HIPPARCOS reductions for multiple stars, VIIIa
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1. Introduction
After my previous work on the main parts of STDDBL and STDMUL, I have
come now to the interesting SEEKDBL-program, which will be used to actually
discover new double stars. The main principles were set down and tested al-
ready in NDAC/LO/071, and more extensive tests were reported in a Bari paper
(NDAC/LO/085). Since then, a clearer picture of the overall reduction schemes
has emerged, and the 'final' SEEKDBL is somewhat more complicated. This
report describes the program and gives realistic estimates of its discovery ca-
pabilities (at least for the standard case of \( H = 8.5 \) systems). These are strongly
related to the \( \Delta \chi^2 \)-statistics accumulated during the IDT preprocessing, which
(cf. NDAC/LO/113) are not well understood even with simulated data. In the
real reductions, it will be very desirable to have a sample of reasonably certain
single stars, which will then help to calibrate the \( \Delta \chi^2 \)-statistics.

An 'VIIIb'-paper with more data for other magnitudes will follow when the
requisite simulations are completed. (As before, this work is CPU-intensive, but
hopefully now rather routine).

2. Key points of SEEKDBL
The SEEKDBL program is used for 'single' stars that has shown a bad fit to a 3-
parameter model for the IDT-counts, as given by the \( \Delta \chi^2 \)-histogram. Although
this automatically excludes such a star for use in the Sphere Reconstitution, a
set of astrometric parameters for the photocentre has usually been obtained in
the main reductions. For consistency, this single-star solution is repeated in
the first part of SEEKDBL, which is actually a variant of STDDBL. Because
the \textit{a priori} photocentre position should not be much in error (but in order
to accomodate some accidental deviation), a 7-point mesh is used for the LS
starting position. The best 'preliminary' solution (only diagonal part of IDT
information matrix used) is then used as the start for the final single star solu-
tion, and so far, the results should not differ from what is already known from
the main reductions. A key parameter is the normalized fit to the observations,
\( S_f(s) \) (cf. NDAC/LO/107), which is later compared with that obtained for a
double star model.

In the second part of SEEKDBL, a standard double star model is explicitly
assumed, with 11 free parameters (common parallax). The magnitude-difference
may always be started at 1.0, the proper motions and parallax are taken from
the single-star solution, and the primary is put at the photocentre position.
The most uncertain part is the secondary position (relative to the primary),
and this is now varied in some specified search-mesh. In this way, a number
of 'preliminary' (diagonal information-matrix to save computing time) LS solutions are made. All solutions in the mesh are tried, and the current best one (smallest $S_\alpha$) is saved as the start for the final solution. With a mesh of 16 points, all components within some 1.3 arcsec are discoverable, but most of the unknown components are expected to have much smaller separations. To save computing time, it is therefore worthwhile to make the search in two passes. In the first pass, a 4-point mesh with a small mesh-spacing is used, and a good final solution may often be obtained already here. Only if this fails, a larger 12-point mesh is used.

More details will be given below, but the seemingly awkward scheme just described seems to be a good compromise between efficiency (computing time) and detection-power. In two (or three) mesh-search parts, the observation equations are weighted by the diagonal elements of the IDT information-matrices, assuming in effect uncorrelated $\beta$-values. This gives a substantial gain in computing-speed, with only an insignificant loss of accuracy. The 'final' solutions use the full information-matrices, and thus the full accuracy of the observations. As stated above, the standard double star solution has 11 parameters, but a 'fixed' 9-parameter solution with no relative proper motions is also made in the end.

As for the practical programming of SEEKDBL, many subroutines from STDDBL may be used with only minor modifications. Because the nominal IDT-pointing is always on the photocentre (single star in Input Catalogue), and at most two components are involved, the systematic weight-corrections and the derivation of the observation equations are rather straightforward. The main difficulty is the multi-loop program structure, but the present SEEKDBL did actually start to work with less problems than STDMUL.

