

Table 2 Test Runs for Randomly Generated Problem Sets of 10

Problem Type	Agents	Tasks	Tasks/Agent	0-1 Variables	LP gap %	LGR gap %	Total Nodes	Seconds to Best Solution	Seconds to Completion	Problems Proven Optimal
D	5	100	20.00	500	0.14	0.06	905	14	17	10 of 10
D	10	50	5.00	500	0.34	0.23	510	14	20	10 of 10
E	5	100	20.00	500	0.16	0.06	639	17	20	10 of 10
E	10	50	5.00	500	0.30	0.23	702	19	25	10 of 10
D	5	150	30.00	750	0.06	0.02	2,387	70	77	10 of 10
D	10	75	7.50	750	0.39	0.06	2,033	60	65	10 of 10
D	15	50	3.33	750	2.85	0.33	1,113	31	48	10 of 10
E	5	150	30.00	750	0.07	0.03	1,407	42	53	10 of 10
E	10	75	7.50	750	0.50	0.09	1,619	42	50	10 of 10
E	15	50	3.33	750	1.74	0.29	12,828	461	570	10 of 10
D	5	200	40.00	1,000	0.03	0.01	2,759	64	68	10 of 10
D	10	100	10.00	1,000	0.24	0.06	3,207	108	132	10 of 10
D	20	50	2.50	1,000	5.10	0.29	467	38	48	10 of 10
E	5	200	40.00	1,000	0.04	0.03	116,487	1,691	2,169	9 of 10
E	10	100	10.00	1,000	0.34	0.15	76,196	1,542	3,001	0 of 10
E	20	50	2.50	1,000	2.44	0.27	6,013	215	346	10 of 10
D	5	250	50.00	1,250	0.04	0.03	124,740	2,246	2,696	3 of 10
D	10	125	12.50	1,250	0.24	0.12	62,122	1,105	3,000	0 of 10
D	25	50	2.00	1,250	3.33	0.21	2,638	147	187	10 of 10
E	5	250	50.00	1,250	0.02	0.01	6,098	189	204	10 of 10
E	10	125	12.50	1,250	0.14	0.03	4,273	148	167	10 of 10
E	25	50	2.00	1,250	8.29	0.44	1,220	78	93	10 of 10
D	5	300	60.00	1,500	0.01	0.01	6,405	332	341	10 of 10
D	10	150	15.00	1,500	0.11	0.02	7,856	265	300	10 of 10
D	20	75	3.75	1,500	1.79	0.19	7,256	456	566	10 of 10
E	5	300	60.00	1,500	0.04	0.03	127,116	2,455	3,000	0 of 10
E	10	150	15.00	1,500	0.19	0.12	54,603	1,895	3,001	0 of 10
E	20	75	3.75	1,500	1.23	0.30	34,739	1,789	3,000	0 of 10
D	10	175	17.50	1,750	0.16	0.10	46,037	1,880	3,000	0 of 10
D	25	70	2.80	1,750	1.82	0.25	25,437	1,449	2,399	3 of 10
E	10	175	17.50	1,750	0.08	0.02	15,496	496	586	10 of 10
E	25	70	2.80	1,750	3.62	0.23	5,580	386	471	10 of 10
D	10	200	20.00	2,000	0.06	0.02	5,961	312	353	10 of 10
D	20	100	5.00	2,000	0.85	0.10	17,979	1,360	1,527	8 of 10
D	25	80	3.20	2,000	1.41	0.32	27,696	2,137	3,002	0 of 10
E	10	200	20.00	2,000	0.06	0.02	12,929	608	746	10 of 10
E	20	100	5.00	2,000	0.85	0.37	29,777	1,857	3,001	0 of 10
E	25	80	3.20	2,000	2.50	0.20	11,953	900	1,167	10 of 10
D	10	225	22.50	2,250	0.19	0.16	38,008	2,098	3,002	0 of 10
D	15	150	10.00	2,250	0.36	0.23	30,427	1,844	3,001	0 of 10
D	25	90	3.60	2,250	1.20	0.39	27,512	1,871	3,000	0 of 10
E	10	225	22.50	2,250	0.05	0.01	11,450	493	564	10 of 10
E	15	150	10.00	2,250	0.17	0.03	14,338	904	1,072	9 of 10
E	25	90	3.60	2,250	1.91	0.21	16,576	1,332	1,776	7 of 10

