Benchmark on DAOOPT and GUROBI with the PASCAL2 Inference Challenge Problems

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Abstract

We report the PASCAL2 benchmark for DAOOPT and GUROBI on MPE task with 330 optimally solved instances from 8 benchmark domains. DAOOPT outperformed GUROBI in 3 domains, while GUROBI was faster than DAOOPT in the rest of the 5 domains. We show that DAOOPT performed well in domains where it could have high quality initial solutions for pruning the AND/OR search space, or skip search when the heuristic upper bounds were converged to the optimal due to MPLP/JGLP algorithms. GUROBI presented excellent performance if cutting planes were applied progressively and its heuristic algorithms could find the optimal solution at the root of branch-and-cut tree.

2011 PASCAL2 Inference Challenge

- Evaluate Inference Algorithms on Large-scale Difficult Problems
- Problems were provided as UAI Factor Table Format
- http://www.cs.huji.ac.il/project/PASCAL/

DAOOPT (Distributed AND/OR Optimization)

- DAOOPT was the winner of MAP/MPE Task
- Search Based on
  - Breadth Rotating AND/OR Branch-and-Bound
- Static Heuristic Evaluation From
  - Mini-Bucket Elimination with Moment Matching
  - Factor Graph/Join Graph Cost Shifting Schemes (MPLP/JGLP)
- Initial Lower Bound (Heuristic Solution) From
  - Guided Local Search++ (SLS4MPE Open Source)
- Variable Ordering From
  - Stochastic Greedy Ordering Scheme

GUROBI v5.5 (Currently, v5.6)

- Commercial Mathematical Programming Solver
- http://www.gurobi.com

ILP Formulation of MPE Task

- MPE Inference
  - Graphical Model

$$R =< \mathbf{X}, \mathbf{D}, \mathbf{F}, \otimes >$$

  - Random Variables

$$\mathbf{X} = (x_1, x_2, ..., x_n)$$

  - Domains of Variables

$$\mathbf{D} = (D_1, D_2, ... D_n), \ \ x_i \in D_i$$

  - Factors

$$\mathbf{F} = \{P_1, P_2, ... P_r\},$$
$$\mathrm{S_j} = Scope(P_j)$$

  - MPE Task

$$\max_{\mathbf{x}} P(\mathbf{x}) = \max_{\mathbf{x}} \prod_j P_j(\mathbf{x})$$
$$= \min_{\mathbf{x}} \sum_j -\log(P_j(\mathbf{x}))$$
$$= \min_{\mathbf{x}} \sum_j f_j(\mathbf{x})$$

- MPE to 0/1 ILP Conversion
  - Decision Variables $\mathbf{x}_j^k \in \{0,1\}$
    - •k-th row of j-th Factor Table
    - •Selecting a row for factor tables
  - Constraints
    - • Mutual Exclusivity

$$\sum_{k=1}^{Nj} x_j^k = 1, \quad \forall j \in \{1..r\},$$
$$Nj = | D_{Var1} \times D_{Var2} .. \times D_{Var|Sj|} |$$

    - •Cross Consistency

$$\sum_{k \sim S} x_j^k = \sum_{l \sim S} x_m^l, \quad \forall j, m \in \{1..r\}$$
$$\forall S \in Val(S_j \bigcap S_m)$$

  - Objective Function

$$\max \sum_{j \in \{1..r\}} \sum_{k=1}^{Nj} x_j^k(-\log(P_j^k)) = \min \sum_{j \in \{1..r\}} \sum_{k=1}^{Nj} x_j^k f_j^k$$

Benchmark Domains

- Benchmark Status
  - 12 Domains, 496 Instances Tested
  - We Report Results From 8 Domains with 328 Instances
    - Optimally Solved by DAOOPT or GUROBI)
    - Grid.Markov, Segmentation, WCSP Grouped by difficulty level

