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The D4A Digitiser

Jean-Pierre De Cuyper

Royal Observatory of Belgium, Ringlaan 3, B-1180 Ukkel, Belgium

Lars Winter

Sternwarte Bergedorf, Gojenbergsweg 112, D-21029 Hamburg, Germany

Joost Vanommeslaeghe

National Geographic Institute, Abdij Ter Kameren 13, B-1000 Brussels, Belgium

Abstract. The aim of the pilot-project "Digital Access to Aero- and Astrophotographic Archives - D4A" is to preserve the historic-scientific information contained in the aerial photographic archives of the National Geographical Institute and the Royal Museum of Central Africa, and in the astrophotographic plate archive of the Royal Observatory of Belgium. In collaboration with the astronomical institutes of the Vrije Universiteit Brussel and the Universiteit Antwerpen, and AGFA-Gevaert, a world-leader in photographic matters, the goal is to acquire the necessary know-how, hardware and software to digitise the information contained in the photographic plates, as well as the associated metadata. The project set out to offer the results to the public and to make them directly usable for scientific research through the modern techniques of the information society. A digital catalogue is under construction as well as an air-bearing digitiser of high geometric and radiometric resolution and precision. This digitiser will be housed in a temperature and humidity stabilised clean room with adjacent archive room.

1. Introduction

Digitising a photographic image can be done:

- 'on the fly' (using a digital detector moving with constant speed in one direction with respect to the photographic plate, i.e. scanning) or
- 'on the step' (using a digital detector at rest with respect to the photographic plate).

The digital detector, a CCD (Charge Coupled Device) or CMOS (Complementary Metal Oxide Semiconductor) based camera can have:

- only one pixel (zero dimensional),
- a row of pixels (one dimensional) or
- an array of pixels (two dimensional).

For most astronomical applications, overlapping digital sub-images can be used. Bright stars in the overlaps are used to tie up the whole image and to transform the measured X and Y positions on the image into celestial α and δ coordinates. Aerial photographs need to be digitised as raster images, requiring an accurate stepping with an exact number of pixel sizes in both the X and Y directions. The digital image can be stored as a tiled file countaining the individual footprints as sub-images. The accuracy of the photographs depends on the type of emulsion used, the type of supporting layer (glass plate or polyester film), the optical quality of the instrument used, the exposure time, etc. Astrophotographic images can have a density range of 5 (i.e. a grey scale or density ranging from 1 to 100,000) and sub-micrometer stellar position accuracy.

2. Commercial Scanners

Commercial colour scanners normally use three one dimensional CCD rows for simultaneously creating on the fly a red, green and blue (RGB) digital image. Each CCD row usually has an adjacent CCD row that is covered up. The electrons created by the infalling light on the exposed CCD rows are, at the end of each integration or exposure, quickly clocked to the adjacent blacked CCD row and read out by clocking them into the ADU (Analogue to Digital Unit) converter at the end of the row. As the detector moves at constant speed in one direction during the integration, a part of the image that is captured by an individual pixel also falls on it during the next integration, while the time the light coming from a point of the original image is projected on a pixel also varies. Hence, the way traditional scanners work means some of the finer details of the image are smeared out over the neighbouring pixels, creating a soft looking digital image. Most commercial scanners also apply an image "sharpening" filtering in order to make edges look sharper. The level of detail in astro and aerial photographic plates requires a very high optical resolution and precision to produce high geometric and radiometric accuracy in the digital copy, and precludes the use of commercial scanners for the digital archiving process.

3. The D4A Digitiser

The D4A project will develop a two-dimensional plate digitiser that will operate on the step in order to create a precise digital optical copy of the original image. A photographic image is made up of an irregular distribution of developed grains of varying sizes whereas a digital image consists of equally spaced and sized square or rectangular pixels. In order to capture the level of accuracy of the analogue photographic images as closely as possible, a digital detector is needed with at least a 10-bit ADU (Analogue-to-Digital converter Unit) read-out and a pixel size of about 5 micrometers (J.-P. De Cuyper et al. 2003). The huge number of exposures requires the use of an electronic shutter. We will mount the digital camera above the plate, perpendicular to its surface, and use an air-bearing open frame XY table to allow us to position the plate with a geometric accuracy of some ten nanometers. A two-sided 1:1 telecentric lens will be used to ensure that, if the original image is not perfectly flat, the introduced error will only slightly enlarge the projected image of a point source, while keeping it isotropic and without displacing it. The part of the footprint of the telecentric objective used will be limited to its central part where the distortion is less than a pre-defined maximum. In this way an 'optical' contact copy of the original image onto the digital detector will be achieved. In order to be able to reach and maintain a high geometric and radiometric accuracy, the digitiser will be placed in a climatised clean room, at a temperature of 18°C ±0.1°C (1σ) and a relative humidity of 50% RH ±1% RH (1σ).

