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SOFTWARE TOOLS FOR DIGITIZATION OF ASTRONOMICAL PHOTOGRAPHIC PLATES*

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Abstract. In this paper we present tools for helping the process of digitization of astronomical photographic plates. The requirements of Virtual Observatory presume that any FITS file, which contains a digital image, has to be equipped with a complete header. Wide-Field Plate Database (WFPDB) offers most of the meta-data needed for the creation of FITS header. The `header2011` software gives the user an appropriate tool for connecting WFPDB catalogues to digitized plate images. The use of modern scanners sometimes imposes conversion of files from the inner format of the scanner (or driver) into FITS format. The `tif2fits` software converts VueScan row-tiff format to FITS and also separates plate image and wedge image in case of scanning with grayscale wedge.

1. Introduction. The Wide-Field Plate Database (WFPDB) is the basic source of data for the wide-field (larger than or equal to 1 square degree) astronomical photographic plates obtained with professional telescopes world-wide

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(see [1], [9]). It consists of four parts: Catalogue of Wide-Field Plate Archives (CWFPAs); Catalogue of Wide-Field Plate Indexes (CWFPIs) with regular version updates (now for 563 600 plates); Data Bank of digitized plate images (at low resolution for quick plate visualization and easy on-line access, and at high resolution intended for photometric and astrometric measurements); Links to online services and cross-correlation with other existing catalogues and journals (see [9], [4]).

Flexible Image Transport System or FITS is a digital file format used to store, transmit, and manipulate scientific and other images (see [5]). A major feature of the FITS format is that image meta-data is stored in a human-readable ASCII header. Each FITS file consists of a header containing ASCII card images (80 character fixed-length strings) that carry keyword/value pairs and an image data block. The creation of a complete FITS header is an important part of the plates digitization. Because photographic plates are a specific type of astronomical observations, we attempt to make a standard of the keywords in the FITS header, specially for astronomical photographic plates. The corresponding software implementation for this standard has also been created. It is written in C++ using the Qt cross platform application [6]. The WFPDB catalogues are used for obtaining the most important meta-data for the plates at the generation of the FITS header.

2. FITS Header Standard for Photographic Plates. Our proposal for a FITS header standard for photographic plate images is based on the AIP archive of historic Carte du Ciel scans [3] and our experience with meta-data from various plate archives. The FITS header must contain the complete meta-data for the plate, the telescope, the place of the observation, the scanning process, etc. The main part of these data can be extracted from the corresponding WFPDB catalogues. This approach presumes that the collection of plates for digitization (plate archive) is already described in WFPDB. The second part of the data consists of constant values, and the third part can be calculated using the other parts. Tables 1 and 2 present our proposal for a standardization and also the sources of the data in the header fields.

The abbreviations in the first column of the tables define how the value in the corresponding line is filled.

- `fixed`: the value is fixed in the case of plates;

