Best practices for using the multistart algorithm in AIMMS

Marcel Hunting
AIMMS Optimization Specialist

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Overview

- Introduction: Global versus local optimization
- The AIMMS multistart algorithm visualized
- Parallel multistart
- Other changes in AIMMS 4.9
- Remarks & references

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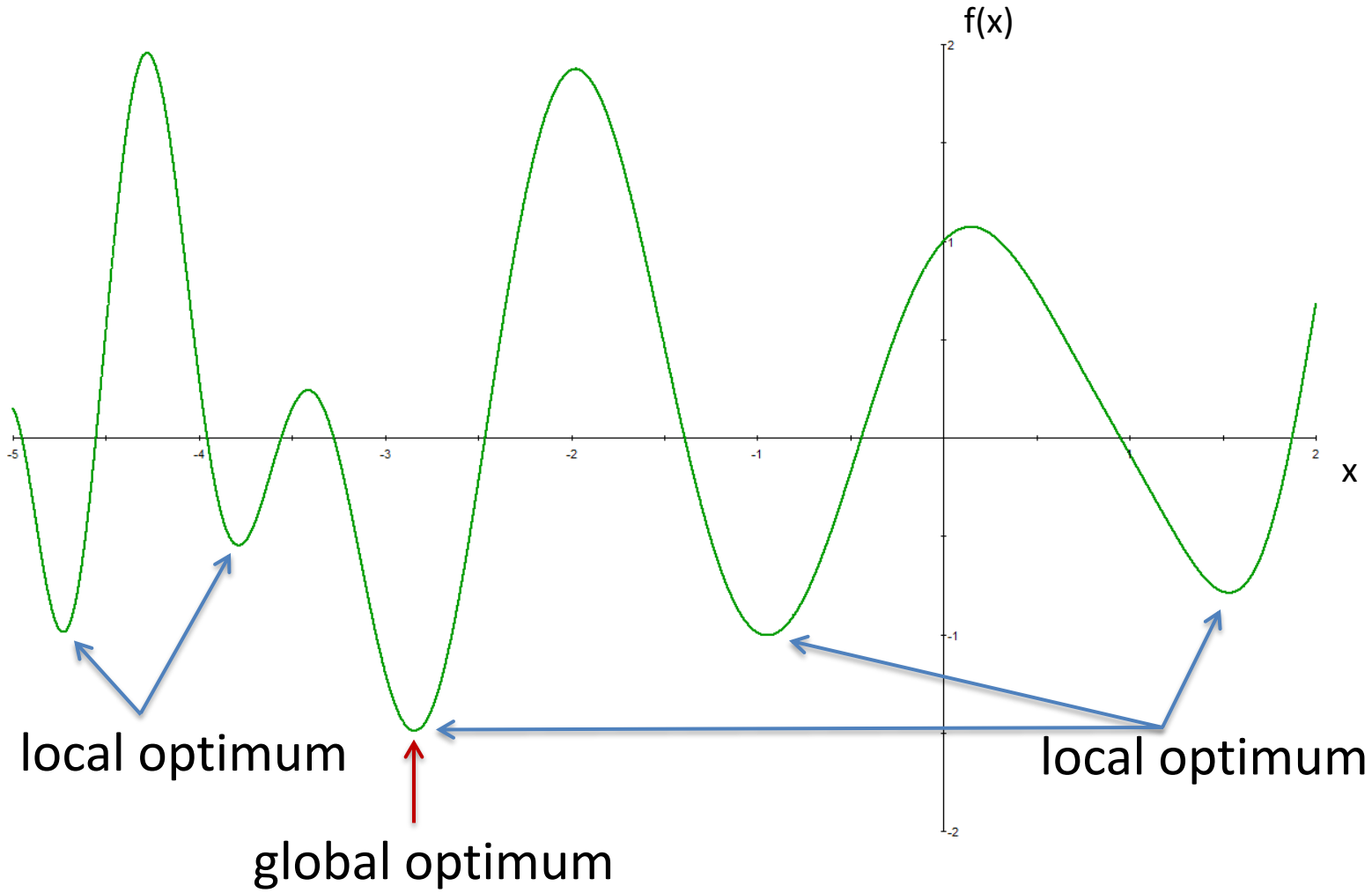
Global versus local optimum



