AD-A185 355 AN ANALYSIS OF AN AVAILABLE SET OF LINEAR PROORAMMING TEST PROBLEMS(U) STANFORD UNIV CA SYSTEMS OPTIMIZATION LAB I J LUSTIG AUG 87 SOL-87-11 N00014-87-K-0142 1/1

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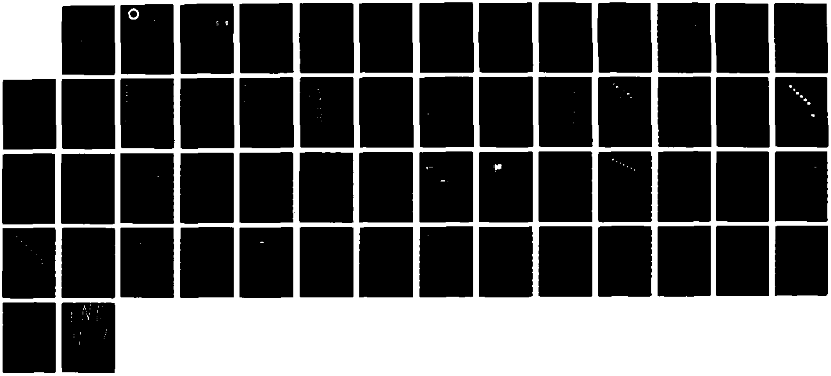

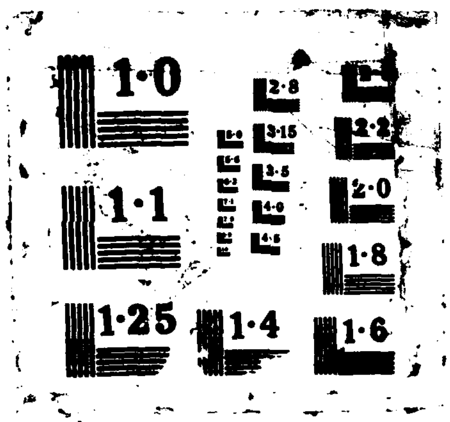
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TECHNICAL REPORT SOL-87-11

August 1987

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An Analysis of an Available Set of Linear Programming Test Problems

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Abstract

A set of linear programming test problems is analyzed with MINOS, Version 5.1. The problems have been run with different options for scaling and partial pricing to illustrate the effects of these options on the performance of the simplex method. The results indicate that the different options can significantly improve or degrade the *performance* of the simplex method, and that these options must be chosen wisely.

For each problem, a picture of the nonzero structure of the matrix A is also presented so that the problems can be classified according to structure.

Keywords: Linear programming, Simplex method, Scaling, Partial pricing, Pictures, Computational comparisons

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1. Introduction

The recent development of new algorithms for linear programming has sparked some serious computational testing of these algorithms, with comparisons often being made against the simplex method (Dantzig, 1963), as implemented in some version of MINOS (Murtagh and Saunders, 1980, 1983, 1987). For such tests, MINOS is usually run with certain options set at their default values. Changing the settings of these options affects the performance of the simplex method, and hence can affect the conclusions one makes when comparing the performance of MINOS to another linear programming code. The purpose of this paper is to analyze how much some of these options can change the speed of MINOS when solving linear programs.

Gay (1985) has made a set of linear programming test problems publicly available via *netlib* (Dongarra and Grosse, 1987). The form of each problem is

$$\begin{aligned} \min \quad & c^T x \\ \text{subject to} \quad & Ax \diamond b, \\ & l \le x \le u, \end{aligned}$$

where the symbol $\diamond$ indicates that each row a_i^T is related to b_i by a relation of the form $a_i^T x \le b_i$, $a_i^T x \ge b_i$, or $a_i^T x = b_i$. At the time of this study, 53 problems were in the library. Table 1.1 lists the problems, ordered by the number of nonzeros. Each problem was given a number by Gay, which is reflected in the last column. For ease of presentation of some graphs later in this report, the problems have been renumbered from 1 to 53, as listed in the first column. The optimal objective values, as reported by Gay, are also listed. Later, it will be interesting to note the slight differences between these values and the values obtained by MINOS when the scaling and partial pricing options are varied. Table 1.2 gives some statistics on each problem indicating the number of different types of rows and columns. A normal row or column has either a lower or upper bound. A bounded row or column has distinct lower and upper bounds. A fixed row or column has equal lower and upper bounds, while a free column has no lower or upper bound.

In Section 2, the testing methodology is explained and the results are presented for six different combinations of MINOS options. Section 3 contains an analysis and discussion of these results. Section 4 presents pictures of the nonzero structure of the constraint matrix for each of the problems.

2. Testing Methodology and Results

The computational testing in this report was performed on a DEC VAXstation II with 13 megabytes of main memory. The operating system was VMS, version 4.5, and the

VMS FORTRAN compiler, version 4.6, was used with the default options, including code optimization. Each run was made as a batch job, and the account used to run the tests was given access to all of the main memory. Hence, the memory used for each test was never paged onto the disk, and the amount of paging was kept to a minimum. The VMS timing mechanism used is slightly affected by disk input and output (such as printing the iteration log), and hence all timing results contain a slight but negligible error.

For each test run, the total time of the run and the solution time were recorded. The solution time was measured by timing the MINOS subroutine M5SOLV. MINOS, Version 5.1, (June 1987) was used. In the course of running the experiments, a degenerate cycle of 6 was discovered in one of the runs on the problem PILOTJA, with this cycle occurring in Phase 2 after 43000 total iterations. MINOS was modified to avoid such cycles and all of the problems were run again. The main changes required were in the step-length procedure M5CHZR. These changes will be documented elsewhere and made available in a later version.

MINOS requires a specifications file for each run. The file used in all cases was of the form:

```
BEGIN  SPECS file for timing LP problems
ROWS                            2400
COLUMNS                        10000
ELEMENTS                       45000
SUMMARY FILE                       9
MPS FILE                          10
ITERATIONS                    100000
PRINT LEVEL                        0
SCALE OPTION                       s
PARTIAL PRICE                      p
END
```

The options changed were the scaling option s and the partial pricing option p. The default values are $s = 0$ and $p = 1$. The six combinations used were $s = 0$ with $p = 1$ and 10, and $s = 2$ with $p = 1$, 10, 20, and 40. The effects of partial pricing can be analyzed with the runs corresponding to $s = 2$, while the effects of scaling can be analyzed when $p = 1$ and $p = 10$. It should be noted that most researchers report the results for $s = 0$ and $p = 1$, the usual default values. (In some cases, the default value for p may not be 1.)

By default, MINOS chooses a triangular initial basis from the matrix $[A\ I]$, as opposed to an initial basis consisting of only the slack variables. Certainly, a different scheme used to choose the initial basis would produce different computational results.

Tables 2.1–2.6 contain the computational results for the 53 problems using the options above. The column for "Phase 1 Its." is the number of iterations needed to find the first feasible point. The column for "Phase 2 Its." is the number of iterations needed after the first feasible point has been found. The column for "Total Its." is the sum of the preceding two columns. The column for "Blocked Its." is the number of simplex iterations for which movement was blocked, i.e., the number of iterations for which the MINOS routine `M5CHZR` returned the variable `MOVE` equal to `.FALSE`. This happens when a small step is taken and provides a measure of the degree of degeneracy of each problem. The column for "Total Time" is the number of CPU seconds that MINOS used from beginning to end (including reading in the problem data and writing out the solution). The column for "Solution Time" is the number of CPU seconds used by the call to the routine `M5SOLV`.

3. Analysis of Results

Since linear programs are solved in finite-precision arithmetic, the "optimal" objective value may change depending on the chosen options. Using the optimal value for `SCALE OPTION 2` and `PARTIAL PRICE 1` for comparison, Table 3.1 indicates the relative error of the optimal objective value reported. Each column represents one scaling and pricing combination, and only nonzero relative errors are given. The first column contains the optimal objective value used for comparison.

To compare the efficiencies of the different options, *performance factors* are used. Let $t_{s,p}$ be the solution time for a specific problem when the MINOS options `SCALE OPTION` s and `PARTIAL PRICE` p are used. Then the performance factor

$$f_{s_1,p_1}^{s_2,p_2} = \frac{t_{s_2,p_2}}{t_{s_1,p_1}}$$

measures the efficiency of the option combination (s_2, p_2) relative to the option combination (s_1, p_1). For example, $f_{0,1}^{2,1} = 0.5$ indicates that when full pricing is used, scaling caused the problem to be solved in half as much time as when scaling was not used.

Performance factors can be computed for each problem to compare any scaling/pricing pairs. Figure 3.2 demonstrates the range of the performance factors $f_{0,1}^{s,p}$ for the different combinations used. The horizontal axis is ordered by problem number, and hence, by the number of nonzeros. Note that a dot representing the value of $f_{0,1}^{0,1}$ (for the default combination of options) is implicitly plotted at the value 1.0 for each problem. All dots below the value 1.0 indicate a combination that performed better than the default combination for MINOS, while dots above the value 1.0 indicate combinations that performed worse than the default combination. It is interesting to note that the factors range from 0.1

to 3.8, indicating that changing the options improved the performance of MINOS by as much as a factor of 10 and worsened the performance by as much as a factor of 3.8. Each vertical line represents one problem, and the ordering of the factors of the six different options varies among the problems, indicating the difficulty of choosing a "best" option. Except for problems 31 and 46 (SCSD6 and SCSD8), the trend seems to indicate that partial pricing is more effective as the number of nonzeros increases. However, for those two problems, the performance deteriorated when scaling was used.

3.1. Effects of Scaling. In order to compare the effects of scaling, the values $f_{0,1}^{2,1}$ and $f_{0,10}^{2,10}$ have been plotted in Figure 3.3. The plot order is determined by sorting on $f_{0,1}^{2,1}$, to make any trend more obvious. This graph indicates that the effects of scaling are usually independent of the partial pricing option chosen. (For problem 49, PILOTJA, the widely separated values are due to the poor performance when scaling was not used.) Also, 71 out of 106 of the tests exhibited a value of $f_{0,p}^{2,p}$ less than 1.0, indicating that scaling improved the performance of MINOS 67% of the time. 50% of the tests exhibited a value less than 0.9, while 84% of the tests exhibited a value less than 1.1. This means that for half the problems, scaling gave a significant improvement, while for most problems, scaling was either better than or comparable to no scaling.

3.2. Effects of Partial Pricing. The effects of partial pricing are analyzed in Figure 3.4 by plotting the values for $f_{2,1}^{2,p}$ for $p = 10$, 20, and 40. The problems are sorted by $f_{2,1}^{2,10}$ in order to study whether partial pricing improves performance uniformly. Here, we can see that partial pricing does reduce the CPU time for most of the problems. Of course, if the goal were to choose the value of p that minimizes CPU time, the results indicate that determining that value may require extensive experimentation, even for a single problem.

3.3. Iteration Counts. The effects of the different options on iteration counts are analyzed in Figure 3.5 by plotting the values of $\alpha = I/m$, where I is the number of iterations and m is the number of rows. The problems are ordered by the number of rows to reflect any trend in α due to row size. A logarithmic scale was used to demonstrate the range of values of α, which varies from 0.2 to 50. Thus there is a large variance in α, but there is no apparent upward or downward trend. In 35% of the tests, partial pricing reduced the number of iterations as compared to full pricing. Intuitively, one would expect that partial pricing would *increase* the number of iterations used by the simplex method, since the "best" (in terms of minimal reduced cost) column is not chosen on each iteration.

4. Pictures of Problems

In order to develop a further understanding of the problems in this set, the nonzero structure of each constraint matrix is presented here. Free rows and columns for fixed variables were eliminated. The pictures were produced on an Apple Macintosh Plus, using software developed by the author, and then printed on an Apple LaserWriter, which has a resolution of 300 dots per inch. In order to fit the problems on a page, it was necessary to print the problems at various magnifications. A magnification of 1.0 represents 75 rows/columns per inch, so that a 4x4 box of pixels on the laser printer represents one nonzero. Hence, a picture at a magnification of 0.25 has 300 rows/columns per inch, and every nonzero corresponds to one LaserWriter pixel. The various magnifications and the correspondence between nonzero elements and LaserWriter pixels are summarized in Table 4.1. The ordering of the rows and columns is determined by their ordering in the MPS decks that are created by the program EMPS, available from *netlib*.

Magnification	Rows/Columns Per Inch	Nonzeros	LaserWriter Pixels
10.0	7.5	1	40
4.0	18.75	1	16
2.0	37.5	1	8
1.5	50	1	6
1.0	75	1	4
0.5	150	1	2
0.25	300	1	1
0.125	600	2	1
0.0625	1200	4	1
0.05	1500	5	1

Table 4.1 Magnification Correspondences

It is interesting to note that a large number of problems in this test set have staircase structure. Various subsets of the *netlib* problems have been used to compare the simplex method with interior-point algorithms (Karmarkar, 1984). The more favorable results reported for the interior-point approach tend to be associated with strong staircase structure (see, e.g., Adler, Resende and Veiga, 1986; Monma and Morton, 1987). This is fortuitous, since staircase problems have long been viewed as unusually difficult for the simplex method (Fourer, 1982). These problems tend to require many simplex iterations to solve and to have rather dense basis factorizations. It remains to be seen whether most problems of interest in the "real world" display staircase structure.

5. Conclusions

From these results, it is apparent that scaling and partial pricing can improve the performance of the simplex method most of the time. However, when comparing the performance of the simplex method to some other algorithm, care must be taken when choosing these options in order not to degrade the performance of the simplex method.

The pictures of the problems reveal similarities between groups of problems, and indicate that the test set in *netlib* may have some bias which affects these and other computational results.

Acknowledgements

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Prob. #	Problem Name	Rows	Columns	Nonzeroes	Obj. Value (netlib)	Prob. # (netlib)
1	AFIRO	28	32	88	-4.6475314286000E+02	1
2	ADLITTLE	57	97	465	2.2549496316000E+05	2
3	SC205	206	203	552	-5.2202061211707E+01	15f
4	SCAGR7	130	140	553	-2.3313892547843E+06	17f
5	SHARE2B	97	79	730	-4.1573224074000E+02	3
6	RECIPE	92	180	752	-2.6661600000000E+02	14f
7	VTPBASE	199	203	914	1.2983146246136E+05	38f
8	SHARE1B	118	225	1182	-7.6589318579000E+04	4
9	BORE3D	234	315	1525	1.3730803942085E+03	1f
10	SCORPION	389	358	1744	1.8781248227381E+03	21f
11	CAPRI	272	353	1786	2.6900129138000E+03	9
12	SCAGR25	472	500	2029	-1.4753433060769E+07	16f
13	SCTAP1	301	480	2052	1.4122500000000E+03	26f
14	BRANDY	221	249	2150	1.5185098965000E+03	7
15	ISRAEL	175	142	2358	-8.9664482186000E+05	6
16	ETAMACRO	401	688	2489	-7.5571522785000E+02	12
17	SCFXM1	331	457	2612	1.8416759028349E+04	18f
18	GROW7	141	301	2633	-4.7787811814712E+07	8f
19	BANDM	306	472	2659	-1.5862801845000E+02	10
20	E226	224	282	2767	-1.8751929066000E+01	8
21	STANDATA	360	1075	3038	1.2576995000000E+03	37f
22	SCSD1	78	760	3148	8.6666666743334E+00	23f
23	GFRDPNC	617	1092	3467	6.9022359995488E+06	6f
24	BEACONFD	174	262	3476	3.3592485807000E+04	5
25	STAIR	357	467	3857	-2.5126695119000E+02	11
26	SCRS8	491	1169	4029	9.0429695380079E+02	22f
27	SEBA	516	1028	4874	1.5711600000000E+04	20
28	SHELL	537	1775	4900	1.2088253460000E+09	17
29	PILOT4	411	1000	5145	-2.5810162253381E+03	11f
30	SCFXM2	661	914	5229	3.6660261564999E+04	19f
31	SCSD6	148	1350	5666	5.0500000078262E+01	24f
32	GROW15	301	645	5665	-1.0687094129358E+08	9f
33	SHIP04S	403	1458	5810	1.7987147004454E+06	30f
34	FFFFF800	525	854	6235	5.5567996085000E+05	16
35	GANGES	1310	1681	7021	-5.2473581036000E-12	18
36	SCFXM3	991	1371	7846	5.4901254549751E+04	20f
37	SCTAP2	1091	1880	8124	1.7248071428571E+03	27f
38	GROW22	441	946	8318	-1.6083433648256E+08	10f
39	SHIP04L	403	2118	8450	1.7933245379704E+06	29f
40	PILOTWE	723	2789	9218	-2.7190896937050E+06	13f
41	SIERRA	1228	2036	9338	1.5394362183632E+07	35f
42	SHIP08S	779	2387	9501	1.9200982105346E+06	32f
43	SCTAP3	1481	2480	10734	1.4240000000000E+03	28f
44	SHIP12S	1152	2763	10941	1.4892361344061E+06	34f
45	25FV47	822	1571	11127	5.5018458883000E+03	14
46	SCSD8	398	2750	11334	9.0499999992546E+02	25f
47	NESM	663	2923	13988	1.4076121092176E+07	42f
48	CZPROB	930	3523	14173	2.1851966989000E+06	15
49	PILOTJA	941	1988	14706	-6.1100885456374E+03	12f
50	SHIP08L	779	4283	17085	1.9090552113891E+06	31f
51	SHIP12L	1152	5427	21597	1.4701879193293E+06	33f
52	80BAU3B	2263	9799	29063	9.8722419288205E+05	3f
53	PILOT	1442	3652	43220	-5.5742017351000E+02	13

Table 1.1 Problem Statistics I

Problem Name	Rows			Columns			
	Normal	Fixed	Bounded	Normal	Free	Fixed	Bounded
AFIRO	19	8	0	32	0	0	0
ADLITTLE	41	15	0	97	0	0	0
SC205	114	91	0	203	0	0	0
SCAGR7	45	84	0	140	0	0	0
SHARE2B	83	13	0	79	0	0	0
RECIPE	24	67	0	85	0	26	69
VTPBASE	143	55	0	87	1	18	97
SHARE1B	28	89	0	225	0	0	0
BORE3D	19	214	0	302	0	1	12
SCORPION	108	280	0	358	0	0	0
CAPRI	129	142	0	192	14	16	131
SCAGR25	171	300	0	500	0	0	0
SCTAP1	180	120	0	480	0	0	0
BRANDY	54	166	0	249	0	0	0
ISRAEL	174	0	0	142	0	0	0
ETAMACRO	128	272	0	426	0	82	180
SCFXM1	143	187	0	457	0	0	0
GROW7	0	140	0	21	0	0	280
BANDM	0	305	0	472	0	0	0
E226	190	33	0	282	0	0	0
STANDATA	199	160	0	955	0	16	104
SCSD1	0	77	0	760	0	0	0
GFRDPNC	68	548	0	834	0	0	258
BEACONFD	33	140	0	262	0	0	0
STAIR	147	209	0	373	6	82	6
SCRS8	106	384	0	1169	0	0	0
SEBA	1	507	7	521	0	0	507
SHELL	2	534	0	1399	0	250	126
PILOT4	123	287	0	635	88	30	247
SCFXM2	286	374	0	914	0	0	0
SCSD6	0	147	0	1350	0	0	0
GROW15	0	300	0	45	0	0	600
SHIP04S	48	354	0	1458	0	0	0
FFFFF800	174	350	0	854	0	0	0
GANGES	25	1284	0	1277	0	0	404
SCFXM3	429	561	0	1371	0	0	0
SCTAP2	620	470	0	1880	0	0	0
GROW22	0	440	0	66	0	0	880
SHIP04L	48	354	0	2118	0	0	0
PILOTWE	139	583	0	2335	80	78	296
SIERRA	699	528	0	0	0	20	2016
SHIP08S	80	698	0	2387	0	0	0
SCTAP3	860	620	0	2480	0	0	0
SHIP12S	106	1045	0	2763	0	0	0
25FV47	305	516	0	1571	0	0	0
SCSD8	0	397	0	2750	0	0	0
NESM	94	480	88	1009	0	175	1739
CZPROB	39	890	0	3294	0	229	0
PILOTJA	279	661	0	1250	88	311	339
SHIP08L	80	698	0	4283	0	0	0
SHIP12L	106	1045	0	5427	0	0	0
80BAU3B	2262	0	0	6244	0	498	3057
PILOT	1208	233	0	2320	0	203	1129

