# COMPILATION OF THE NIRS USING THE EICHHORN METHOD

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ABSTRACT. The Eichhorn method of simultaneously estimating both target parameters and model parameters is applied to the compilation of a complete star catalogue. The input material of the *Northern International Reference Stars* (NIRS) is used and the resulting catalogue is compared to the NIRS catalogue compiled by Corbin (1977) using traditional techniques. By simultaneously using all available constraints on all available data, it is shown that the new estimates of the star parameters have smaller formal errors than estimates derived from the same material but using conventional procedures. Both versions of the NIRS are used to predict the star positions of the later observed *Perth 70: A Catalogue of Positions of 24900 Stars* and these predicted positions are compared to the actual observed positions. It is found that a simultaneous reduction results in a slight but significant improvement in the declination system of the NIRS.

## 1. THE ESTIMATION OF SYSTEMATIC DIFFERENCES

The difference between the position estimates of a star in two catalogues originates in the errors of the observations, the deficiencies of the reduction algorithms and the inconsistencies of the systems defined by the star positions of the catalogues. In computing corrections to "bring a catalogue onto a system," one seeks to minimize the differences between the defining systems without changing the accidental errors in the individual position estimates. Once systematic differences are found, they can be applied to the positions in one catalogue as systematic corrections in order to bring the two catalogues ideally onto the same system. When the catalogues are on the same system, estimates for the mean position and proper motion can be calculated.

Regardless of the functional form of the model for the systematic differences between two catalogues, when more than two catalogues are being combined, there are, in principle, two distinct methods to compute these systematic differences. The traditional methods utilize the comparisons of the positions of only those stars common to each independent catalogue (IC) and the reference system (the FK4 in this case) for the derivation of the systematic corrections for that IC. Systematic corrections are then determined from these individual comparisons only. By comparing an IC only to the reference system, not all available constraints are used



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in estimating the model parameters. That is, the procedure which estimates the model parameters does not constrain these model parameters to minimize the systematic differences between all ICs but rather the model parameters are constrained only to minimize the systematic differences between each IC and the fundamental system.

A simultaneous reduction, on the other hand, solves for target parameters (star positions and proper motions) and model parameters (systematic errors) at the same time. The advantage here is that all available constraints on all available data are used to estimate both sets of parameters. In this way not only are the systematic differences between the independent source catalogues and the fundamental system of the FK4 minimized, but the systematic differences between all catalogues are minimized as well. The idea that all parameters, used in the construction of a complete catalogue, should be solved for in a single adjustment was first suggested by Eichhorn (1974) and later described by him in more detail (Eichhorn 1980). Within the framework of this research this principle has been employed to estimate simultaneously systematic corrections for the 64 ICs used to construct the NIRS on the basis of the same model and from the same raw material as those used in the original compilation of the NIRS. The only difference between the reductions was the method of computing systematic differences.

Due to computational considerations, an iterative solution was used rather than a solution which solves a system of equations in closed form. The first iteration contained only ten ICs which could be directly reduced to the FK4 and resulted in a catalogue of 6317 positions and proper motions. With this first iteration NIRS catalogue, systematic corrections could be computed for all ICs on the second iteration. For the second and subsequent iterations, an NIRS catalogue of 20149 stars was compiled.

## 2. RESIDUALS BETWEEN THE TWO VERSIONS OF THE NIRS

After compiling the new NIRS, positions and proper motions were compared to those in the original version compiled by Corbin. Position and proper motion residuals were computed in the sense original minus new.

Table I - Residuals Statistics: Original - New

| | $\alpha\cos\delta$ | $\delta$ | $\mu_\alpha\cos\delta$ | $\mu_\delta$ |
|---|---|---|---|---|
| Mean Residual | $-0^s\!.00005$ | $0''\!.0007$ | $-0^s\!.0016$/cy | $-0''\!.016$/cy |
| Dispersion | $0^s\!.0021$ | $0''\!.037$ | $0^s\!.014$/cy | $0''\!.22$/cy |

The mean residuals from table I show that the two versions of the NIRS agree quite well. The fact that the dispersions of the residuals are about half of the mean errors of either catalogue (see Table II) shows that the positions and proper motions in the two catalogues are highly correlated.

