A New Multistart Algorithm

Marcel Hunting
AIMMS Optimization Specialist

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Motivation & Credits

- Presentation by John Chinneck about CCGO at INFORMS 2015
- CCGO was compared with Knitro multistart and AIMMS multistart
- Joined work with Benjamin Harrach

MINES Nantes

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Overview

> Introduction: Global versus local optimization

> The AIMMS multistart algorithm visualized

> The new dynamic algorithm
  - Constraint Consensus Method
  - How to use it

> Experimental results

> Conclusions & remarks

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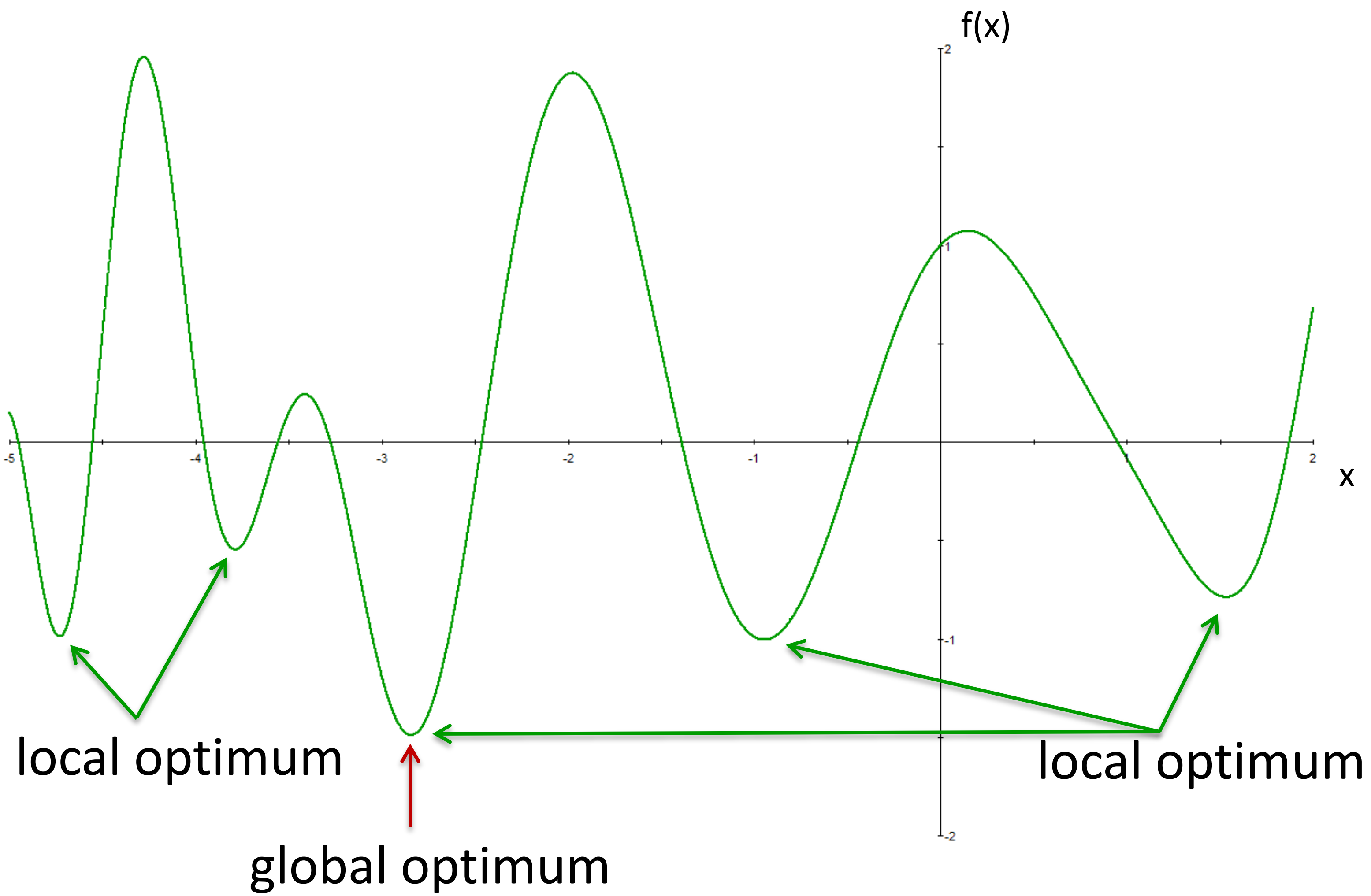
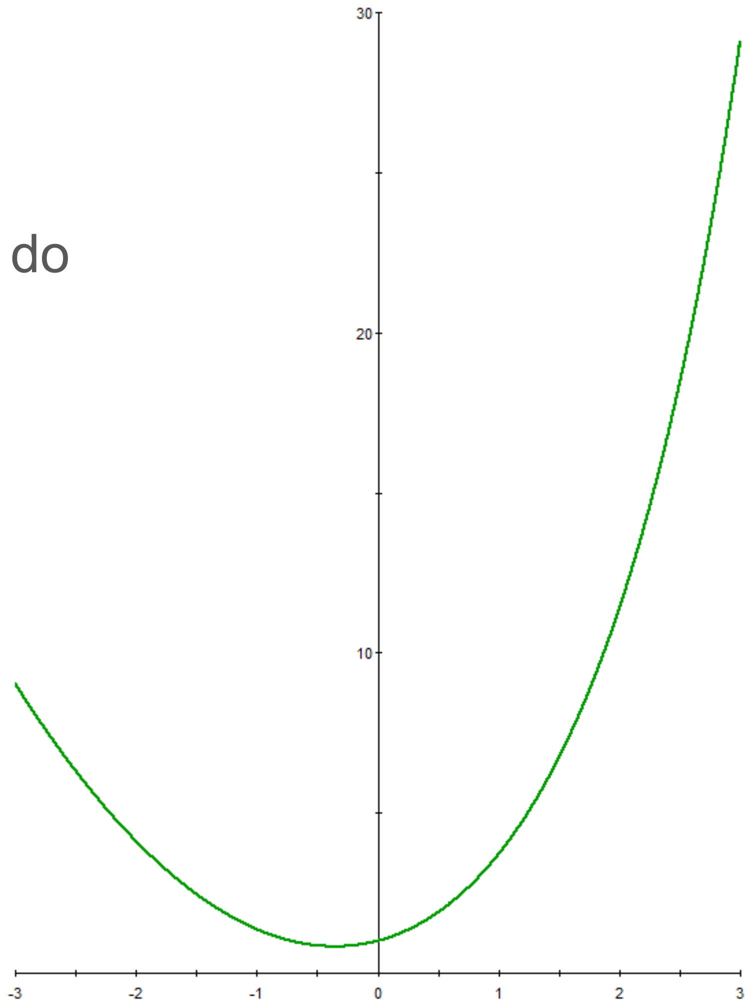
Global versus local optimum