continued

Table 2 continued

Problem Type	Agents	Tasks	Tasks/Agent	0-1 Variables	LP gap %	LGR gap %	Total Nodes	Seconds to Best Solution	Seconds to Completion	Problems Proven Optimal
D	10	250	25.00	2,500	0.21	0.18	34,948	2,130	3,002	0 of 10
D	20	125	6.25	2,500	0.64	0.36	23,957	1,815	3,001	0 of 10
D	25	100	4.00	2,500	1.07	0.43	24,838	2,093	3,002	0 of 10
E	10	250	25.00	2,500	0.03	0.01	23,447	1,153	1,222	10 of 10
E	20	125	6.25	2,500	0.41	0.05	19,836	1,229	1,827	9 of 10
E	25	100	4.00	2,500	1.35	0.16	20,008	1,642	2,314	6 of 10
D	10	275	27.50	2,750	0.20	0.18	30,747	1,801	3,000	0 of 10
D	25	110	4.40	2,750	0.90	0.41	21,986	1,665	3,000	0 of 10
E	10	275	27.50	2,750	0.06	0.04	29,331	1,748	2,096	7 of 10
E	25	110	4.40	2,750	1.06	0.14	16,306	1,423	2,028	6 of 10
D	10	300	30.00	3,000	0.22	0.20	27,723	2,185	3,000	0 of 10
D	15	200	13.33	3,000	0.25	0.19	22,721	1,953	3,000	0 of 10
D	20	150	7.50	3,000	0.49	0.32	18,507	2,174	3,000	0 of 10
D	25	120	4.80	3,000	0.77	0.39	20,301	1,970	3,000	0 of 10
D	30	100	3.33	3,000	1.28	0.45	16,209	2,012	3,001	0 of 10
E	10	300	30.00	3,000	0.03	0.01	31,785	1,692	2,113	9 of 10
E	15	200	13.33	3,000	0.10	0.03	27,500	1,693	2,244	5 of 10
E	20	150	7.50	3,000	0.33	0.07	22,070	1,956	2,452	5 of 10
E	25	120	4.80	3,000	0.89	0.15	13,961	1,615	1,921	5 of 10
E	30	100	3.33	3,000	2.29	0.27	14,460	1,704	2,258	5 of 10

Note. Suboptimality tolerance = 0%.

guidelines. For this limited comparison set the results show that our algorithm is comparable to PLL's for some problem sets and up to a factor of almost 40 times faster for other problem sets.

In Table 5 we compare our algorithm with that of Chu and Beasley's (CB) genetic algorithm (1997).

Since CB's approach is heuristic in nature we compare the average time for CB to generate a "best solution" (see the second-to-last-column in Table 2 of their paper) with the time for our algorithm to find a solution to match or beat CB's best solution. In addition we report the time required for our algorithm to find

Table 3 Comparison of Savelsbergh and Nauss Algorithms

Problem Type	Size	Savelsbergh Algorithm		Nauss Algorithm	
		Average Nodes Examined	Maximum Nodes Examined	Average Nodes Examined	Maximum Nodes Examined
<i>Node Comparison</i>					
D	10 × 50	648	1,896	510	1,150
D	20 × 50	395	1,712	467	1,564
<i>CPU Comparison</i>					
		Adjusted CPU Average Seconds	Adjusted CPU Maximum Seconds	Average CPU Seconds	Maximum CPU Seconds
D	10 × 50	1,377	6,319	20	42
D	20 × 50	251	1,172	48	137

Note. Suboptimality tolerance = 0%. Problems are randomly generated with 10 problems to a set. The comparison is for different sets of 10 problems for each algorithm. The Savelsbergh node figures and CPU times are from his paper and have been adjusted for machine differences between the Pentium II 300 MHz and the IBM RS6000/590, based on the SPECFP95 benchmarks of 8.15 for the Pentium II 300 MHz and 9.69 for the IBM RS6000/590. Thus, the IBM RS6000/590 is 1.19 times faster than the Pentium II 300 MHz.

