Pattern matching applied to automatic astronomical data reduction

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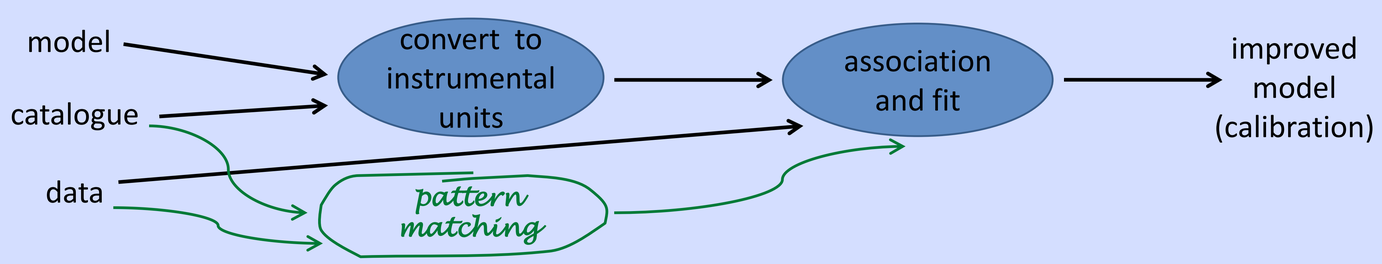
Robustness and flexibility are key requirements for an automatic data-reduction pipeline. Robustness is the capability to manage unexpected situations due to hardware failures, supplying precise information about what went wrong, and granting in this way a thorough and safe monitoring of the instrument health. Flexibility, on the other hand, is obtained by the utilisation of algorithms, which are general enough to withstand any hardware upgrade, ideally leading to instrument independent data reduction systems. Pattern-matching techniques extend the palette of tools available to solve calibration problems, including instrument modelling and correlation methods, and are especially useful in the critical context of automatic data reduction.

Using reference objects for calibration

Stars	• Astrometry • Photometry
Spectral lines	• Wavelength
Spectral edges	• Spatial curvature
Slit positions	• Mask-to-CCD transformation

Instrument calibration is based on the observation of reference objects with known physical characteristics. The comparison of instrumental physical quantities enables the definition of a calibration model.

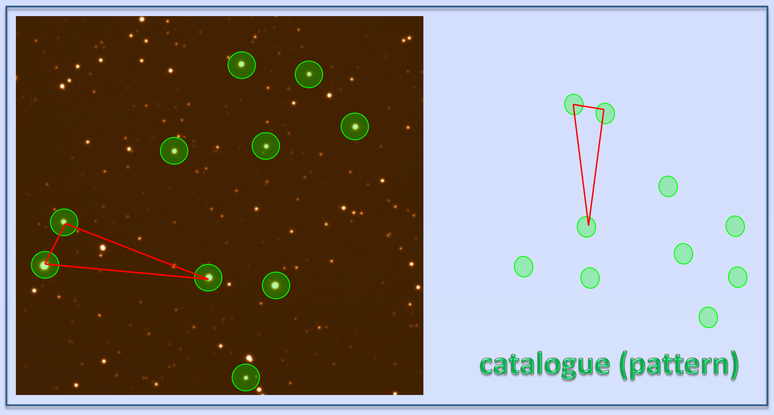
Instrument calibration



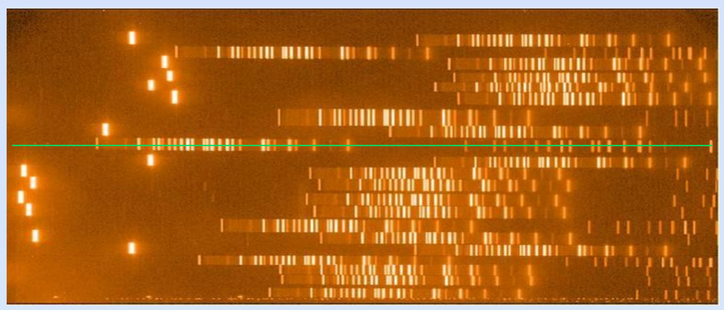
Correct identification of the observed reference objects is critical to the calibration process. Traditionally, a first-guess instrument model is applied to transform the reference physical quantities into instrumental ones; the observed objects are then identified by their close-to-expectations response. This requires a good preliminary knowledge of the instrument, and it assumes that the instrument behaviour is stable. As an alternative, reference objects may be identified by pattern matching between data and catalogue, emancipating the reference object identification from the instrument model. This strategy is in use in the ESO FORS pipeline*, and is going to be extended to other instrument pipelines (WFI, X-Shooter).