Convex problems…

…local solver will do



Basic multistart algorithm

Input: X & Y

0. Preprocess model

1. Randomly generate X starting points and select Y best from X

2. FOR all Y starting points DO:
    - Skip starting point if it belongs to a cluster
    - Solve NLP to obtain local solution
    - IF local solution belongs to a cluster THEN update cluster
      ELSE create new cluster

3. STOP if iteration or time limit exceeded; else GOTO 1.

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Dynamic multistart algorithm

Input: X & Y

0. Preprocess model.

1. Randomly generate X starting points and select Y best from X

2. FOR all Y starting points DO:
   - Skip starting point if it belongs to a cluster
   - Solve NLP to obtain local solution
   - IF local solution belongs to a cluster THEN update cluster ELSE create new cluster

3. STOP if iteration or time limit exceeded; else GOTO 1.

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Dynamic multistart algorithm

0. Preprocess model. Select X&Y. **Create sampling box.**

1. Randomly generate X starting points and select Y best from X

2. FOR all Y starting points DO:
   - Skip starting point if it belongs to a cluster
   - Solve NLP to obtain local solution
   - IF local solution belongs to a cluster THEN update cluster ELSE create new cluster

3. STOP if iteration or time limit exceeded; else GOTO 1.

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Dynamic multistart algorithm

0. Preprocess model. Select X&Y. Create sampling box. **Apply CCM.**

1. Randomly generate X starting points and select Y best from X

2. FOR all Y starting points DO:
   - Skip starting point if it belongs to a cluster
   - Solve NLP to obtain local solution
   - IF local solution belongs to a cluster THEN update cluster
     ELSE create new cluster

3. STOP if iteration or time limit exceeded; else GOTO 1.

Dynamic multistart algorithm

0. Preprocess model. Select X&Y. Create sampling box. Apply CCM.

1. Randomly generate X starting points and select Y best from X
   Iteration 3: Restrict variable bounds if large infeasibilities

2. FOR all Y starting points DO:
   - Skip starting point if it belongs to a cluster
   - Solve NLP to obtain local solution
   - IF local solution belongs to a cluster THEN update cluster ELSE create new cluster

3. STOP if iteration or time limit exceeded; else GOTO 1.

Dynamic multistart algorithm

0. Preprocess model. Select X&Y. Create sampling box. Apply CCM.

1. Randomly generate X starting points and select Y best from X
   Iteration 3: Restrict variable bounds if large infeasibilities
   Iteration > 5: Apply CCM if no solution found

2. FOR all Y starting points DO:
   - Skip starting point if it belongs to a cluster
   - Solve NLP to obtain local solution
   - IF local solution belongs to a cluster THEN update cluster
     ELSE create new cluster

3. STOP if iteration or time limit exceeded; else GOTO 1.

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Dynamic multistart algorithm

0. Preprocess model. Select X&Y. Create sampling box. Apply CCM.

1. Randomly generate X starting points and select Y best from X
   Iteration 3: Restrict variable bounds if large infeasibilities
   Iteration > 5: Apply CCM if no solution found

2. FOR all Y starting points DO:
   - Skip starting point if it belongs to a cluster
   - Solve NLP to obtain local solution
   - IF local solution belongs to a cluster THEN update cluster
     ELSE create new cluster

3. STOP if **Iteration ≥ 5 and Bayesian rule satisfied** or
   if time limit exceeded; else GOTO 1.

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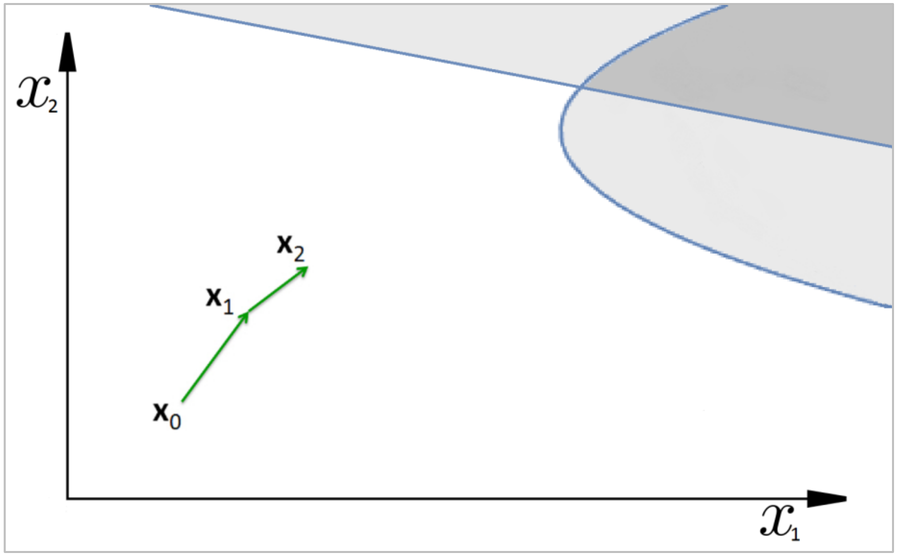
Constraint Consensus Method

