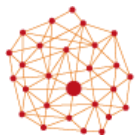


LocalSolver

LocalSolver: recent advances in solving hydro valley optimization problems

Thierry Benoist Julien Darlay Bertrand Estellon
Frédéric Gardi Romain Megel

www.localsolver.com

Who we are

Bouygues, one of the French largest corporation, €33 bn in revenues

http://www.bouygues.com

Innovation24

Operations Research subsidiary of Bouygues
15 years of practice and research

http://www.innovation24.fr

LocalSolver

Mathematical optimization solver commercialized by Innovation 24

http://www.localsolver.com

LocalSolver 5.0

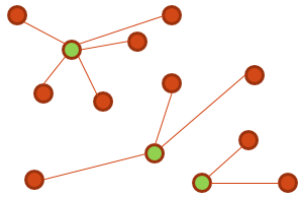
Hybrid math optimization solver

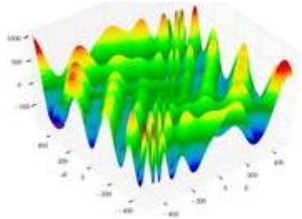
For combinatorial, numerical, or mixed-variable optimization

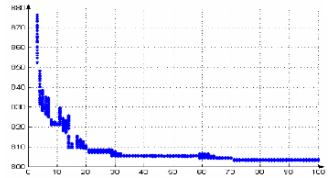
Particularly suited for large-scale non-convex optimization

High-quality solutions in seconds without tuning

LocalSolver
=
LS + CP/SAT + LP/MIP + NLP







free trial with support – free for academics – renting licenses from 590 €/month – perpetual licenses from 9900 €

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LocalSolver 5.0

Quick tour

Combinatorial optimization

P-median: select a subset P among N points minimizing the sum of distances to each point from N to the nearest point in P.

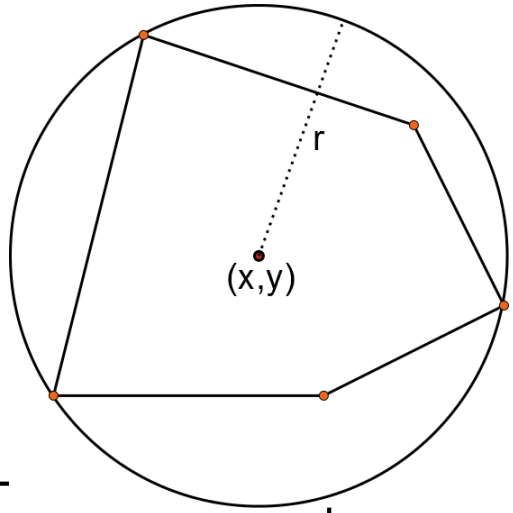
```
function model() {
  x[1..N] <- bool() ; // decision : point i is in P iff x[i] = 1

  constraint sum[i in 1..N](x[i]) == P ;

  minDist[i in 1..N] <- min[j in 1..N](x[j] ? Dist[i][j] : InfiniteDist);

  minimize sum[i in 1..N]( minDist[i] ) ; // minimize sum of distances
}
```

Nothing else to write: "model & run" approach

- Straightforward mathematical model
- Direct resolution: no tuning

Numerical optimization

Smallest circle: find a circle with minimal radius which contains a set of points in the plane.



Quantitative (continuous) decisions

Quadratic expression

```
x <- float(minX, maxX);
y <- float(minY, maxY);

r2 <- max[i in 1..n](pow(x-coordX[i],2) + pow(y-coordY[i],2));

minimize sqrt(r2);
```

Mathematical operators

Decisional	Arithmetic			Logical	Relational
bool	sum	sub	prod	not	==
float	min	max	abs	and	!=
int	div	mod	sqrt	or	<=
	log	exp	pow	xor	>=
	cos	sin	tan	if	<
	floor	ceil	round	array + at	>

