

Batched optimization solvers: a tour d'horizon

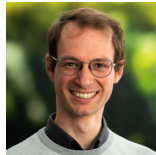
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<https://madsuite.org/>



Batch optimization problems

Batch LPs

For $\theta_k = (c_k, b_k, A_k)$, $k = 1, \dots, N$, define

$$\begin{aligned} \text{LP}(\theta_k) &:= \min_{x_k \in \mathbb{R}^n} c_k^\top x_k \\ &\text{subject to } A_k x_k = b_k, x_k \geq 0. \end{aligned}$$

Solution is $X = [x_1 \dots x_N] \in \mathbb{R}^{n \times N}$.

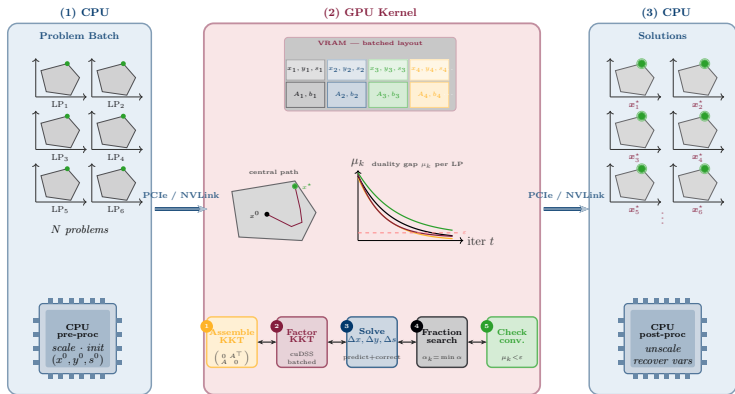
Numerous applications:

- Parametric programming
- Stochastic optimization
- Energy studies
- Neural optimization layer

GPU-accelerated optimization algorithms

- First order (PDLP, ADMM)
- **Second order** (interior-point)

MadIPM: an open-source batch optimization solver



Performance tricks

- Preprocessing is key;
- Data should be contiguous in memory;
- Leverage NVIDIA cuDSS to solve the linear KKT systems in batch;
- Small overhead from KernelAbstractions.jl.

Current performance

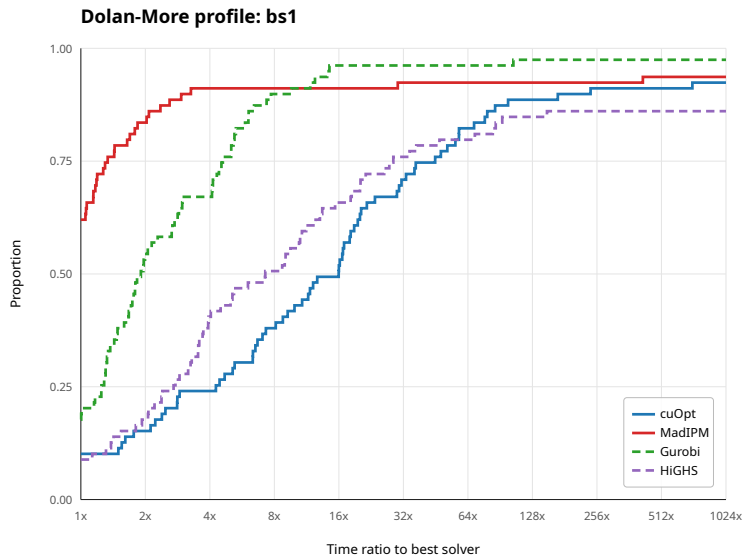


Figure: Performance profile on 76 large-scale LP instances from MIPLIB. $N = 1$.