Identifying catalogue stars

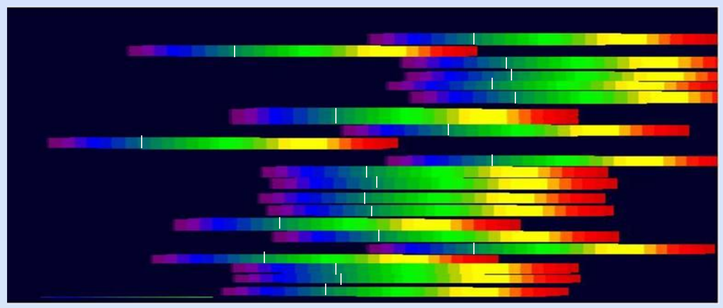
Point pattern matching is commonly used for the identification of observed stars. Typically hundreds of stars are detected, but only the brightest ones will be used for calibration purposes. A reference star catalogue supplies the pattern to be searched and matched: from a rough knowledge of the pointing position of the telescope and of the size of the field of view, a subset of stars can be selected from the catalogue. Their celestial coordinates are converted into the gnomonic coordinate system centred on the telescope pointing, no matter what the orientation and the scale of the field of view are. Matches are obtained by identifying similar triangles present both on the pattern and on the data point distributions (see Ref. 1).



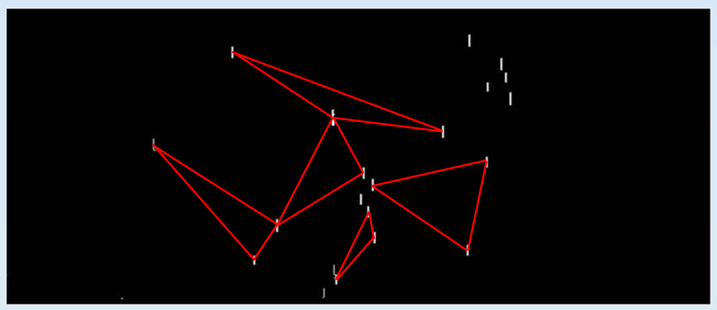
Determining the extraction mask on Multi-Object Spectroscopy Observations



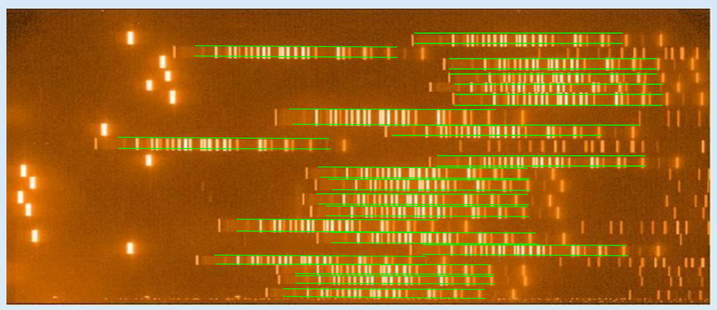
1. identifying peaks: a reference arc lamp exposure is scanned along the dispersion direction. The detected peaks are identified by matching the pattern supplied by a reference line catalogue, enabling the determination of a preliminary wavelength calibration.



2. finding and tracing spectra: the single spectra are found thanks to discontinuities in the preliminary wavelength solution. Any region containing an arbitrary wavelength can be used as a starting point for tracing the spatial curvature on an associated flat field exposure.



3. identifying slits: the positions of the regions containing the arbitrary reference wavelength can also be matched to the known positions of the slits on the telescope focal plane (by applying the similar matching triangles as described above).



4. final extraction mask: the knowledge gathered in the previous steps is used to derive a global description of the instrument optical distortions, enabling the determination of an accurate spectral extraction mask: the calibration phase is completed.

Advantages

- able to cope with unexpected position and/or number of spectra
- instrument independency
- robust object identification
- applicable to any kind of data
- low maintenance cost

Disadvantages

- inapplicable if very few reference objects are available
- difficult to determine the reason of a failure

Ref. 1: G. S. Cox et al. (1991) "*A New Method of Rotation, Scale and Translation Invariant Point Pattern Matching Applied To the Target Acquisition and Guiding of an Automatic Telescope*".

* http://www.eso.org/pipelines