Table 1.2 Problem Statistics II

Problem Name	Phase 1 Its.	Phase 2 Its.	Total Its.	Blocked Its.	Total Time	Solution Time
AFIRO	3	6	9	5	2.5	0.4
ADLITTLE	18	126	144	18	12.5	8.3
SC205	0	139	139	14	25.8	19.0
SCAGR7	70	21	91	9	13.9	8.3
SHARE2B	57	48	105	22	12.8	7.6
RECIPE	7	26	33	3	8.6	2.2
VTPBASE	372	51	423	160	65.4	56.9
SHARE1B	117	169	286	2	42.5	34.4
BORE3D	78	33	111	90	30.6	19.7
SCORPION	86	52	138	58	44.4	31.3
CAPRI	206	114	320	25	72.8	59.4
SCAGR25	247	225	472	70	157.1	140.5
SCTAP1	168	221	389	106	95.1	80.3
BRANDY	178	118	296	36	71.7	59.6
ISRAEL	42	256	298	52	60.0	48.3
ETAMACRO	305	335	640	210	181.1	161.6
SCFXM1	215	178	393	112	108.3	91.6
GROW7	0	167	167	7	53.6	39.2
BANDM	172	273	445	36	134.6	117.7
E226	88	493	581	83	134.3	119.7
STANDATA	215	158	373	247	130.7	107.3
SCSD1	81	212	293	127	74.2	55.4
GFRDPNC	314	368	682	329	284.0	254.6
BEACONFD	33	54	87	6	29.3	13.5
STAIR	252	274	526	31	254.5	233.4
SCRS8	113	890	1003	200	430.2	402.4
SEBA	146	66	212	31	107.9	75.3
SHELL	46	212	258	48	143.6	105.6
PILOT4	954	2857	3811	562	2069.3	2037.7
SCFXM2	504	344	848	235	424.5	392.1
SCSD6	167	637	804	311	295.5	263.3
GROW15	0	512	512	22	262.8	233.9
SHIP04S	11	137	148	28	91.3	57.0
FFFFF800	1706	321	2027	615	895.0	862.4
GANGES	274	404	678	148	484.4	432.4
SCFXM3	815	540	1355	365	1023.7	975.7
SCTAP2	776	727	1503	613	1198.3	1144.6
GROW22	0	901	901	41	630.3	588.2
SHIP04L	10	210	220	37	159.1	112.4
PILOTWE	2460	13270	15730	2406	15527.7	15463.6
SIERRA	553	763	1316	639	1145.8	1076.2
SHIP08S	17	229	246	61	231.2	174.9
SCTAP3	835	920	1755	911	1821.6	1750.0
SHIP12S	37	411	448	86	478.2	410.9
25FV47	2603	6469	9072	720	8836.3	8779.9
SCSD8	433	786	1219	569	912.2	846.2
NESM	1642	3511	5153	1	4051.3	3958.5
CZPROB	923	918	1841	57	1798.4	1716.2
PILOTJA	14948	35615	50563	10613	64719.7	64643.5
SHIP08L	12	437	449	68	561.4	469.2
SHIP12L	36	837	873	177	1344.2	1225.7
80BAU3B	2047	6012	8059	791	19041.2	18828.0
PILOT	22693	17554	40247	1192	136832.0	136648.6

Table 2.1 Results for SCALE OPTION 0 and PARTIAL PRICE 1

Problem Name	Phase 1 Its.	Phase 2 Its.	Total Its.	Blocked Its.	Total Time	Solution Time
AFIRO	3	6	9	5	2.5	0.4
ADLITTLE	17	128	145	16	12.1	7.8
SC205	0	143	143	14	25.7	18.7
SCAGR7	65	25	90	10	13.1	7.5
SHARE2B	62	45	107	22	12.8	7.5
RECIPE	7	26	33	3	8.3	1.9
VTPBASE	281	85	366	139	52.9	44.7
SHARE1B	153	130	283	2	37.4	29.3
BORE3D	99	30	129	101	32.9	21.4
SCORPION	76	50	126	57	42.0	28.0
CAPRI	169	105	274	18	59.1	45.3
SCAGR25	242	200	442	80	134.1	117.4
SCTAP1	326	189	515	123	104.4	89.3
BRANDY	214	133	347	27	74.7	62.6
ISRAEL	38	339	377	44	70.5	58.7
ETAMACRO	310	374	684	231	164.2	144.6
SCFXM1	210	220	430	115	100.3	83.8
GROW7	0	166	166	7	55.7	41.2
BANDM	172	246	418	32	116.5	98.7
E226	106	579	685	103	136.4	122.3
STANDATA	35	58	93	42	40.7	17.2
SCSD1	66	199	265	204	42.5	23.7
GFRDPNC	298	563	861	343	300.8	271.0
BEACONFD	34	53	87	6	25.7	10.3
STAIR	296	292	588	41	257.1	235.6
SCRS8	284	829	1113	206	388.1	359.7
SEBA	287	120	407	64	148.5	115.6
SHELL	70	270	340	59	127.7	88.6
PILOT4	910	3388	4298	617	2044.9	2013.6
SCFXM2	542	399	941	203	402.3	370.3
SCSD6	152	502	654	192	132.4	99.5
GROW15	0	493	493	39	269.3	240.2
SHIP04S	12	165	177	30	74.3	40.3
FFFFF800	1241	383	1624	435	584.8	552.3
GANGES	345	402	747	164	469.8	416.7
SCFXM3	798	660	1458	337	930.3	882.7
SCTAP2	1110	924	2034	799	1279.7	1224.9
GROW22	0	748	748	79	547.0	504.2
SHIP04L	14	264	278	50	115.9	68.9
PILOTWE	1791	10212	12003	1758	9211.8	9147.2
SIERRA	520	769	1289	644	816.5	747.8
SHIP08S	19	236	255	62	177.1	121.3
SCTAP3	1169	899	2068	988	1699.3	1626.6
SHIP12S	41	392	433	80	335.8	268.3
25FV47	2491	7310	9801	729	7911.9	7855.1
SCSD8	554	960	1514	568	671.0	605.2
NESM	1708	2456	4164	5	2126.4	2033.9
CZPROB	754	921	1675	62	1079.3	996.8
PILOTJA	12814	28395	41209	7345	45598.1	45521.0
SHIP08L	13	426	439	60	351.1	258.8
SHIP12L	39	856	895	180	778.5	659.6
80BAU3B	1698	5515	7213	774	9327.7	9114.7
PILOT	14851	16384	31235	1162	93568.3	93384.7

Table 2.2 Results for SCALE OPTION 0 and PARTIAL PRICE 10

Problem Name	Phase 1 Its.	Phase 2 Its.	Total Its.	Blocked Its.	Total Time	Solution Time
AFIRO	2	4	6	3	2.6	0.3
ADLITTLE	19	95	114	13	12.0	7.2
SC205	0	110	110	14	22.3	14.6
SCAGR7	60	28	88	10	14.3	8.1
SHARE2B	54	61	115	20	14.4	9.0
RECIPE	7	26	33	3	9.4	2.2
VTPBASE	55	34	89	38	20.4	10.9
SHARE1B	156	118	274	10	40.6	31.3
BORE3D	101	47	148	85	39.3	26.5
SCORPION	70	34	104	44	38.3	23.0
CAPRI	145	100	245	25	57.3	42.1
SCAGR25	151	156	307	48	105.4	86.7
SCTAP1	107	109	216	60	61.4	44.3
BRANDY	296	181	477	28	111.5	97.0
ISRAEL	34	262	296	17	63.3	49.9
ETAMACRO	350	268	618	122	190.8	167.6
SCFXM1	183	132	315	41	92.9	73.5
GROW7	0	160	160	6	53.2	36.0
BANDM	233	221	454	28	139.7	120.5
E226	154	318	472	91	112.9	96.6
STANDATA	70	59	129	74	63.6	36.0
SCSD1	76	547	623	394	145.3	124.8
GFRDPNC	266	393	659	271	288.2	251.5
BEACONFD	40	58	98	17	33.1	15.4
STAIR	300	118	418	52	253.4	228.2
SCRS8	109	559	668	180	302.3	269.5
SEBA	217	147	364	58	158.6	122.1
SHELL	46	212	258	48	150.2	107.3
PILOT4	523	1010	1533	186	841.0	804.6
SCFXM2	534	340	874	118	441.2	402.2
SCSD6	168	1393	1561	606	553.4	516.3
GROW15	0	464	464	12	235.6	201.3
SHIP04S	10	134	144	25	95.7	56.5
FFFFF800	800	139	939	346	435.1	395.2
GANGES	495	204	699	204	529.5	470.1
SCFXM3	761	462	1223	183	915.2	855.6
SCTAP2	256	497	753	419	602.5	541.3
GROW22	0	756	756	23	507.7	456.6
SHIP04L	10	221	231	36	171.7	117.8
PILOTWE	350	6346	6696	1090	6457.3	6379.7
SIERRA	614	737	1351	552	1148.9	1060.0
SHIP08S	17	223	240	60	232.2	167.8
SCTAP3	296	648	944	564	988.3	906.2
SHIP12S	36	363	399	68	436.0	359.1
25FV47	2309	6133	8442	714	7684.4	7618.6
SCSD8	580	3755	4335	2722	3288.1	3214.0
NESM	1200	1687	2887	0	2377.5	2271.6
CZPROB	720	805	1525	94	1519.5	1421.0
PILOTJA	1939	5175	7114	613	7751.9	7664.9
SHIP08L	12	437	449	73	576.8	470.9
SHIP12L	36	833	869	171	1384.4	1248.7
80BAU3B	1525	15941	17466	1177	37894.1	37642.0
PILOT	11460	6705	18165	2044	84860.0	84640.5

Table 2.3 Results with SCALE OPTION 2 and PARTIAL PRICE 1

Problem Name	Phase 1 Its.	Phase 2 Its.	Total Its.	Blocked Its.	Total Time	Solution Time
AFIRO	2	4	6	3	2.7	0.3
ADLITTLE	25	67	92	12	9.8	5.0
SC205	0	114	114	12	22.0	14.5
SCAGR7	63	23	86	10	13.3	7.1
SHARE2B	63	53	116	20	13.7	7.7
RECIPE	7	26	33	3	9.3	2.0
VTPBASE	73	30	103	43	21.2	11.4
SHARE1B	165	104	269	8	34.4	25.5
BORE3D	138	54	192	98	41.5	28.5
SCORPION	70	40	110	42	39.5	24.4
CAPRI	163	86	249	23	52.5	37.3
SCAGR25	175	186	361	68	111.6	93.1
SCTAP1	159	143	302	62	64.9	48.7
BRANDY	270	210	480	40	101.3	86.9
ISRAEL	16	226	242	17	48.2	34.7
ETAMACRO	286	200	486	112	128.2	105.0
SCFXM1	256	151	407	62	98.4	78.7
GROW7	0	175	175	19	59.1	41.9
BANDM	212	252	464	25	126.1	107.1
E226	122	415	537	91	106.5	90.3
STANDATA	37	65	102	42	46.5	19.8
SCSD1	91	348	439	227	62.4	41.4
GFRDPNC	243	446	689	284	244.7	208.6
BEACONFD	37	79	116	21	32.6	14.7
STAIR	305	133	438	42	240.2	215.0
SCRS8	115	494	609	148	215.4	183.5
SEBA	268	172	440	59	148.4	111.9
SHELL	70	235	305	55	126.1	82.9
PILOT4	434	1216	1650	169	798.0	762.2
SCFXM2	530	371	901	127	376.8	337.4
SCSD6	201	1149	1350	720	265.0	227.8
GROW15	0	430	430	58	232.0	196.7
SHIP04S	13	138	151	27	77.2	38.2
FFFFF800	956	234	1190	304	440.3	401.0
GANGES	503	247	750	202	491.7	432.4
SCFXM3	837	483	1320	218	804.0	744.7
SCTAP2	282	502	784	399	475.9	414.5
GROW22	0	657	657	65	465.7	414.7
SHIP04L	13	264	277	47	124.0	70.8
PILOTWE	480	6217	6697	899	4931.9	4853.7
SIERRA	683	654	1337	594	854.7	765.7
SHIP08S	17	252	269	62	194.0	129.8
SCTAP3	401	728	1129	688	909.6	827.0
SHIP12S	39	393	432	77	362.2	284.6
25FV47	2583	6633	9216	734	6697.7	6631.1
SCSD8	685	3124	3809	2179	1745.3	1670.8
NESM	1275	1951	3226	1	1611.6	1506.3
CZPROB	707	900	1607	98	1020.5	921.6
PILOTJA	1882	5099	6981	607	6440.1	6353.4
SHIP08L	12	466	478	70	363.1	257.2
SHIP12L	38	814	852	165	779.0	642.3
80BAU3B	1580	9447	11027	1070	13917.3	13664.8
PILOT	12254	6681	18935	4220	80158.6	79939.9

Table 2.4 Results with SCALE OPTION 2 and PARTIAL PRICE 10

Problem Name	Phase 1 Its.	Phase 2 Its.	Total Its.	Blocked Its.	Total Time	Solution Time
AFIRO	2	4	6	3	2.6	0.3
ADLITTLE	33	94	127	18	11.6	6.9
SC205	0	120	120	23	22.1	15.0
SCAGR7	56	28	84	8	13.4	7.1
SHARE2B	70	54	124	25	14.5	8.5
RECIPE	7	28	35	3	9.2	2.0
VTPBASE	40	22	62	22	16.6	6.8
SHARE1B	120	137	257	11	33.5	24.5
BORE3D	115	41	156	77	35.9	22.9
SCORPION	66	39	105	41	37.2	22.0
CAPRI	162	95	257	26	53.1	37.9
SCAGR25	162	209	371	64	111.8	93.2
SCTAP1	169	120	289	65	61.9	45.7
BRANDY	277	213	490	34	100.8	86.5
ISRAEL	19	276	295	15	55.5	42.1
ETAMACRO	260	272	532	125	135.4	112.3
SCFXM1	246	172	418	63	97.7	78.2
GROW7	0	175	175	14	56.3	39.3
BANDM	202	268	470	34	126.1	107.1
E226	165	317	482	99	93.3	77.1
STANDATA	72	94	166	82	56.4	29.5
SCSD1	74	284	358	202	51.5	31.0
GFRDPNC	265	448	713	277	245.9	209.8
BEACONFD	66	67	133	24	34.0	16.2
STAIR	279	103	382	40	216.7	191.5
SCRS8	95	482	577	201	196.0	163.3
SEBA	306	183	489	70	160.7	124.9
SHELL	77	240	317	59	123.5	80.4
PILOT4	510	1120	1630	121	789.0	752.7
SCFXM2	590	305	895	120	371.5	332.0
SCSD6	186	1231	1417	574	245.0	207.7
GROW15	0	429	429	40	231.5	196.3
SHIP04S	15	148	163	32	76.1	37.0
FFFFF800	906	235	1141	281	404.4	364.6
GANGES	552	218	770	196	489.2	429.4
SCFXM3	857	523	1380	245	831.7	772.2
SCTAP2	312	529	841	396	493.2	431.5
GROW22	0	737	737	48	497.7	446.4
SHIP04L	15	254	269	43	115.3	61.9
PILOTWE	587	4058	4645	574	3369.7	3291.2
SIERRA	677	675	1352	609	823.2	734.3
SHIP08S	17	251	268	70	178.0	113.6
SCTAP3	432	738	1170	655	896.2	814.8
SHIP12S	42	392	434	77	340.3	263.1
25FV47	2634	5695	8329	757	5830.0	5763.8
SCSD8	970	2959	3929	1888	1616.5	1541.8
NESM	1261	1529	2790	4	1286.4	1180.9
CZPROB	619	913	1532	84	932.7	833.3
PILOTJA	1907	4630	6537	894	5961.1	5874.1
SHIP08L	12	507	519	88	352.8	246.7
SHIP12L	44	811	855	155	715.2	579.2
80BAU3B	1834	9289	11123	1223	13325.9	13073.7
PILOT	13352	7870	21222	4667	86119.7	85900.0

Table 2.5 Results with SCALE OPTION 2 and PARTIAL PRICE 20

Problem Name	Phase 1 Its.	Phase 2 Its.	Total Its.	Blocked Its.	Total Time	Solution Time
AFIRO	2	4	6	3	2.6	0.3
ADLITTLE	35	89	124	19	11.4	6.7
SC205	0	130	130	22	24.5	16.9
SCAGR7	51	29	80	11	12.2	6.1
SHARE2B	62	36	98	15	12.3	6.6
RECIPE	7	28	35	3	9.1	1.9
VTPBASE	62	31	93	36	19.4	9.6
SHARE1B	148	167	315	7	38.8	30.1
BORE3D	126	52	178	90	39.4	26.4
SCORPION	75	44	119	41	40.9	25.6
CAPRI	152	114	266	29	54.0	38.8
SCAGR25	171	200	371	70	110.5	92.0
SCTAP1	182	140	322	64	66.3	49.5
BRANDY	326	191	517	33	104.4	90.5
ISRAEL	14	238	252	15	49.5	36.2
ETAMACRO	258	245	503	142	125.8	102.7
SCFXM1	255	153	408	70	98.1	78.3
GROW7	0	176	176	17	56.5	40.0
BANDM	191	196	387	23	105.8	87.3
E226	175	443	618	138	115.3	99.1
STANDATA	95	91	186	93	58.4	31.0
SCSD1	90	377	467	306	59.2	38.1
GFRDPNC	259	519	778	300	260.0	223.8
BEACONFD	80	61	141	22	34.9	17.1
STAIR	276	122	398	31	227.5	202.8
SCRS8	141	458	599	185	205.1	172.9
SEBA	219	157	376	44	125.9	89.3
SHELL	105	241	346	63	129.8	86.8
PILOT4	573	1114	1687	138	811.3	775.5
SCFXM2	504	311	815	129	336.8	297.3
SCSD6	237	815	1052	318	184.3	147.8
GROW15	0	472	472	42	249.9	214.6
SHIP04S	19	156	175	33	77.1	38.2
FFFFF800	809	299	1108	354	388.3	348.5
GANGES	542	229	771	198	478.7	418.7
SCFXM3	816	497	1313	217	784.4	724.6
SCTAP2	364	608	972	453	561.0	499.3
GROW22	0	641	641	59	437.7	386.8
SHIP04L	33	272	305	45	118.1	64.3
PILOTWE	492	4377	4869	490	3498.8	3419.8
SIERRA	610	682	1292	542	772.9	683.7
SHIP08S	17	253	270	63	173.2	109.5
SCTAP3	430	742	1172	643	897.4	815.6
SHIP12S	43	373	416	71	342.0	264.9
25FV47	2162	5137	7299	684	5044.6	4978.5
SCSD8	929	2767	3696	1825	1419.2	1345.1
NESM	1280	1153	2433	3	1055.8	950.0
CZPROB	744	912	1656	95	976.5	877.7
PILOTJA	2052	4948	7000	537	6276.7	6190.1
SHIP08L	12	522	534	87	342.6	236.7
SHIP12L	46	844	890	175	723.7	588.5
80BAU3B	1503	9153	10656	1006	12000.6	11747.8
PILOT	11660	6701	18361	4234	71991.3	71772.9