Table 1 The Approximation Errors for the Electoral College

States	Vote	Shapley-Shubik index			Normalized Banzhaf index			Absolute Banzhaf index												
		Exact		Relative error (%)	Exact		Relative error (%)	Exact		Relative error (%)										
		$m = 0$	$m = 5$	$m = 10$	$m = 0$	$m = 5$	$m = 10$	$m = 0$	$m = 5$	$m = 10$										
CA	54	0.1081254	2.22	0.74	0.29	0.17	0.09	0.1114275	—	1.23	0.28	0.12	0.03	0.46645413	3.05	0.55	0.11	0.04	-0.01	
NY	33	0.0629683	6.52	1.03	0.41	0.24	0.13	0.0620104	9.10	-0.28	-0.07	-0.03	-0.01	0.25958612	16.12	0.40	0.07	0.01	-0.03	
TX	32	0.0609327	6.76	1.06	0.42	0.25	0.13	0.0600106	8.99	-0.24	-0.06	-0.03	-0.01	0.25121433	16.56	0.43	0.07	0.01	-0.03	
FL	25	0.0469309	8.84	1.31	0.52	0.30	0.16	0.0463107	8.69	-0.26	-0.06	-0.03	-0.01	0.1938643	20.73	0.56	0.10	0.01	-0.03	
PA	23	0.0430063	9.62	1.42	0.56	0.33	0.18	0.0424838	8.60	-0.27	-0.07	-0.03	-0.01	0.1778442	22.38	0.62	0.11	0.02	-0.04	
IL	22	0.0410561	10.0	1.17	0.59	0.34	0.18	0.0405825	8.56	-1.12	-0.07	-0.03	-0.01	0.16988528	23.31	0.45	0.11	0.02	-0.04	
OH	21	0.0391138	10.5	1.27	0.61	0.36	0.19	0.0386888	8.52	-1.03	-0.07	-0.03	-0.01	0.16195807	24.34	0.50	0.12	0.02	-0.04	
MI	18	0.0333336	12.2	1.58	0.71	0.41	0.22	0.0330491	8.46	-0.81	-0.09	-0.04	-0.01	0.13834904	28.12	0.68	0.14	0.02	-0.05	
NJ	15	0.0276212	14.6	1.98	0.84	0.49	0.26	0.0274628	8.56	-0.70	-0.11	-0.04	-0.01	0.1149639	33.44	0.89	0.17	0.02	-0.06	
NC	14	0.0257317	15.6	2.14	0.90	0.52	0.28	0.0256108	8.65	-0.68	-0.11	-0.05	-0.01	0.1072112	35.73	0.97	0.18	0.03	-0.06	
GA, VA	13	0.0238495	16.7	2.32	0.87	0.56	0.30	0.0237633	8.79	-0.68	-0.30	-0.05	-0.01	0.09947716	38.37	1.06	0.15	0.03	-0.06	
IN, MA	12	0.0219744	18.1	2.52	0.96	0.61	0.32	0.0219199	8.99	-0.69	-0.27	-0.06	-0.01	0.09176031	41.47	1.16	0.18	0.03	-0.07	
MO, TN, WA, WI	11	0.0201063	19.7	2.77	1.06	0.59	0.35	0.0200802	9.26	-0.71	-0.26	-0.17	-0.01	0.08405922	45.13	1.28	0.20	0.01	-0.08	
MD, MN	10	0.0182451	21.6	3.05	1.18	0.67	0.38	0.0182440	9.64	-0.75	-0.24	-0.14	-0.01	0.07637249	49.53	1.41	0.23	0.02	-0.08	
AL, LA	9	0.0163908	23.9	3.39	1.33	0.76	0.38	0.0164109	10.14	-0.81	-0.24	-0.13	-0.07	0.06869873	54.93	1.58	0.26	0.03	-0.11	
AZ, CO, CT, KY, OK, SC	8	0.0145433	26.8	3.82	1.50	0.87	0.45	0.0145805	10.84	-0.89	-0.25	-0.13	-0.05	0.06103658	61.68	1.78	0.30	0.04	-0.11	
IA, MS, OR	7	0.0127026	30.6	4.37	1.73	0.99	0.52	0.0127526	11.81	-1.01	-0.27	-0.13	-0.04	0.05338472	70.38	2.04	0.35	0.05	-0.13	
AR, KS	6	0.0108685	35.6	5.10	2.02	1.17	0.62	0.0109269	13.20	-1.16	-0.29	-0.13	-0.03	0.04574181	81.99	2.38	0.41	0.06	-0.14	
NE, NM, UT, WV	5	0.0090410	42.5	6.10	2.43	1.41	0.75	0.0091029	15.24	-1.39	-0.35	-0.14	-0.02	0.03810655	98.27	2.86	0.50	0.07	-0.17	
HI, ID, ME, NH, NV, RI	4	0.0072200	53.0	7.62	3.03	1.76	0.94	0.0072805	18.43	-1.74	-0.42	-0.17	-0.02	0.03047764	122.71	3.57	0.62	0.09	-0.21	
AK, DC, DE, MT, ND, SD, VT, WY	3	0.0054055	70.4	10.1	4.04	2.36	1.27	0.0054593	23.92	-2.35	-0.57	-0.23	-0.03	0.0228538	163.49	4.77	0.83	0.12	-0.28	
Sum		0.9999999																		

Note: All power indices have been calculated to an accuracy of eight decimal places. The exact indices have been computed by the method of generating functions.

