Object Identification and Classification

Cataloging of the Northern Sky from the POSS-II using a Next-Generation Software Technology

Digitization of the Second Palomar Observatory Sky Survey (POSS-II) is now in progress at STScI. The resulting data set, the Palomar-STScI Digital Sky Survey (DPOSS), will consist of about 3 TB of pixel data, or about 1 GB per plate (1 arcsec pixels, 2 bytes per pixel, 23040 x 20340 pixels/plate, approx. 900 survey fields in 3 colors). In order to extract useful information from this set of images, we have developed a software system to catalog, calibrate, classify, maintain and analyze the scans. This system, called SKICAT, incorporates the latest in machine learning and expert systems software technology, in order to classify the detected objects objectively and uniformly, and facilitate handling of the enormous (by the present-day astronomical standards) data sets resulting from DPOSS. We are also conducting an intensive program of CCD calibrations using Palomar 60-inch telescope; these CCD images are used both for magnitude zero-point calibrations, and as training and test data for star-galaxy object classifiers. The resulting Palomar Northern Sky Catalog (PNSC) is expected to contain about 50 million galaxies, and over 500 million stars, in 3 colors (JFN ~ BRI ~ gri), down to the limiting B magnitude of ~ 22, with the star-galaxy classification accurate to 90 - 95% down to the B magnitude of ~ 21. The catalog will be continuously upgraded as more calibration data become available. It will be made available to the community via computer networks and/or suitable media, probably in instalments, as soon as scientific validation and quality checks are completed. Analysis software (parts of SKICAT) will also be freely available. The first, partial releases may be available within a year or two from now, depending on the funding support. A vast variety of scientific projects will be possible with this data base, including the studies of large-scale structure, Galactic structure, automatic identifications of sources from other wavelengths (radio through x-ray), generation of objective catalogs of clusters and groups of galaxies, searches for quasars, variable or extreme-color objects, etc.

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Star Images Identification and Characterization in Astrographic Plates

We present our results on the automatic process of detection and measurement of objects in astrographic plates measured by overlapping of adjacent fields.

It includes several steps:

- The identification of objects in each field.
- The storage of coordinates, magnitude, size and shape parameters in a file.
- The global analysis of the plate, getting final positions and other parameters.

This process will be applied to different kinds of plates:

- Asteroid plates with single or overlapped exposures.
- Field plates with high star density.

The main purposes of our process are:

- The automatic measurement of star and/or asteroid plates.
- The identification of special objects (faint asteroids, comets, galaxies, supernovae) in astrographic plates.

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Image Inventory by the Wavelet Transform

In order to get the required information from large astronomical images we need a *vision model*. Many kinds of such models are implemented. The classical vision models used on many sets of images failed to bring a complete analysis because they are based on a single scale for the adapted smoothing and for the background mapping. A multiscale analysis permits us to get a background adapted to a given object and to optimize the detection of different size objects. This is the reason why we were interested in the use of the Wavelet Transform. It is a linear transformation covariant under translations and dilations. Our vision model is based on the splitting of the image into scale space allowing us to detect objects of different sizes.

For the discrete wavelet transform we choose an isotropic wavelet and the à trous algorithm which provides a redundant transform. The wavelet images correspond to the difference of the images at two successive B-spline approximations.

An object is defined in the *3D* wavelet space. In a first step, we perform an image segmentation scale/scale in this space. Secondly, we link the labelled fields from a scale to the following one. That leads to the construction of a tree of neighbourhoods, from the largest scale to the smallest one. After this operation we can say if a large scale field contains smaller ones which contains smaller ones, and so on. The image is a set of connected trees, corresponding to different objects. We define an object as a subtree resulting from the image segmentation in the wavelet space.

A reconstruction algorithm based only on the wavelet coefficients corresponding to a given object provides its image. Then it is easy to compute from each of them any kind of parameters: mean position, total intensity, pattern parameters, etc. Now, our experiments show us that the quality of the detection is very nice in this procedure and that photometric quantities are available.

This vision model may be improved using the stellar profile. In the wavelet space, we can recognize the wavelet images connected to star-like objects. The procedure is more complicated and we used it only for the image restoration.