Table 2.6 Results with SCALE OPTION 2 and PARTIAL PRICE 40

Problem Name	Scaled PP 1 Objective Value	Scaled PP 10	Scaled PP 20	Scaled PP 40	Unscaled PP 1	Unscaled PP 10
AFIRO	-4.6475314285714E+02					
ADLITTLE	2.2549496316238E+05					
SC205	-5.2202061211707E+01					
SCAGR7	-2.3313898243310E+06	3.1E-08	3.1E-08	3.1E-08	3.1E-08	
SHARE2B	-4.1573224074142E+02					
RECIPE	-2.6661600000000E+02					
VTPBASE	1.2983146246136E+05					
SHARE1B	-7.6589318579186E+04					
BORE3D	1.3730803942085E+03					
SCORPION	1.8781248227381E+03					
CAPRI	2.6900129137682E+03					
SCAGR25	-1.4753433060769E+07					
SCTAP1	1.4122500000000E+03					
BRANDY	1.5185098964881E+03					
ISRAEL	-8.9664482186305E+05					
ETAMACRO	-7.5571521856065E+02	5.9E-10	1.1E-09	6.4E-10	7.1E-09	7.5E-09
SCFXM1	1.8416759028349E+04					
GROW7	-4.7787811814712E+07					
BANDM	-1.5862801845012E+02					
E226	-1.8751929066371E+01					
STANDATA	1.2576995000000E+03					
SCSD1	8.6666666743334E+00					
GFRDPNC	6.9022359995488E+06					
BEACONFD	3.3592485807200E+04					
STAIR	-2.5126695119296E+02					
SCRS8	9.0429998618888E+02		3.4E-06	3.4E-06	3.4E-06	3.4E-06
SEBA	1.5711600000000E+04					
SHELL	1.2088253460000E+09					
PILOT4	-2.5811397876813E+03	3.5E-13	1.7E-09	2.9E-10	4.8E-05	3.9E-05
SCFXM2	3.6660261564999E+04					
SCSD6	5.0500000078262E+01					
GROW15	-1.0687094129358E+08					
SHIP04S	1.7987147004454E+06					
FFFFF800	5.5567959102690E+05	4.0E-08	3.6E-08	3.6E-08	6.7E-07	4.6E-05
GANGES	-1.0958576909180E+05	3.4E-08	6.2E-08	6.2E-08	3.0E-07	3.0E-07
SCFXM3	5.4901254549751E+04					
SCTAP2	1.7248071428571E+03					
GROW22	-1.6083433648256E+08					
SHIP04L	1.7933245379704E+06					
PILOTWE	-2.7200979898204E+06	1.9E-06	2.4E-07	2.1E-07	3.7E-04	5.2E-04
SIERRA	1.5394362183632E+07				3.9E-04	2.0E-06
SHIP08S	1.9200982105346E+06					
SCTAP3	1.4240000000000E+03					
SHIP12S	1.4892361344061E+06					
25FV47	5.5018458882867E+03					
SCSD8	9.0499999992546E+02					
NESM	1.4076086885553E+07	6.1E-07	9.4E-08	4.9E-07	1.1E-06	1.4E-06
CZPROB	2.1851966988566E+06					
PILOTJA	-6.1130625520046E+03			3.0E-10	4.7E-04	4.6E-04
SHIP08L	1.9090552113891E+06					
SHIP12L	1.4701879193293E+06					
80BAU3B	9.8722925484290E+05	6.1E-07	2.3E-06	1.7E-07	5.1E-06	5.1E-06
PILOT	-5.5740380063326E+02	4.7E-06			6.5E-05	7.5E-05

Table 3.1 Relative Error in Objective Compared to SCALE OPTION 2 and PARTIAL PRICE 1

Figure 3.2
Solution Time Factors Compared to No Scaling, Full Pricing

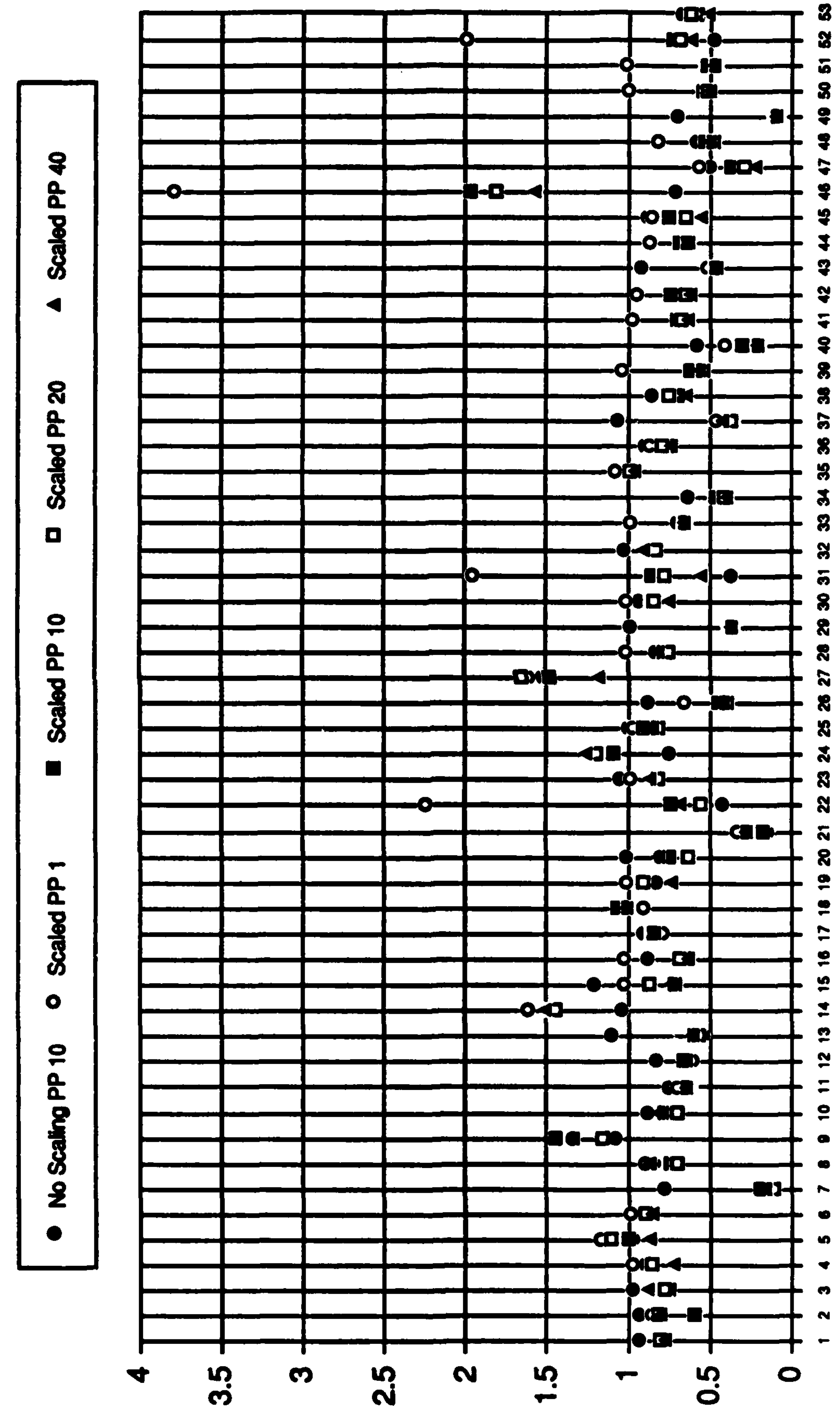


Figure 3.3
Solution Time Factors Compared to No Scaling Equivalents
Sorted by Factor for Full Pricing

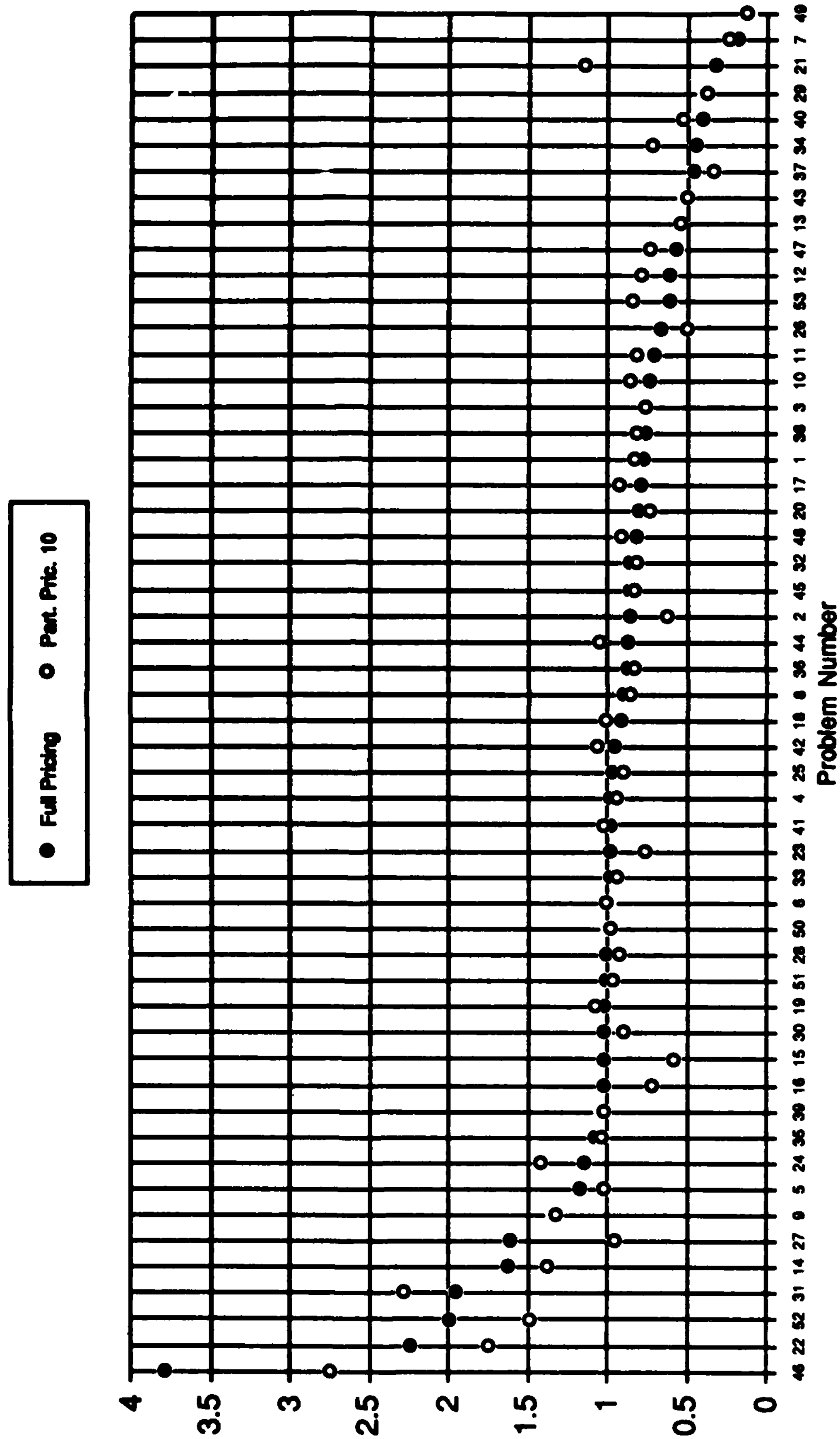


Figure 3.4
Solution Time Factors Compared to Scaling, Full Pricing Ordered by Factor for Partial Price 10

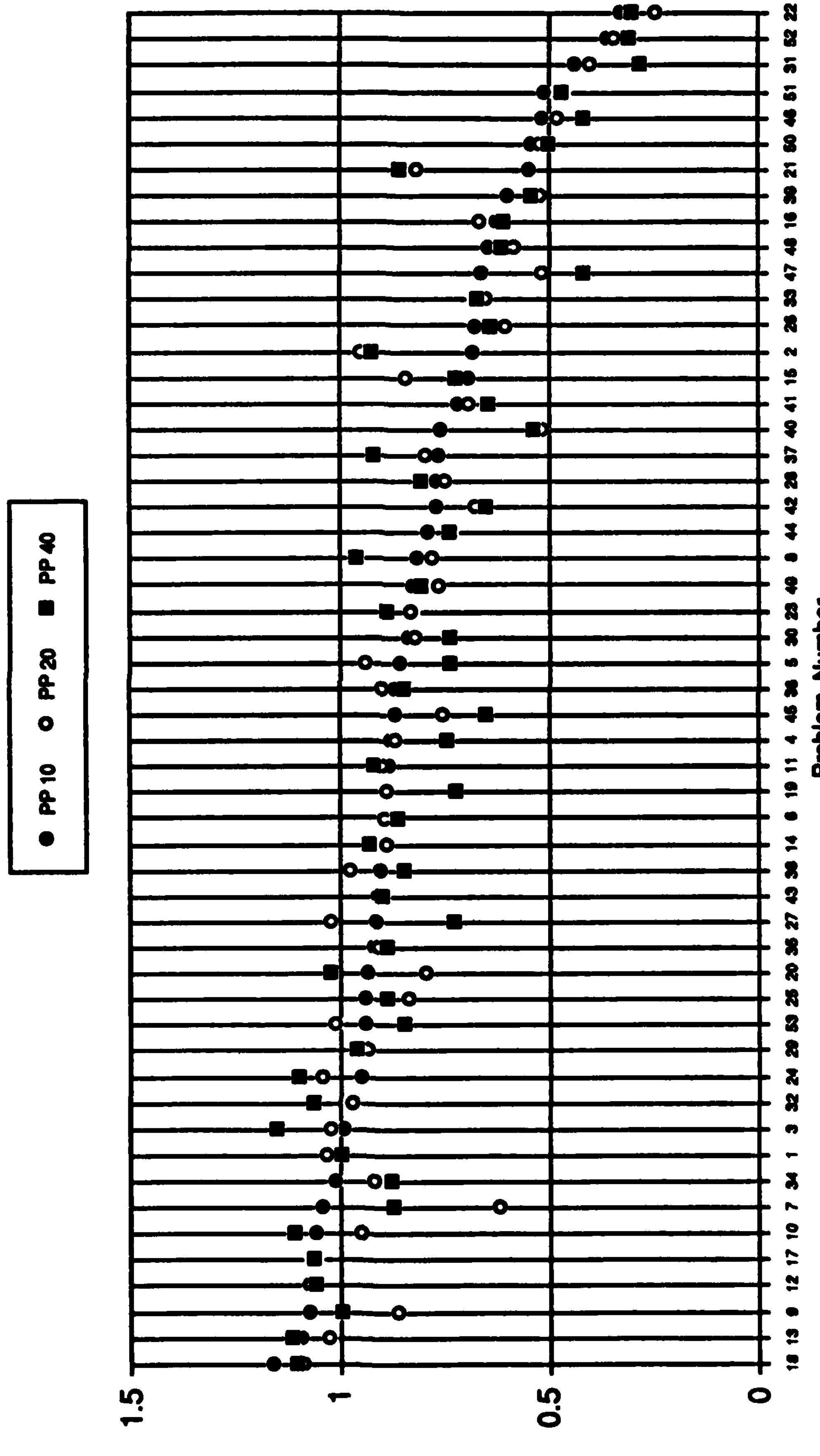
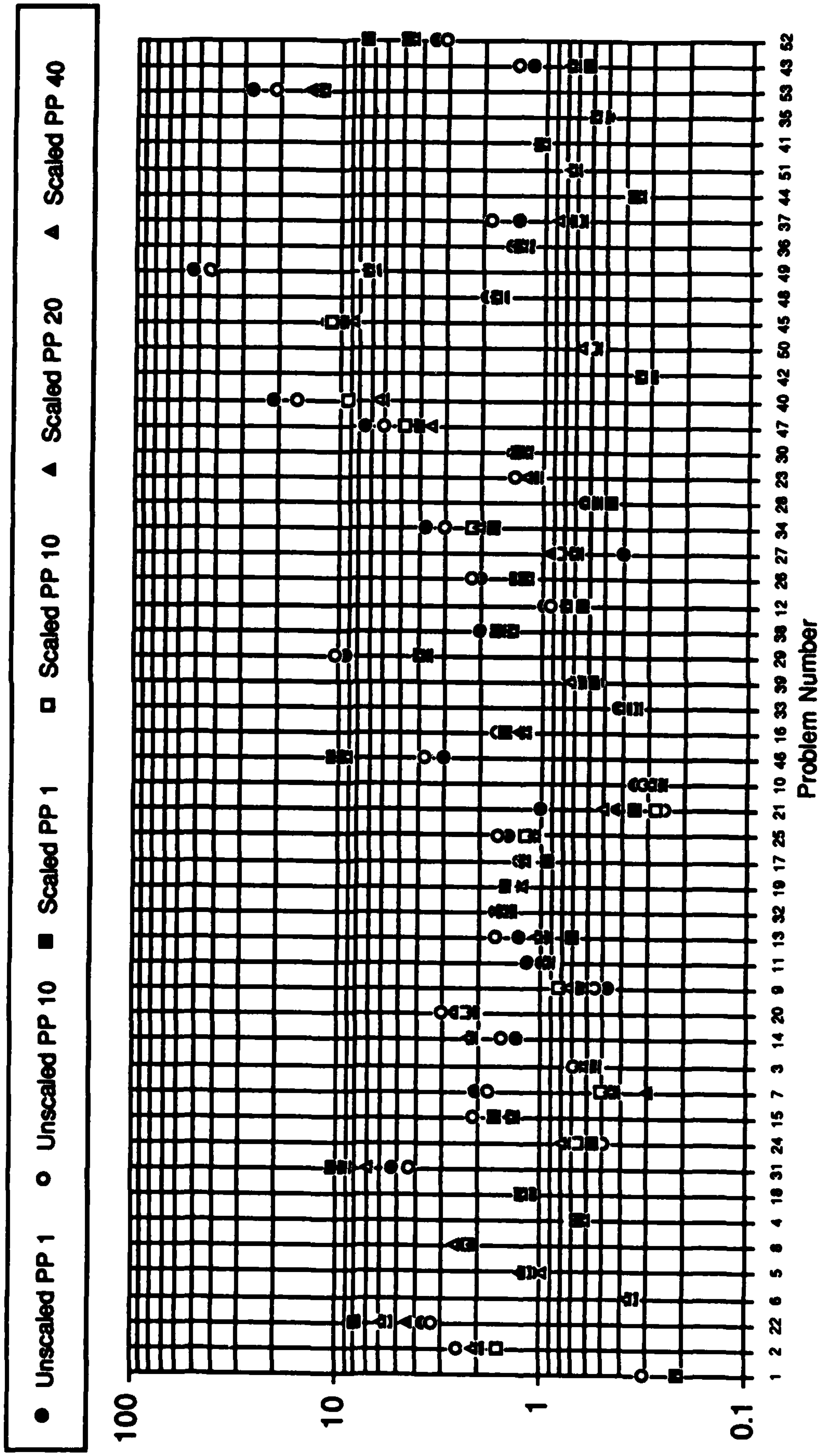
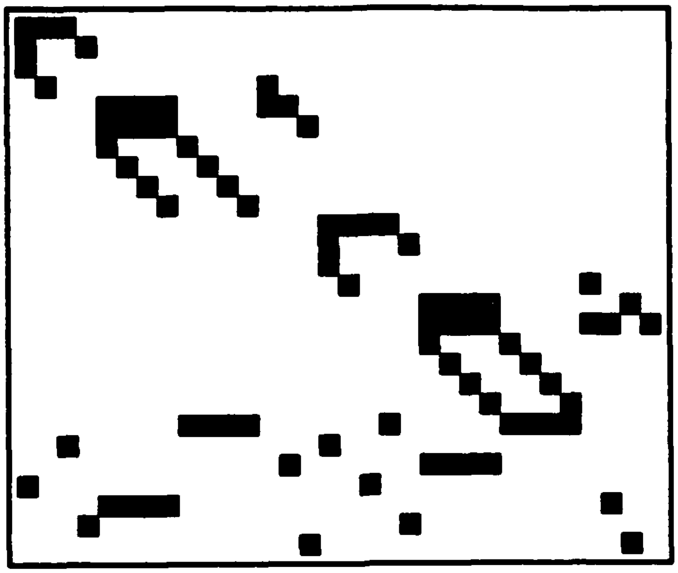