New in 5.0: operator piecewise to model piecewise linear functions

Hydro valley optimization

Hydro valley optimization

Management of hydro valleys

- Hydroelectric dams with pumps
- Forecasted/approximate energy prices over the horizon
  Or thermal power plants to manage for pricing
- From daily to yearly horizon

→ Nonlinear large-scale dynamic system with mixed-variable (on/off + quantitative) decisions and tight coupling constraints

Solved through MIP solvers by approximating/relaxing nonlinearities

Difficulties

Mixed, layered decisions

- Combinatorial on/off decisions
- Quantitative production decisions
- Two layers of decisions → structures

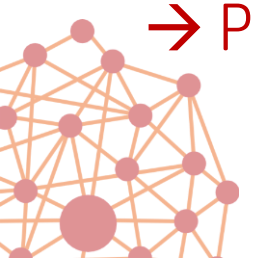
Hard coupling constraints

- Hard constraints on on/off decisions (ex: ramping constraints)
- Hard constraints on quantitative decisions (ex: flows with tight capacities)

Nonlinearities

- Piecewise-linear constraints and costs
- Quadratic (possibly non-convex) constraints and costs

→ Poor linear relaxation, hard for rounding & diving MIP heuristics



LocalSolver approach

Structure detection

Automatic detection of layered decisions

- Detection of the link between on/off and quantitative layers
- Allow to search on structured subspaces
- Allow to recover feasibility easier and faster at each iteration

Automatic detection of global constraints (= subproblems)

- Knapsack subproblems
- Dynamic nonlinear systems: s(t) = s(t-1) + f(not depending on s)
- Allow to apply specific algorithms to solve these subproblems

→ Relying on structures to improve and speedup the search

Structured neighborhood search

Neighborhood search over combinatorial subspace

- Move on/off decisions locally
- Recover feasibility over combinatorial constraints using local/tree search

Neighborhood search over quantitative subspace

- Recover feasibility over continuous subspace
- Based on continuous randomized local/greedy search approach
- If identified structure, dedicated search algorithms (ex: knapsack, LP)

→ Relying on the appropriate optimization techniques
to explore efficiently the appropriate neighborhoods

Benchmarks

Unit commitment: hydro + thermal

Prototyped problem coming from KEPCO

- 1-year global optimization of all hydro + thermal power units
- 100-line model using LocalSolver modeling & scripting language (LSP)
- Mixed decisions: boolean (on/off) and continuous (power)

- Business scale:
  - 365 * 24 = 8760 time steps
  - 30 thermal power units
  - 4 dams and 18 hydro power units
- Mathematical scale:
  - 3 M expressions (= variables)
  - 1 M decisions whose 560,000 are binaries
  - 80,000 constraints

THE KANSAI ELECTRIC POWER CO.,INC.

Unit commitment: hydro + thermal

Prototyped problem coming from KEPCO

- Hours to obtain good-quality solutions using MIP
- LocalSolver 5.0

1 sec	483,805,637
1 min	483,639,031
10 min	483,632,703

Lower bound based on linear relaxation: 483,338,873

LocalSolver 6.0

Planned for the end of 2015

- New operators based on collections to model routing problems (TSP, VRP)
- New technicalities to solve efficiently these problems

Don't wait to start using LocalSolver

- We offer you free trial or academic licenses
- We offer you a free support for modeling & solving your problems

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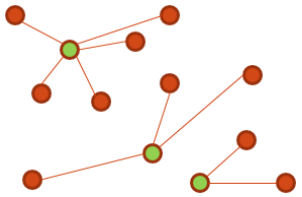

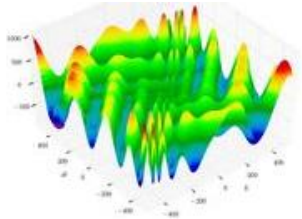

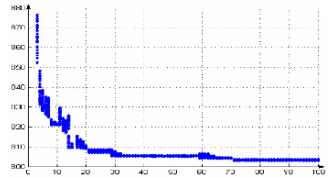

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