CCD ASTROMETRY WITH DUEART

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Abstract. *DueArt* (*Digital aUtomated Enhanced Astrometric Reduction Tools*) is a program written in Delphi 3.0 language (32 bit) for *Windows 95/NT* operating system by Paolo Chiavenna and authored and reviewed in cooperation with Augusto Testa.

1. Introduction

Program *DueArt* is based on the experience of the amateur astronomers working at the Observatory of Sormano in the field of astrometry and research of minor planets, an activity performed by using a *ST6* CCD camera. When the blinking process reveals the presence of a moving object, the image undergoes a series of processing steps, having the aim of computing the astrometric coordinates of the suspected minor body. Program *DueArt* is born as an aid for automatizing as much as possible all the steps required by this process, while maintaining the highest accuracy in the final astrometric result. This goal is obtained through a suitable *GUI* (*Graphical User Interface*).

In the following sections I shall briefly describe the basic components of *DueArt* :

- image input and decompression
- image pre-processing
- image blinking
- centroid computation
- astrometric reduction

2. Image input and decompression

The image formats presently supported by the program are :

- *ST6* native (uncompressed) format
- *ST6* compressed format
- *FITS* 16-bit format

However, the functionality of the program is restricted only to image display and blinking when *ST6* formats are used, since we have decided to adopt *FITS* format as the standard way to store images, due to its higher portability and independence on the type of the CCD camera.

3. Image pre-processing

A series of algorithms are implemented in order to optimize the image display :

- an **auto-contrast algorithm** is invoked every time an image is loaded : the program determines the levels of the background and the peak signal intensity and remaps the CCD reading to a suitable scale of display intensities (gray tone display) or colors. However, the user has the possibility of modifying interactively the parameters of the mapping (cutoff and range values) in order to obtain the best result;
- four kinds of **palette** can be selected :
  - gray tones
  - negative gray tones
  - false colors (green to yellow)
  - negative false colors (green to yellow)
- *DueArt* offers a series of filters based on convolution matrices, performing both low-pass and high-pass filtering; these filters are activated only by a specific request of the user.

4. Image blinking

DueArt is capable of blinking simultaneously up to six images. Before blinking, the images are aligned in a very fast way through the use of the mouse and directional buttons. The blink speed can be modified by the user, and the portion of the image pointed by the mouse is also displayed in an enlarged view (zooming factor 2X).

5. Centroid computation

Surely, the implementation of the algorithm for centroid computation was the most difficult and time-consuming part of the project. Our initial goal was to keep the centroid error as low as possible and, in particular, below the threshold of 0.5 arcsec (which is the order of magnitude of the astrometric accuracy of star catalogues like *GSC* and *USNO*).

The centroid calculation is activated interactively by a simple click of the mouse on the desired object. In order to make easier the pointing of the object, the program displays (together with the whole image) an enlarged view (4X) of a small region (21×21 pixels) centered at the current position of the cursor. When the selected object is pointed approximately by the user, a simple click of the mouse activates the algorithm of centroid fitting. The coordinates of the centroid are obtained by isolating from the background the list of pixels which are considered as belonging to the object, subtracting from the corresponding ADU reading the value of the background, and then computing the barycenter. The selection of the list of pixels to be used is performed by analyzing in succession 22 matrices of pixels

centered at the location of the highest ADU value and having different sizes (from 2×2 to 7×7 pixel); the selected combination is the one corresponding to the highest number of object pixels. However, the user is given the possibility of modifying this automatic mechanism, by changing manually the ADU reading associated with any of the pixels, or by excluding some of them from the computation; this possibility is useful in the astrometry of comets or in particular conditions (vicinity of another object, CCD defects and cosmic rays, and so on). The result of the centroid computation is then passed to the astrometric reduction procedure.

6. Astrometric reduction

The astrometric reduction section of *DueArt* is simply a *GUI* invoking program *CCDAR* (*CCD Astrometric Reduction*) written by Mario Carpino. In turn, *CCDAR* makes use of program *SExtractor* by Emanuel Bertin for computing the centroids of all the stars to be used as astrometric references; pixel coordinates of the minor bodies can be also computed with *SExtractor*, or with the centroid algorithm described in the previous section. The interface gives also the user the possibility of displaying, editing, printing, sending by FAX and deleting any of the accessory files used or produced by *CCDAR*.

DueArt is presently at its first distributed version, and will be improved in the next future by the addition of new features and utilities. For instance, one of such improvements will be the capability of handling images of different sizes (still in *FITS* format). As a final remark, I would like to express my personal satisfaction for the fact that the program is the result of a cooperation involving both amateur and professional astronomers.