Table 1. FITS header standard for photographic plates. Part I

fixed	SIMPLE	T	file does conform to FITS standard [T/F]
fixed	BITPIX	16	number of bits per data pixel [16]
fixed	NAXIS	2	number of data axes [2]
tif2fits	NAXIS1	15024	length of data axis 1 [int]
tif2fits	NAXIS2	15024	length of data axis 2 [int]
fixed	EXTEND	T	FITS dataset may contain extensions [T/F]
fixed	BZERO	65536	[65536]
fixed	BSCALE	1	[1]
fixed	INVERTED	T	T — big-endian & F — little-endian
tif2fits	DATE	'2011-07-01 11:36:42'	last change of file [yyyy-MM-dd hh:mm:ss]
calc	FILENAME	'BAM010C001397.fits'	source file name
calc	PLATENUM	'1397 '	in the original observation catalogue
calc	PLATE-ID	'BAM010C001397 '	WFPDB identifier of plate
md	FIELD	'-90 DEG '	field name
man	OBJECT		star name
md	RA	'00:00:56 '	center of plate FK5 [hh:mm:ss]
md	DEC	'-89:47:52 '	center of plate FK5 [sgg:mm:ss]
fixed	EQUINOX	2000.0	definition of equatorial coordinates
calc/md	RAEPOBS	'01:00:00 '	center of plate at epoch of observation
calc/md	DECEPOBS	'-90:00:00 '	center of plate at epoch of observation
calc/md	EPOCH	1963.72328767	epoch of plate [years]
md	DATE-OBS	'1963-09-22 '	date of observation [yyyy-MM-dd]
md	TIME-OBS	'22:19:00 '	UT at start of observation [hh:mm:ss]
md	EXPTIME	60.0	exposure time [minutes]
calc	TIME-END	'23:19:00 '	UT at end of observation [hh:mm:ss]
calc	UT	'1963-09-22 22:49:00'	date and UT at mean epoch
calc	JD	2438295.45069400	JD at mean epoch
calc/not	ST	'00:08:50 '	ST at the start of the observation [hh:mm:ss]
md	MULTIEXP	1	number of exposures of the plate [int]
man	DETNAM	'Photographic Plate'	
md	EMULSION	'GEVAERT '	photoemulsion type
md	FILTER	'NO '	filter type

Table 2. FITS header standard for photographic plates. Part II

md	COLOR	'Pg '	
md	PRIZMANG	'NO '	prism angle [YES/NO]
man	INSTRUME	' '	
man	DISPERS		dispersion [A/mm]
man	WEDGE	' '	type of photometric step-wedge
qual	PQUALITY	'1 '	quality of plate
calc/md	PLATESZ	'16 × 16'	plate size [cm]×[cm]
calc	CUNIT1	15.05	X field size [deg]
calc	CUNIT2	15.05	Y field size [deg]
obser	OBSERVER	'KNIGGE '	observer name
cat	OBSERVAT	'Dr. Remeis Obs.'	observatory name
cat	SITELONG	'+26:24:18.0 '	longitude of the observatory [sgg:mm:ss]
cat	SITELAT	'-29:02:18.0 '	latitude of the observatory [sgg:mm:ss]
cat	SITEALTI	1387	altitude of the observatory [m]
cat	TELESCOP	'ASTROGRAPH'	telescope name
cat	TELAPER	0.1	clear aperture [m]
cat	TELFOC	0.61	focal length [m]
calc	TELSCALE	338.57	telescope scale [arcsec/mm]
man	SCANNER	'EPSON V750'	scanner name
man	SCANRES	2400	scan resolution
calc	XPIXELSZ	10.5833	X pixel size [microns]
calc	YPIXELSZ	10.5833	Y pixel size [microns]
fixed	SCANHCUT	255	scan Hcut
fixed	SCANLCUT	0	scan Lcut
fixed	SCANGAM	1.0	scan gamma value [1.0]
fixed	SCANFOC	0.0	scan focus
tif2fits	DATE-SCN	'2011-04-26 12:42:40'	scan date and time [yyyy-MM-dd hh:mm:ss]
man	AUTHOR	'M. Tsvetkov '	author of scan
man	ORIGIN	' '	
man	REFERENC	' '	reference
man	URL	'www.wfpdb.org '	base URL of VO Service to retrieve data
man	COMMENT		
fixed	END		

- `md`: the value is copied from the `maindata` file of CWFPIs
- `not`: the value is copied from the `notes` file of CWFPIs
- `obser`: the value is copied from the `observers` file of CWFPIs
- `cat`: the value is copied from the CWFPAs file
- `calc`: the value is obtained by calculation using other values
- `man`: this value must be inserted manually
- `tif2fits`: the correct value is replaced here at the second step by `tif2fits` program

The second column contains the keywords; the third column – the values and some comments are placed in the last column. The values are only model ones but they show the type and format of the datum — integer or floating point number, coordinate, date and time; text or numeric field, etc.