Figure 3.5
Ratio of Iteration Count to Number of Rows
Ordered by Number of Rows





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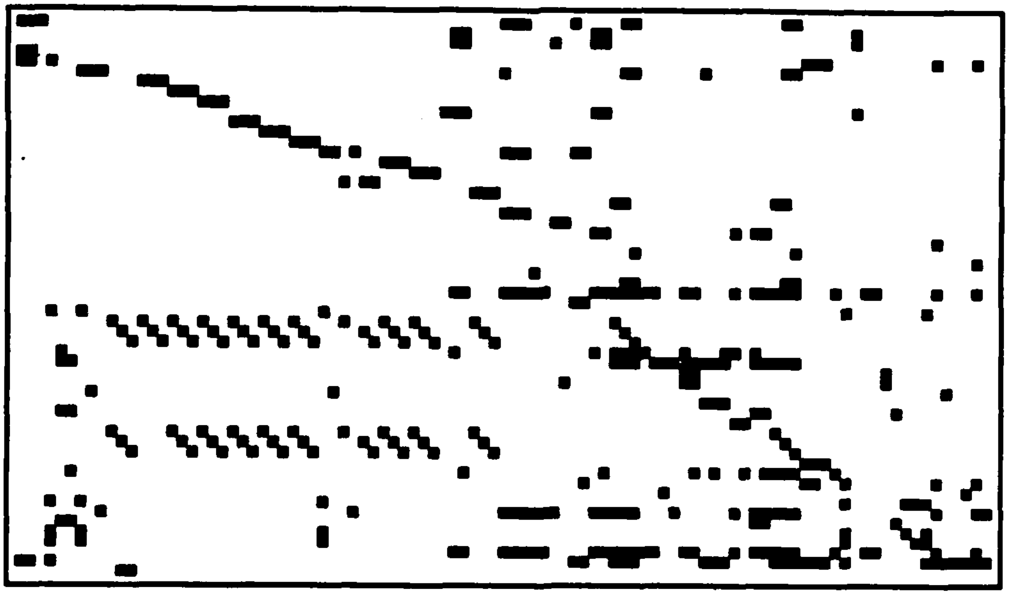

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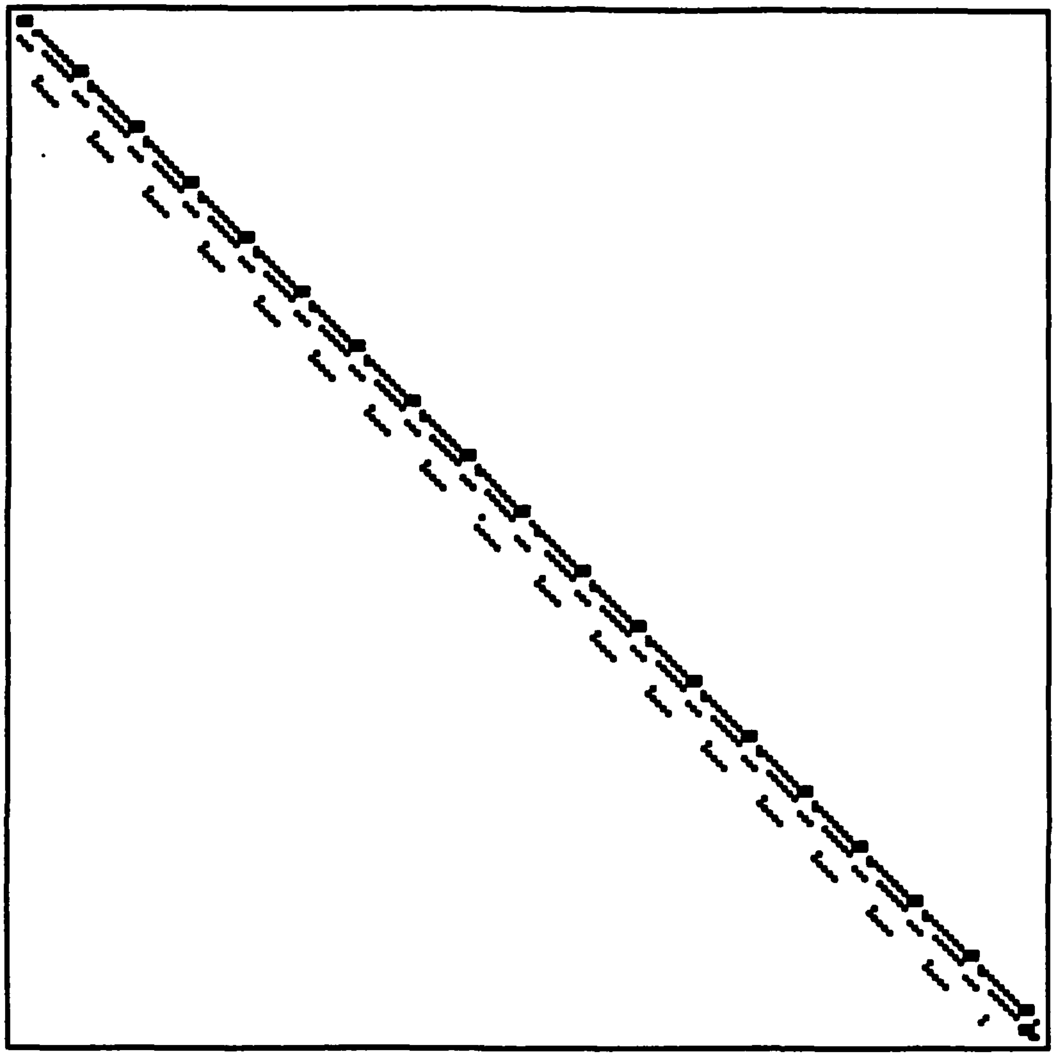

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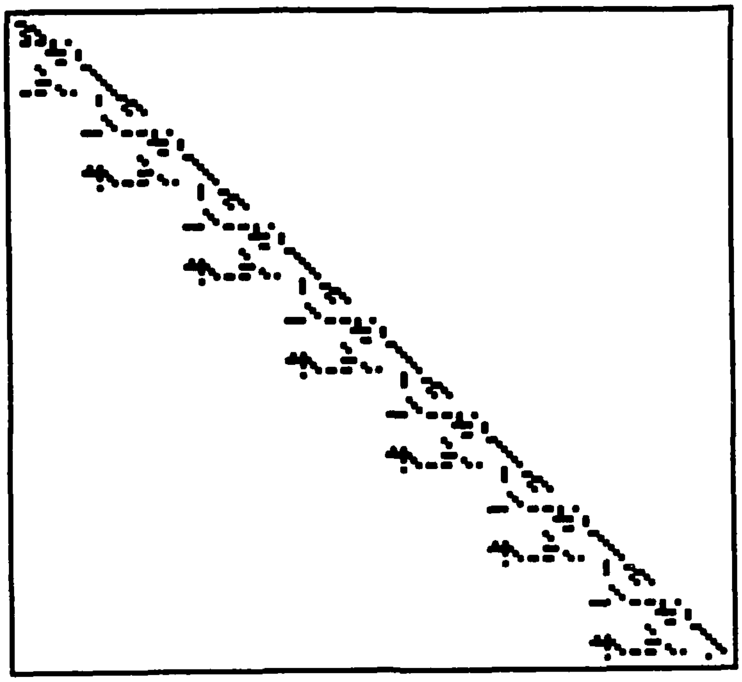

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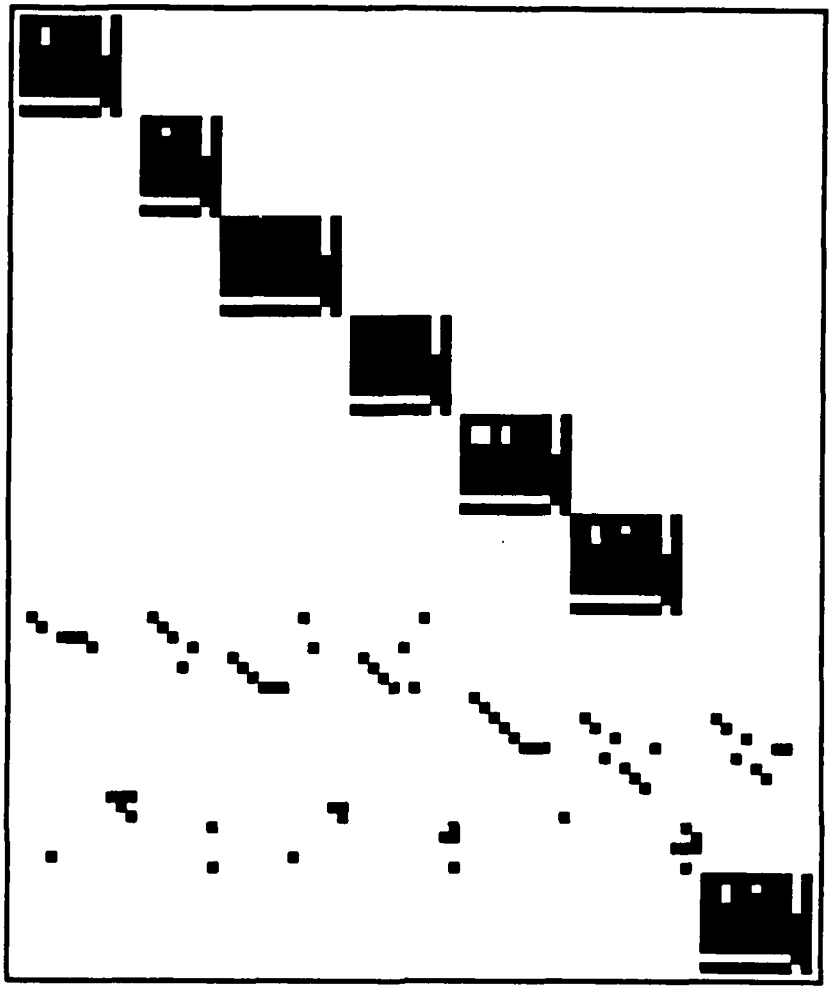

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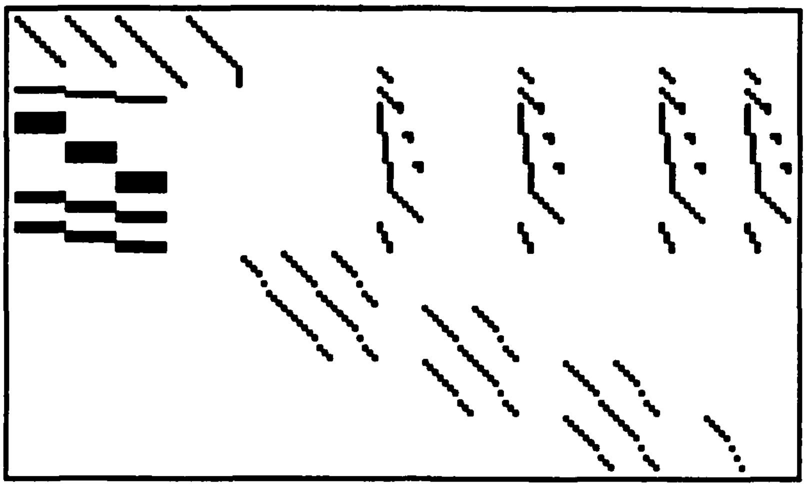

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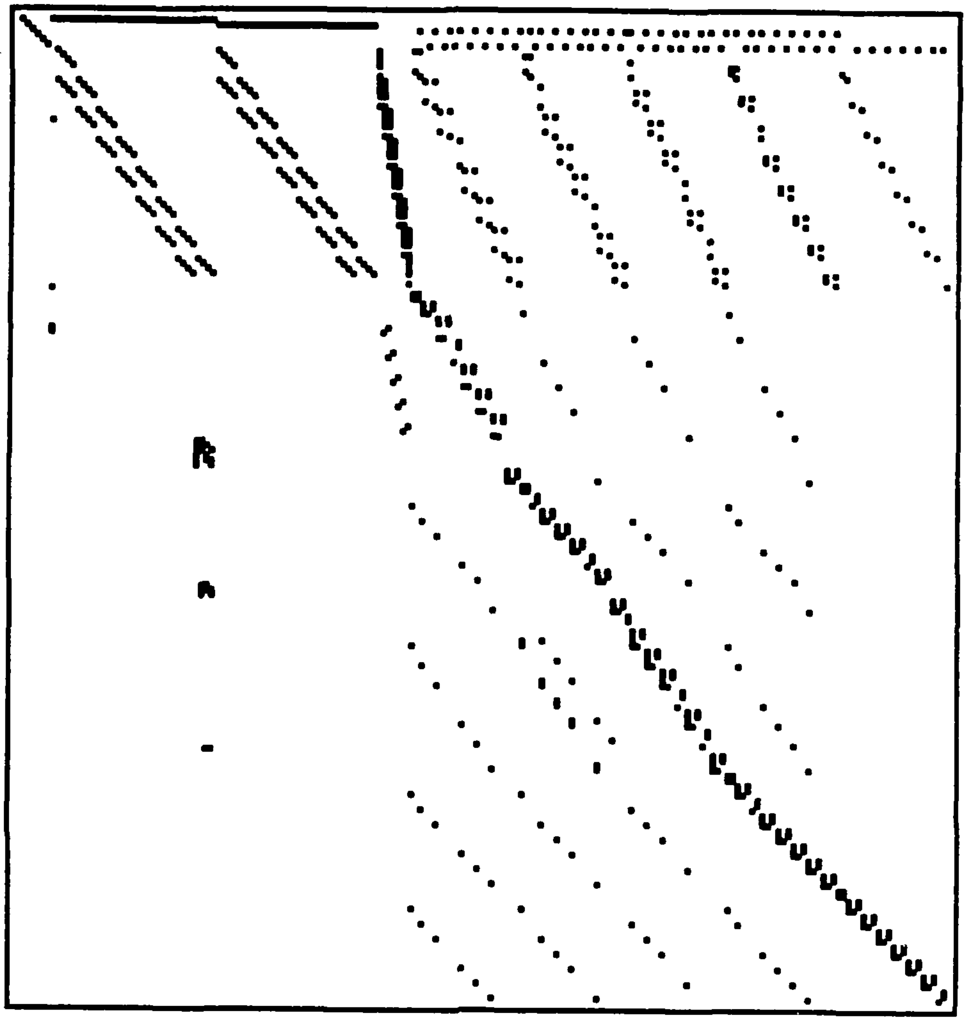

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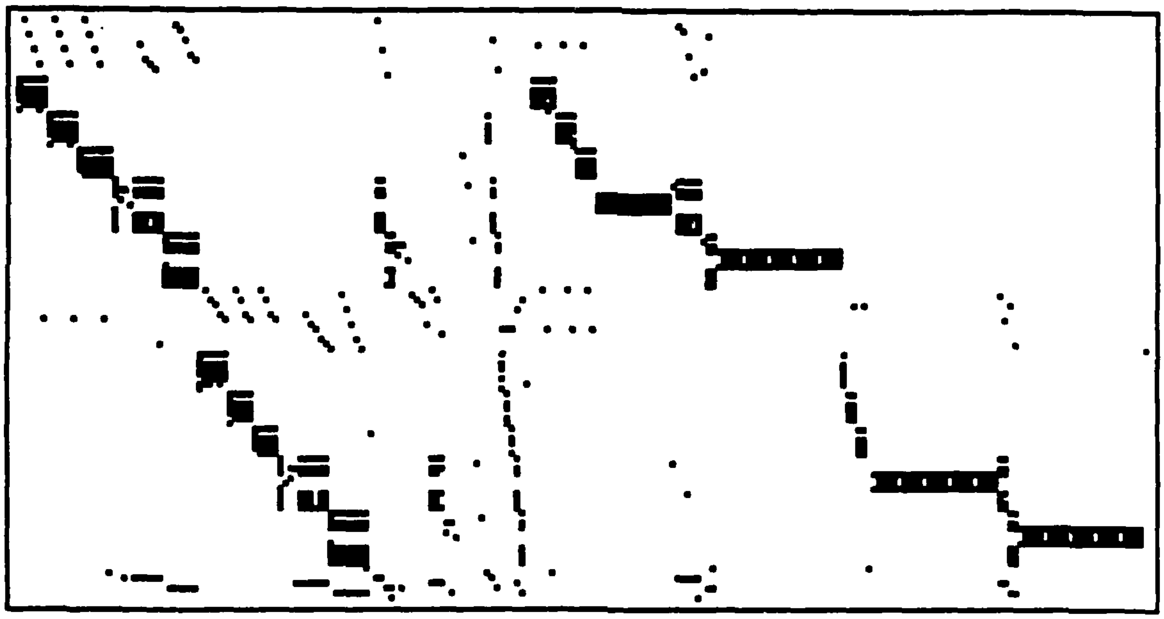

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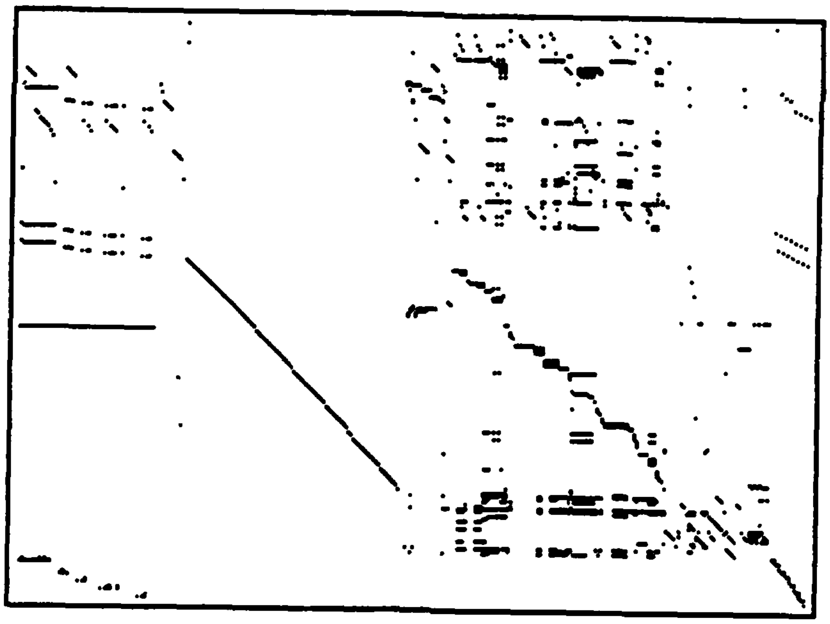

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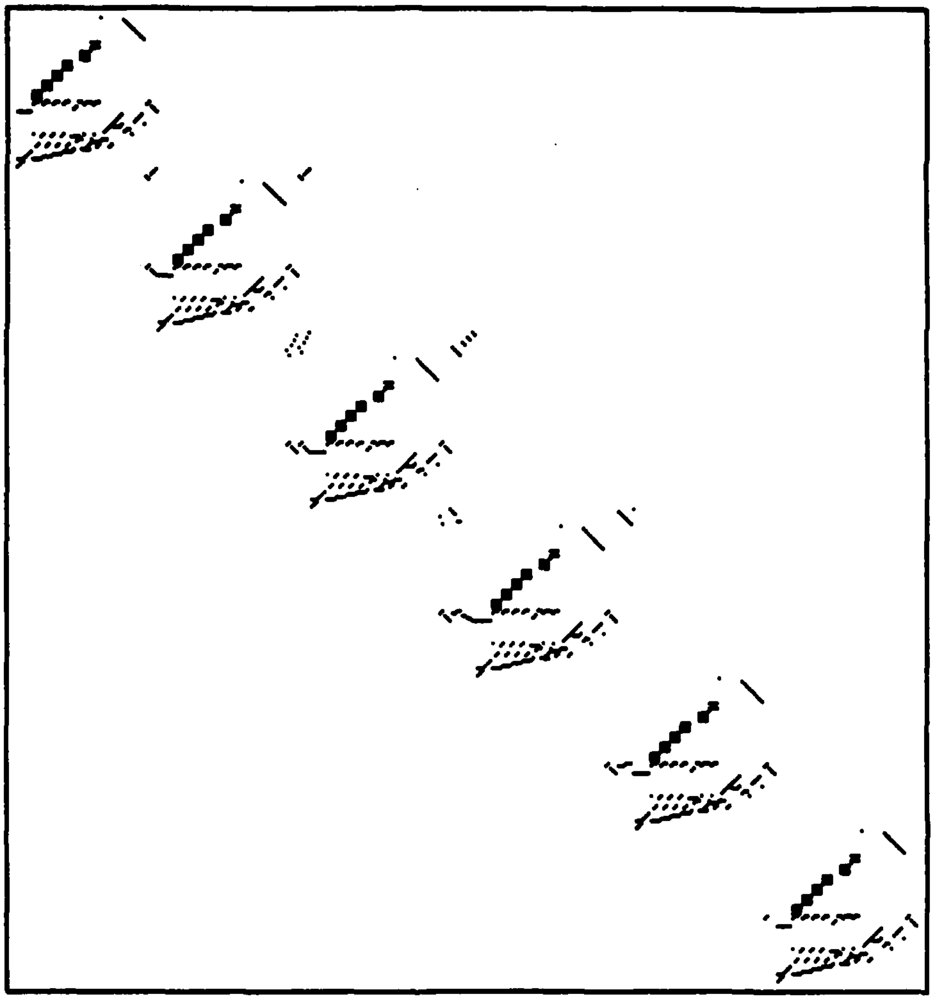