3. Optimization of the program
There are quite a few program-parameters that has to be reasonably chosen, and a full survey of all possibilities is impossible, given the typical 10-20 minutes of CPU-time required for a single solution. The following choices are based on some hundreds of test-runs, and should be useful in the first reductions. Only by experience with the real data will it be possible to refine them reliably.

As mentioned above, the 'single-star' preliminary solutions are made in a 7-point mesh (a priori position plus a 6-point 'ring' at $s(1)$ from this). The mesh-spacing $s(1)$ is dependent on the expected maximum a priori position error, but values up to at least 0.5 arcsec are usable. The maximum number of LS-iterations at each of these mesh-points may be taken as small as 4.

In pass 1 of the double-star search, 4 mesh-points are as effective as 6 in detecting all close components. The mesh-spacing $s(2)$ is somewhat arbitrarily taken at 0.15 arcsec, and the maximum number of LS-iterations to 7. This last figure is a true optimization based on many experiments. (A too small value does not give the solutions enough time to approach the true parameters, while too large ones may give 'false' convergence to a poor solution).

In pass 2 of the double-search, my old 12-point mesh (cf. NDAC/LO/071) was again found equally effective as the 18-point 'circular' one used in STDDBL and STDMUL in searching for the primary position. The mesh-spacing $s(3)$ is
preliminarily taken at 0.40 arcsec (4 points at 0.40 arcsec, 8 points at 0.97 arcsec from the primary), which should catch all bright enough secondaries less than 1.3 arcsec from the primary.

Finally, we come to the parameters defining the 'quality' of the solutions. After pass 1 of the double-star search, we often have a 'solution', but in order to be accepted, it has to pass a 'reasonability'-test. First, the fit to the observations \( S_f(d) \) has to be below some estimated maximum \( S_f(max) \) (depending rather critically on the details of the weighting), and secondly, the separation \( (\rho) \) and the magnitude-difference \( (dm) \) have to be 'possible'. These limits are magnitude-dependent, and should be adapted to the experimental results below. (In the first tests, simple 'square' regions of allowed \( \rho, dm \) were used). After pass 2, the same \( (\rho, dm) \)-limits are used, but no constraint on \( S_f \), because there may exist valid solutions with an accidental or significant poor fit to the observations.

4. The first tests
In the first large-scale test of SEEKDBL, some 350 systems ("Ser. A") with separations 0.05-1.0 arcsec and magnitude-differences 0-4 were simulated. The total magnitude of each system was \( H=8.5 \), and the stars were uniformly distributed over the sky. The 'uncorrected' information-matrices in the IDT preprocessing gave too large \( \Delta \chi^2 \)-values, but this is taken care of by similar simulations for 'singles' (actually doubles with very small separations and/or very large magnitude differences).

The \( \Delta \chi^2 \)-histograms (for doubles or singles) were first parameterized by the simple 7 d.o.f \( \chi^2 \) fit with respect to the nominal (flat) single-star histogram

\[
C_H = \sum_{i=1}^{8} \frac{(H_i - \bar{H})^2}{\bar{H}}
\]

where \( H_i \) and \( \bar{H} \) are the individual and mean histogram counts. As shown in NDAC/LO/113, the single-star histograms are not flat, and thus the mean \( C_H \)-value is higher than 7. From 165 single-star runs, the mean \( C_H \) is about 18, with 95 % of the values below 20, and 98 % below 33. Although rather uncertain, the latter value is taken as the 'detection-limit' for the double-star processing. (Some 2% of the true singles would then be selected for double-star treatment, which is an acceptable figure). Of the original double-star simulations, 247 have \( C_H \) larger than 33.

These 247 (and the others also) simulated systems were then analyzed by SEEKDBL, using the parameters described above. By luck, the \( S_f(max) \) used (1.50) was nearly optimal, as it turned out that the mean \( S_f \) for good solutions was about 1.14, with a standard deviation of 0.10. Ideally, the mean should be 1.0, and the enhanced value is related to the 'optimistic' information-matrices. (In the real reductions, this will have to be calibrated by 'known' singles).