3. A Software Tool for FITS Header Formation.

Simutaneously with the scanning of plates, we have to create meta-data for FITS files (FITS header). The user interface (Fig. 1) of the program `header2011` offers a choice of file name for CWFPIs and identifier of a plate in this catalogue. The user can traverse the list of plate names using the keys `Next` and `Prev`. In some cases it is appropriate to sort the catalogue with respect to plate identifiers. Some value fields of the header are colored to indicate:

- fixed values for all plates (green)
- values, which depend on other fields' values and are updated immediately when the user changes those values (light blue)
- values, which are not up-to-date at the time of using this tool (in dark blue).

A plain text file is used to save the FITS header generated by this program.

4. A Software Tool for Producing FITS Files. This software is designed for converting row-tiff files, produced by VueScan [8], to FITS format

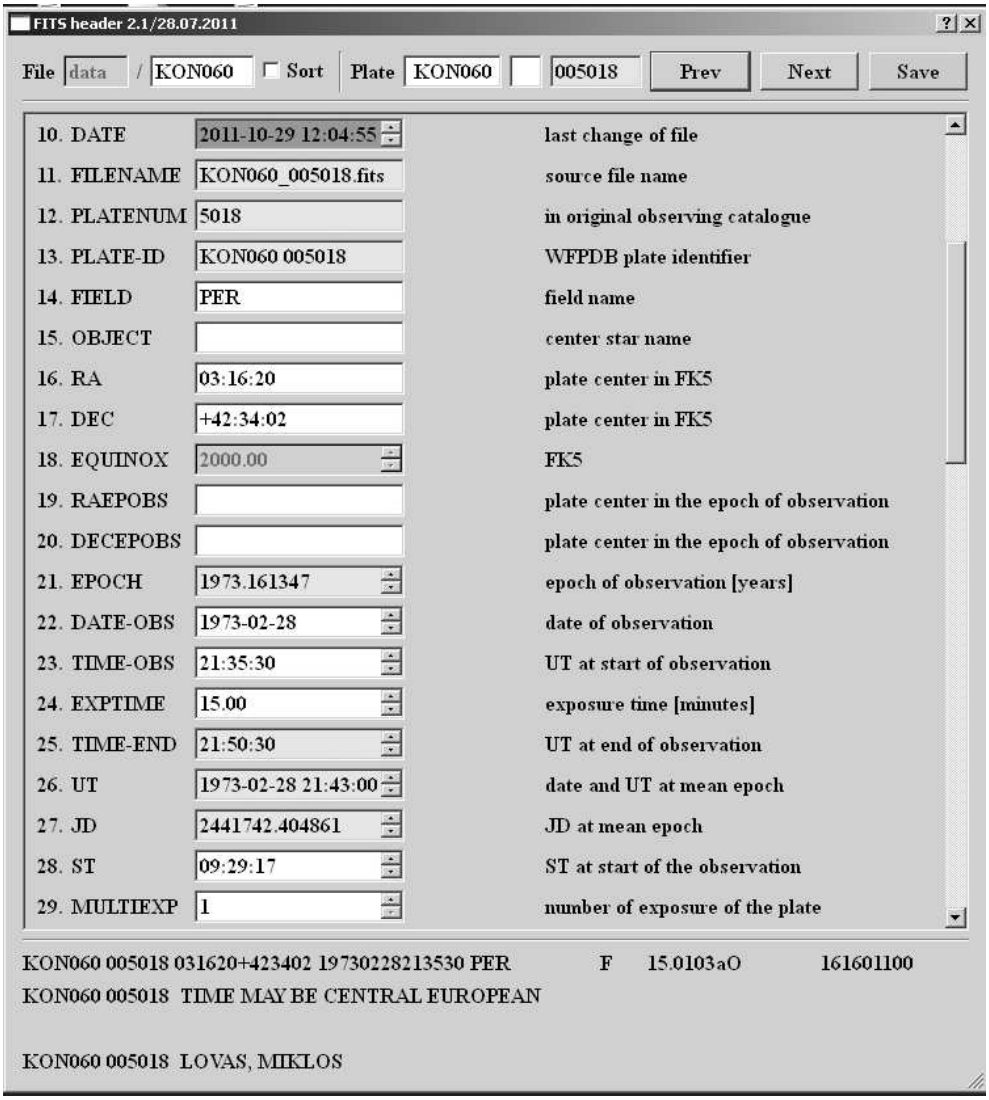

Fig. 1. The user interface of `header2011` software tool

files which satisfiy the VO requirements [7]. The input data for a plate consist of an image file and a header file. In the conversion process the values in fields `DATE-SCN` (the scan date and time) and `DATE` (last change of file) are updated to restore the scanning date and to fix the file creating date and time. The image size is changed as well — the fields `NAXIS1` and `NAXIS2`. All other header fields

are copied from the input header file. In the case of scanning with a wedge, the program separates the wedge part of the image and produces two FITS files — one for the plate and one for the wedge.

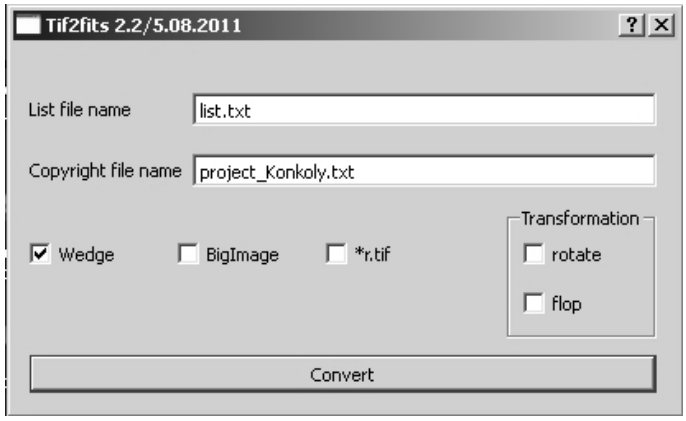

Fig. 2. The user interface of the `tif2fits` software tool

The user interface offers a small window for choosing a list file and a copyright file. The list file must be a plain text file with the list of plate identifiers (in WFPDB format), which the `tif2fits` program will convert. The text of the copyright file is included in the FITS header in the form of a comment.

