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Astrometry with A-Track Using Gaia DR1 Catalogue

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Abstract. In this work, we built all sky index files from Gaia DR1 catalogue for the high-precision astrometric field solution and the precise WCS coordinates of the moving objects. For this, we used build-astrometry-index program as a part of astrometry.net code suit. Additionally, we added astrometry.net's WCS solution tool to our previously developed software which is a fast and robust pipeline for detecting moving objects such as asteroids and comets in sequential FITS images, called A-Track. Moreover, MPC module was added to A-Track. This module is linked to an asteroid database to name the found objects and prepare the MPC file to report the results. After these innovations, we tested a new version of the A-Track code on photometrical data taken by the SI-1100 CCD with 1-meter telescope at TÜBİTAK National Observatory, Antalya. The pipeline can be used to analyse large data archives or daily sequential data. The code is hosted on GitHub under the GNU GPL v3 license.

Keywords. techniques: image processing, catalogs, minor planets, asteroids, astrometry.

1. A-Track

A-Track is a fast, open-source, cross-platform pipeline, for detecting the moving objects (asteroids and comets) in sequential telescope images in FITS format. The pipeline is coded in Python 3. The moving objects are detected using multiple image line detection algorithm, called MILD.

Once the candidate objects are found for each image (catalog file) by SExtactor Bertin & Arnouts (1996), MILD looks for points from different images that would form a line when plotted on the same graph. MILD investigates all of the possible 3-point combinations obtained from all of the candidate files (.cnd), each point coming from a different image. For each 3-point combination, it performs three checks (Atay, T. *et al.* (2016)).

2. Building GAIA Index Files for Astrometry.net

In order to use GAIA DR1 catalogue in astrometry.net code, we built new astrometry.net index files for high precision astrometric solution. To build such index files "hp-split" and "build-astrometry-index" commands were used respectively Lang, D. *et al.* (2016) for five (0 - 4, <24) different scales. However, GAIA DR1 catalogue as FITS table is approximately 350 GB. To compare the results with 2MASS catalogue and to reduce the size of GAIA DR1 some limitations similar to 2MASS were applied to GAIA DR1. Besides that to reach high accurate astrometric results, stars with the errors of RA and Dec greater than 1 milliarcsecond were excluded. After this elimination, we produced new index files (GAIA Index Files version 1) with 48 healpixes from homogeneously built GAIA DR1 catalogue ($\sim$ 178 million stars).

3. Using GAIA Index Files version 1 (GIFv1)

A newly developed module is added to the A-Track which obtains WCS coordinates of CCD frame by using GIFv3. With the obtained WCS coordinates, known asteroids passing through the region are listed with the query of MPC and SkyBoT and are compared with the moving objects found by A-Track. The objects found in the comparison are listed to the user in MPC format. If the moving object detected by A-Track has no match with the database, it is added to the MPC file as a new object.

4. Results and Comparisons for GIFv1 and 2MASS Index Files

The archived data taken from 1-meter telescope equipped with SI 1100 CCD was solved astrometrically using both 2MASS index files and GIFv1. Then all the asteroids in the frames were queried by the SkyBot database and the residuals of the coordinates were plotted (Fig. 1 and Fig. 2).

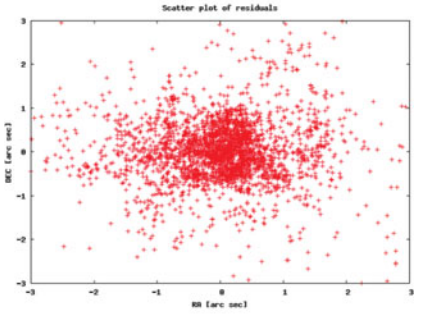

Figure 1. Scatter plot of residuals for 2MASS index files

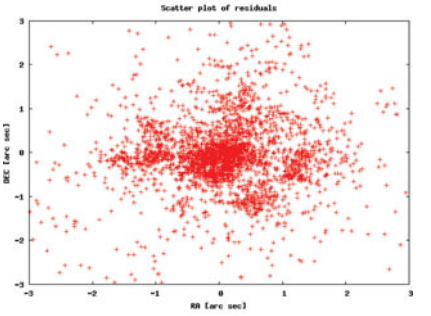

Figure 2. Scatter plot of residuals for GIFv1

5. Conclusions

As shown in Table 1a and Table 1b, the results obtained through GIFv1 are just as sensitive as 2MASS index files.

Residual (")	Detected Asteroids	Percentage (%)
<0.2	235	7.3
<0.5	1000	30.9
<1.0	2079	64.3
<2.0	2834	87.7
<2, <8	399	12.3
<8	3233	100

(a) Residuals for 2MASS index files

Residual (")	Detected Asteroids	Percentage (%)
<0.2	327	9.3
<0.5	1107	33.4
<1.0	1850	55.8
<2.0	2898	87.5
<2, <8	415	12.5
<8	3313	100

(b) Residuals for GIFv1

Table 1. Residuals

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