PRAIA - Platform for Reduction of Astronomical Images Automatically

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Introduction

PRAIA performs high precision differential photometry and astrometry on digitized images (CCD frames, Schmidt plate surveys, etc). The package main characteristics are automation, accuracy and processing speed. Written in FORTRAN 77, it can run in scripts and interact with any visualization and analysis software. PRAIA is in cope with the ever growing amount of observational data available from private and public sources, including data mining and next generation fast telescope all sky surveys, like SDSS, Pan-STARRS and others. PRAIA was officially assigned as the astrometric supporting tool for participants in the GAIA-FUN-SSO activities and will be freely available for the astronomical community.

1. PRAIA astrometric structure

Figure 1 displays the astrometric scheme of PRAIA package. The photometric part of the platform is out of scope in this text and will not be presented here.

1.1 Information extraction, parameter configuration. Results and information archiving.

PRAIA is composed of separate independent programs. Each program runs in automatic fashion without interaction with the user. Each program has an input data file which must be filled in. Due to the high degree of development of the algorithms used in the image and data treatments, there are quite a few critical parameters which cannot be internally computed and must be furnished by the user. Most of the information in the input data files regards to input and output file names. There are also parameters indicating reduction models and other auxiliary information. In some cases, there are also other input data files that must be present in order to run a task. Usually, those regard to target and to image header information. Image header extraction furnishes critical FOV information like field size, (α,δ) central coordinates and exposure mid-instants. Other auxiliary information is also extracted, as exposure time, filters, object name, image file name. Note that PRAIA reads only FITS format images, but recognizes many FITS header "free" styles. One can always edit and change the extracted information. Target information files contain: (α,δ), JD, standard object name. PRAIA includes programs which can automatically generate target files for solar system bodies by ephemeris extraction, using web services (IMCCE/Skybot or JPL/Horizons) and NAIF/SPICE package. More than one target, with or without changing coordinates with time, can be included in a single target file.

Results are archived on two types of output files with redundancy: (α,δ), exposures mid-times, magnitudes (psf-based and from catalogue), seeing, proper motions (computed, from catalogue), number of reference stars, position errors (mean error, standard error, (O-C)s, …), (x,y), Gaussian psf parameters and errors, magnitude errors, filters, object name, fits file, etc. One file type regards to individual image output and includes information for all objects measured in the FOV. The other type refers to the list of targets and gives in one single file the results from all treated images, only for the targets identified in the FOVs. All the files are formatted and written in standard ASCII, making it very easy for the user to analyze data using their own graphic and statistic tools.