The final optimization is made using statistical post-processing programs. The basic 'single/double/problem' solution categories are defined as in my old runs (NDAC/LO/071), but with an updated parametrization: An a priori 'double' solution is one where the normalized fit to the observations \( S_f(d) \) is smaller
than the corresponding single-star \( S_f(s) \). An \textit{a priori} ‘single’ solution has \( S_f(s) < S_f(d) \) and \( S_f(s) < S_f(\text{max}) \) The ‘problem’ cases have larger \( S_f(s) \) but still none or a poor double star solution. Using this scheme, the 247 original Ser. A solutions divide into 227 double, 11 single, and 9 problem-cases.

So far, I have not used any knowledge of the true double-star parameters. With this knowledge, it is possible to further classify the double solutions into ‘good’ and ‘bad’. Somewhat arbitrarily, I have put the dividing-line at a maximum \( S_e \) (squared sum over the five astrometric parameters of the observed minus true values divided by their estimated mean errors) equal to 45, corresponding to 3\( \sigma \) deviations in all five parameters. With this definition, only 9 of the 227 double solutions are ‘bad’.

As noted also in NDAC/LO/071, a very useful measure of the ‘difficulty’ of a double is the \( dH_{eff} \)-parameter, which I now call D:

\[
D = \begin{cases} 
  dH - 5.5 \lg(\rho/0.32) & \rho < 0.32 \text{ arcsec} \\
  dH & \rho \geq 0.32 \text{ arcsec}
\end{cases}
\]  

(2)

with \( dH, \rho \) equal to the true magnitude-difference and separation. Separating the systems according to \( D \), we obtain the statistics in Table 1. A very interesting datum is the ratio of the ‘good’ double solutions to the total number of systems in a certain \( D \)-interval, \textit{irrespective} of the \( C_H \)-value. The ‘total’ column gives the \( D \)-distribution for \textit{all} my simulated doubles, and the ‘good/total’ gives these ratios. The natural 50\% discovery-limit comes close to \( D=3.7 \), comparing favourably with the value 3.6 given in NDAC/LO/085. As will be seen below, the \( C_H \) detection criterion is \textit{not} always optimal, although it seems very good in this case.

Table 1. Numbers of solutions of different categories in different ranges of \( D \) for the original Ser. A systems, selected for double-star treatment by \( C_H \)-limit.

<table>
<thead>
<tr>
<th>( D )(mag)</th>
<th>total</th>
<th>sing</th>
<th>prob</th>
<th>bad</th>
<th>good</th>
<th>good/tot(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0-2.0</td>
<td>37</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>37</td>
<td>100</td>
</tr>
<tr>
<td>2.0-2.5</td>
<td>54</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>52</td>
<td>96</td>
</tr>
<tr>
<td>2.5-3.0</td>
<td>51</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>48</td>
<td>94</td>
</tr>
<tr>
<td>3.0-3.5</td>
<td>61</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>48</td>
<td>79</td>
</tr>
<tr>
<td>3.5-4.0</td>
<td>60</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>28</td>
<td>47</td>
</tr>
<tr>
<td>4.0-4.5</td>
<td>40</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>4.5-5.0</td>
<td>28</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

5. An alternative standard series
After I finished the experiments reported in NDAC/LO/113, a new series (‘Ser. B’) of 500 simulated 8.5-mag doubles was created with the \( \varepsilon_{1,2} \)-parameters 0.090 and 0.000090 in the information-matrix derivations. As shown in that report, this gives flat histograms for the singles, and indeed a mean value 7.0 for \( C_H \). We may then use \( \chi^2 \)-statistics, and the estimated 98\% -level is \( C_H = 17 \) (consistent with one value at 18.1 in 40 single-star runs). Of the 500 Ser. B doubles, 284 had \( C_H > 17 \).