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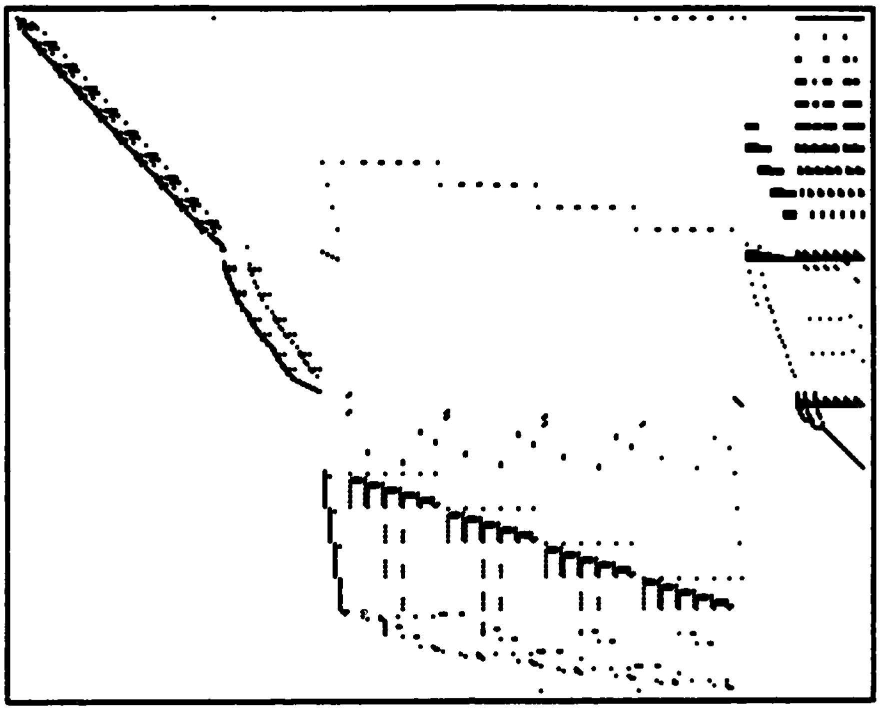

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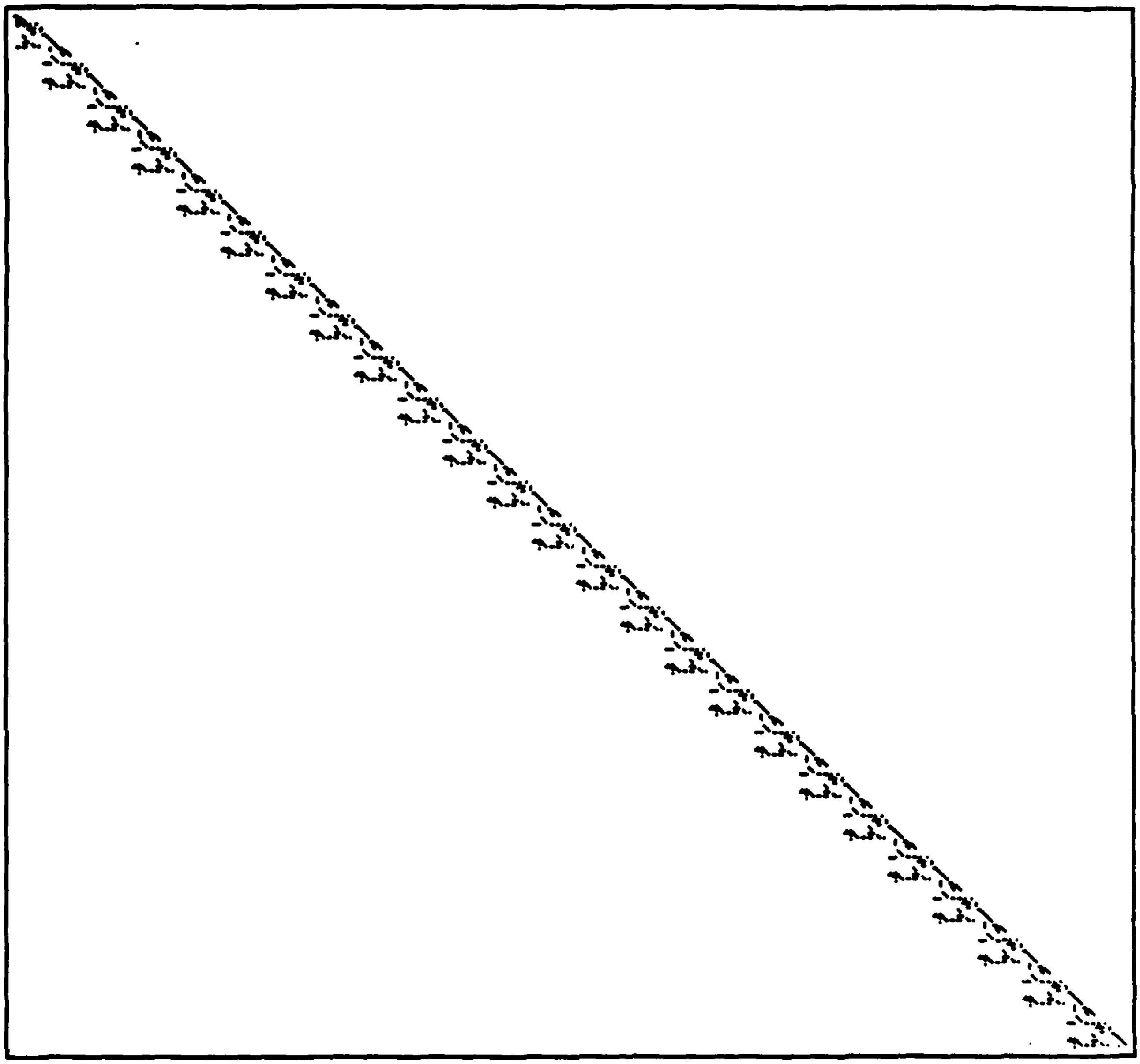

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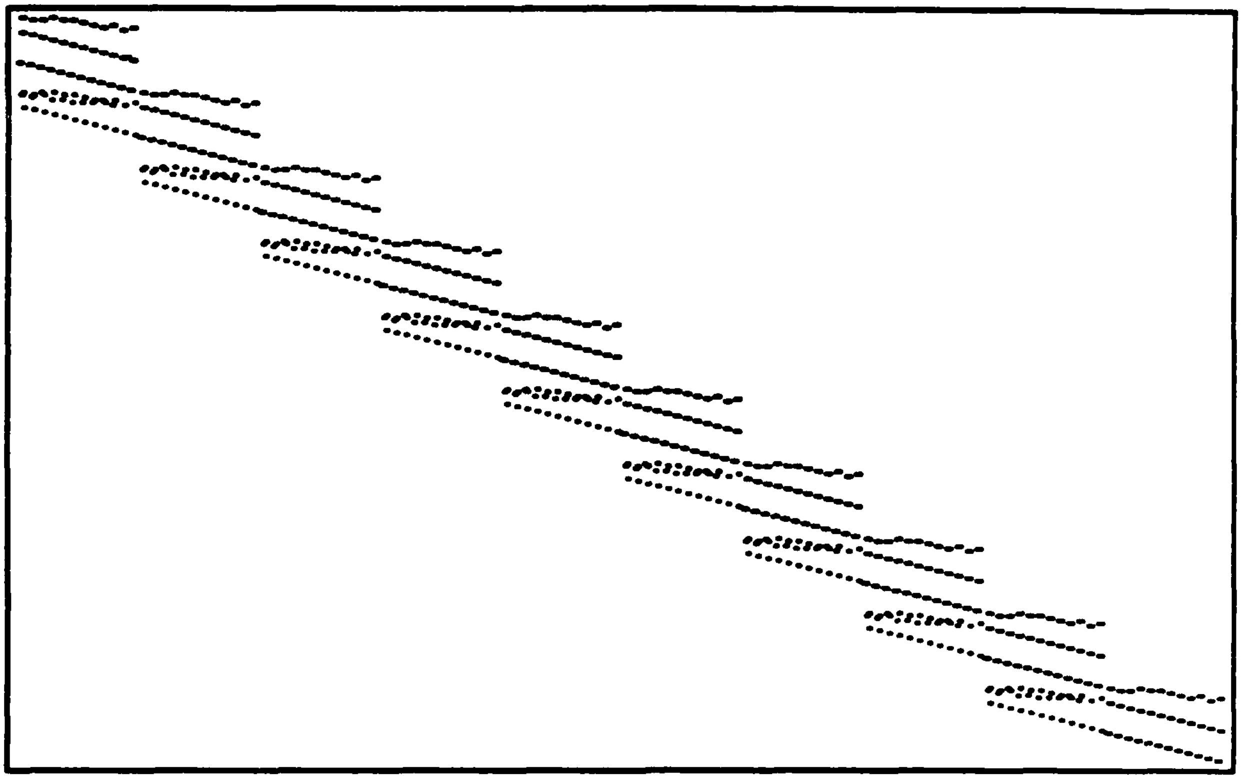

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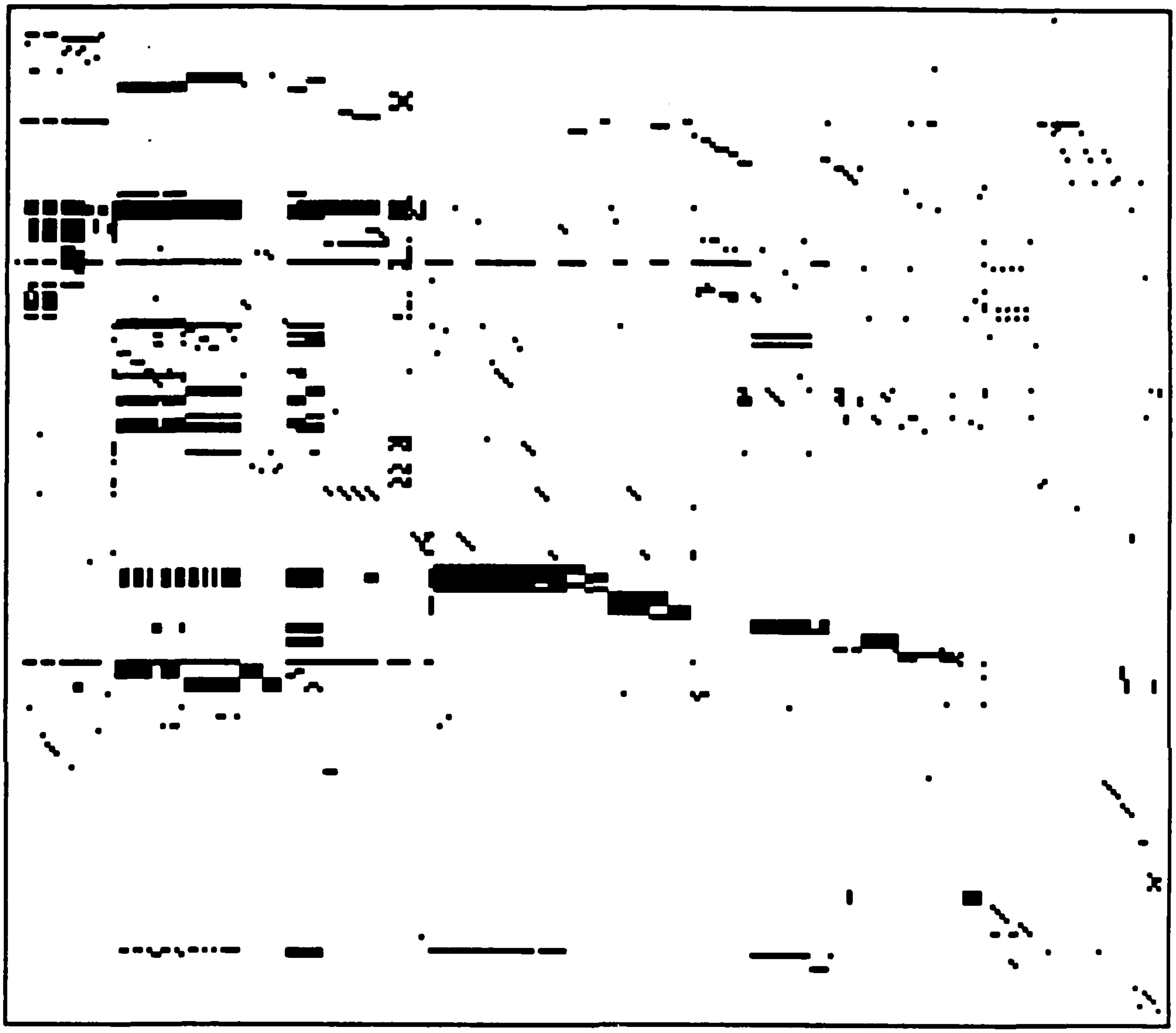

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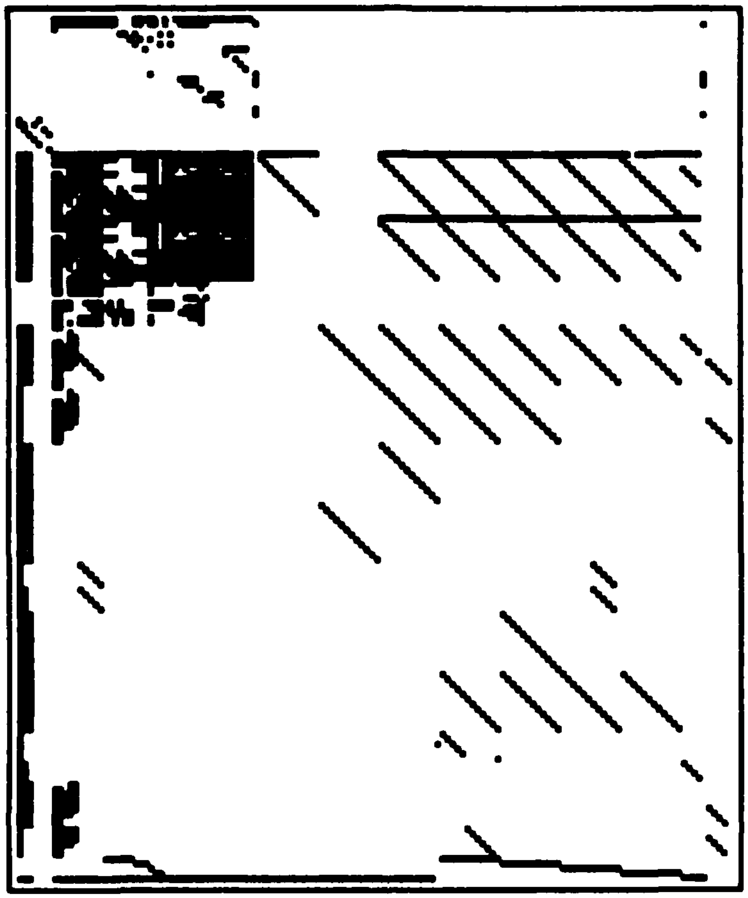

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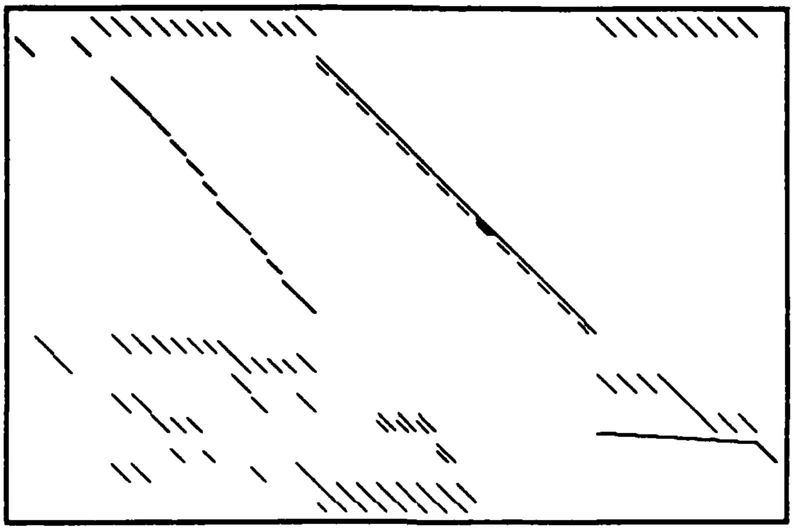

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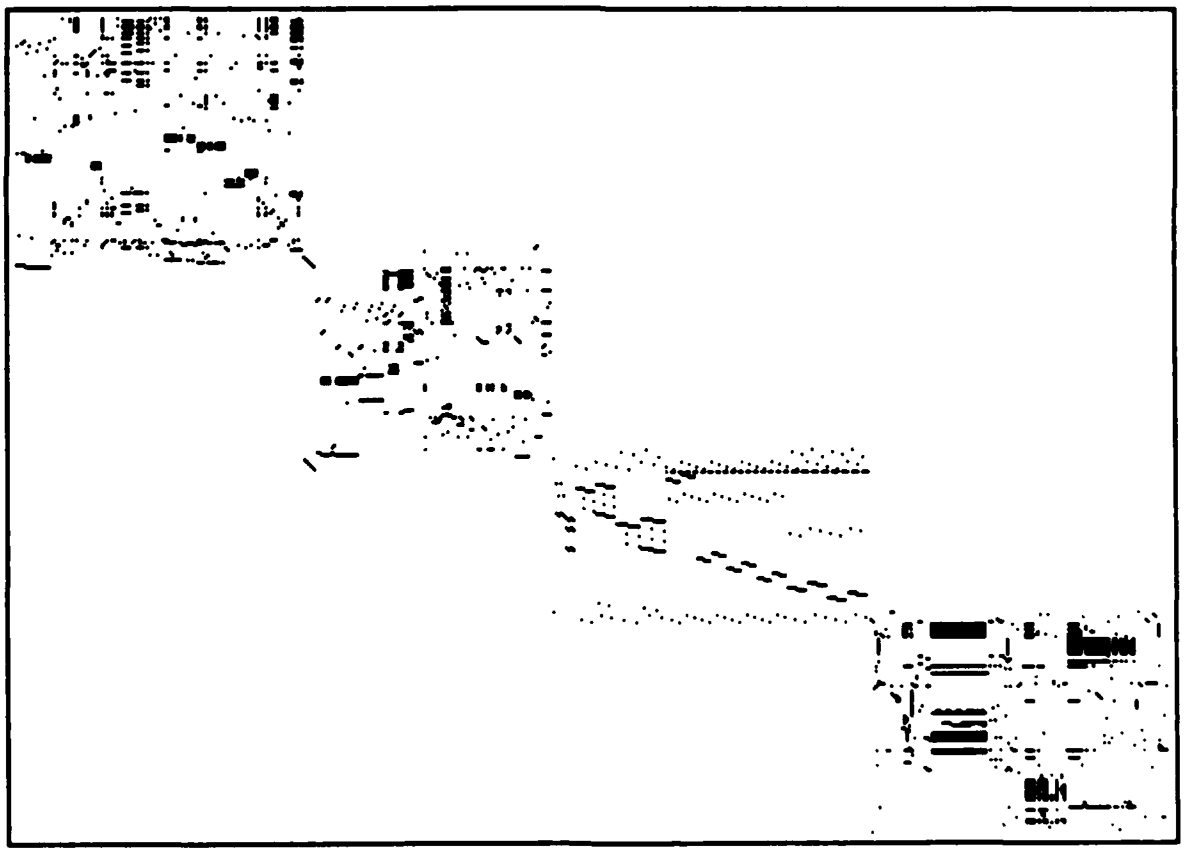