- > Developed by John Chinneck (et al.)
- > Goal is to find an almost feasible solution
- > Projection method: iteratively adjust point to reduce constraint violations
- > Fast! In each iteration “only” the violation of each constraint is calculated



- > Rapid initial progress but slow if feasible region is approached
- > GMP::Instance::FindApproximatelyFeasibleSolution

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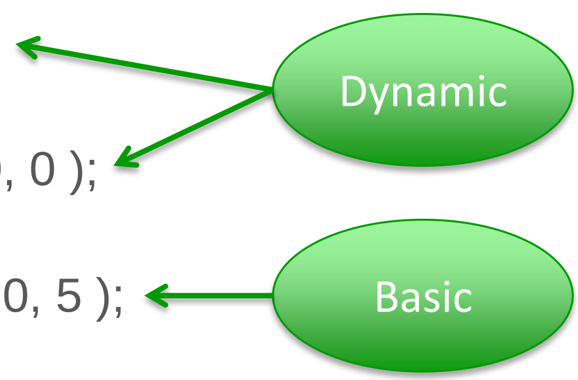
How to use Multistart?

> Install system module **Multi Start**

> Generate myGMP := GMP::Instance::Generate(MP);

> Call **DoMultiStart** procedure in module:

- Has two optional arguments for specifying “X” and “Y” (default 0)
- MulStart::DoMultiStart(myGMP);
- MulStart::DoMultiStart(myGMP, 0, 0);
- MulStart::DoMultiStart(myGMP, 10, 5);



Experimental results - Setup

> Compare performance of dynamic MS, basic MS, and single solve

> Using AIMMS 4.32 (64-bit) with CONOPT as solver (MS: 1 thread)

> Time limit of 300 seconds

> 140 medium sized NLP models:

- 91 models from Chinneck test set for CCGO (Princeton/CUTE library):

  45 models with linear constraints; 27 convex

  46 models with nonlinear constraints

- 49 models from MINLPLib2 (of which 3 relaxed MINLP models)

> Intel(R) Core(TM) i7 CPU 860, 2.8 GHZ, 12.00 GB computer with 8 Cores using Windows 7