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Analysis of the Palomar-STScI Digital Sky Survey: an Overview of the SKICAT System

In this paper we present a general overview of the Sky Image Cataloging and Analysis Tool (SKICAT), a suite of programs designed to facilitate the maintenance and analysis of astronomical surveys comprised of multiple, overlapping images. More generally, SKICAT provides a powerful, integrated environment for the manipulation and scientific investigation of catalogs from virtually any source. The system serves three principal functions: image catalog construction, catalog management, and catalog analysis. Through use of the Faint Object Classification and Analysis System (FOCAS) and the GID3* decision tree induction software, SKICAT automates the process of cataloging and classifying objects within CCD and digitized plate images. To exploit these catalogs, the system also provides tools to merge them into a large, complex database which may be easily queried and modified when new data, or better methods of calibrating or classifying the old, become available. The most innovative feature of SKICAT is the facility it provides to experiment with and apply the latest in machine learning technology to the tasks of catalog construction and analysis. The very same classification learning software used to create the classifiers in SKICAT's automated image cataloging tools are available for use on any SKICAT data set, or even data from external sources. SKICAT provides a unique environment for implementing these tools for any number of future scientific purposes.

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From Radio to Gamma-Ray Sources: Accurate MAMA Identification and Measurement of Optical Counterparts

Besides programmes for which special purpose or survey plates are the basic origin of observational data, the fast and accurate MAMA microdensitometer is used in a variety of studies conducted at wavelengths ranging from radio to gamma rays. Such contributions provide identification of optical counterparts as well as astrometric/photometric calibrations.

One typical situation requiring accurate positions, is the preparation of new observations with instruments which have to be positioned on the sky within a (small) fraction of second of arc, for instance a multi fibre optics spectrograph mounted at the focus of a large telescope for redshift determination. It should be noted that the need for more and more accurate coordinates is no longer specific to the optical domain: radio aperture synthesis (VLA, VLBA...) is working at levels below one tenth of a second of arc; the coming HIPPARCOS and TYCHO catalogues will allow MAMA (accurate to 0.6 micron), to reach this quality on Schmidt plates.

Original positions around which optical counterparts have to be detected and calibrated by MAMA, are coming from observations taken at infrared wavelengths (IRAS sources), in the millimetre range (VLA mapping), or in the high energy part of the spectrum (X or gamma-ray sources). This last domain was open by the advent of space astronomy and is rapidly developing.

From EINSTEIN and GINGA to ROSAT, from PROGNOZ 9, INTERNATIONAL COMETARY EXPLORER, SOLAR MAXIMUM MISSION, VENERA 13..., to CGRO and the INTERPLANETARY NETWORK (PHEBUS, BATSE/CGRO, ULYSSES, MARS OBSERVER), the error boxes are continuously decreasing. However, the combination of Schmidt plates (taken with the appropriate emulsions and filters), an accurate measuring machine like MAMA, and a high quality astrometric catalogue (PPM), remains indispensable to the study of objects as various as pre-main sequence objects embedded in molecular clouds, variable X-ray emitters in the LMC or other galaxies, or gamma-ray bursters of still mysterious origin.

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Image Simulation for Schmidt Plate Astrometry

In this poster we present the principles of a new method of producing realistic synthetic star images of typical digitized Schmidt plates. It is shown that the method can successfully simulate very bright (and highly saturated) stars as well as stars close to the plate limit.

The simulation can be used to test a wide variety of image processing methods, like image finders and classification algorithms. In particular, we present results on the performances of different astrometric centroiders with emphasis on the capabilities of non-parametric techniques.

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Classification: Astronomical and Mathematical Overview

We begin with a short description of modern statistical graphics environments. We will then proceed to a discussion of (1) feature selection, and (2) discrimination methods. The latter are also referred to as supervised classification methods. We will consider linear and non-linear methods, and contrast model-based to non-parametric methods. Such methods are highly dependent on the features used to characterize the objects under investigation. We will describe a number of experiments to assess features based on measures of texture. Object texture, we find, can be a useful complement to other object features. We conclude with a look towards other features and other discrimination methods, which show potential for the type of problem posed by object classification using digitized images.