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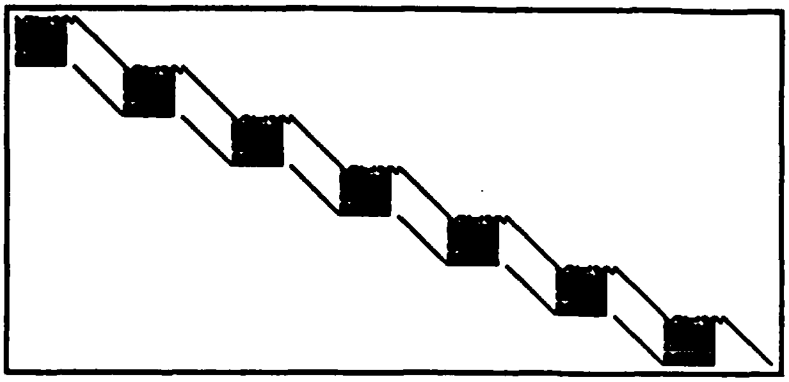

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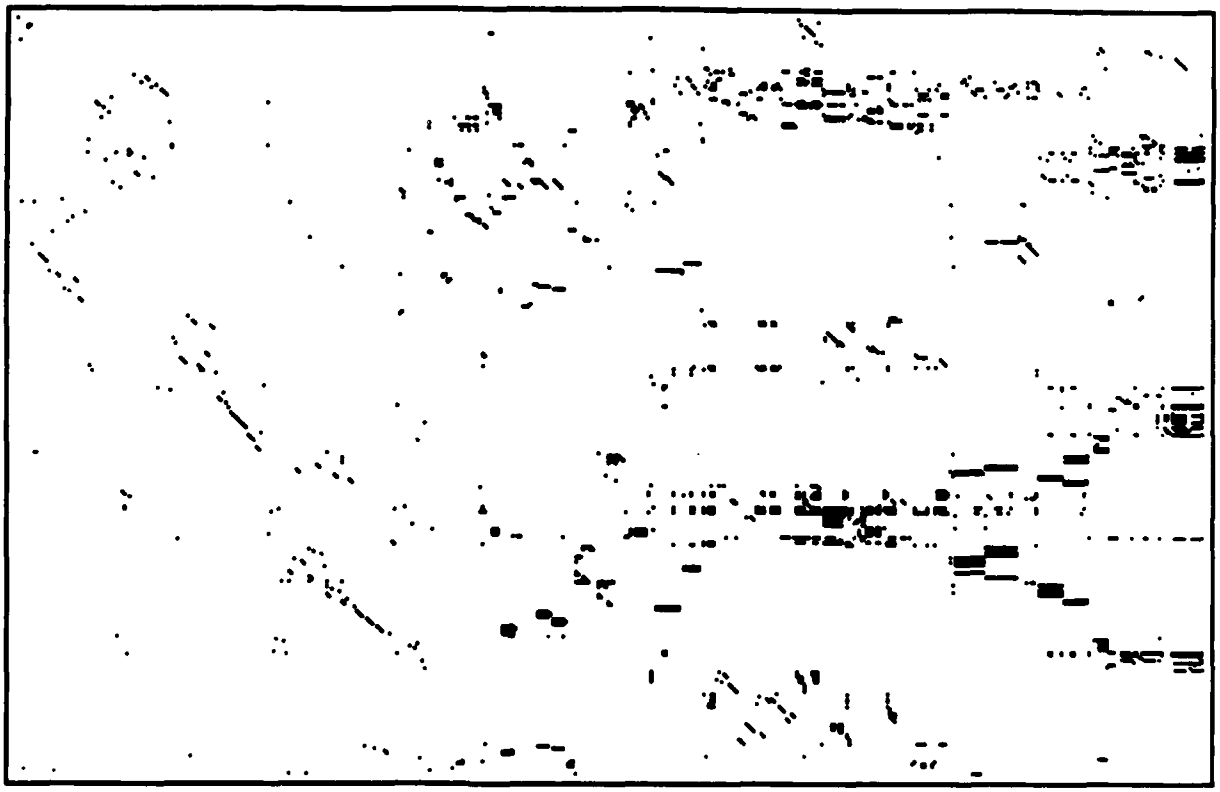

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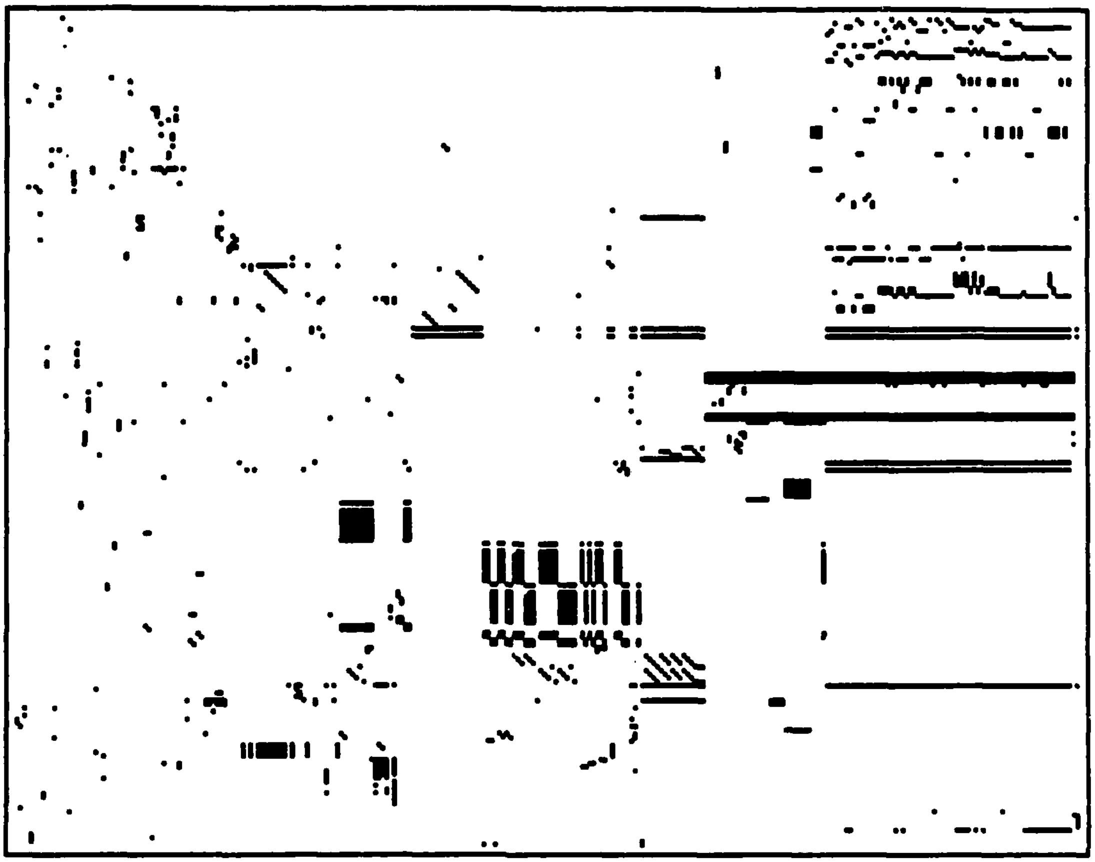

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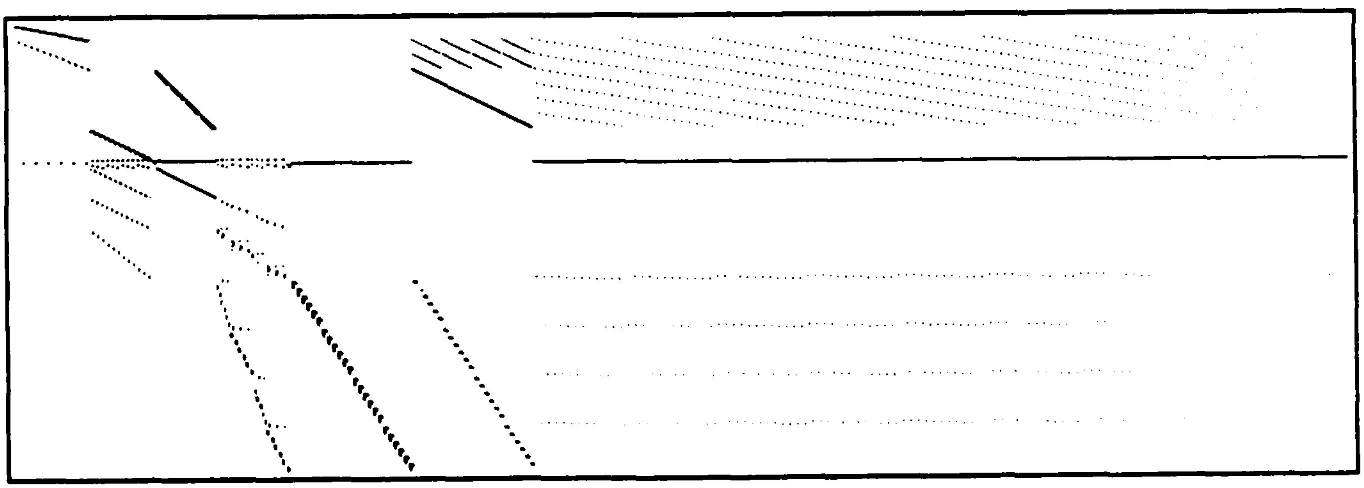

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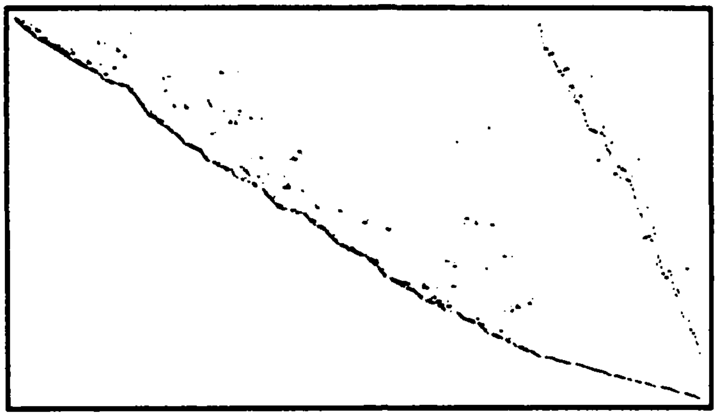

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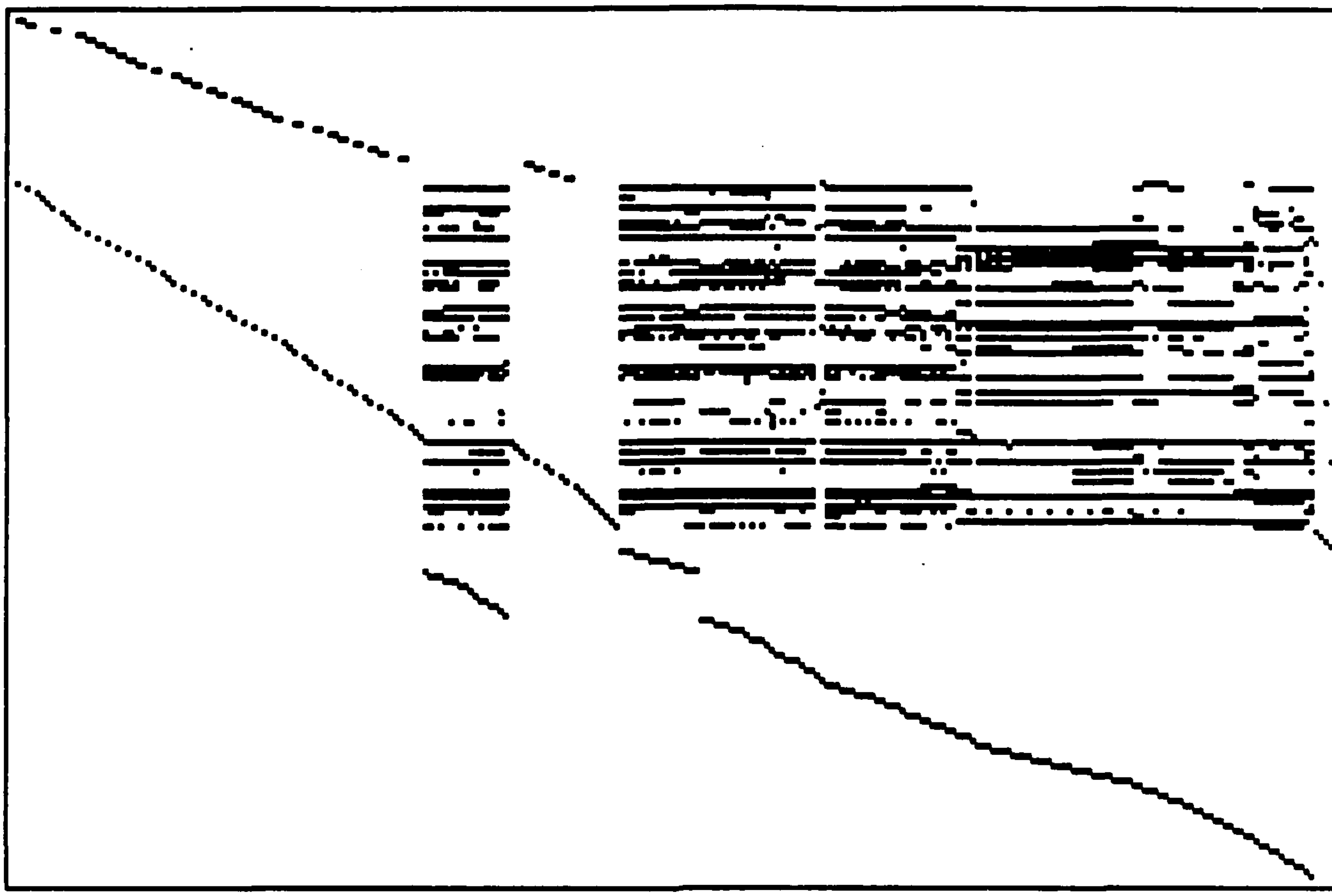

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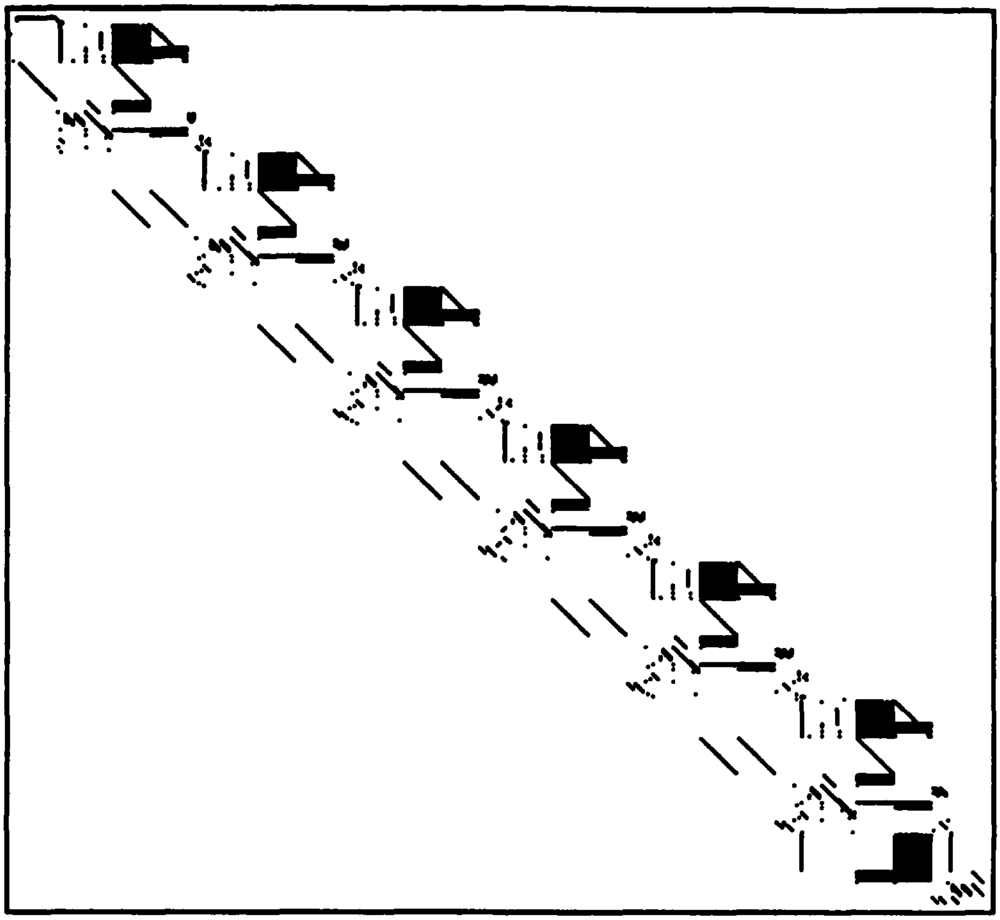

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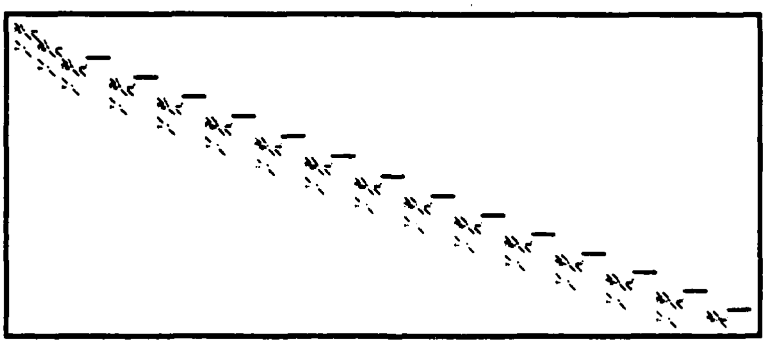

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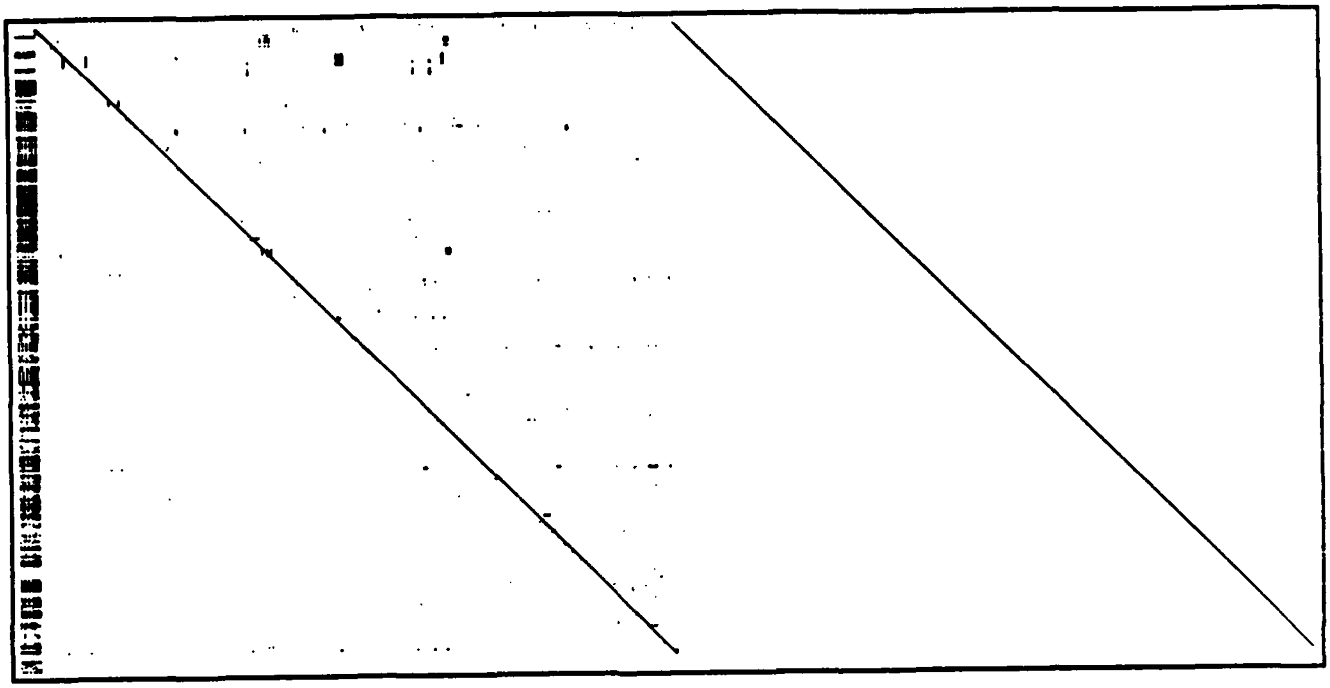