Table 1 Routes That can be Constructed for the Example in Figure 2 Without Using Delays

Plane	Routes												
A	Route 1				Route 2				Route 3				
	Flt	Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane	
	14	EWR	MSN	A	14	EWR	MSN	A	14	EWR	MSN	A	
	17	MSN	MDW	A	17	MSN	MDW	A	13	MSN	EWR	B	
	28	MDW	MSN	A	28	MDW	MSN	A	24	EWR	MSN	B	
	21	MSN	SAV	A	25	MSN	OAK	B	21	MSN	SAV	A	
	22	SAV	MSN	A					22	SAV	MSN	A	
	Route 4				Route 5				Route 6				
	Flt	Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane	
	14	EWR	MSN	A	14	EWR	MSN	A	14	EWR	MSN	A	
	13	MSN	EWR	B	21	MSN	SAV	A	25	MSN	OAK	B	
	24	EWR	MSN	B	22	SAV	MSN	A					
	25	MSN	OAK	B									
	B	Route 7				Route 8				Route 9			
		Flt	Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane
18		MDW	MSN	B	18	MDW	MSN	B	18	MDW	MSN	B	
15		MSN	OAK	A	15	MSN	OAK	A	11	MSN	SAV	B	
16		OAK	MSN	A	16	OAK	MSN	A	12	SAV	MSN	B	
17		MSN	MDW	A	17	MSN	MDW	A	17	MSN	MDW	A	
28		MDW	MSN	A	28	MDW	MSN	A	28	MDW	MSN	A	
21		MSN	SAV	A	25	MSN	OAK	B	21	MSN	SAV	A	
22		SAV	MSN	A					22	SAV	MSN	A	
Route 10				Route 11				Route 12					
Flt		Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane	
18		MDW	MSN	B	18	MDW	MSN	B	18	MDW	MSN	B	
11		MSN	SAV	B	11	MSN	SAV	B	11	MSN	SAV	B	
12		SAV	MSN	B	12	SAV	MSN	B	12	SAV	MSN	B	
17		MSN	MDW	A	13	MSN	EWR	B	13	MSN	EWR	B	
28		MDW	MSN	A	24	EWR	MSN	B	24	EWR	MSN	B	
25		MSN	OAK	B	21	MSN	SAV	A	25	MSN	OAK	B	
					22	SAV	MSN	A					
Route 13				Route 14				Route 15					
Flt		Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane	Flt	Departure Station	Arrival Station	Initial Plane	
18		MDW	MSN	B	18	MDW	MSN	B	18	MDW	MSN	B	
11		MSN	SAV	B	11	MSN	SAV	B	13	MSN	EWR	B	
12		SAV	MSN	B	12	SAV	MSN	B	24	EWR	MSN	B	
21		MSN	SAV	A	25	MSN	OAK	B	21	MSN	SAV	A	
22		SAV	MSN	A					22	SAV	MSN	A	