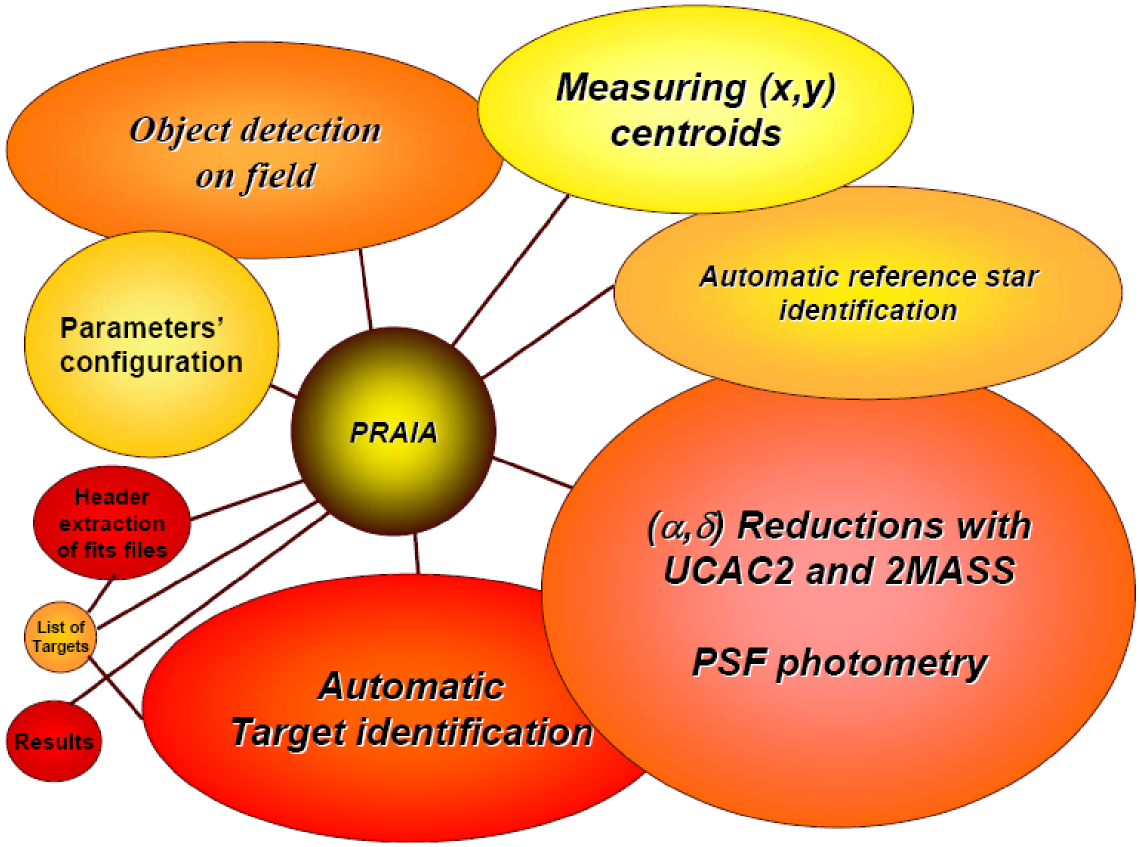

Fig. 1 – Astrometric scheme of PRAIA package.

1.2 Object detection, measuring. Automatic reference star identification. (α,δ) reduction.

Prior to object detection, the images undergo bad pixel elimination (including saturated ones) and sky background flattening (absence of previous photometric flat field corrections, vignette, Moon and sky background scattered light). Object identification is based on a local maxima spiral search algorithm. Sky background threshold and variation is evaluated from the histogram of counts. Objects above background by a given factor from the sky variation are stored and evaluated. Only pixels within 1 FWHM are computed in the iterative Gaussian fit procedure. The Gaussian psf fits furnish among other parameters (like psf magnitude) the (x,y) centroid and FWHM (seeing) of the object profile. Objects within a given FWHM range are validated and kept for astrometry. These procedures prove to be efficient against false detections by cosmic rays, spurious artificial structures and bright star image subdivisions. It is efficient for fitting saturated star images and blended objects. Field distortion pattern masks can be applied to the (x,y) measurements prior to the (α,δ) reductions. The reference star identification procedure settles the catalogue stars, the pixel scale and axis orientations automatically. Orientation, pixel scales and pairs of (x,y) and (α,δ) projected in the tangent plane are tried with 4 Constant and higher order polynomial models. The best match is then stored. This is made very fast with bright measured stars and the 2MASS catalogue, so that reference stars are recognized even with small or star-devoid FOVs. The (α,δ) reductions can be made with any chosen polynomial model (first, second, third degree plus third or fifth radial distortion terms plus magnitude and color terms) which relates (x,y) and (α,δ) coordinates in the tangent plane. Reductions are automatically performed with four different sets of reference star catalogues: UCAC2, 2MASS and two modified versions of 2MASS. The first 2MASS modified version consists of 2MASS positions corrected to the UCAC2 frame by means of polynomial-based model fits in the tangent plane in much the same way as in a normal reduction. In the second modified version, the positions are further corrected by proper motions, using the average values from faint UCAC2 stars within an area twice as large as the FOV. Based on reference stars (O-C)s, outliers are eliminated one-by-one in an iterative way, until a given (O-C) threshold is reached. For each set of reference stars, output files for individual frames and for targets are generated. Many error estimates are derived from the (x,y) Gaussian psf fits and from the (α,δ) reductions, like (x,y) Gaussian fit errors, (α,δ) mean errors and standard errors from the variance-covariance matrix. After (α,δ) reductions, proper motions are computed for each 2MASS star, using the positions in that catalogue as the other epoch. In the case of overlapping FOVs, firstly the individual frames are reduced. Then, the (α,δ)s are matched and averaged and an intermediary instrumental catalogue is generated, containing all objects from all FOVs. The positions in this intermediary catalogue are further corrected to the reference catalogue (say, the UCAC2) by means of polynomial-based model fits in the tangent plane. The resulting intermediary catalogue is then used as reference in new individual frames (α,δ) reductions. The procedure is repeated until convergence is reached in the positions of all objects. For consistency, only “fixed” objects like stars should be used in the procedure. Entries in the target list can be excluded, like solar system moving objects. Table 1 presents a sample of results which show PRAIA astrometry and data handling performance according to object type (star, quasar, solar system object), field size, reference star number, field star number, brightness and epoch.