Terminated?	Yes	No	Total	Terminated?	Yes	No	Total
Grid.Bayes* (UAI08)	32	0	32	WCSP	18	43	61
Pedigree*(UAI08)	22	0	22	WCSP.Spot5	6	14	20
Grid.Markov.20	5	0	5	WCSP.Easy	8	0	8
Grid.Markov.40	8	0	8	WCSP.Hard	4	0	4
Grid.Markov.80	8	0	8	DBN	60	48	108
Segmentation.K2	50	0	50	*Alchemy*	*1*	*0*	*1*
Segmentation.K21	50	0	50	*Protein-Protein*	*0*	*8*	*8*
Promedas	68	0	86	*Object Detection*	*0*	*37*	*37*
Protein Folding	7	3	10	*Image Alignment*	*0*	*10*	*10*

Benchmark Problem Statistics

- Problem Statistics for Graphical Models and Integer Programming

Name	#.	n_{min}/n_{max}	f_{min}/f_{max}	k_{min}/k_{max}	s_{min}/s_{max}	w_{min}/w_{max}	h_{min}/h_{max}	row_{max}	col_{max}
Grid(Bayes)	32	144/2500	145/2501	2	3	16/81	53/309	17102	19602
Pedigree	22	298/1015	335/1290	3/7	4/5	15/35	53/160	8429	9986
Grid(Markov).20	5	400	1161/1201	2	2	26/46	66/73	9201	4001
Grid(Markov).40	8	1600	4721/4801	2	2	53/95	144/149	36801	16001
Grid(Markov).80	8	6400	19041/19201	2	2	107/197	307/313	147201	64001
Segmentaion.K2	50	221/237	823/887	2	2	15/19	44/68	9699	3071
Segmentaion.K21	50	221/237	823/887	21	2	15/19	44/68	93451	291187
Promedas	68	196/1911	201/1928	2	3	4/116	33/162	9856	11565
WCSP.spot5	6	67/209	272/1395	4	2/3	6/26	15/87	88620	12390
WCSP.Easy	8	25/71	82/686	3/11	2	6/21	15/30	168583	9479
WCSP.Hard	4	16/179	208/7110	4/44	2	7/42	8/90	104103361	340305
ProteinFolding	7	337/1364	1360/5220	81	2	22/38	58/164	1030679	2699598
DBN	60	70	16167	2	2	29	29	12986347	34691

- #. Total Number of Instances
- n Number of Variables
- f Number of Factors
- k Maximum Domain Size
- s: Maximum Scope Size
- w: Width of the Best Ordering Found
- h : Height of the Pseudo Tree
- row/col: Size of Constraint Matrix

Benchmark Settings

- DAOOPT Input Parameters

PARAMETERS	SET1	SET2	SET3
MBE-MM i bound	Maximum i Selected by DAOOPT within 4GB Memory Limit		
MPLP Iteration	2 sec	30 sec OR 500 Iter	60 sec OR 2,000 Iter
JGLP Iteration	2 sec	30 sec OR 250 Iter	60 sec OR 2,000 Iter
CVO Iteration	3 sec OR 500 Iter	60 sec OR 10,000 Iter	180 sec OR 30,000 Iter
SLS Time Limit	2 x 2 sec	10 x 6 sec	20 x 10 sec
BRAOBB Time	To Termination or Time-out Greater Than GUROBI Termination Time		

- GUROBI Input Parameters
  - Default, Except Explicitly Setting Root LP-Relaxation as Dual-Simplex
- Benchmark Platform
  - Turn-off Parallel Processing Capability, Disk Usage Algorithms

RESOURCE	TOTAL AVAILABLE	RESTRICTED FOR BENCHMARK
CPU	2 x 2.66 GHz Intel Core2 Duo	Single Thread
Memory	6 GB	MAX 4GB

