TECHNIQUES FOR SCHMIDT PLATE REDUCTIONS WITH APPLICATION TO GSC1.2

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1. Introduction

Over the last few years there has been considerable progress in developing successful algorithms for obtaining astrometric quality positions from Schmidt plates which compensate for deficiencies of the polynomial approach; the *sub-plate* method (Taff 1989), the *mask* method (Taff *et al.* 1990), the *collocation* method (Bucciarelli *et al.* 1993) the *filter* method (Röser *et al.* 1995) and a filter weighting according to the *method of infinitely overlapping circles* (Morrison *et al.* 1996b.) However, none of these nor any other studies have investigated the magnitude dependence of the position estimates outside the magnitude range of standard reference catalogs. Often Schmidt plates cover the magnitude range from $6^{\rm m}$ to $19^{\rm m}$ (for the GSC it is $6^{\rm m}$ to $15^{\rm m}$). Presently available reference catalogs, however, have a limiting magnitude of $V \approx 10^{\rm m}$. Therefore, no magnitude dependent term for fainter stars can be reliably found by reducing the measurements based only on comparisons with reference stars.

2. Method of removing systematic errors

What is needed is a dense all-sky reference catalog covering the same magnitude range of the Schmidt plates with sufficiently accurate positions at the epoch of the plate material. The Astrographic Catalog (AC) is an interesting prospect, it contains 10 millions measurements of roughly 4 million stars with a $0.3''$ rms error per star position, and a limiting magnitude of $12^{\rm m}$ (but in many cases it is as faint as $13.5^{\rm m}$). However, the AC has a mean epoch of 1903 and contains no proper motions; therefore there are roughly 80 years difference between the epochs of the two catalogs and neither catalog contains proper motion information. We have developed a method of reduction where this difference in the epochs is *inconsequential.*

The AC was used in two steps; to remove the systematic errors which are a function of magnitude and radial distance from the plate center and to remove those that are only a function of location on the plate. In both steps the average systematic errors were found by 'stacking' all the AC plates onto the GSC plate-based coordinate system. For each GSC/AC match the differences in position were binned and averaged in the GSC plate system. The grid pattern for the two steps was different, but in both cases the large number of AC stars and the high degree of overlap of the AC plates (50% in α and 50% in δ) resulted in each bin containing an enormous number of matches (at least, tens of thousands). Therefore, we can assume that after the averaging the random errors in the AC and GSC positions cancel out, leaving only the signal of the average systematic distortions in the GSC plates. Note also that the systematic errors on the AC plates cancel out because the the AC and GSC plate centers are uncorrelated.

Part of the effects of the unaccounted proper motion are also taken care of by the averaging process. The components of proper motion can be separated into the peculiar motions of the stars plus the induced proper motion arising from the galactic rotation and solar motion. By assuming the peculiar motion of the stars to be random, after the averaging process, the effects caused by these motions cancel out leaving only those from the galactic and solar motion. We will show later, in our method of utilizing the AC, these physical effects either cancel or subtract out. As a consequence the final positions at epoch are unaffected by any physical motions of the stars in the Galaxy.

Numerous tests we have performed on the magnitude effect have proven that the overwhelming part of it is radial. Therefore, concerning this effect, we are only interested in determining for each GSC/AC match the difference (GSC–AC) in radial distance from the GSC plate center. For a set of specified magnitude ranges this difference is found for all the matches and then binned and averaged in thin rings ($2.7'$) centered on the center of the GSC plate-based coordinate system. In this process the proper motions induced by galactic and solar motion cancel out. The magnitude effect is then corrected by spline fits to the radial difference between the GSC and AC positions as a function of distance from the plate center and magnitude.

After the above correction was applied to the GSC positions, the removal of the position-only dependent systematics was accomplished by constructing a vector mask of residuals (*i.e.*, a grid of points in the GSC plate-based system containing the binned and averaged GSC-AC positional residuals). This mask represents the average systematic distortions plus the constant from the remaining proper motions. From previous studies using the PPM, we know that the mask of distortions is nearly zero in the central region. The average residual vector in this region is simply the constant caused by the galactic and solar motion over the 80 years. Subtracting this value from all the grid points, leaves the mask representing the mean positional errors on the Schmidt plates. The resulting mask can then be applied to GSC positions based on their location on the plate.

In conclusion, using a combination of the filter and mask method we have removed the mean systematic deformations which have plagued the GSC Schmidt plates (and other similar Schmidt plates). Also using a rather unconventional approach, we have developed a method where a nonuniform, inhomogeneous, imprecise, single early epoch reference catalog (the AC) can be a *powerful* tool for removing the mean of magnitude dependent systematics.

References

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