Table 1 – PRAIA: astrometry and data handling.

Object	Tels.	PRAIA minus Target αΔcosδ Δδ (mas)		PRAIA minus Target σα σδ (mas)		No. Img	CCD Field (')	Number comptd (α,δ)s	PIV 3.2GHz Procces time	FITS data	Ep. (yrs)	Mag V	Ncat	Sα Sδ (mas)	
254 qsos	0.6m	+00	+11	42	48	3546	10x10	5626000	110.9hs	29.0GB	2000.3	15-18.5	22 U2	44	42
215 qsos	1.6m	-04	-06	50	52	2445	5x5	3997412	106hs	19GB	2000.7	15-21	21 MA	34	34
62 qsos	0.5m	+06	+14	47	52	4124	7.4x7.4	641756	8.8hs	3.5GB	2005.1	15-17.5	22 MA	39	43
Pluto	0.6m	-20	+09	60	42	1541	10x10	12577580	23.4hs	19.0GB	2004.2	14.0	79 U2	52	50
Pluto	1.6m	-20	+00	52	60	398	5x5	446.512	12hs	2.1GB	1997.9	14.0	16 MA	65	54
Triton	0.6m	+18	-135	60	63	273	10x10	31540	1.8hs	1.5GB	2006.5	13.5	17 U2	59	57
Elara	0.6m	-47	-135	29	36	89	10x10	179516	1.0hs	329MB	2006.1	17.2	17 UC	52	53
Himalia	0.6m	-112	-10	31	26	98	10x10	142768	1.0hs	319MB	2006.1	15.3	19 UC	53	54
Phoebe	0.6m	+67	-99	22	50	16	10x10	47524	0.6hs	174MB	2006.1	16.2	12 UC	55	60
Pasiphe	0.6m	+62	-43	84	68	41	10x10	56704	0.4hs	137MB	2006.1	17.6	17 UC	66	58
Iapetus	0.6m	+85	-116	91	99	40	10x10	57044	0.5hs	156MB	2006.1	10.9	10 UC	62	62
Titan	0.6m	+94	+28	132	183	15	10x10	29436	0.3hs	100MB	2006.1	8.2	5 UC	52	59
Hiperion	0.6m	+174	-74	---	---	1	10x10	5760	0.1hs	29MB	2006.1	14.2	8 UC	53	56
60 O.C.	1m Mex.	----	----	---	---	1880	6.7x6.7	1161886	10hs	4.6GB	2003.5	12-18	181 2M	72	74

Conclusion

PRAIA was officially assigned as the astrometric supporting tool for participants in the GAIA-FUN-SSO activities. No interaction is needed to run the programs of the package. PRAIA automatically identifies reference stars and targets, performs photometric and astrometric measurements, and computes positions and errors. All polynomial models, including radial distortions, magnitude and color terms are available. Default reference catalogues are the UCAC2 and the 2MASS. Others may be used, including secondary catalogues generated (or not) from former PRAIA runs. It also performs astrometry over overlapping frames, from single observations or from CCD mosaics for instance. All results - including those for pre-selected targets - plus complete observational and reduction information are archived in one or few output files with redundancy. PRAIA also allows for a fast visual inspection of the results by screen plots of graphics, tables and statistics using your preferred tools. PRAIA astrometric and photometric performance is certified by a number of publications given in the references. They are examples of high precision photometry and astrometry of CCD observations of asteroids, occultation candidate stars, TNOs, ICRF radio sources and natural satellites. The photometric precision is compatible with DAOPHOT performance to 0.001mag or better. Depending on the reference catalogue, instrument, field size and exposition, positional errors range between 30mas and 70mas and astrometric accuracy (repeatability) can be as good as 20mas to 10mas.

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