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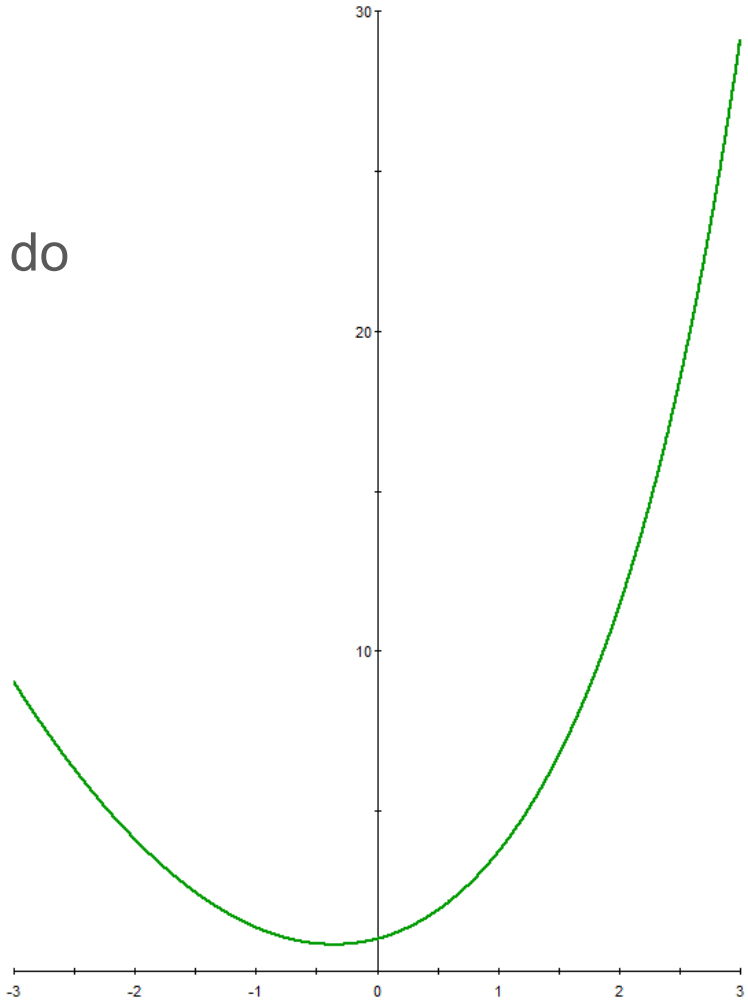
Convex problems…

…local solver will do



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Global nonlinear solvers (+ drawbacks)

> BARON

- Can “only” handle problems up to 10,000 variables and constraints
- Cannot handle problems with goniometric functions, external functions, if-then-else, x^y

> CPLEX

- Can solve non-convex quadratic programming problems
- Option Solution Target

BARON and CPLEX can also handle problems with integer variables

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Multistart parameters

- MulStart::IterationLimit
- MulStart::UsePresolver
- MulStart::UseInitialPoint
- MulStart::ShrinkFactor
- MulStart::NumberOfBestSolutions
- MulStart::ShowSolverProgress
- MulStart::ThreadLimit
- MulStart::UseOpportunisticAlgorithm

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Parallel multistart

- Controlled by the parameter MulStart::ThreadLimit
  - Default 0: Use as much threads as possible

- Amount of threads used is limited by:
  - Number of cores
  - AIMMS license & Solver

- Uses one solver
  - Not possible: a CONOPT solve in parallel with an IPOPT solve

- Can be *deterministic* or *opportunistic*
  - Deterministic means that multiple runs with the same model using the same parameter settings and the same solver on the same computer will produce the same results

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Parallel multistart – Results

Model: Elec Minimization, 601 vars, 201 cons, 1201 nz

Iterations: 2 Selected sample points: 8 (from 16)

Mode	Deterministic				Opportunistic			
Threads	**1**	**2**	**4**	**8**	**1**	**2**	**4**	**8**
# Solves	16	16	16	16	16	16	16	16
# Solutions	16	16	16	16	16	16	16	16
Objective	18439	18439	18439	18439	18439	18439	18439	18439
Time	131.6	80.3	53.4	42.1	129.3	73.5	51.7	41.7
Speed up	1.00	1.64	2.47	3.13	1.02	1.76	2.50	3.10

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Parallel multistart – Results (cont'd)

Model: Trainf Minimization, 20001 vars, 10003 cons, 60001 nz

Iterations: 5 Selected sample points: 8 (from 16)