Benchmark Results

- Runtime Summary Per Domains

Name	#.	Param	i-bound*	A.M of Td	A.M of Tg	G.M of Td	G.M of Tg	A.M of (Tg/Td)
GUROBI WAS FASTER THAN DAOOPT								
Grid(Bayes)	32	Set 1	(16,22.31,25)	382.8	2.7	51.01	1.35	0.038
Pedigree	22	Set 2	(10,17.91,23)	232.4	27.3	181.41	9.66	0.096
Grid(Markov).20	5	Set 1	(20,20,20)	14.6	7.2	14.28	7.21	0.524
Grid(Markov).40	8	Set 2	(20,20,20)	212.1	84.1	212.1	78.22	0.396
Grid(Markov).80	8	Set 3	(18,18,18)	T-out	2125	T-out	1661	-
Segmentaion.K2	50	Set 1	(15,17.14,19)	7.14	0.26	7.12	0.26	0.037
Segmentaion.K21	50	Set 1	(4,4,4)	55.4	11.36	55.33	11.23	0.205
Promedas	68	Set 1	(4,20.6,27)	143.71	0.2	40.57	0.16	0.006
DAOOPT WAS FASTER OR SOLVED YET GUROBI WAS MEMORY OUT								
WCSP.spot5	6	Set 1	(6,12,19)	59.5	197.65 (5)**	18.91	47.31 (5)	23.23
WCSP.Easy	8	Set 1	(6,10,15)	43	620.33	19.88	94.99	14.83
WCSP.Hard	4	Set 1	(3,7.5,11)	1208 (3)	5388 (2)	729 (3)	5386 (2)	-
ProteinFolding	7	Set 3	(3,3,3)	3005	79 (1)	1004	79 (1)	-
DBN	60	Set 3	(28,28,28)	342.35	M-out	342.35	M-out	-

- DAOOPT was Faster or DAOOPT Solved yet GUROBI was Memory Out
  - WCSP (15/18), Protein Folding (6/7), DBN (60/60) Domains
- GUROBI Dominated GUROBI for Rest Domains
  - Grid.Bayes (32/32), Grid.Markov (21/21), Pedigree (22/22)
  - Segmentation (100/100), Promedas (68/68)

- Log Summary Per Domains
  - DAOOPT
    - SLS Found Optimal Solutions for Segmentation, Protein Folding, WCSP, DBN.
    - Exact Upper Bounds from MPLP+JGLP+MBE-MM for Segmentation.
  - GUROBI
    - Fast when GUROBI Solved Near at the Root Node
    - Grid Bayes, Grid Markov(average 0.5 Nodes), Grid.Markov(average 67 Nodes)

Name mean n,f,k,s,i,w,h	SLS-OPT GAP	SLS-UB GAP	Mean OR	Mean Nodes	Mean Iter	Mean 0-1/2 Cuts
	#sls hit opt.	#sls hit ub.	Mean AND	# solved at root	Mean Gomory	Mean Clique
Grid(Bayes) (649,650, 2, 3,22,35,121)	0.40%	0.95%	29779829.13	0.5	4804.16	71.69
	14/28	8/28	32069771.13	24/32	5.59	68.66
Pedigree (736,918,5,4,18,24,99)	0.01%	0.76%	14040647	210.32	41678.45	240.64
	15/22	4/22	17328814.82	1/22	5.95	14.32
Grid(Markov).20 (400,1185, 2, 2,20,38,70)	1.28%	1.39%	1326.2	0	4259.8	336.4
	0/5	0/5	1379.2	5/5	10.4	7.2
Grid(Markov).40 (1600,4761, 2, 2,20,74,147)	1.86%	1.90%	24042.38	1.13	16378.25	994.88
	0/8	0/8	24835.75	7/8	16.25	26
Grid(Markov).80 (6400,19121, 2, 2,18,152,310)	2.46%	2.59%	T-Out	176.88	101722.5	3828.5
	0/8	0/8	T-Out	4/8	42.75	513.13
Segmentaion.K2 (229,852, 2, 2,17,17,55)	0.00%	0.00%	133.34	0	1225	0
	50/50	50/50	134.34	50/50	0	0
Segmentaion.K21 (229,852, 21, 2,4,17,55)	0.00%	0.00%	96.08	0	4080.6	0
	50/50	50/50	97.08	50/50	0	0

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