The D4A digitiser will be able to digitise photographic greyscale and colour images and spectra on glass plates and polyester film sheets as well as on film rolls to an extremely high level of precision. (See also the notes on SuperCosmos (N.C. Hambley et al. 1998) and on StarScan (L. Winter and E. Holdenried, 2001)). The photographic plates will be put emulsion side up in a square plate holder with an opening of the same dimensions. Through the use of pneumatic cylinders, the plate holder is pushed up to bring the outer edge of the emulsion in contact with an equally sized counter pressure plate, in order to put the top of the emulsion layer in the focal plane of the digital camera. For thin glass plates (Schmidt plates, etc.) and film sheets or rolls the plate holder contains a supporting glass with a groove on the sides. The thin plate or film is put flat by pumping the air away between the plate/film and the supporting glass plate after lifting the plate/film against the counter pressure plate. For the transmissive illumination a diffuse light source will be used. In order to allow the digitisation of colour images a RGB filter wheel will be placed in the light way. A neutral density filter wheel is used to regulate the light intensity in function of the density level of the photographic image.

In order to automatise the digitisation process in the most stable possible conditions, a film roll transport system mounted on two opposite sides of the inner open airbearing frame will fully automatically spool the film roll to put the next image above the plate holder and next to the granite table a turntable and a plate holder stack is foreseen, operated by two pneumatic arms to exchange plates or film sheets.

4. Climatised Archive Room

Photographic plates consist of a distribution of (silver) grains embedded in a gelatine layer fixed on a glass plate or polyester sheet. As such, they are very sensitive to changes in temperature, relative humidity (RH) and chemicals, and are at great risk of degradation, such as chemical reactions from fingerprints, humidity causing destructive fungi and so on. Most photographic collections were/are stored in conditions that are far from being ideal. In order to improve the lifetime of its astrophotographic plates, the Royal Observatory is constructing a climatised plate archive that will be kept at 18 °C and 50 % RH and that is large enough to become an international plate archive center.

5. Benchmark

The most essential quality parameter of a measuring machine is its stability. Hence the benchmark procedure has to include a very simple test, which measures the stability of the machine: A target (for example a dot) is moved into the center of the field of view (FOV) of the digital camera and a number of pictures are taken, while the XY-table is hold on that position under servo. Analysing the images, in fact centering the dot and measuring its position with respect to the digital detector, will reveal thermal movements, jitter and mechanical noise in the system. In addition we get an estimate of the centering error of the dot. This test is called static repeatability, as the position of the XY-table is not being changed.

The next important test is the dynamic repeatability. The machine is moved in a repeated pattern and a different point of the dot plate is put in the center of the FOV each time the position changes. After the whole plate area has been covered, we start again with the first point. The better the machine can go back to the same position after one pattern has been covered, the better its dynamic repeatability. Important for the pattern is to choose at least two points, that will make a back and forth motion possible, to get a measure for the bi-directional repeatability during this test as well. The proposed minimal pattern will consist of nine points, the center, corners and midpoints between the corners of a square that covers most of the measuring area of the XY-table.

The last and very conclusive test of any XY-table is the measurement of a calibration plate with known accuracy. This would be a measurement of a, geometrical very precise, chrome dots on glass plate. This measurement determines the metric accuracy of the machine as compared to a normal (in this case the geometric dot plate). Another way to do this test is to use a calibration laser. Both results should be compared to give the best understanding of the behaviour of the machine. The systematic errors found can then be corrected by tabulating them into the positioning software of the XY-table.

6. Testing

In order to determine their applicability depending on the introduced geometric and radiometric deformations this project will also study in detail:

- the technique of first making an analogue copy on roll film,allowing unattended all time scanning,
- the photochemical cleaning of plates containing fungi or ageing deteriorations.

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