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Electrostatic Detection Apparatus Enhancement Using Astronomical Image Stacking and Processing Software

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To overcome the practical challenges of imaging very distant, dim, and moving astronomical objects, astronomers have well developed techniques for "tracking and stacking" multiple images of the same object to increase the signal-to-noise ratio of the final image. We have successfully applied the same techniques to multiple electronic detection device (EDD) lifts off the same document to enhance impressions too weak to be read from a single film.

Introduction

Forensic document examiners, having used electrostatic detection device (EDD), frequently develop impressions of handwritings from a document which are tantalisingly—frustratingly—too faint to interpret. Many efforts have been made to optimise the laboratory technique for using the instrument. These fall into 2 broad categories. Firstly, Seward (1999) suggested 9 steps for optimal development including humidification of the specimen, duration of charging, and duration of discharge prior to application of toner; Tanaka (2007) demonstrated the use of charging probes to control the extent of charging the film. Secondly, software can be used to enhance images of the developed film. Sperry and Tolliver (2001) used a scanner to capture greyscale images of the EDD lifts and then Photoshop image-manipulation software to enhance the image, generally using Brightness/Contrast and Curves/Levels adjustments, as well as various image-blurring tools within the package.

Astronomers, when attempting to image deep sky objects such as nebulae and galaxies, face a similar challenge—to capture and optimise an image of a very distant, dim, and moving object. This usually involves the use of a sensitive detection instrument, commonly a charge-coupled device (CCD) camera; a telescope with high quality optics on a sturdy mount, precise focus, alignment, and tracking; and above all, long exposures. Because objects are very dim and there is an inherent level of noise and other interference involved in the use of CCD cameras and software, exposures of 1 hour or longer are often needed to arrive at an image with acceptable signal-to-noise ratio. Exposures of this duration require very expensive computerised tracking and guiding mechanisms for the telescope and are usually outside the budget of amateur astronomers. To overcome this, amateur astronomers using good quality, though less sophisticated, mounts take a number of shorter duration images and use software to add the images together—a technique called "tracking and stacking." The process works because stars, galaxies, nebulae, or any other object remain essentially unchanged from frame to frame whilst random noise does not. When 2 images are added in a stack, the signal (stars, galaxies, etc.) doubles (a 2x signal increase), but random noise only increases by the square root of 2 (a 1.4x increase). The brightness levels of the target have improved by a factor of 1.4 over the background noise. If 4 images are stacked, the signal increases by 4x; but the background increases only by the square root of 4 (i.e., 2). Hence, the signal-to-noise ratio improves 2x (4x signal increase divided by 2x noise). Note an important point here: this is *not* the same as stacking 4 copies of the *same* image. Under such circumstances the signal would increase 4x, *but so would the noise increase 4x*, yielding no improvement in signal-to-noise ratio. Typically, a series of separate astronomical images

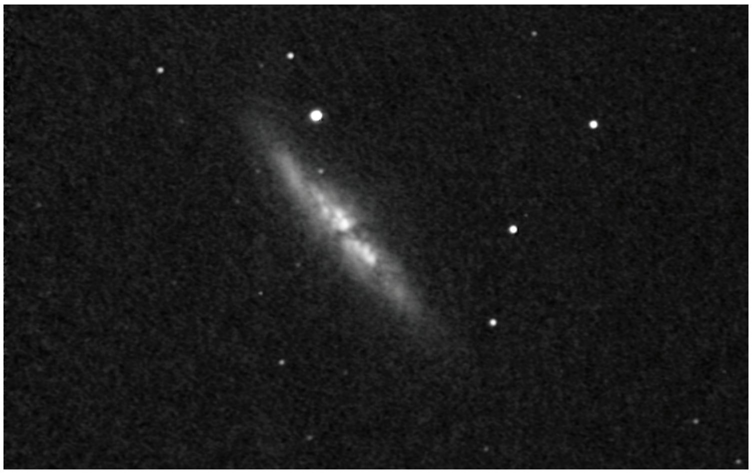

Figure 1a. M-82. Single unprocessed 20-second exposure.

