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HIPPARCOS reductions for multiple stars, Vc.
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The grid-search problems described in NDAC/LO/097 have prompted a development of improved procedures, and a markedly better performance is now obtained.

1. The use of the a priori information

As described in NDAC/LO/089, the grid-search for the primary position has been so far made with assumed values for the relative position and for the parallax and proper motions. The three "free" variables have been the position coordinates and the magnitude of the primary, and the (erroneous) constraints on the other parameters has given large values for the chisquare fits to the observations. In most cases, the minimum chisquare did give a useable start for a final solution, but as described in NDAC/LO/097, there were sometimes problems.

The new idea is to make a 'soft' use of the a priori information. An almost full set of variables is used (the relative parallax and proper motion is set to zero), but the observation equations are augmented by suitably weighted a priori parameter values. These weights do not seem to be very critical, and I have used simply

w(xk)=ndof/sig(xk)**2 (1)

where sig(xk) is the a priori estimated mean error of parameter xk, and ndof (=5*nfov) is the number of observations. In this way, the a priori information contributes with a 'force' comparable to that from the observed data. [The former 'fixing' of parameters corresponds of course to infinite w(xk)]. The augmented normal equations are solved as usual, but the chisquare fit (S) is calculated only for the 'real' observations, not for the a priori data.

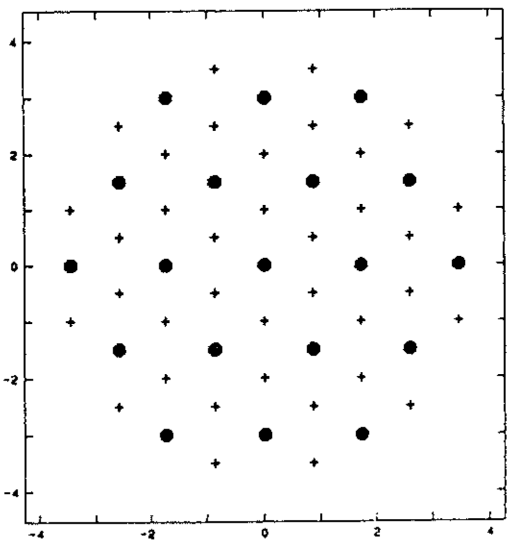
With this new scheme, a suitable grid-point start for the primary position will often result in such a small S that the search may be immediately terminated. In other cases, the minimum S for the whole grid is taken (see below), and mostly, the final LS-solution (including the relative parallax and proper motions) will now converge. An important benefit of the present procedure is the more rapid convergence at each grid-point. Before, I did not break the iterations until about mxit=9 , but now it is quite feasible to use mxit=5 instead. A somewhat closer grid-spacing is then necessary, but the total number of iterations is still smaller.

2. The grid-search pattern

Although the 12-point ('octagonal') grid used so far (cf. NDAC/LO/071) is mostly sufficient, I have now implemented a hexagonal scheme that covers a greater range of a priori (erroneous) primary positions.

The idea is to search first in a 19-point 'main' grid (see figure). Mostly, at some grid-point the S-value will be small enough that the program will jump to the final solution. In other cases, all 19 points have to be tried, and the one with minimum S is selected. This may then give a good final solution, but in some cases it does not. A 36-point 'complementary' grid is then defined as shown in the figure, and the search process is repeated. The size of the grid-patterns is specified by the parameter g, specifying the maximum distance to a grid-point of the main grid for primary star positions less than g*sqrt(13) from the true one. With the 36-point grid added, the maximum distance shrinks to g/sqrt(3) out to about the same distance limit.

Grid-search pattern. (g=1.0)



A 'small' value for g will almost always give convergence with the main grid, but only if the a priori position error is within the above bound. A larger g necessitates the use of the complementary extension, but one is then able to cope with larger position errors. Clearly, the optimum g will depend on the quality of the Input Catalogue, and probably different g-values will be used for different stars.

3. New results

The new ideas described above have been implemented in the old (experimental) solution program, and a set of low-latitude test-runs have been made. (The scan-angle distribution gives most problems at low latitude, and results for higher latitude may safely be expected to be better). In Table 1 are shown mean total numbers of LS-iterations for different values of g for 200 systems with a 'typical' (?) primary position error 1".25. (The eight different series of 25 runs each were made with primary magnitude=8.5, ecliptic latitude=10 deg, a priori primary position error=1".25, and a priori relative position error=0".25. Ser. A3 and B3 had photocentre pointing, A4 and B4 individual IFOV pointing).

Table 1. Mean total number of LS-iterations required for a solution (grid-search plus final), as function of the grid-size parameter g. In parenthesis is given the percentage of runs where the 36-point grid was used.

Series /g	0".40	0".45	0".50	0".60
A1 (sep=0".4, dm=0.0)	74 (8)	72 (4)	81 (16)	127 (48)
B1 (sep=0".4, dm=1.5)	75 (4)	86 (16)	106 (36)	80 (20)
A2 (sep=1".5, dm=0.0)	64 (0)	66 (0)	63 (8)	82 (24)
B2 (sep=1".5, dm=1.5)	67 (0)	68 (0)	94 (12)	81 (20)
A3 (sep=10" , dm=0.0)	76 (0)	85 (8)	82 (16)	69 (12)
B3 (sep=10" , dm=1.5)	77 (0)	74 (0)	77 (4)	94 (24)
A4 (sep=10" , dm=0.0)	65 (0)	92 (20)	101 (32)	89 (36)
B4 (sep=10" , dm=1.5)	67 (0)	67 (0)	68 (4)	66 (16)
Mean for A1-A4,B1-B4	71 (2)	76 (6)	84 (16)	86 (25)

There are large random variations in these numbers, but as expected, smaller g-values are generally advantageous as long as (like in this case) the primary position error is smaller than about 3.6 g. The increase in the numbers of iteration with increasing g is rather modest, however, and large g-values may thus be used routinely. The 36-point grid has then to be used more often, but a solution will almost always be found even for primary position errors around 2-2.5 arcsec.

As a comparison with the rather discouraging results reported in NDAC/LO/097, Table 2 gives corresponding iteration numbers for some 'half-slit' problem cases. (Again 25 runs in each series, magnitudes 8.5+8.5, ecliptic latitude 6 deg, and a priori primary position error 1".25). Clearly, more iterations (and more use of the complementary grid) are required for these systems, but the search does not fail completely as before. As in the old runs, the a priori relative error was varied. This has now a much smaller effect on the grid-search efficiency, and 0".30 is certainly allowed.

Table 2. Data as in Table 1 but for some equal-magnitude 'problem cases'. The a priori relative position errors are (H1-H4) 0.30,0.25,0.20,0.25 arcsec.

Series /g	0".40	0".45	0".50	0".60
H1(sep=0".65)	82 (0)	89 (8)	108 (24)	132 (48)
H2(sep=0".65)	78 (8)	90 (24)	122 (36)	84 (28)
H3(sep=0".65)	70 (0)	85 (12)	113 (36)	110 (44)
H4(sep=1".85)	68 (0)	83 (8)	93 (28)	94 (36)
Mean for H1-H4	74 (2)	87 (13)	109 (31)	105 (39)

In summary, the present grid-search procedure seems to work well even in difficult cases. The CPU-time per star is about 7 minutes (14 for individual IFOV pointing), which is acceptable as it is, but may also probably be reduced. Such further optimization will be made when a prototype "real" double star reduction program has been created using the present ideas.