Current performance

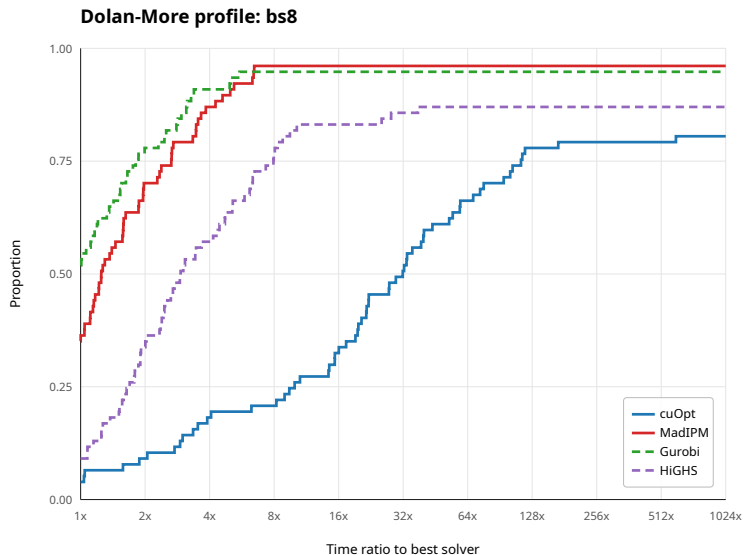


Figure: Performance profile on 76 large-scale LP instances from MIPLIB. $N = 8$.

Current performance

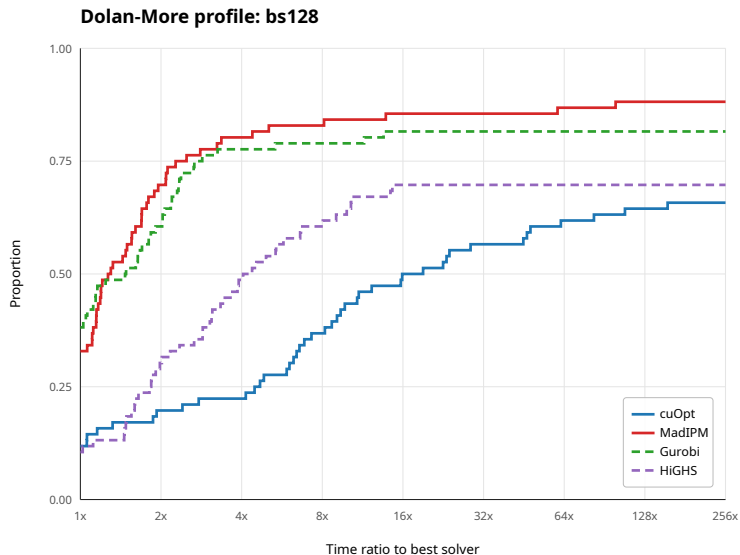


Figure: Performance profile on 76 large-scale LP instances from MIPLIB. $N = 128$.

Challenge #1: how to make it user friendly?

Observation

At the moment → BatchQuadraticModels (require advanced knowledge)

Next steps:

- ExaModels
- MathOptInterface/JuMP (BatchOptInterface.jl)

```
using JuMP, MadIPM, BatchOptInterface
const BOI = BatchOptInterface

model = Model(MadIPM.BatchOptimizer)
@variable(model, x >= 0)
@variable(model, p in BOI.BatchedParameter([1.0, 2.0, 4.0]))
@constraint(model, x >= 0.5 * p)      # batched right-hand side
@objective(model, Min, p * x)      # batched objective coefficient

optimize!(model)
```

Challenge #2: how to leverage the LP structure?

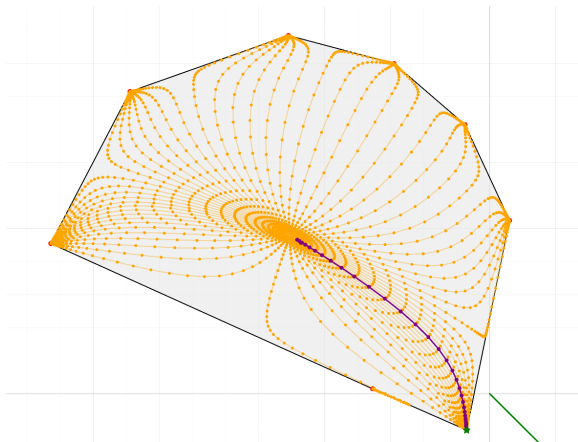


Figure: Central paths obtained for different costs vectors c_k on the same feasible set. Image generated by lpviz.net.

Research challenge

If the parameters $\theta_k = (c_k, b_k, A_k)$ are structured, the solution matrix X is likely to be low rank. **How can we exploit this structure efficiently in IPM?**