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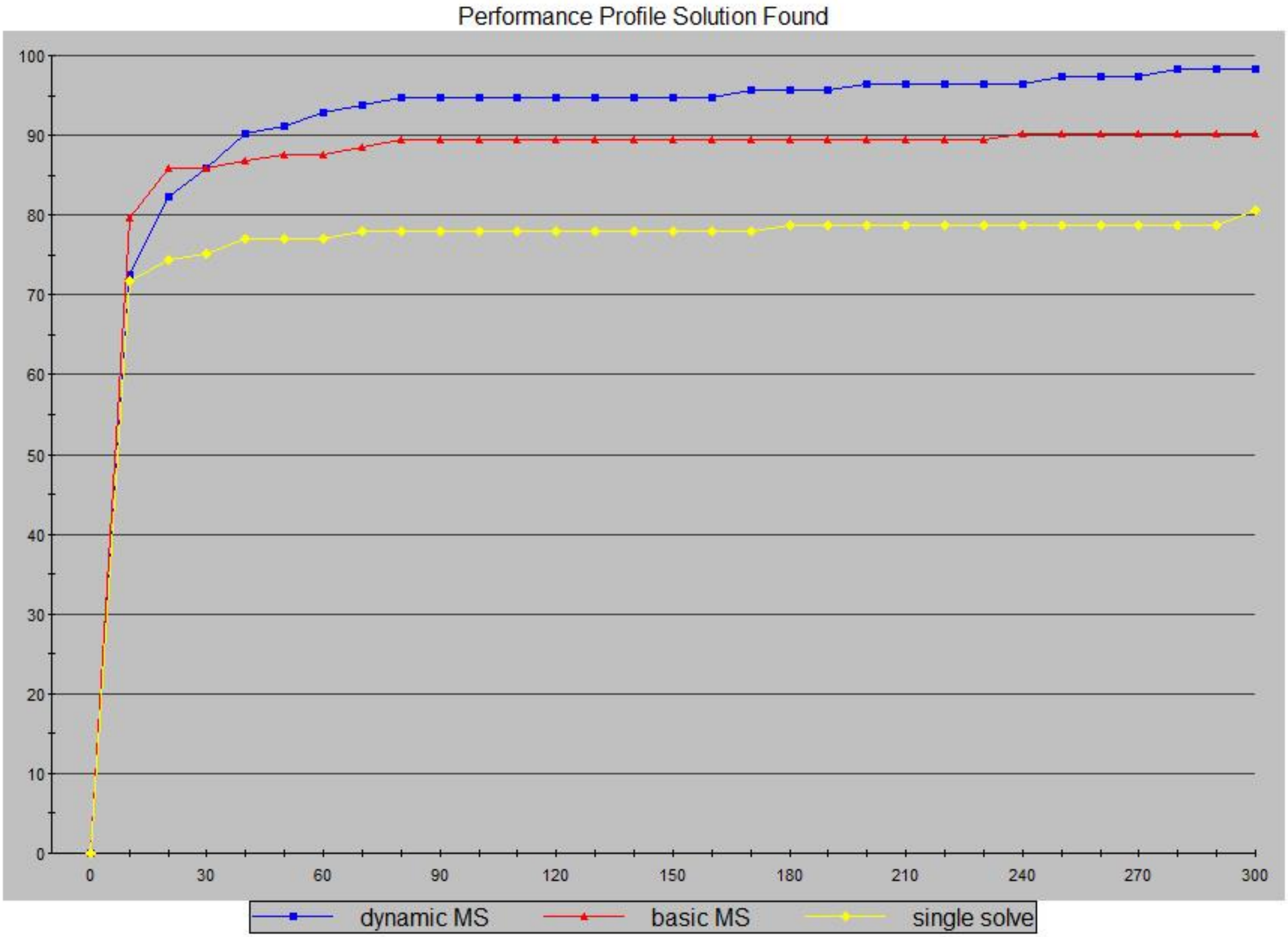