continued

Table 1 Measurement Items and Constructs Reliability

Items and Constructs ^a	Alpha	Source
Trust in the purchasing manager ^b	0.76	Adapted from Rempel et al. (1985)
<ol style="list-style-type: none"> 1. My contact person has always been evenhanded in negotiations with me. 2. My contact person may use opportunities that arise to profit at my expenses. (R) 3. I know how my contact person is going to act. S/he can always be counted on to act as I expect. 4. Based on past experience, I cannot with complete confidence rely on my contact person to keep promises made to me. (R) 5. My contact person is trustworthy. 		
Functional influence	0.78	New scale
<p>How much do individuals from the following functional areas in your business unit constrain your decisions about the business relationship with Supplier X during the <i>past year</i>?</p> <ol style="list-style-type: none"> 1. Manufacturing 2. Engineering 3. Research and Development 4. Quality 5. Finance/Accounting <p>(Scale: Seven-point Likert scale ranging from (1) Not at all, to (7) To a great extent. Measure: Items sum)¹³</p>		
Organizational tenure	n.a.	
<ol style="list-style-type: none"> 1. How long have you been working for <i>this company</i>? (Measure: logarithm of years) 		
Clan culture	0.69	Adapted from Moorman et al. (1993)
<ol style="list-style-type: none"> 1. Our business unit is a very personal place. It is like an extended family. People seem to share a lot of themselves. 2. The glue that holds our business unit together is loyalty and tradition. Commitment to this firm runs high. 3. Our business unit emphasizes human resources. High cohesion and morale are most important. <p>(Measures: 0 to 100 points based on how much each statement describes the respondent's company. Scale: Items sum)</p>		
Trust in the partner organization ^b	0.77	Adapted from Rempel and Holmes (1986)
<ol style="list-style-type: none"> 1. Customer X has always been evenhanded in its negotiations with us. 2. Customer X may use opportunities that arise to profit at our expense. (R) 3. Based on past experience, we cannot with complete confidence rely on Customer X to keep promises made to us. (R) 4. We are hesitant to transact with Customer X when the specifications are vague. (R) 5. Customer X is trustworthy. 		
Common fate	0.66	Adapted from Anderson and Narus (1990)
<ol style="list-style-type: none"> 1. A problem solved by Supplier X means a problem solved for our business unit. 2. We view Supplier X as our ally against competition. 3. We see our success as directly dependent upon the success of Supplier X. 		
Extendedness of business relationship	0.93	Heide and Miner (1992)
<ol style="list-style-type: none"> 1. Our business unit expects our relationship with Supplier X to last a long time. 2. It is assumed that agreements with Supplier X will be renewed. 3. Our business unit makes plans not only for the terms of individual purchases, but also for the long-term relationship with Supplier X. 		

continued

Table 1 continued

Items and Constructs ^a	Alpha	Source
Size	n.a.	
1. Please let us know the number of full-time employees working in your company at this time. (Measure: logarithm number of employees)		
Past duration of the relationship ^c	n.a.	
1. How long have you known the contact person at Customer/Supplier X? (Measure: logarithm mean of purchasing manager and supplier representative responses)		
Frequency of communication ^c	0.74	New scale
On average, about how often did you use the following to communicate with your contact person during the <i>past year</i> ?		
1. Telephone		
2. Fax		
3. Scheduled Meetings		
4. Unscheduled Meetings		
5. E-mail		
(Scale: 1 = never; 2 = yearly; 3 = quarterly; 4 = monthly; 5 = weekly; 6 = twice a week; 7 = daily. Measure: sum of purchasing manager and supplier representative responses)		
Age difference ^c	n.a.	
1. How old were you on your last birthday? (Measure: purchasing manager age – supplier representative age)		
Same gender ^c	n.a.	
1. Please indicate your gender. (Measure: 1 = same, 0 = different)		

Note. ^aUnless indicated otherwise, items measured with a seven-point Likert scale ranging from (1) Strongly disagree, to (7) Strongly agree; scale items averaged

^bFrom supplier representatives' questionnaires

^cFrom purchasing manager and supplier representatives' questionnaires

(R) = reverse scored.

Table 2 Constructs, Descriptive Statistics, and Zero-Order Correlations

Variables	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11
1. Trust in the purchasing manager	5.92	1.06											
2. Age difference	0.13	10.86	-0.00										
3. Same gender	0.71	0.46	-0.18	-0.11									
4. Size	6.70	2.12	0.00	-0.11	0.15								
5. Past duration of the relationship	1.37	0.75	0.15	0.06	0.17	-0.11							
6. Frequency of communication	33.35	7.46	0.06	-0.01	-0.07	0.04	-0.03						
7. Trust in the partner organization	5.54	1.04	0.64**	0.06	-0.15	-0.08	0.18	0.10					
8. Common fate	5.01	0.97	0.23*	0.03	0.01	-0.01	0.17	0.13	0.16				
9. Extendedness of business relationship	5.70	1.66	0.14	-0.05	-0.08	-0.13	0.03	0.04	0.07	0.214			
10. Functional influence	10.77	5.90	-0.22*	-0.25**	0.06	0.13	-0.30**	0.12	-0.13	-0.14	0.02		
11. Organizational tenure	1.85	0.89	0.27**	0.18	0.05	0.13	0.49**	-0.05	0.15	0.18	-0.16	-0.23*	
12. Clan culture	59.08	47.01	0.21*	0.15	0.06	-0.32**	0.09	0.04	0.25*	0.01	0.09	0.01	0.02

Note. **Correlation is significant at the 0.01 level (two-tailed); *Correlation is significant at the 0.05 level (two-tailed) N = 119.

R = reverse scored