STEP 3 SOLUTION OF ASTROMETRIC PARAMETERS AND SLIT ERRORS FOR SINGLE STARS

(Task Description)

BACKGROUND

Before outlining the proposed task I shall briefly describe the relevant parts of the data processing planned by the Northern Data Analysis Consortium (NDAC). Fuller descriptions are found in our proposal (1981) and subsequent working papers.

The scientific data processing aims at estimating, as accurately as possible, the five astrometric parameters ($\alpha$, $\delta$, $\mu_\alpha$, $\mu_\delta$, $\Pi$) for each of the 100,000 stars observed by the HIPPARCOS satellite. Input for this are raw data such as photon counts from the main detector (ITD). The processing will proceed in several steps as follows.

Step 0. The smooth rotation of the satellite causes star light to be modulated by a focal-plane grid. In Step 0, one-dimensional stellar coordinates, grid coordinates, are determined by Fourier analysis of the photon counts. This gives in fact only the fractional part of the grid coordinate (expressed in units of the basic grid period, $s = 1.2$ as), due to the 2% ambiguity of the modulation phase. The integer part of the grid coordinate must be inferred from the approximately known satellite attitude and star position. Because of uncertainties in these, it will often happen that the derived grid coordinate is wrong by an periods. Such errors are called slit errors and cannot be detected in Step 0.

Step 1. Combining grid coordinates obtained in a time interval of about 12 h, it is possible to make a least-squares solution for the stars' positions along a selected Reference Great Circle (RGC), eliminating in the process the precise attitude of the instrument at each instant. These one-dimensional coordinates, the star abscissae, can be determined without knowing very precisely the perpendicular coordinates of the stars (their ordinates, or distances from the RGC), since the angle between the grid coordinate axis and the RGC is never more than a few degrees. In Step 1 it is possible to detect inconsistent slit errors, i.e. cases where a given star is affected by different slit errors at the different times it is observed. In such cases the grid coordinates from Step 0 are arbitrarily adjusted by adding small integer values, until only consistent slit errors remain. These cannot be detected in Step 1.

Step 2. This aims at determining the abscissa origin for each RGC in a consistent, global celestial coordinate system. This is done by determining, in a single least-squares solution, the astrometric parameters for some 1000 Primary Reference Stars (PRS), while imposing some suitable global system orientation e.g. from FK5. Input for this are (relative) abscissae of the PRS obtained in Step 1, i.e. angles between these stars. By using as PRS only stars with very accurate a priori positions (e.g. FK5 stars), there is very little risk that their abscissae are affected by slit errors; hence this problem does not enter Step 2.
Step 3. This step will solve, for one star at a time, the five astrometric parameters and the slit errors afflicting the individual abscissae of the star. Input for Step 3 are the abscissae determined in Step 1, with zero point corrections from Step 2, and preliminary astrometric and other data from the Input Catalogue. Because of the possible slit errors, this cannot be performed as a simple least-squares adjustment of the astrometric parameters. One should rather regard it as a minimisation problem with periodic (instead of parabolic) loss function; i.e., an abscissa residual of \( r+n \) grid periods must be equivalent to a residual of \( r \) periods, if \( n \) = integer. Thanks to the many different position angles of the RGC's across a given star, and the high accuracy of the abscissae compared to the grid period, this problem will almost certainly find a unique solution in which all slit errors are correctly determined. If a good solution cannot be found for certain stars, it will indicate that they may be double or multiple. Such cases will be treated by special routines which are however not part of Step 3.

PROPOSED TASK

The task is to develop and implement an algorithm for solving the slit errors and astrometric parameters of single stars in Step 3. The algorithm should eventually produce the following output for each of the 100,000 stars:

- star identification;
- estimated astrometric parameters;
- estimated covariance of astrometric parameters;
- rms abscissa residual and other statistics (goodness-of-fit);
- individual abscissa residuals, slit errors, RGC position angles, etc.

The process (Step 3 = Backsubstitution) will be more precisely defined, with detailed I/O data specifications, before May 1983 (WP7100). The proposed task roughly corresponds to WP7200 (development) and WP7300 (implementation), and can be subdivided in subtasks e.g. as follows:

1. To formulate the problem mathematically, e.g. in terms of the maximum likelihood method, and to derive theoretical distributions, statistics etc.
2. To simulate input data for Step 3.
3. To devise a numerical algorithm for the solution.
4. To optimise the algorithm with respect to numerical accuracy, robustness, and computing time constraints.
5. To test the algorithm under widely varying input conditions, determine possible failure modes and remedies/error exits.
6. To determine the statistical behaviour of the algorithm (bias, covariance, goodness-of-fit statistics) by Monte Carlo, for a few representative cases, and compare with theoretical expectations.
7. To code and prepare the algorithm with appropriate interfaces.

Written progress reports or working papers (in English) at suitable intervals or milestones, and complete documentation of the final algorithm, is part of the task.

L Lindegren (1982 Oct 15)
Lund Observatory