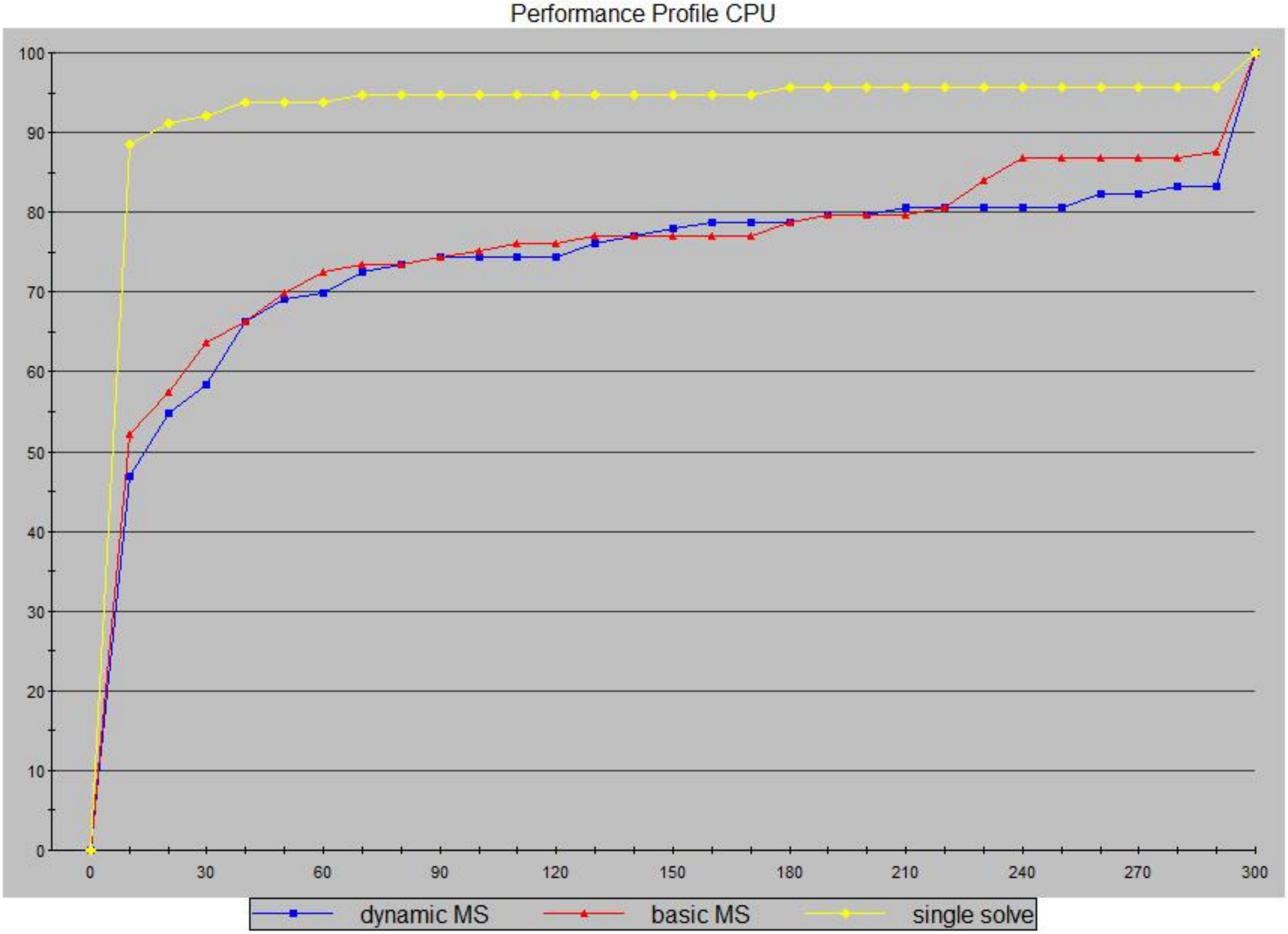
Results – Feasible solution



