

Automatic Astrometric and Photometric Calibration with SCAMP

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Abstract. Astrometric and photometric calibrations have remained the most tiresome step in the reduction of large imaging surveys. I present a new software package, SCAMP which has been written to address this problem. SCAMP efficiently computes accurate astrometric and photometric solutions for any arbitrary sequence of FITS images in a completely automatic way. SCAMP is released under the GNU General Public Licence.

1. Introduction

Modern astronomical imaging surveys make use of a large number of “dithered” exposures to cover sky areas. Nowadays, the throughput and the number of focal plane arrays involved in wide-field imagers are such that tens of thousands of individual CCD images are routinely involved in survey stacks, as those of the CFHTLS processed at the TERAPIX¹ centre (e.g. Bertin et al. 2002). SCAMP was developed at TERAPIX with the purpose of combining the positions and flux measurements of the millions of detections found in these images to derive in a global and optimal way their astrometric and photometric “plate solutions”. Like other TERAPIX software packages, SCAMP is not survey-specific and is intended to work with many kinds of imaging data.

In the following sections I describe briefly the three main steps of the astrometric part of the processing: measurement of centroids, matching with reference catalogues, and computing the global solution. Finally, I present some sample results and discuss some technical issues. More detailed information will be presented in Bertin (2006).

2. Measuring the Centroids of Detections

SCAMP operates on binary catalogues produced by SEXTRACTOR (Bertin & Arnouts 1996), containing pixel coordinates for each detection. SEXTRACTOR’s X_IMAGE and Y_IMAGE “isophotal” centroids were found to be suboptimal in terms of accuracy, and were replaced by Gaussian-weighted centroids XWIN_IMAGE and YWIN_IMAGE. These new parameters (available in SEXTRACTOR version 2.4 and above) prove to be as precise as positions derived from

¹<http://terapix.iap.fr>

PSF-fitting on background-noise limited images, albeit being much faster to compute.

3. Matching with a Reference Catalogue

SCAMP starts by assuming that the World Coordinate System information found in the original image header is accurate to a few arcminutes (typically). The image pixel scale is assumed to be accurate to within a factor of \approx two, and image orientation up to 180° . A possible flipping is also considered. An astrometric reference catalogue (currently GSC, USNO, UCAC or 2MASS) for the corresponding sky area including a margin is automatically downloaded from the VizieR database at CDS (Ochsenbein et al. 2000) using the CDSCLIENT tool². As in Kaiser et al. (1999), pixel scale and image orientation are found by cross-correlating the 2D histograms of source pair coordinates in the log(projected distance) - position-angle space for field detections and the reference catalogue. The position of the correlation peak indicates the relative image scaling and rotation angle to apply to the field WCS. Once this is done, another cross-correlation is performed in the space of projected coordinates to compute and correct for the shift with respect to the true position. Finally, all sources are cross-matched and each set of overlapping exposures is projected to a local, common stereographic projection.

4. Computing the Astrometric Solution

The astrometric solution is the result of a χ^2 minimisation. The adopted χ^2 is the quadratic sum of differences in position between overlapping detections from pairs of fields. One of those fields may be a reference field, or both may be uncalibrated. In both cases, coordinates used in the differences are *reprojected* coordinates $\vec{\xi}$, common to all fields of a same group. The $\vec{\xi}$'s are derived from the measured detector coordinates \vec{x} , and the reprojection operator $\vec{\xi}(\vec{x})$ is different for each focal plane array.

Minimising (1) leads to a solution which adjusts best (in the χ^2 sense) all the various fields at once whilst tightening the whole group to the reference catalogue:

$$\chi^2 = \sum_s \sum_a \sum_{b>a} w_{sab} \|\vec{\xi}_a(\vec{x}_{sa}) - \vec{\xi}_b(\vec{x}_{sb})\|^2, \quad (1)$$

where w_{sab} is the non-zero weight for the pair of detections in exposures a and b related to source s . This is similar to the so-called ‘‘overlapping plates method’’ (Eichhorn 1960), with the difference here that proper motions are neglected during the first iteration. Similar approaches were followed by Deul et al. (1995) and Radovich et al. (2004) for his ASTROMETRIX³ package. SCAMP distinguishes itself from previous implementations by trying to reduce as much as possible

²<http://cdsweb.u-strasbg.fr/doc/cdsclient.html>

³<http://www.na.astro.it/%7Eradovich/wifix.htm>

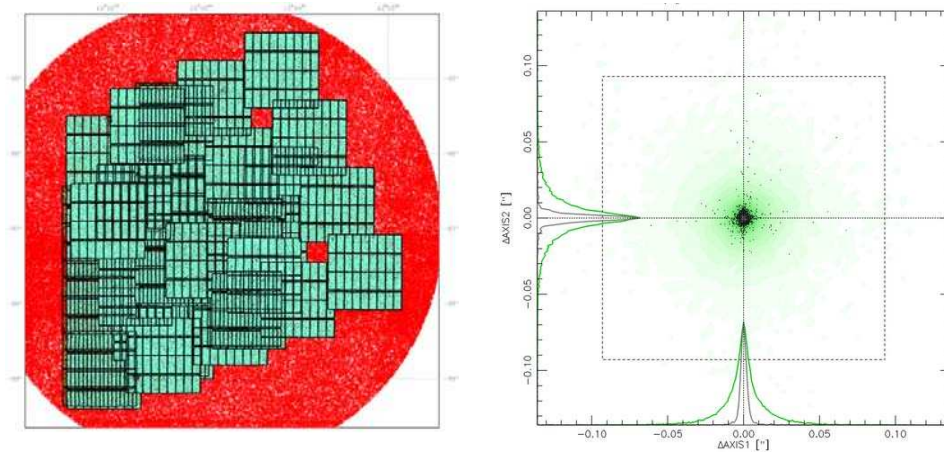


Figure 1. Two examples of diagnostic plots produced by SCAMP. *Left*: overlapping CFHTLS exposures; cross-matched detections are plotted as bright dots within the camera boundaries; unmatched sources from the USNO-B1 astrometric catalogue are shown as dark squares. *Right*: pair-wise internal scatter of all (smooth, wider distribution) and $S/N > 200$ (dotted, sharper distribution) CFHTLS detections around the mean after calibration; the dashed square indicates the MEGACAM pixel footprint for reference. The dispersion measured for high S/N sources is 6 mas.

the number of free parameters (which otherwise can grow uncontrollably large in deep stacks with CCD mosaics): for instance, with the MEGACAM instrument one can make the assumption that the high order part of the astrometric distortion pattern is stable within a given observing run, while the linear part varies globally over the field of view from exposure to exposure. This allows much more robust solutions to be computed, especially when crowded or empty images are involved.

5. Additional Features

SCAMP comes with various calibration modes for typical instruments, including those with stable focal planes or “loose” mosaics. Differential chromatic refraction, as well as proper motions can be automatically computed with the appropriate data (several filters or epochs, respectively). In addition to updated image headers, SCAMP can output merged catalogues, as well as a summary file in XML and a choice of diagnostic plots (Figure 1).

6. Performance and Availability

SCAMP is written in C, and is fully multithreaded to take advantage of multiple processors and cores. The current processing speed for shallow stacks is about 5s per MEGACAM exposure (with an average of 20,000 sources) on a quadri-

Opteron 2.4GHz. SCAMP is released under the GNU General public licence and will be made available in Q4 2005 on the TERAPIX WEBSITE⁴.

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⁴<http://terapix.iap.fr/soft/scamp>