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## 3. INTERNAL ERRORS

The qualitative concept of the precision of a parameter is generally associated with the variance of that parameter. The rms error is the accepted least squares estimate of the square root of the variance of a parameter. In the new compilation of the NIRS, 17433 stars had three or more independent right ascension positions and 17467 stars had three or more independent declination positions, enabling rms errors to be calculated for these positions and proper motions. For comparison, the original NIRS had 17682 stars with three or more right ascension and/or declination observations.

Table II - Mean RMS errors

| | $\alpha\cos\delta$ | $\delta$ | $\mu_\alpha\cos\delta$ | $\mu_\delta$ |
|---|---|---|---|---|
| Original NIRS | 0$^s$.0050 | 0".087 | 0$^s$.030/cy | 0".46/cy |
| New NIRS | 0$^s$.0048 | 0".082 | 0$^s$.028/cy | 0".44/cy |
| Significance level of difference | <1% | <1% | <1% | <1% |

The formal, internal errors of a process of data reduction are very dependent on the model, the assumptions of that model and the method of solution used. But when one compares two investigations which use the same model, the same assumptions concerning that model and the same method of obtaining estimates, the rms errors become a valid basis for that comparison. The new NIRS does have rms errors which are significantly smaller than those of the original NIRS.

## 4. PERTH 70 RESIDUALS

The real test of any research comes in the form of predicting future observations. The *Perth 70: A Catalogue of Positions of 24900 Stars* (Perth 70) (Hog and von der Heide 1976) is a catalogue with a mean epoch of 1970, 26 years later than the mean epoch of the NIRS. 3324 stars of the Perth 70 were matched with the NIRS. Perth 70 positions were then predicted and residuals were computed with the two version of the NIRS. Table III gives the mean residuals and one sigma dispersion of the position residuals between the Perth 70 and the two versions of the NIRS.

Table III - Residuals Statistics: Perth 70 - NIRS

| | Mean residual | | Dispersion | |
|---|---|---|---|---|
| | $\alpha\cos\delta$ | $\delta$ | $\alpha\cos\delta$ | $\delta$ |
| Original NIRS | 0$^s$.0038 | 0".084 | 0$^s$.0143 | 0".300 |
| New NIRS | 0$^s$.0039 | 0".064 | 0$^s$.0141 | 0".302 |
| Significance level of difference | 43% | 0.3% | 14% | 35% |
| First iteration of 6317 stars | 0$^s$.0030 | 0".048 | 0$^s$.0131 | 0".304 |

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Table III shows that the only significant difference between the residuals of the Perth 70 against the two versions of the NIRS is in declination. At this point it might be asked if these mean residuals are due to the system of the NIRS or that of the Perth 70. An indication of how much of the mean residual is due to the system of the Perth 70 and that of the NIRS can be found using the first iteration of the new NIRS which included only those ICs which could be directly compared to the FK4. The first iteration catalogue of 6317 stars was compared to the Perth 70. It is seen that the mean declination residual of the new NIRS is closer than the original NIRS to the mean declination residual of this first iteration system which represents the system of the FK4 more accurately than that of either NIRS.

Table III shows no significant difference in the dispersion of the residuals which indicates that the new NIRS has not improved the individual positions, but the reduction in the mean declination residual shows that the declination system of the new NIRS is closer to that of the FK4 in a systematic sense.

## 5. CONCLUSIONS

This research has shown that a simultaneous reduction is valid within the context of catalogue compilation and that the resulting catalogue is superior to one compiled by traditional methods. The advent of modern electronic computers has made the Eichhorn method computationally feasible.

The new compilation of the NIRS, like most astrometric data, is generally most useful in machine readable form. Therefore, this catalogue is available from the author on magnetic tape. It must also be noted that the original version of the NIRS has been available to and has been used by the the astrometric community for several years. If one wishes to maintain consistency in astrometric research, the original version of the NIRS should be considered for use.

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Discussion:

**ROESER** You compared your declination system with Corbin's with the result that the two systems were pratically identical. In comparing both systems with Perth 70, you found systematical differences. Can you comment on this?

**COLE** Table 1 shows mean residuals from -5° to +90°, but in the zone -5° to +5° there are noticeable differences between the two versions of the NIRS in both declination and proper motion in declination.

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