With the same parameters as before, I started running the SEEKDBL-program for these 284 systems (and the remaining 216 too). It was apparent,
however, that $S_f(\text{max})=1.5$ was now a bit high, and 1.30 was adopted instead. (With the calibrated information-matrices, the mean $S_f$-values are now closer to unity). Qualitatively, a similar picture as in the preliminary runs emerges, and Table 2 gives the corresponding solution statistics.

Table 2. Numbers of solutions of different categories in different ranges of $D$ for Ser. B. Selection by CH-criterion.

<table>
<thead>
<tr>
<th>D(mag)</th>
<th>total</th>
<th>sing</th>
<th>prob</th>
<th>bad</th>
<th>good</th>
<th>good/tot(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-2.0</td>
<td>90</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>88</td>
<td>98</td>
</tr>
<tr>
<td>2.0-2.5</td>
<td>59</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>48</td>
<td>81</td>
</tr>
<tr>
<td>2.5-3.0</td>
<td>73</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>61</td>
<td>84</td>
</tr>
<tr>
<td>3.0-3.5</td>
<td>71</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>38</td>
<td>53</td>
</tr>
<tr>
<td>3.5-4.0</td>
<td>101</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>4.0-4.5</td>
<td>101</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4.5-5.0</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Surprisingly, however, the 50%-limit is now as low as $D=3.3$, which is too poor to be acceptable. In order to have values comparable to those in Table 1, the $C_H$-threshold has to be lowered to about 10, which would include an unacceptable 20% of the true singles. For some reason, the $C_H$-criterion is not as efficient when the information-matrices have been corrected to give flat $\Delta \chi^2$-histograms, and some alternatives have to be tried.

Already when he introduced the $\Delta \chi^2$-histograms (cf. NDAC/LO/075), Lindegren proposed using a statistic $t$ using the excess of counts in the two or four 'highest' $\Delta \chi^2$-bins. I later made only very limited tests that seemed to indicate that the $C_H$ used above was superior, but I have now reintroduced the $t$-statistics in the following form

\[ t_1 = \frac{(H_1 - \bar{H})}{\sqrt{0.875\bar{H}}} \]
\[ t_2 = \frac{(H_1 + H_2 - 2\bar{H})}{\sqrt{1.5\bar{H}}} \]
\[ t = \min(t_1, t_2) \]  

(3)

(The sensitivity is increased by using only the two highest bins, and by using both, there should be no large problems with an excess of $\Delta \chi^2$ 'spikes' in bin 1). For single stars, both $t_1$ and $t_2$ should be $N(0,1)$-distributed, and one may show that they have a correlation of $\sqrt{3}/7$. This theoretical bivariate normal distribution may be integrated to give the probability that $t$ (i.e both $t_1$ and $t_2$) shall be above a given threshold. Again accepting 2% singles in the double star reductions, this limit for $t$ is found to be 1.60. (Only 40 single simulations are available, but for these, as expected, one system has $t$ above 1.6).

Using this $t$-criterion, the above solutions may be re-classified, and a dramatic improvement is obtained as can be seen comparing Table 3 with Table 2. The 50%-limit is now at $D=3.6$, quite comparable to the Ser. A data in Table 1. It is natural to ask then if these 'old' runs may be made even better by using the $t$-criterion here too. This necessitates first a study of the 125 old single-runs, because $t_1$ and $t_2$ no longer have zero mean. They still look normally distributed, but with means 2.7 and 2.6, standard deviations 1.2 and 1.1. These figures give a 2%-limit at about $t=4.5$, and indeed, only 2 of the 125
singles have \( t \) above 4.5. A re-classification of the Ser. A-solutions can now be made, giving a 50%-limit at \( D = 3.6 \). In this case, the \( C_H \)-criterion is apparently better, but only marginally so.