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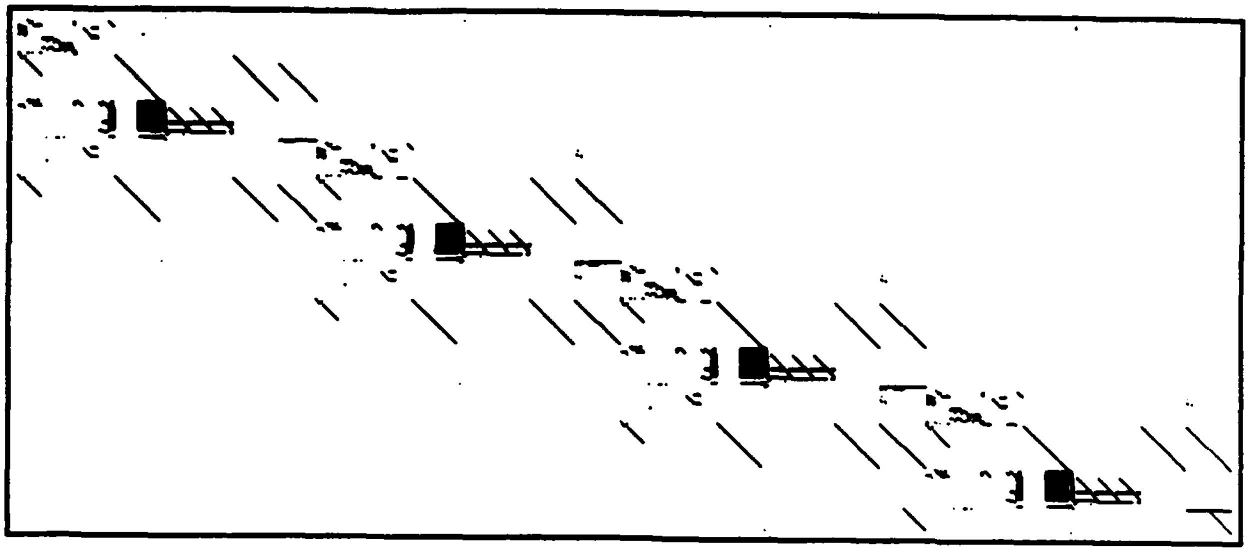

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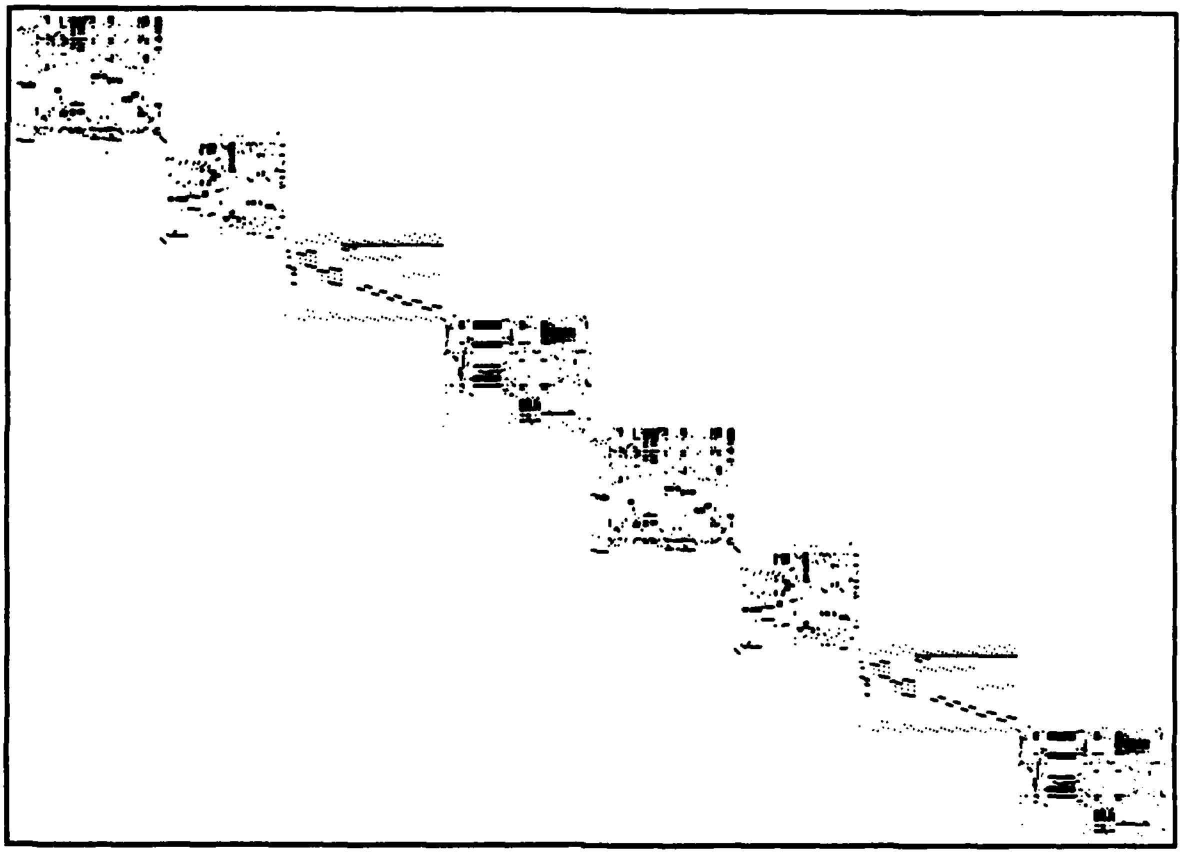

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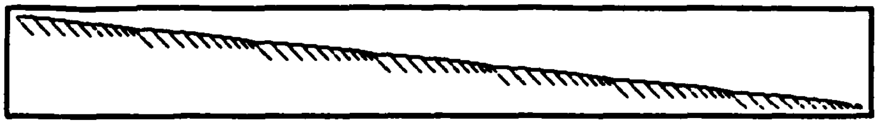

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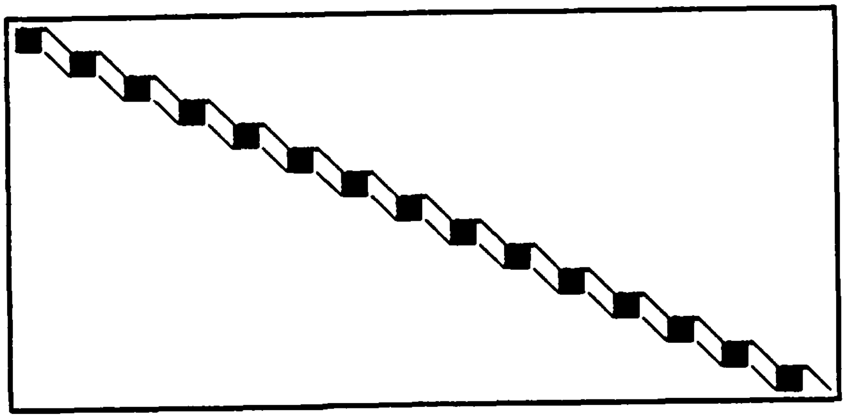

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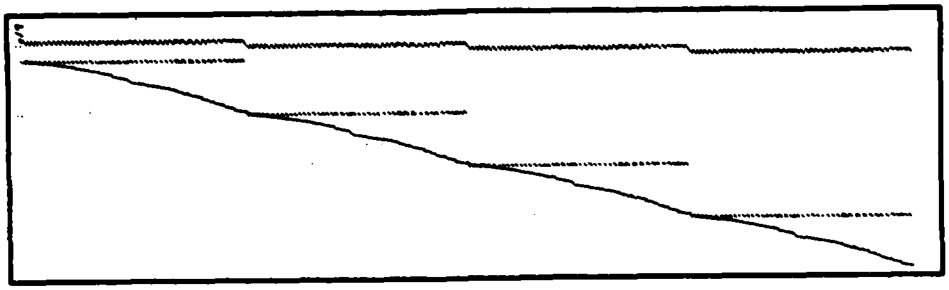

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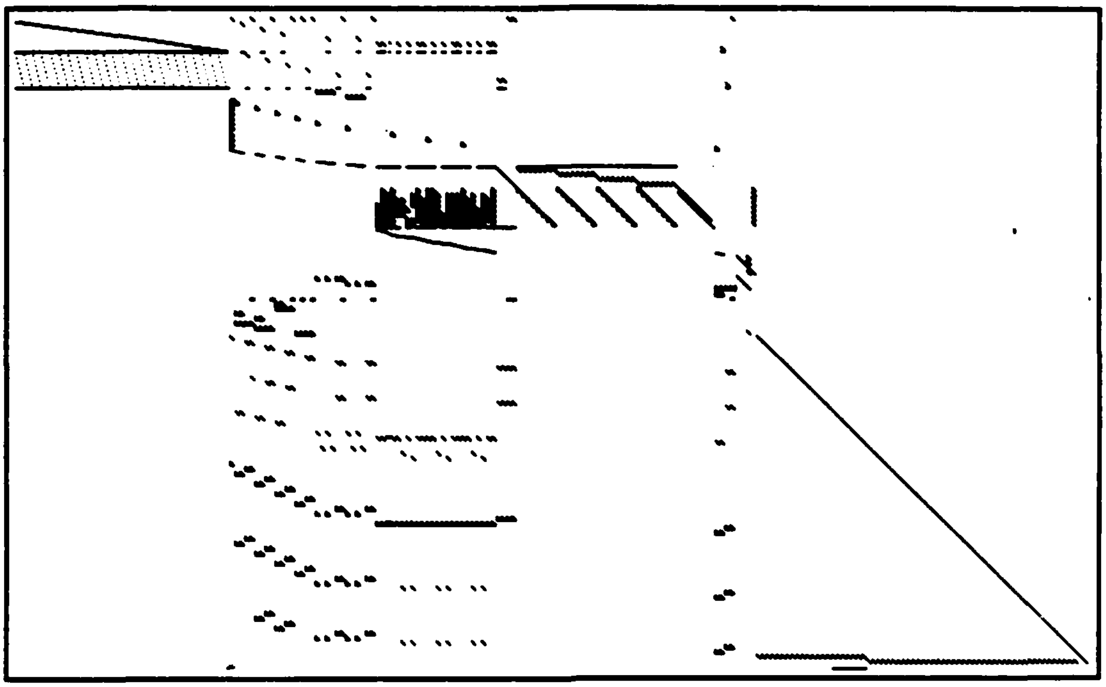

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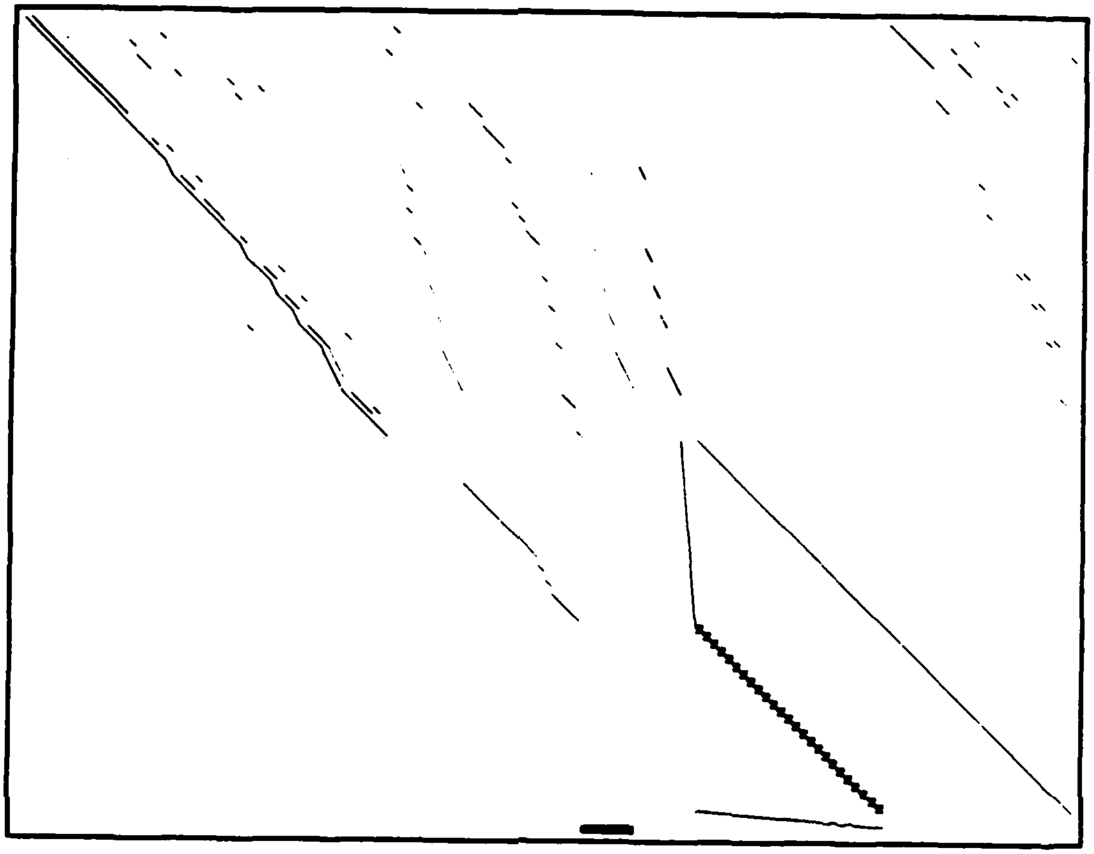

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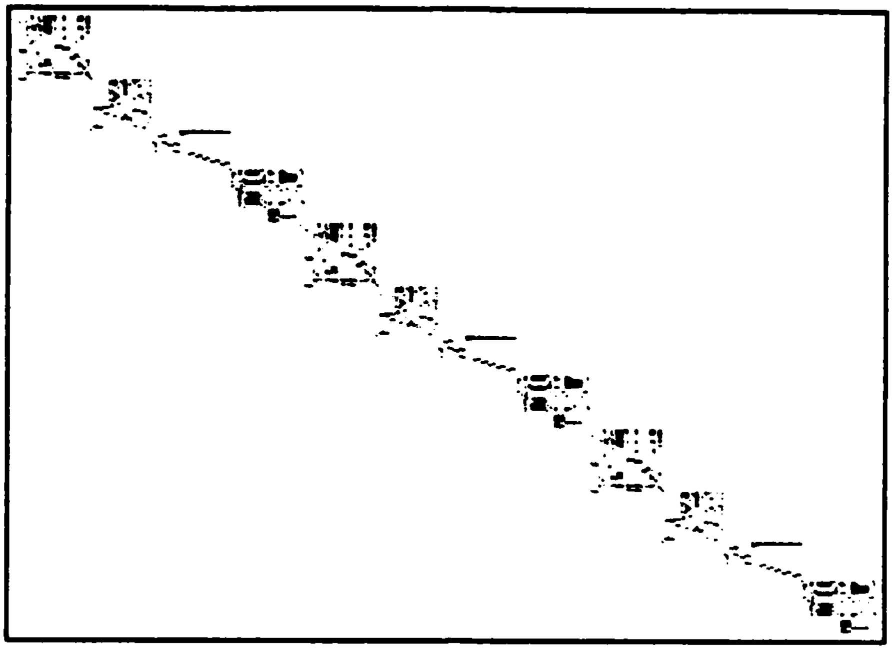

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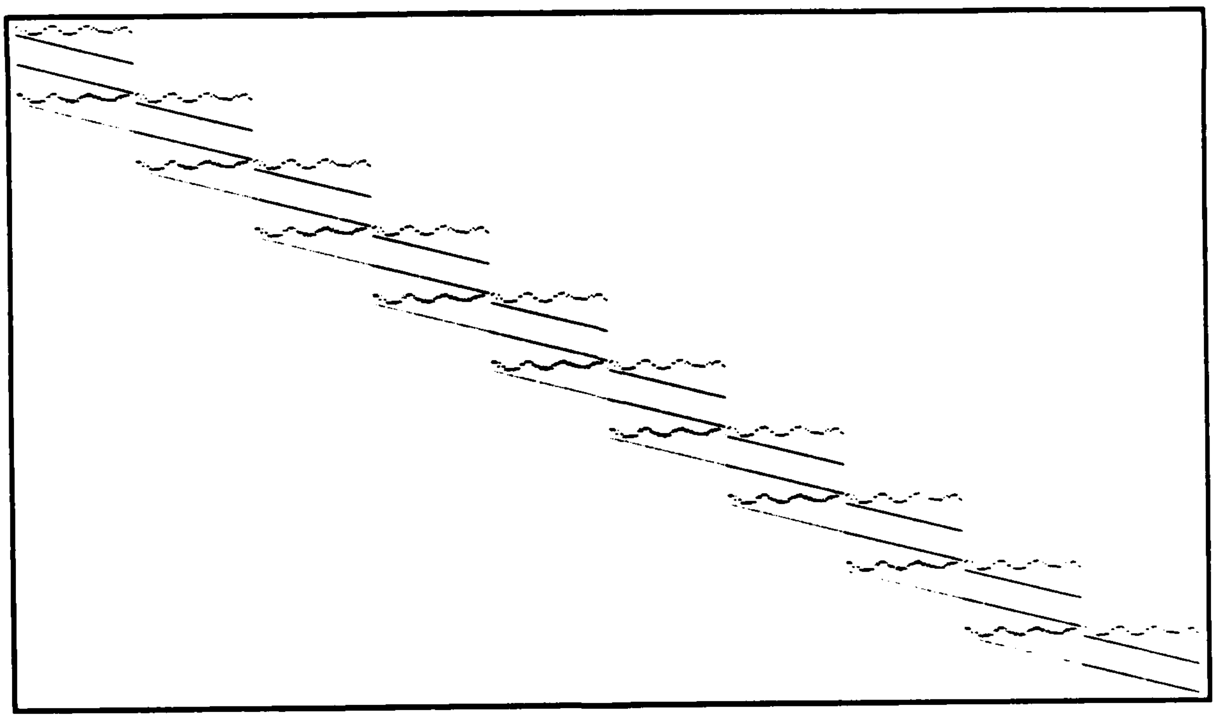