Results – Running times



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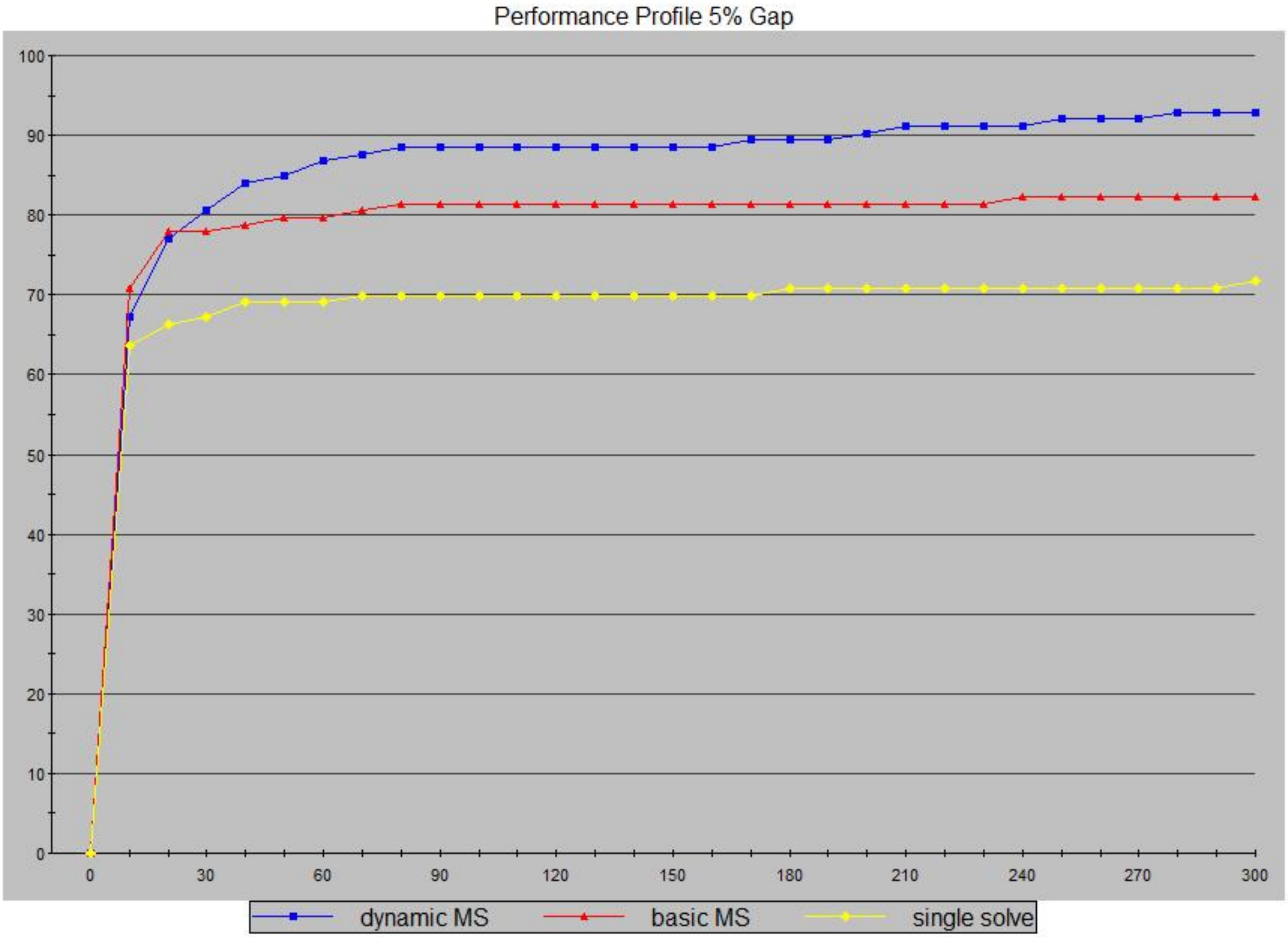
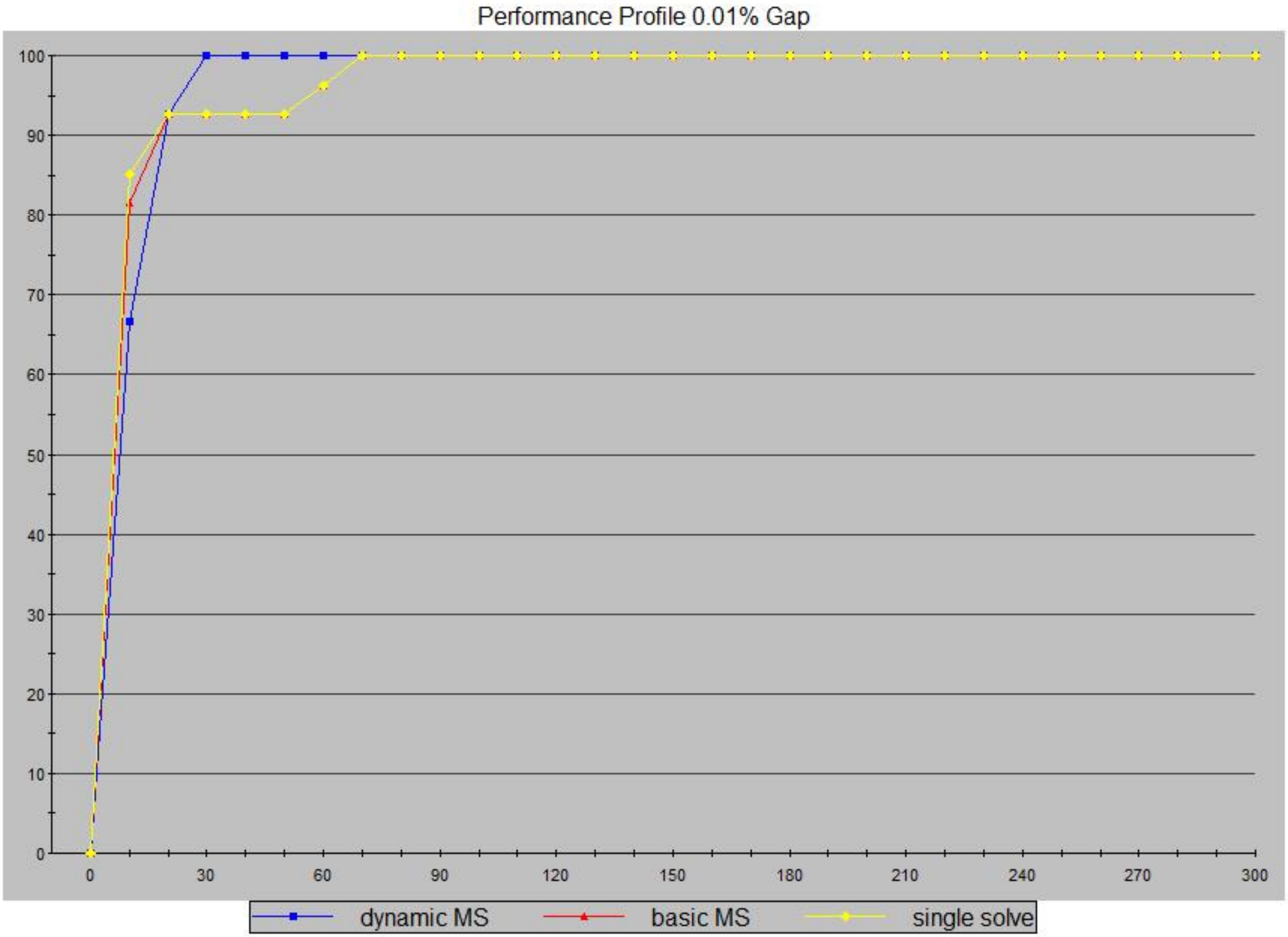
Results – Good solution