Table 3. Numbers of solutions of different categories in different ranges of \( D \) for Ser. B. Selection by \( t \)-criterion.

<table>
<thead>
<tr>
<th>( D ) (mag)</th>
<th>total</th>
<th>sing</th>
<th>probl</th>
<th>bad</th>
<th>good</th>
<th>good/tot(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-2.0</td>
<td>90</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>88</td>
<td>98</td>
</tr>
<tr>
<td>2.0-2.5</td>
<td>59</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>50</td>
<td>85</td>
</tr>
<tr>
<td>2.5-3.0</td>
<td>73</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>65</td>
<td>89</td>
</tr>
<tr>
<td>3.0-3.5</td>
<td>71</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>48</td>
<td>68</td>
</tr>
<tr>
<td>3.5-4.0</td>
<td>101</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>4.0-4.5</td>
<td>101</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>4.5-5.0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Using only the \( t \)-criterion, the figure shows all the good double-star solutions as large dots, while the small points show all the other simulated systems. (No distinction is made thus between untried solutions, due to a too small \( t \)-value, and unsuccessful ones). The \( D = 3.6 \) line is indicated, with an ad hoc cut-off at \( \rho = 0.1 \) arcsec. This figure shows graphically the double star detection capabilities of HIPPARCOS. Compared with the similar one given in NDAC/LO/085, the present version has a 'fuzzier' but probably more realistic limit. (The empty area at lower right would presumably contain only successful solutions).

![Graph showing distribution of solutions](image)

6. Astrometric and photometric accuracy

With the above solutions, a lot of statistics about the expected accuracies in different parameter intervals could be presented, but in most cases, this has already been done with STDDBL runs. (Because the basic simulation/solution methods are the same, the final results will be identical. The only difference with SEEKDBL is the lacking \( a \) priori knowledge; once a solution is found, it will be as accurate as one for a previously known double).
A point of some interest, however, is the comparison between the two different series above, the 'old' (A) standard one, and the 'new' (B) one with modified IDT information-matrices. In order to have a large sample of uncomplicated systems, I have selected all with \( D = 2.0-3.0 \), \( \rho = 0.15-0.30(\text{c}) \) or \( 0.30-1.0(\text{w}) \) arcsec. For these two \( \rho / D \)-areas, all good solutions have \( C_H \) or \( t \) above the 2%-limits, and mean rms and \( S_e \)-values are given in Table 4.

<table>
<thead>
<tr>
<th>Ser.</th>
<th>n</th>
<th>Sf</th>
<th>rms(pr)</th>
<th>rms(pc)</th>
<th>rms(rel)</th>
<th>Se(pr)</th>
<th>Se(pc)</th>
<th>Se(rel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ac</td>
<td>41</td>
<td>1.17(.02)</td>
<td>3.2(.5)</td>
<td>1.0(.1)</td>
<td>7.4(.9)</td>
<td>5.6(0.8)</td>
<td>5.5(0.8)</td>
<td>4.7(.5)</td>
</tr>
<tr>
<td>Bc</td>
<td>48</td>
<td>1.03(.01)</td>
<td>2.3(.2)</td>
<td>1.0(.1)</td>
<td>6.2(.4)</td>
<td>6.7(0.8)</td>
<td>4.1(0.4)</td>
<td>3.8(.4)</td>
</tr>
<tr>
<td>Aw</td>
<td>45</td>
<td>1.09(.01)</td>
<td>1.4(.1)</td>
<td>1.3(.1)</td>
<td>8.3(.6)</td>
<td>8.8(1.0)</td>
<td>8.8(1.1)</td>
<td>4.1(.3)</td>
</tr>
<tr>
<td>Bw</td>
<td>47</td>
<td>1.00(.01)</td>
<td>1.2(.2)</td>
<td>1.2(.1)</td>
<td>9.2(.9)</td>
<td>7.8(0.9)</td>
<td>10.4(1.3)</td>
<td>4.6(.6)</td>
</tr>
</tbody>
</table>