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Faint Object Classification using Artificial Neural Networks

We propose a method to classify faint objects from digital astronomical images based on a layered feedforward neural network which has been trained by the backpropagation procedure (Werbos 1974).

The classifier proposed in this work (Artificial Neural Network Classifier, NNC hereafter) is briefly described in Serra-Ricart et al. (1991), and follows the general concepts of optimal classification described by Sebok (1979) using the fact that neural network techniques behave as a Bayesian decision rule (Garrido & Gaitan 1991). A comparison of the classification results obtained from simulated data by the NNC and by the well-established resolution classifier (Valdes 1982) is performed in order to assess the reliability and limitations of the NNC. A similar behaviour, up to the same faintness limit to which the resolution classifier works, is found in both classifiers.

The NNC has several practical advantages over well-established astronomical classifiers. The NNC allows uniform and objective classification of large amounts of astronomical data in short computing times. The NNC is trained according to a subset classified by a human expert and then it can classify the full data set; if more than one investigation contributes to the initial classification, the NNC learns each decision rule, and produces a final uniform classification. The NNC algorithms are based on the dot-product calculation, so software implementations in conventional computers are very fast. On the other hand neural network architecture is intrinsically parallel, and therefore computer performance can be increased considerably using vectorial/parallel computers. Neuro-chips implementations could strengthen even more the potential of the NNC.

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An Extended Scheme of Spectral Classification for Objective Prism Spectra

An extended set of criteria has been developed in order to exploit the information contained in objective prism spectra taken with the UK Schmidt telescope. The medium dispersion spectra (830 A/mm at H_γ) which detect stars as faint as V≈16.5 mag can be classified with an accuracy of about 2 spectral subtypes and for the brighter stars the luminosity class can also be specified. Under this scheme an automatic technique is under implementation at the Observatory of Trieste in order to provide spectral types of stars in extended regions of the Magellanic Clouds and make use of the existing surveys of the southern skies.

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Automatic Morphological Classification of Galaxies

We propose a simple method of morphological classification of galaxies based on two photometric parameters in a single colour band. One is the central concentration index of the luminosity distribution and the other the mean surface brightness. Both are measured within the isophote of a fixed brightness level and are distance independent. The method is little sensitive either to the image size or to the inclination of galaxies.

We have applied the method to about 800 nearby bright galaxies with a reasonably high success rate to classify galaxies into early and late types. The method is applied to galaxies in a few clusters at different distances. The clusters were observed with the Kiso 105-cm Schmidt telescope with a 2000 x 8144 mosaic CCD camera and, in part, with photographic plates. The performance and limitation of the method is investigated in terms of the magnitude and the image area of galaxies and of the seeing size.

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Slitless Spectroscopy with Photographic or CCD Detectors

We have undertaken a search for ultraviolet-excess and emission line objects using the ESO 1m Schmidt telescope with and without the 4 degree objective prism. A reduction scheme leading to obtaining accurate (160 km/s) recession velocities of the emission-line objects is described. The prism objective plates are digitized with the MAMA microdensitometer of the Observatoire de Paris. The quality of the velocities allows large structure and luminosity function studies without the need for slit spectrography follow-up. Spectrophotometric results are also derived from the plates allowing a classification of the discovered emission-line objects. This work may be easily extended to slitless spectroscopy performed with CCD detectors. The foreseeable advent of large CCD mosaics adaptable to Schmidt telescopes or large-field prime foci of 3 – 4 m class telescopes will open new prospects which are beyond the reach of photographic plate work (such as recession velocities of galaxies with only absorption line).

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Present State of the Work on Automated Spectral Classification by Means of Objective Prism Spectra

An automated spectral classification technique for objective prism spectra has been developed by Malyuto and Schvelidze (*Astroph. Sp. Sci.*, 1989, **155**, 71) and by Malyuto, Pelt and Schvelidze (*Baltic Astronomy*, 1992, **1**, 473).

To improve our classification technique and to extend the spectral type range a recalibration of the spectral criteria has been performed with the use of additional calibration stars. Application of the results to fields near the North Galactic Pole is discussed.

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