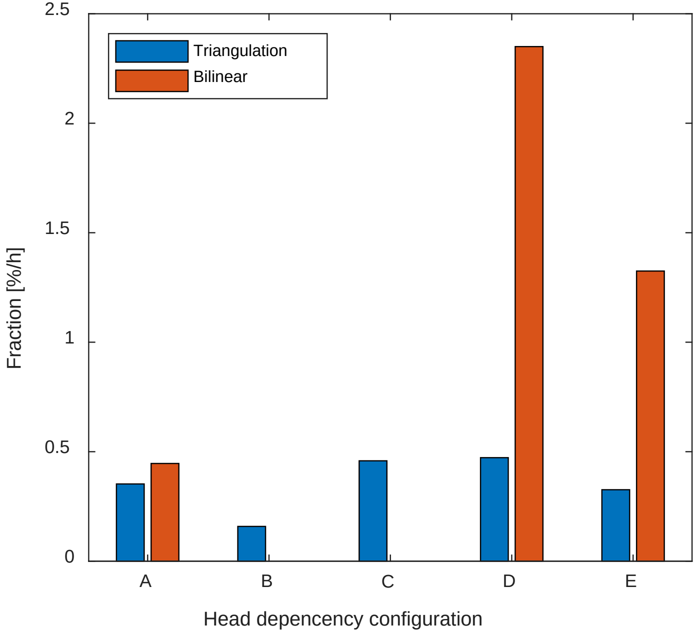
Head dependency comparison (1/2)





Head dependency comparison (2/2)

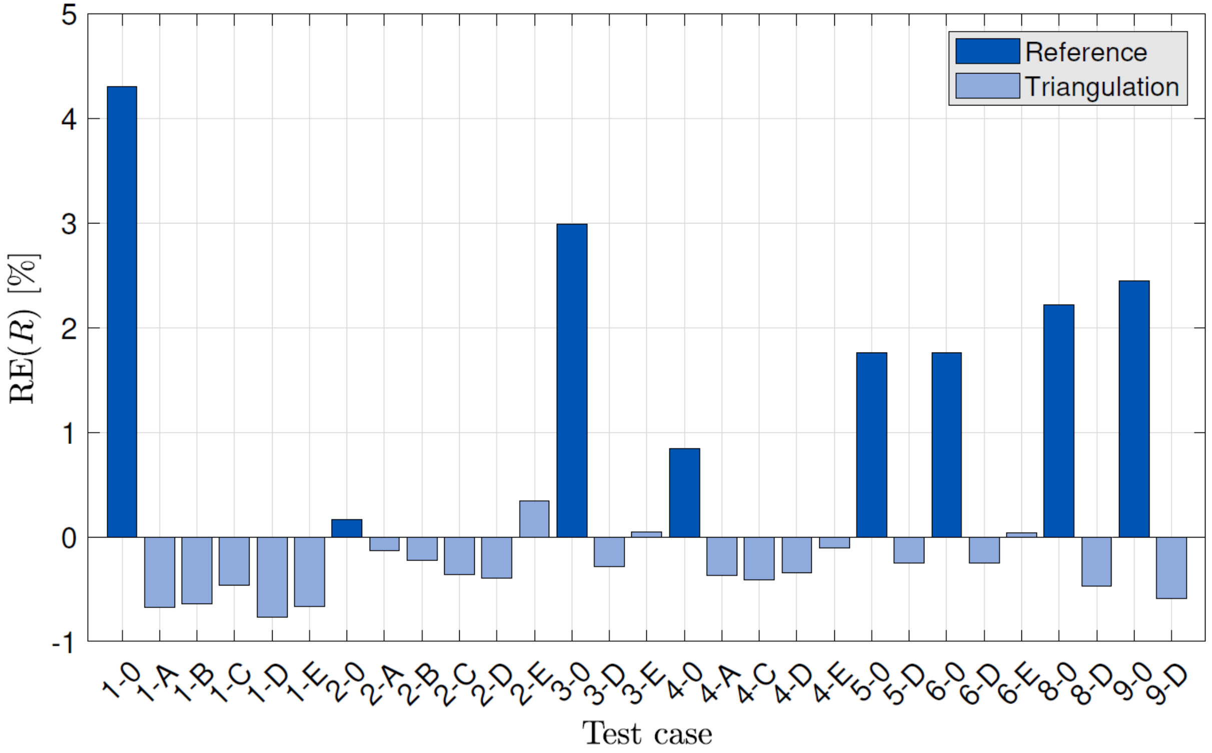
- Accuracy/time trade-off
- Indeed, a rudimentary measure
- But – It visualizes some things
  - Tri.: for (very) high accuracy
  - Bilinear: offers a good trade-off
  - Distribution method 1 outperforms method 2
  - Third triangulation head-curve not crucial