Results – Convex models



Experimental results - Observations

- For two models the solution returned by “single solve” contained large infeasibilities (0.3 and 40).
- Largest infeasibility using MS was 8e-5.
- If the MS algorithm finds multiple optimal solutions then it returns the one with the smallest infeasibility
- The dynamic MS algorithm found a solution for all Chinneck models except one (drcav3lq)
- The dynamic MS algorithm found a solution within 1% gap for all Chinneck models except two (drcav3lq, cresc132)

Conclusions & remarks

> Using multistart helps to find better solutions for nonlinear models

> The new dynamic multistart algorithm performs better than the old basic multistart algorithm

> Several minor improvements have been made from which also the basic multistart algorithm benefits

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

> GMP-AOA (MINLP) can be used in combination with multistart
- Install system module **Multi Start**
- Set GMPOuterApprox::UseMultistart := 1;

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References

- Chapter 17.2 in the AIMMS Language Reference: The AIMMS Multistart Algorithm.
- W. Ibrahim and J.W. Chinneck, Improving Solver Success in Reaching Feasibility for Sets of Nonlinear Constraints, *Computers and Operations Research* **35**(5), 2008, pp. 1394–1411.
- L. Smith, J. Chinneck, V. Aitken, Improved constraint consensus methods for seeking feasibility in nonlinear programs, *Computational Optimization and Applications* **54**(3), 2013, pp. 555–578.
- 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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