SOFTWARE FOR PROCESSING OF DIGITIZED ASTRONEGATIVES FROM ARCHIVES AND DATABASES OF VIRTUAL OBSERVATORY

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ABSTRACT. The paper discusses and illustrates the steps of basic processing of digitized image of astro negatives. Software for obtaining of a rectangular coordinates and photometric values of objects on photographic plates was created in the environment LINUX / MIDAS / ROMAFOT. The program can automatically process the specified number of files in FITS format with sizes up to 20000 x 20000 pixels. Other programs were made in FORTRAN and PASCAL with the ability to work in an environment of LINUX or WINDOWS. They were used for: identification of stars, separation and exclusion of diffraction satellites and double and triple exposures, elimination of image defects, reduction to the equatorial coordinates and magnitudes of a reference catalogs.

Key words: astrometry – methods: data analysis – virtual observatory tools – catalogs

1. Introduction

General algorithm of data processing was developed in 2010-2012 for photographic plates from the archives of Nikolaev Astronomical Observatory (Protsyuk, 2014). In the next years, the algorithm was almost not changed, capabilities of individual programs were just extended, automation of repetitive functions was added. The main processing steps are: initial data processing in MIDAS package, identification of stars, astrometric reduction of plate data, final data processing.

2. Initial data processing

Usually we scan 5-6 times every plate using 16 bit FITS format by *Scanfits* program (Barbieri, 2003). Scanning was made placing the negative with emulsion side down and choosing a linear gamma curve in the scanner settings. File name has the form of XXXX_N.fit or XXXX-N.fit, where XXXX – plate number and N – ordinal number of the scan. In principle, one can scan by standard scanner software using 16-bit gray TIFF format and with subsequent conversion to 16 bit FITS format by using the *ImageMagic* package (www.imagemagick.org). Scanned FIT files are copied to the folder on the computer with the Linux operating system and installed *MIDAS* package

(www.eso.org/sci/software/esomidas). This can be either a local computer or a virtual server or a remote computer, as on Figure 1. All of these options have been tested and have shown identical results. Option of remote access to the LINUX / MIDAS PC can be used for the collective processing of photographic plates by several observatories, for example within the framework of cooperation on UkrVO (Vavilova, 2010, 2011, 2012a, 2012b).

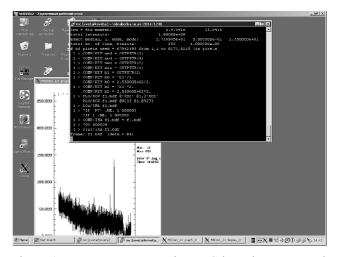


Figure 1: Remote access to Linux PC by using *Putty* and *Xming* programs and processing plate images in MIDAS environment.

In Linux PC we used program *full_pl* for forming sequential file list. The program renames all files in the current folder in names like 3333NNNN.fit, where NNNN file sequence number from 000 to 999. The numbers are based on the size of files, the smaller files are first in order. This is done for further batch processing of heterogeneous FIT files, which may be obtained with different values of dimensions for X and Y during scanning.

After that, we run the MIDAS package and program **00PLATE.PRG**, written in the internal language of package for image processing (Andruk, 2005, 2010, Yatsenko, 2011). The program processes all of the images in batch mode. Depending on the number of source files,

it can take up to several days. As the result of program work, we obtain: filtered FIT files, multiple DAT files with linear coordinates, intensity and other parameters of found objects. The large number of files for each plate (from 10 to 40 depending on the size of the source file) is generated due to limit of 20,000 objects per output file. DAT files contain information about objects on a strip of width of 500-700 pixels with an overlap of 50 pixels. After completing the program *00PLATE*, we again use *full_pl* program to restore the primary file names and copy all DAT files to Windows PC.

3. Stars identification

Using folder with DAT files on Windows PC, we run the program *dat2dir* for gluing strips of each processed plate in one file and for create the structure layout of data on disk. The program generates and executes the script that creates a folder XXXX by number of plate, then creates a sub-folder with the numbers from 1 to 6, in which the glued file *3000001.dat* is formed using the original DAT files (up to 43 strips on the plate).

For each record in the folder 1, we create file *coord.txt* with the initial coordinates of the plate center and the epoch of observation. In case of their absence, these values are entered by operator at the start of the program *plate gr*.

In the folder with the number 1, we run the program plate gr (Protsyuk, 2014), which is designed for identification of stellar images processed in the MIDAS package using the TYCHO2, UCAC4 catalogs (or another one). The program makes analysis of the quality of taking into account the identification, specific characteristics of the photographic observations in NAO, and calculates the coordinates of objects registered on the photographic plate. The program generates the sky image obtained on the plate in the left window and the image of the same area from the catalog in the right window by using the original DAT file and reference catalog. The brightness and size of stars in the windows is adjusted to achieve a visual correspondence between both images. The program may carry out:

-elimination of the image defects, such as spots, scratches, inscriptions,

-identification of stars in the image,

-allocation and exclusion from further processing of stellar images obtained during the second and the third exposures,

-exclusion of diffraction satellites of bright stars for images obtained with a diffraction grating,

-control of identification,

-reduction using models with different equations,

-analysis of the results.

After completion of data processing in folder 1, we use the script *2copy* to transfer data of identification and selection of exposure or diffraction satellites to folders with names from 2 to 6. In these folders, we also execute program *plate_gr*. Since they already have identification with the first folder, the abridged processing is carried out, which includes only cleaning of the image from defects and accurate snap of identified stars from image 1 to the current image. After that we made reduction of the current plate and exit the program.

When we make changes to the program or improve processing algorithms, all previously processed data can

be reprocessed in a batch mode for a time from a few seconds to a few minutes for each frame according to the number of objects on the plate. We historically use the separate program for the final astometric reduction.

4. Astrometric reduction and usage of results

To carry out reduction of all processed plates in batch mode, we create file *lim.txt* in the root folder of all subfolders with plate data. File *lim.txt* includes the input parameters for subsequent use by the program *00plate.exe* (Protsyuk, 2014), which makes final reduction. In root folder, we run the script *run00*, which performs the sequence data processing of all plates sub-folders by program *00plate*.

The obtained data can be used to compile catalog or to determine the coordinates of a selected object in a series of plates. For example, to create a catalog of positions of all stars in plates and to conduct data analysis we used *mid_an* program. To create a catalog of positions and proper motions of the two plates with a large difference of epochs, we used *plate_in_cat* program. Search for a specific object on all plates and determination of its average coordinates as well as the coordinates at the moment of observation, we implemented by programs *findobj* and *midobj*.

Also in the package of programs, we have a program for visualization of the magnitude equation, the systematic errors of the scanner, the functional connection of various parameters, aberrations of telescope optics, residual error of scan processing, etc.

5. Conclusion

We created the package of programs for image processing with the following parameters: images with resolutions from 600 to 2400 dpi, image size up to 20000x20000 pixels and up to 400,000 objects on the plate, field of view up to 20 degrees. PC with 2GB of RAM is enough to work in full mode.

The package has been successfully used for creation of several catalogs (Protsyuk, 2014) and determination of the coordinates of the planets of the Solar system.

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