Astronomical Data Analysis Software and Systems XIII
ASP Conference Series, Vol. 314, 2004
F. Ochsenbein, M. Allen, and D. Egret, eds.

Representations of distortions in FITS world coordinate systems

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Abstract. Of particular interest to the fields of astrometry and spectroscopy, the fourth in a series of papers defining conventions for encoding world coordinate information in FITS headers will consider the problem of representing small systematic errors, or distortions. Here we present a preview of work in progress.

1. Introduction

Standard methods for specifying world coordinate systems (WCS) in FITS images (Hanisch et al. 2001) have been developed by Greisen & Calabretta (2002) and applied by Calabretta & Greisen (2002) to the problem of celestial coordinates (Papers I & II). The extension to spectral coordinate systems (Greisen et al. 2003, Paper III) is also at an advanced stage.

However, these methods implicitly assume ideal astronomical instrumentation and are not easily adapted to describe the complex distortions found in some imaging devices. Examples abound, from classical "plate solutions", to spectrometer wavelength calibration. It may also happen that the distortion is "inherent" to the object of study, for example the oblateness of the Sun and Earth. Irregularity of form is carried to an extreme by various minor bodies of the Solar System.

Work in progress, summarised here, extends the current FITS WCS formalism by providing methods to describe the distortions inherent in the image coordinate systems of real astronomical data. It is envisaged that a range of distortion functions will be provided, including N-dimensional polynomial, cubic

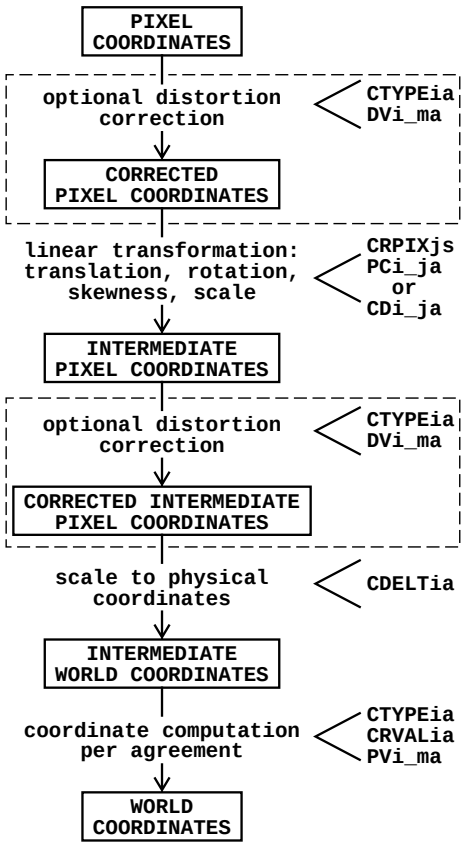

Figure 1. Conversion of pixel coordinates to world coordinates showing optional distortion corrections enclosed in the dashed boxes.

spline, B-spline, and table lookup methods; that these will be applicable over multiple image dimensions; and that they may be applied either before or after the standard linear transformation stage of the coordinate calculation.

An early draft of Paper IV is available[1] for comment. We invite input from the general FITS user community regarding the adequacy of the proposed methods for existing or future applications.

2. Methodology

The new steps to be introduced into the algorithm chain are enclosed in dashed boxes in Figure 1. Key features are:

* For each axis a distortion function may be applied to either the pixel coordinates or intermediate world coordinates (but not both).
* The distortion function is defined in the pixel-to-world direction. Polynomial, cubic spline, B-spline, and table lookup functions will be provided.

[1] `http://www.atnf.csiro.au/people/mcalabre/`

* The `CTYPE`*ia* header cards will indicate that a distortion function is to be applied, its type, and whether before or after the linear transformation.
* New `DV`*i_ma* header cards perform several functions:
  - Define which coordinate axes form the independent variables of the distortion function (axis coupling).
  - Provide an offset and scale for renormalization of the independent variables of the distortion function.
  - Encode the parameters required for the distortion function.
* `DVERR`*ja* will record the maximum error of the distortion correction on axis *j*, and `DVERR`*a* will record the maximum error of the combined distortion functions for all axes.
* Methods will be provided to define different distortion functions for different regions of the image, e.g. as may be required for arrays of CCD detectors.

Of course, the exact details are subject to change in response to feedback from the FITS user community.

Acknowledgments. The Australia Telescope is funded by the Commonwealth of Australia for operation as a National Facility managed by CSIRO.

The National Optical Astronomy Observatory is a facility of the (U.S.) National Science Foundation operated under cooperative agreement by Associated Universities for Research in Astronomy, Inc.

The National Radio Astronomy Observatory is a facility of the (U.S.) National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

UCO/Lick Observatory is operated by the University of California.

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