No major differences between the 'A'- and 'B'-data can be discerned, but as already noted, the normalized fit to the observations is close to 1.0 for the B solutions. As noted in NDAC/LO/085, the error in the relative positions is about the same for close and wide systems with the same effective magnitude difference \( (D) \). The error for the primary star is greater for close systems, because only the photocentre is well determined. For the wide systems, on the contrary, the photocentre is not a useful quantity, and the primary star errors are smaller. The \( S_e \)-values are higher than the nominal (5 for pr, pc; 4 for rel, where the parallax is common) for 'wide' primary (and pc) data, but never by more than a factor 2 (corresponding to true errors 40% larger than the formal ones). The 'random' photometric errors (not given in Table 4) are close to their formal mean errors, but there are some systematic effects that need calibration. Still, the 'A'- and 'B'-solutions are quite comparable.

The conclusion to be drawn is that moderate modifications of the IDT information matrix have rather little influence on the final astrometric and photometric accuracies. Theoretically, there is some advantage in a modification (Ser. B) that gives \( S_f \) close to unity, but in practice, the \( S_f \)-values will always have to be calibrated relative to single-star data, and all acceptance-limits scaled accordingly.

7. Tests for brighter and fainter systems
So far, all runs have been for systems with \( H = 8.5 \). A small number of tests have been performed with \( H = 6.0 \) and \( H = 11.0 \) also. For the bright stars (\( H = 6.0 \)), 200 simulations were made with an 'intermediate' correction to the information-matrices, viz. \( \varepsilon_1 = 0 \), \( \varepsilon_2 = 0.00056 \). From a series of single-star runs with the same \( \varepsilon \)'s, the 5%-limit is around \( C_H = 32 \), and the 10%-limit around \( C_H = 27 \). Because the number of bright systems is small, a larger percentage of singles is acceptable, and \( C_H > 30 \) is chosen as the detection criterion. The solution-check after pass 1 in SEEKDBL was made in a non-standard way, which lead to some false rejections, but a simple count of solutions shows a 50% efficiency of double-star detections at \( D \) about 4.3. A larger statistical material is necessary.
in order to check and improve this value (using also the alternative \( t \)-criterion), but it is consistent with the estimate in NDAC/LO/085.

For the faint systems with \( H=11.0 \), a mere 100 simulations have been made, with \( c_1=0.18 \), \( c_2=0.0011 \). From the corresponding single-star runs in NDAC/LO/113, the mean \( C_H \) is about 8, and the 10\%-limit about 13. With this \( C_H \)-limit, the 'typical' detection-limit is about \( D=1.9 \), but with only 38 good solutions, this figure is rather uncertain. Interestingly, if we decrease the \( C_H \)-limit, SEEKDBL is able to solve for many systems with \( D \) up to 3.0 (which was the highest simulated). If all systems are run through SEEKDBL, 23 out of 30 systems with \( D=2.5-3.0 \) get 'good' solutions, which is quite remarkable considering the faintness of the secondaries (\( H=13.5-14 \) at large separations). Perhaps it may be possible to run almost all the faintest stars (\( H >11.5 \)?) through the double-star processing, and thereby maximize the discovery rate of close components. More simulations are needed here too.

8. Solutions after only 1 year of observations

The above tests were all made for the nominal 2.5 year life-time of HIPPARCOS. Recently, I have realized that it will be very worthwhile to start the STDDBL solutions already after about one year of observations are collected, and a preliminary sphere-reconstitution is finished. The available attitudes do not have their final accuracy, but tests have shown that the mesh-iterations for the primary star position may be successfully completed for some 75 % of the known doubles. The question is now if a search for unknown doubles is meaningful at this stage also.