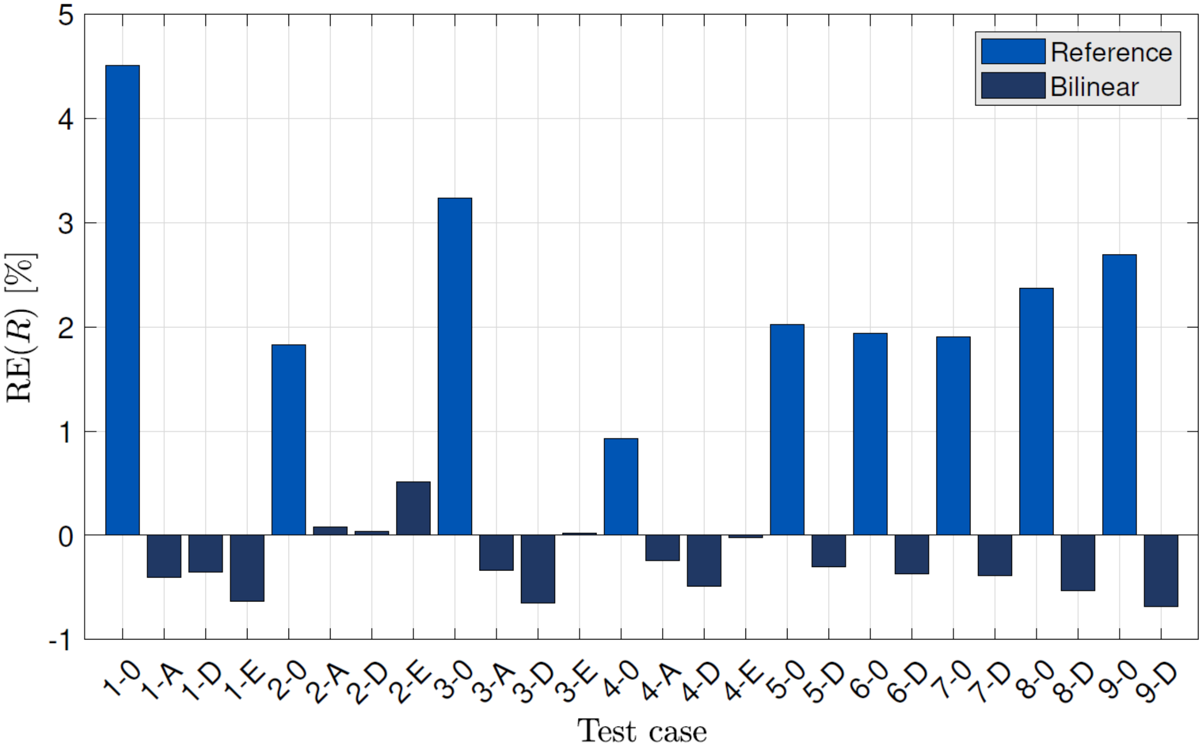
Conservativeness

- Two following slides
- Illustrating
  - Reference (head neglecting) case overestimating revenues
  - Both methods conservative majority test cases

Triangulation relative revenue error



Bilinear relative revenue error



Summary of results

- Proposed new approach seems attractive
  - Triangulation
    - 59 % reduction of RMSE (to its corresponding reference)
    - Longer computational times:
  - Bilinear approach
    - 51 % reduction of RMSE (to its corresponding reference)
    - Shorter computational times:
- Efficient: stations subset considering head effect

Conclusion

- Discussion
- Conclusion
- Future Work

Discussion

- Dependency on model parameters at hand
  - Not extrapolate conclusions too far
  - Different rivers have different conditions
    - E.g., stricter water-rights judgements => UC importance
  - Quality of data
    - Production curves E.g., two head curves in triangulation
    - Reservoir shape
- Comparison focused on power RMSE
  - Accuracy measures depending on study?
  - Revenue? Reservoir volumes? Flows?

Conclusion

- Proposed model show promising properties
- Station head-dependencies can be quantified & ranked
  - Note: Scenario-dependent component required
  - Usage motivated from accuracy/time trade-off analysis

Future work (1/2)

- Bilinear
  - Investigate the impacts of nonconcavity
    - Compare global with local(QC)QP solvers
  - Improve/finish the parameter estimation
    - E.g., segment lengths head dependent
    - Million strategy-dependent options of improvement
- “Fairer” competition for analysis
  - Increase time limits – challenging cases excluded
  - Scenarios chosen
  - Etc.

Future work (2/2)

- Many other modeling approaches in pipe
  - Purely linear =>
    - Generally: Maybe faster and good “enough”
    - Head effect importance: Alleviate low-head issue
  - Two-curve triangulation => simpler model type
    - Head: convex combination or binary selection
    - Turbine discharge: piecewise linear concave
- Analyze usefulness of using multiple cores
  - Theoretically triangularization method (MILP) should benefit more
  - Memory
  - Thorough study needed

The End

- Questions?
- Discussion …
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