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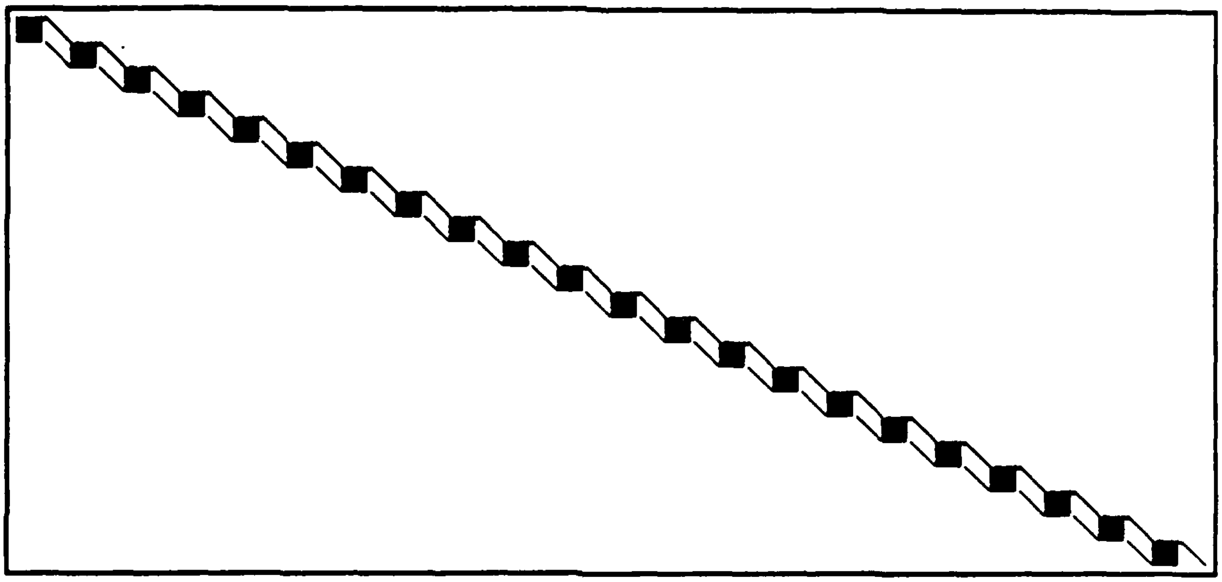

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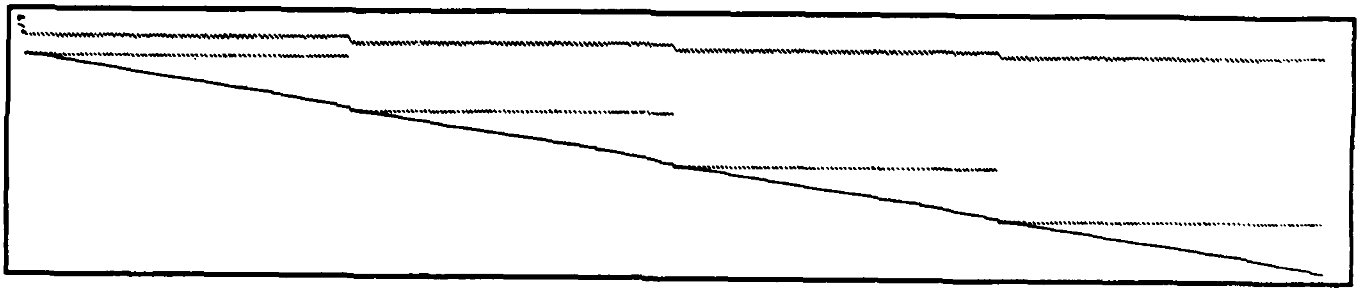

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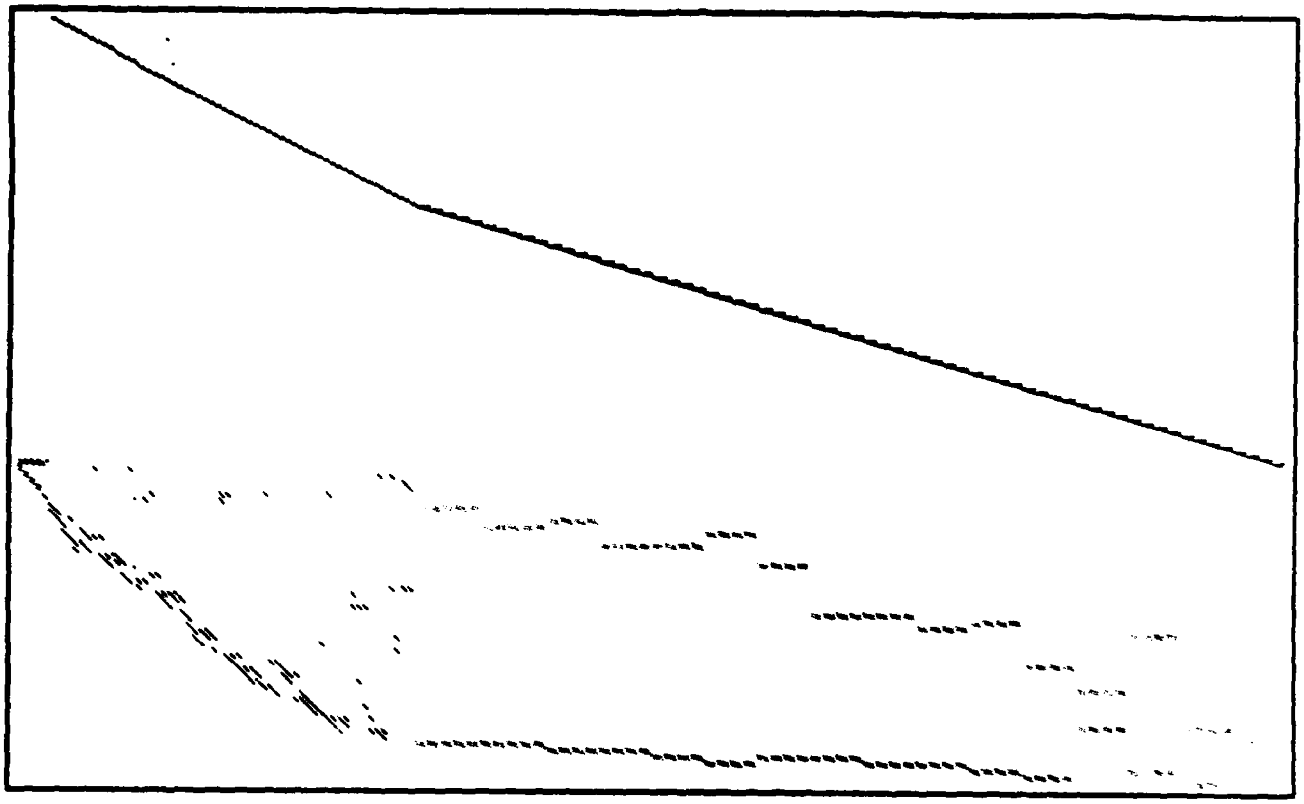

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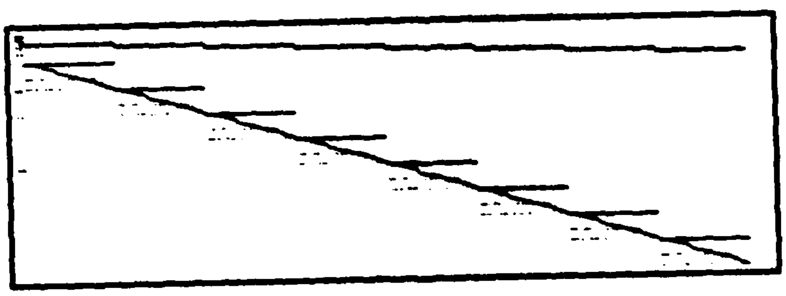

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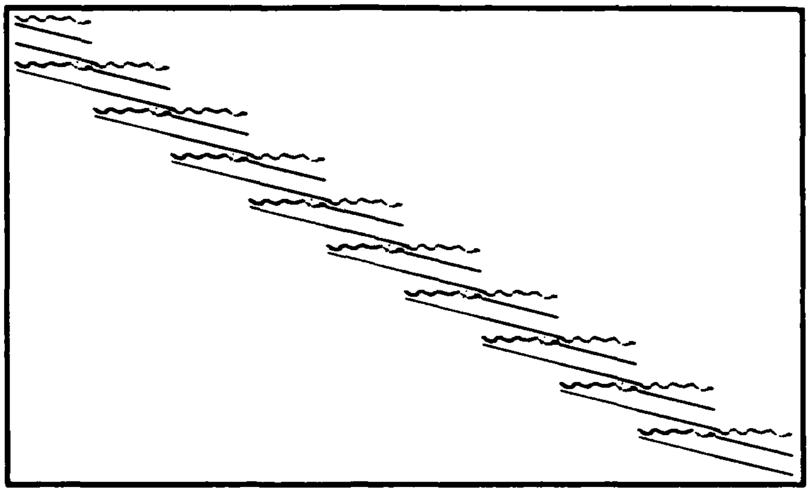

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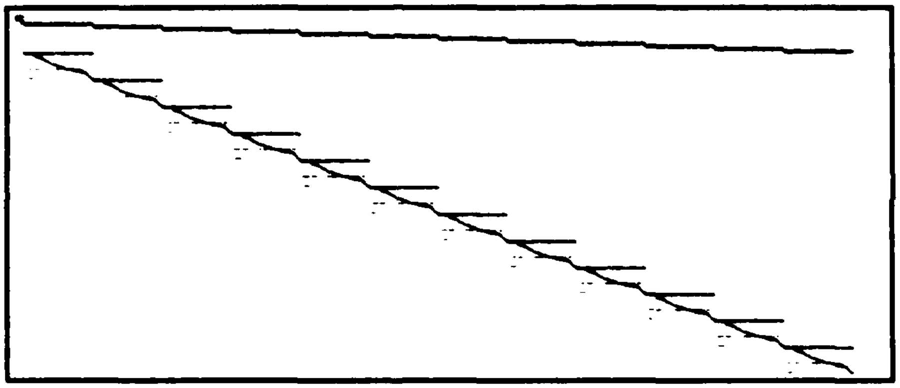

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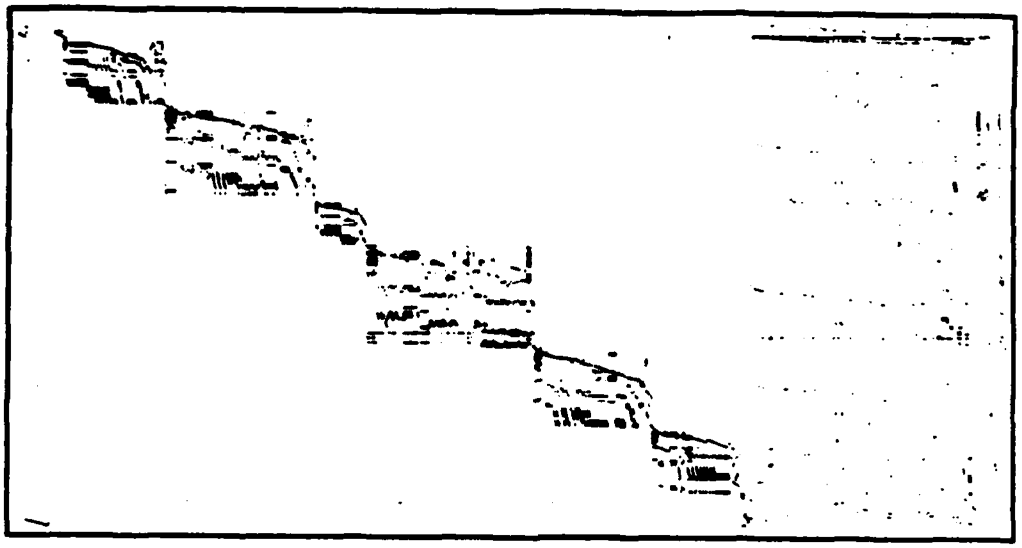

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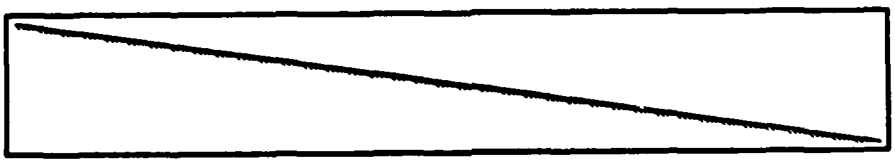

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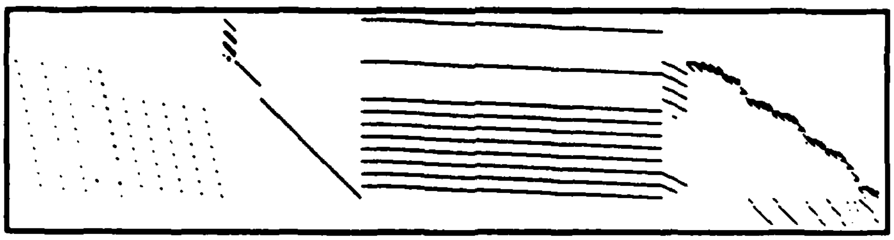

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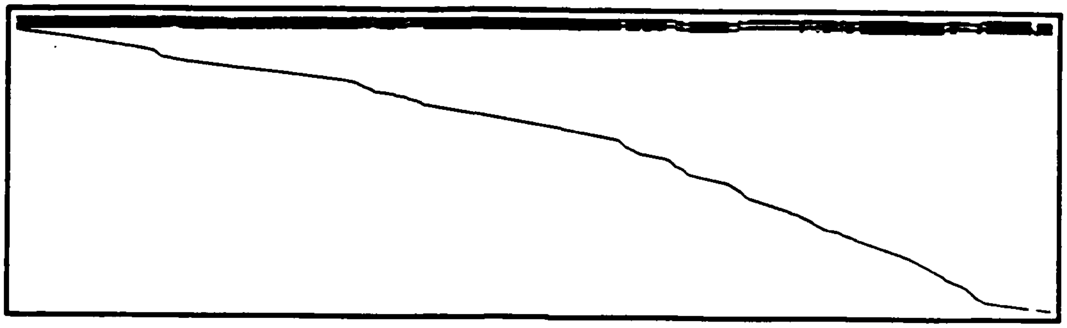

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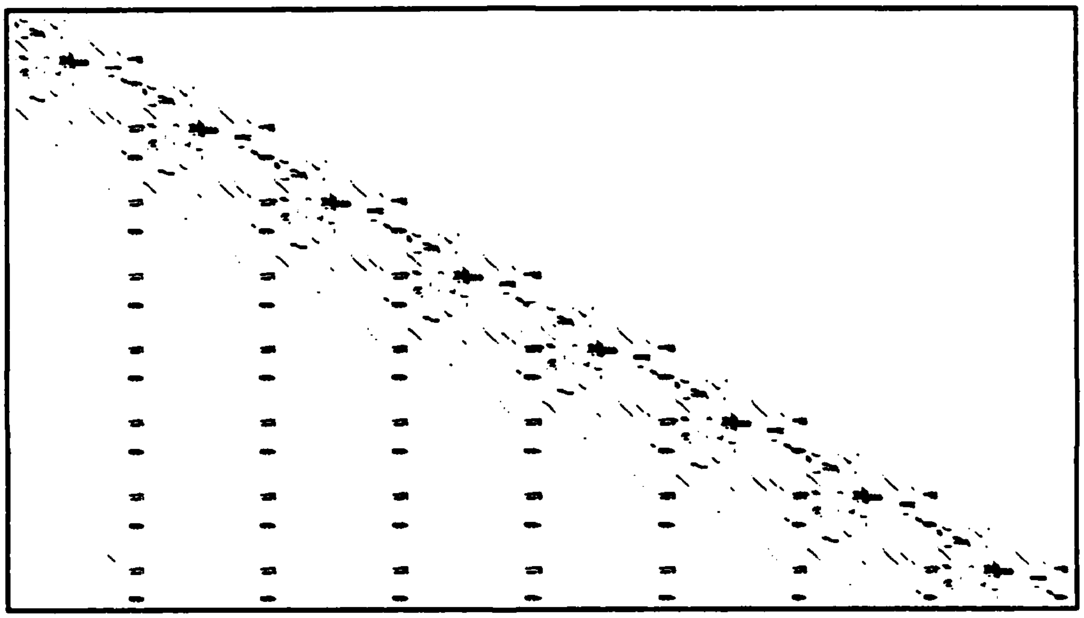

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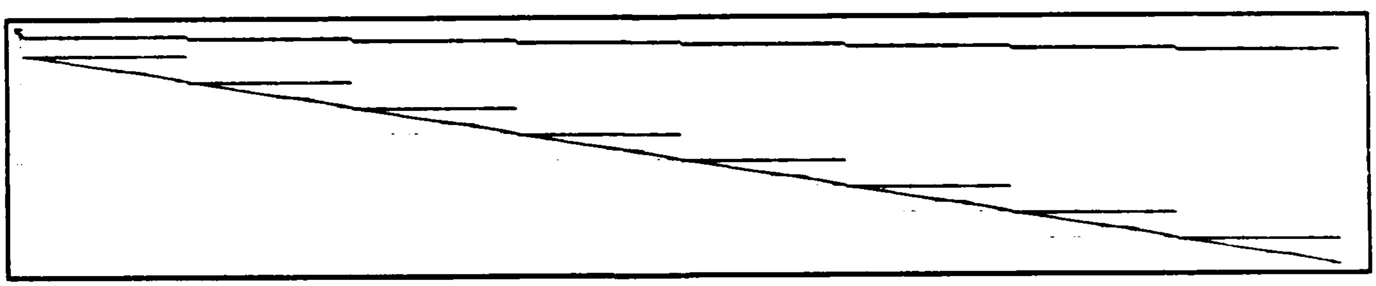

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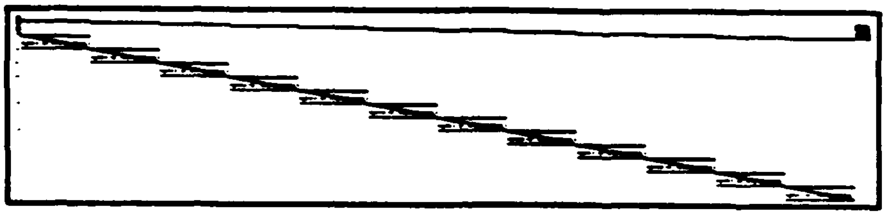

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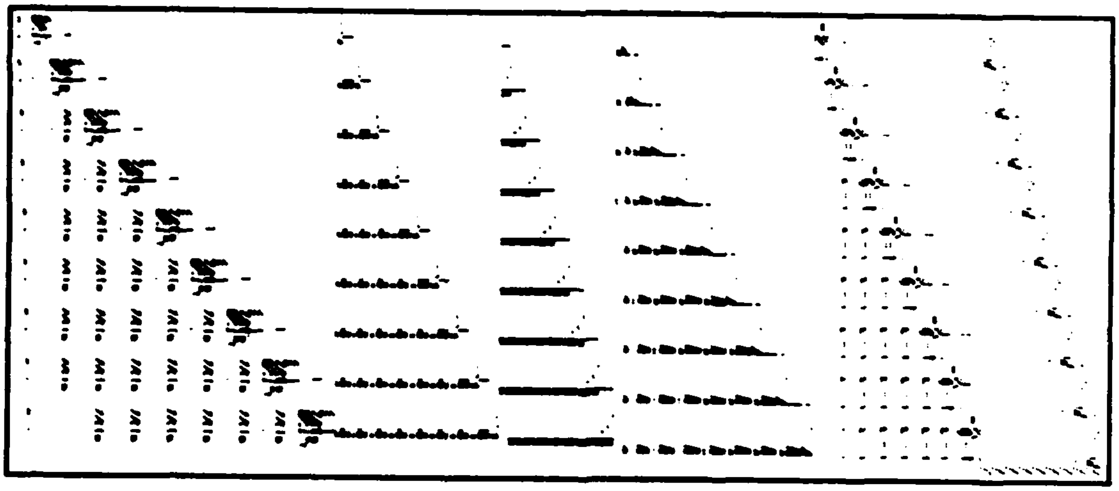

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Abstract

A set of linear programming test problems is analyzed with MINOS, Version 5.1. The problems have been run with different options for scaling and partial pricing to illustrate the effects of these options on the performance of the simplex method. The results indicate that the different options can significantly improve or degrade the performance of the simplex method, and that these options must be chosen wisely.

For each problem, a picture of the nonzero structure of the matrix A is also presented so that the problems can be classified according to structure.

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