Mode	Deterministic				Opportunistic			
Threads	**1**	**2**	**4**	**8**	**1**	**2**	**4**	**8**
# Solves	7	6	8	8	7	8	7	8
# Solutions	1	1	1	1	1	1	1	1
Objective	3.1034	3.1034	3.1034	3.1034	3.1034	3.1034	3.1034	3.1034
Time	115.8	85.1	80.6	73.9	115.9	77.1	69.1	73.0
Speed up	1.00	1.36	1.44	1.57	1.00	1.50	1.68	1.59

Remark: First solve takes much longer than rest

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Parallel multistart – Results (cont'd)

Model: South Maximization, 82 vars, 67 cons, 379 nz

Iterations: 100 Selected sample points: 32 (from 64)

Mode	Deterministic				Opportunistic			
Threads	**1**	**2**	**4**	**8**	**1**	**2**	**4**	**8**
# Solves	75	89	95	95	75	90	94	97
# Solutions	62	72	78	78	62	73	77	79
Objective	596.34	601.83	601.83	601.83	596.34	601.83	601.83	601.83
Time	15.6	14.6	14.5	13.8	15.1	13.7	14.0	13.7
Speed up	1.00	1.07	1.08	1.13	1.03	1.10	1.08	1.10

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Parallel multistart – Results (cont'd)

Model: Blotter Maximization, 24491 vars, 1180 cons, 126261 nz

Iterations: 3 Selected sample points: 32 (from 64)

Mode	Deterministic				Opportunistic			
Threads	**1**	**2**	**4**	**8**	**1**	**2**	**4**	**8**
# Solves	77	78	78	78	77	78	78	79
# Solutions	77	78	78	78	77	78	78	79
Objective	847.09	847.09	847.09	847.09	847.09	847.09	847.09	847.09
Time	9689.9	6851.3	5160.9	4087.6	9834.0	5329.1	3300.7	2953.3
Speed up	1.00	1.41	1.88	2.37	0.99	1.85	2.94	3.33

Remark: With 8 selected sample points objective is 844.85

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Solvers suitable for parallel multistart

> Solver has to be thread-safe
  - CONOPT
  - KNITRO

> Not thread-safe are: MINOS, SNOPT, (BARON)

> Special case: IPOPT
  - Thread-safety depends on Linear Solver (used to solve sparse symmetric indefinite linear systems)
    - MUMPS (not thread-safe) ← Only one available in AIMMS
    - MKL Pardiso (thread-safe)
    - HSL (thread-safe)

Build yourself. For instructions see:
https://projects.coin-or.org/AIMMSlinks

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Multistart changes in AIMMS 4.9

- Parallel multistart
- Use AIMMS Presolver by default
- Improved documentation in the Language Reference
- Progress window

MulStart::ShowSolverProgress

```
SOLVER          : CONOPT 3.14V
  Phase         : MultiStart
  Iterations    : 1
  Solves        : 2          (Threads: 1)
  Solutions     : 2
  Best Solution : 18438.90757
  Time          : 20.61 sec
```

```
SOLVER          : CONOPT 3.14V
  Phase         : 4
  Iterations    : 171
  Max Gradient  : 8.78       (NSB: 222)
  Objective     : 18451.27206
  Best Solution : na
  Solving Time  : 4.09 sec   (Memory: 0.7 Mb)
```


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Some remarks

> KNITRO has its own parallel multistart algorithm
  - No clustering
  - No extra license requirements

> GMP-AOA (MINLP) can be used in combination with multistart

In procedure SolveNLPSubProblem, replace

```
GMP::SolverSession::Execute( ssNLP ) ;
GMP::Solution::RetrieveFromSolverSession( ssNLP, SolNumb ) ;
GMP::Solution::SendToModel( GNLP, SolNumb ) ;
```

by

```
MulStart::DoMultiStart( GNLP, 10, 5 );   ! You can play with the input values
GMP::Solution::RetrieveFromModel( GNLP, SolNumb ) ;
GMP::Solution::SendToSolverSession( ssNLP, SolNumb ) ;
```


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References

> Language Reference

- The AIMMS multistart algorithm: Chapter 17.2 (AIMMS 4)

> Z. Ugray, L. Lasdon, J. Plummer, F. Glover, J. Kelly, and R. Marti, Scatter search and local NLP solvers: a multistart framework for global optimization, *INFORMS Journal on Computing* **19**(3), 2007, pp. 328–340.

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