5. Our Experience. As a result of the complete digitization of an astronomical photographic plate, at least six files are produced. Table 3 gives an example of the file names and file attributes of a digitized plate with WFPDB identifier `KON060 005018`.

We use the tools for several types of plates (Table 4). The archive names in the first column of the table are given from the CWFPAs.

6. Conclusions. The presented software is a part of a technology (full pipe-line) for digitization of astronomical photographic plates. It speeds up the processing time and decreases the possibility of errors in FITS header. Separating image with grayscale step wedge is a new feature in such software. Nevertheless it needs to be improved in several directions:

- to bring the FITS header in line with the requirements of the new FITS standard 3.0 (see [2], [5]);

Table 3. Files produced by the system as a result of the digitization of a plate

File name	Size	Type	Produced by	Comment
`KON060_005018.jpg`	1.4M	color image	–	preview
`KON060_005018.tif`	477M	16bit grayscale	VueScan	scan
`KON060_005018.hdr`	6K	text	header2011	header
`KON060_005018.fits`	440M	16bit grayscale	tif2fits	plate
`KON060_005018.hdrf`	7K	text	tif2fits	header
`KON060_005018w.fits`	38M	16bit grayscale	tif2fits	wedge

Table 4. Some parameters of digitized plates from different archives

Telescope (archive)	Scale (arcsec/mm)	Plate size (cm×cm)	Resolution (dpi)	File size (MB)
POT015	138	20×20	2400	681
POT080	17	16×16	1600	193
BAM010C	338	16×16	2400	440
BON030	138	16×16	2400	440
HAR025C	167	20×25	1600	430
ROZ050	120	16×16	2400	440
ROZ200	13	16×16	2400	440
KON060	144	16×16	2400	440

- to include validation rules for some fields in the header software, especially for coordinates, numerical values, etc.
- to implement the algorithm for calculating the coefficients for converting local plate coordinates to the World Coordinate System.

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