A similar series ('C') of 500 \( H=8.5 \) mag systems as 'Ser. B' above was simulated with the same non-zero \( \epsilon \)-values and the same distribution in separation and magnitude-difference. The attitude- uncertainties used in the CHF-derivations were simply doubled with respect to the 'standard' values given in NDAC/LO/095. Several variants of SEEKDBL were tested for the solutions, in order to optimize the set of variables used. First, the standard set used for the 2.5 year runs was used. Then, the 'system' proper motion was kept to its IC value, and finally, an 'economy' program was tried with no proper motions at all. (This means the single-star solution for the photocentre is made with only 2 positions, a magnitude, and a parallax as variables, adding a magnitude-difference and two relative positions for the double-star solutions).

The results show conclusively that the original set of variables should be retained for the one-year runs also. The 'free' proper motions are of course not well-determined, but they help finding a good fit to the observations. The second variant, is again better than the third, because relative motion in the systems may not be neglected. (The simulated doubles are astrophysically 'realistic', and the median yearly relative motion is as high as about 4 mas for separations 0.2-0.4 arcsec). Also, it is in all cases easy to find spurious solutions with separation \( \rho+1 \) gridstep. Instead of trying out uncertain methods to discriminate between true and spurious solutions at large separation, it is probably better to reject all solutions with \( \rho > 1 \) arcsec. It seems in fact advantageous to keep only 4+4 mesh-search points, at 0.15 and 0.40 arcsec, and to concentrate thus on the close systems only.
The results of a series of solutions according to this optimum SEEKDBL is given in Table 5. The $t$-criterion (1.6 limit) is used, and only systems with $\rho < 0.6$ arcsec are counted. A surprisingly large number of systems get good solutions, and the 50% discovery limit may be set at $D = 3.2$. This value is not strictly comparable to the previous ones, due to $\rho$-cutoff, but we do find a large fraction of the unknown doubles already after the first year of observations.

Table 5. Numbers of solutions of different categories in different ranges of $D$ for the Ser. C runs with separation less than 0.6 arcsec. Selection by $t$-criterion.

<table>
<thead>
<tr>
<th>D(mag)</th>
<th>total sing probl bad good good/tot(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-2.0</td>
<td>76 0 3 2 71</td>
</tr>
<tr>
<td>2.0-2.5</td>
<td>42 0 4 1 33</td>
</tr>
<tr>
<td>2.5-3.0</td>
<td>75 1 5 4 48</td>
</tr>
<tr>
<td>3.0-3.5</td>
<td>55 1 4 3 27</td>
</tr>
<tr>
<td>3.5-4.0</td>
<td>79 2 4 0 12</td>
</tr>
<tr>
<td>4.0-4.5</td>
<td>82 3 5 0 1</td>
</tr>
<tr>
<td>4.5-5.0</td>
<td>9 1 0 0 0</td>
</tr>
</tbody>
</table>

9. Conclusions
The main parts of 'SEEKDBL' are now working, and after the present tests, the main conclusions are:

1. In the majority of cases, the program works well and gives reliable solutions. The number of poor solutions increases with the effective magnitude difference $D$, and interactive fine-tuning of the program will be necessary in the real reductions.

2. The major factor influencing the discovery-capability of SEEKDBL is not the program itself, but the criteria used to select candidate doubles from the $\Delta\chi^2$-histograms. Again, this will need fine-tuning with respect to the real data.

3. A rather large proportion of the suspected doubles may give a preliminary double-star solution after only one year of observation. These stars may then be finally processed by STDDBL.

As for STDDBL/MUL, all Input/Output parts of SEEKDBL are lacking. In parallel with further SEEKDBL-simulations, work will now be started on the difficult questions pertaining to the derivation of Case History Files. We must ensure that all the necessary input is available, and that it is possible to make preliminary CHP:s even after a shorter observation interval (1 year). Also, the solution programs have to be both 'automatic' and sufficiently interactive to accommodate the unplanned difficulties that will certainly arise in the real reductions. Finally, the 'minority' programs SEEK3 and ORBSIZ are not yet written.