The ALADIN Project: Calibrations and Tools

1. Introduction

Automatic plate measuring machines make possible the objective quantification of photographic images of the sky, thereby permitting the extraction of the large amount of astronomical data represented by these images. The data is stored in the form of a catalogue consisting of a list of object positions, magnitudes and classifications (star or galaxy), and which, one hopes, represents the greater part of the useful data stored in the complete image. In essence one exchanges the storage medium of the photographic plate for an electronic list of objects. Unavoidably, such a list is defined by the criteria used to construct the catalogue and one cannot then re-extract a new catalogue based on different criteria, for example criteria based on other detection algorithms or on newer calibration data. To do so a user would be forced to request a rescan of his plates on one of the few and overworked machines.

With this in mind, in 1992 the Centre de Données astronomiques de Strasbourg (CDS) conceived the ALADIN project which aims to provide easy electronic access to digitized images of Schmidt plates. The CDS plans to stock images covering the entire sky by using the Space Telescope Science Institute's (STScI) *Digital Sky Survey* (DDS) (with pixel size = 1.8", or 25 micron sampling, and compressed by a factor of 10), and, in addition, to store images at full resolution (pixel size = 0.7", or 10.0 micron sampling, in an uncompressed format) of important regions such as the Galactic and Ecliptic Poles, the Galactic Plane, and the Magellanic Clouds. Access will be facilitated by a graphical interface (the *client*), resident on the user's local computer, which communicates via the computer network to a *server* at CDS, where the images will be stored in an optical disk juke-box. ALADIN will aid source cross-identifications, with its ability to overlay the positions of sources detected in other wavebands, and the preparation of observations, permitting the visualization of the selected sky region and access to relevant information. In this manner ALADIN will be an indispensable tool for data quality control of the Simbad database. A general description of the ALADIN project is given by Paillou et al. (1994). Presently there exists a prototype with access to 10 Schmidt plates and the ability to plot the Guide Star Catalog positions and overlay objects contained in the Simbad database or in a user-defined data file. The archiving system of 520 Gbytes has been installed and the development of image and catalogue servers is currently underway.

To take advantage of the full image data requires both astrometric and photometric calibrations for each plate and astronomical 'tools' for object extraction and image analysis. Here we present our approach to these calibrations and our design of the ALADIN client's astronomical toolbox. We have adopted a two-tiered approach in which the first level represents ready-made calibrations for immediate use, while the second will permit the *recalibration* of an image with up-to-date standards. In this latter case the user will have the choice of using either his own data or new catalogues of standards (such as Tycho/Hipparcos) stored at CDS.

2. Astrometry

An astrometric calibration is routinely supplied by the measuring machine, based in the case of the MAMA (Machine A Mésurer pour l'Astronomie) at CAI (Centre d'Analyse des Images) (Berger et al. 1991) on the PPM catalogue, and thus will represent the **level 1** calibration. For **level 2** ALADIN will provide the ability to choose a new set of astrometric standards and then to redetermine the plate constants. These new standards may either come from the user himself, or be taken from the CDS archives which will be continually updated with new, large catalogues of standards as they become available. Star positions will be defined as the centre of the best fitting two-dimensional gaussian, while galaxy positions will be given as the object's density weighted barycentre. ALADIN will also supply the actual plate coordinates as these are needed for high precision studies of relative proper motions (Bienaymé & Soubiran 1992).

3. Photometry

The photometry breaks down naturally into two categories: stellar photometry and surface photometry. For the stellar photometry, ALADIN will employ a relation between the angular size of a star and its magnitude. Humphreys et al. (1991) have shown that the form of this relation remains constant from plate to plate, at least for the POSS-I, demonstrating only variations in absolute normalization (zero point variations). For a stellar calibration, one thus requires only a few photometric standards per plate in order to find the zero point. For **level 1** ALADIN will supply this relation, normalized by the Guide Star Photometric Catalog (GSPC) of standards. According to Humphreys et al. this should yield an accuracy of ~ 0.2 magnitudes. However, as their photometric standards and those of the GSPC were chosen to lie near survey plate centres, this estimated accuracy only applies to these regions. The effects of variable plate sensitivity and vignetting will probably increase the photometric error to ~ 0.5 magnitudes over a whole plate. A **level 2** calibration/tool will permit the recalibration of the relation with new standards. This is particularly important for a user who requires a high photometric accuracy, but who is not working near a plate centre. In this case, his calibration will maximise the photometric accuracy in the region of interest.

Surface photometry proves more difficult. In this case one needs the calibrated relation between plate optical density and actual intensity. Once again, the form of the relation appears to be universal (Liu et al. 1992), but the *surface brightness* standards necessary to normalize the relation do not exist for every Schmidt plate. Generally, one uses calibration spots or wedges, when they exist, and in some cases one may have access to CCD images of galaxies. However, to systematically calibrate ALADIN's surface photometry tool, we will attempt to 'create' our own standards by using the GSPC stars and the known PSF of the relevant optical system. This will form the basis of the **level 1** calibration, which should have close to the same accuracy as the stellar calibration, i.e. ~ 0.5 magnitudes over a plate. The **level 2** will once again permit the user to use his own surface brightness standards (CCD frames) to recalibrate the relation. For this, ALADIN will provide a tool to match-up the CCD pixels with those of the plate.

4. Object Detection and Classification

The advantage of ALADIN over a preselected catalogue of objects is the capability to redefine the selection criteria and re-extract a new catalogue from the original image. To this end, the client will provide some detection and classification (star/galaxy separation) routines. The first version of the ALADIN client will be equipped with a standard detection routine which searches for N connected pixels each with an optical density above $t\sigma_{sky}$. At **level 1** the number of pixels N and the threshold t will be preset, while at **level 2** these parameters will be adjustable. We are currently studying the performance of more sophisticated detection routines, drawing on expertise from the field of image analysis, and which in the future we hope to integrate into the ALADIN client.

There are two general approaches to separate stars from galaxies: parametric and non-parametric algorithms. A parametric algorithm describes each object by a set of shape parameters, such as the areas above a set of density thresholds, and then defines a galaxy as an object for which these parameters are sufficiently different from those of a stellar image, whose shape is solely a function of the PSF. This is usually accomplished by defining a 'distance' ψ from the stellar locus in the parameter space. The completeness and stellar contamination level of the resulting galaxy catalogue is then determined by choosing a 'cut' ψ_c. This is the approach we will initially adopt for ALADIN, where **level 1** will have a preset ψ_c and **level 2** will leave this to the choice of the user. For their eventual inclusion into ALADIN, we will evaluate other classification schemes, for example the aforementioned non-parametric approaches which compare each object to a set of image templates created with a library of identified sources (Weir & Picard 1992). Another possibility is to use neural networks to decide the nature of an object, either based on a set of image parameters (Odewahn et al. 1992) or on the entirety of the object's pixels. Here again we are also studying a variety of techniques coming from fields not traditionally aligned with astronomy.

The final product of this tool will be a list of classified objects together with their positions and magnitudes. The catalogue may be extracted over a full plate or plate subregion. This will permit ALADIN to fulfil its rôle as a new form of 'adaptive' astronomical catalogue.

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