Figure 1b. M-82. Twenty-three stacked 20-second exposures plus image enhancement.

Figure 1c. M-51. Eighty-nine stacked 20-second exposures plus image enhancement.

adding up to 45 minutes combined together can achieve a higher signal-to-noise ratio than a single 30-minute exposure.

Figure 1a shows a rather unprepossessing raw single 20-second image we took of the Messier object M-82 (the Cigar Galaxy) taken straight from the CCD camera. The image is characterised by graininess, lack of colour and detail, general noise, and the odd hot pixel. Figure 1b shows the result of combining and enhancing 23 such images; greater clarity, colour, detail, and a smoother background result. Figure 1c shows a combined image of eighty-nine 20-second exposures of M-51 (the Whirlpool Galaxy)—equivalent to a 30-minute exposure.

We have adopted a similar approach to EDD lifts by making 5 or 6 lifts of the same document, each revealing very faint and largely illegible impressions. We then scanned the images with a flatbed scanner and investigated the use of astronomical stacking and image processing software to combine these images.

Materials and Methods

Instrument

Our laboratory is equipped with an Electrostatic Detection Apparatus (ESDA) which we used for these tests.

Preparation of Documents for ESDA Examination

A number of sheets of 100-gsm white bond Character brand paper were placed 1 on top of the other. A Cross black medium-point ballpoint pen was used to make writings on the topmost sheet. The aim was to create a set of sheets beneath, with diminishing ESDA responses, selecting 1 showing a poor ESDA response for further work (see below).

ESDA Technique

No humidification was used. ESDA lifts were prepared using a Foster + Freeman ESDA machine with 50 sweeps of the corona wire followed by a 1-minute charge development interval and then a 4-second burst of powder cloud. ESDA lifts were preserved using self-adhesive film. Visual inspection followed of each of the ESDA lifts of the lower sheets of the stack. Sheets 2 and 3 gave clear enough impressions not to require further work. Sheet 5 and onwards appeared to bear no impressions. Sheet 4 had a hint of impressions, insufficient to read but visible enough to merit further work.

Preparation of Sheet for Further Analysis

Four Post-it Notes were placed around the area of interest on Sheet 4 where the faint impressions could be seen. (This was a non-destructive method of establishing points of reference on the test document for later stacking.) The sheet was then subjected to ESDA examination 5 times in the manner described above. Another sheet of paper bearing no impressions was then similarly processed to serve as a blank.

Preparation of Electronic Images for Stacking

Each of the 5 ESDA lifts of Sheet 4 (and each of the blanks) was scanned to create 5 greyscale bitmap computer files using a Canon Canonscan 5000F flatbed scanner and Arcsoft Photostudio 5 imaging software. The stacking software used in the next step, being designed to accept output from a CCD camera, required the images to be scanned at exactly the same pixel dimensions, vertically and horizontally. In the example shown in Figure 2, the area of interest selected for scanning was 2480 pixels wide by 1604 pixels tall.

Since the stacking software to be used had been designed for astronomical images, 2 "stars" were added electronically to each image in an identical position to aid in the stacking process. To achieve this, and to preserve the original scanned image intact and unaltered, a new layer was created above the image layer in the Photostudio software (*Layer* | *New*). Using the Pen Tool of the software, a 0.5 mm white dot was placed at the corner of 2 of the Post-it Note images. Minor inaccuracy in placing the dots could be dealt with using the Move Tool within the software. A 2nd new layer was now added above the 1st layer *(Layer | New),* and in this 2nd layer two 3.0 mm black dots were placed over the white dots. Finally, the 2 new layers were reversed so that the white dots appeared above the black ones and above the original image. (Our initial approach was to place the larger black dot over the image first and then centre the white dot over the black dot afterwards. This led to inaccurate positioning of the critical white dot over the original image, so this back-to-front approach was adopted to overcome this problem.) The process was repeated for all 5 scanned ESDA images.

Stacking of Images

AIP4Win v 2 software was used to stack the images. This software was accompanied by a book entitled, *The Handbook of Astronomical Image Processing,"* by Richard Berry and James Burnell.

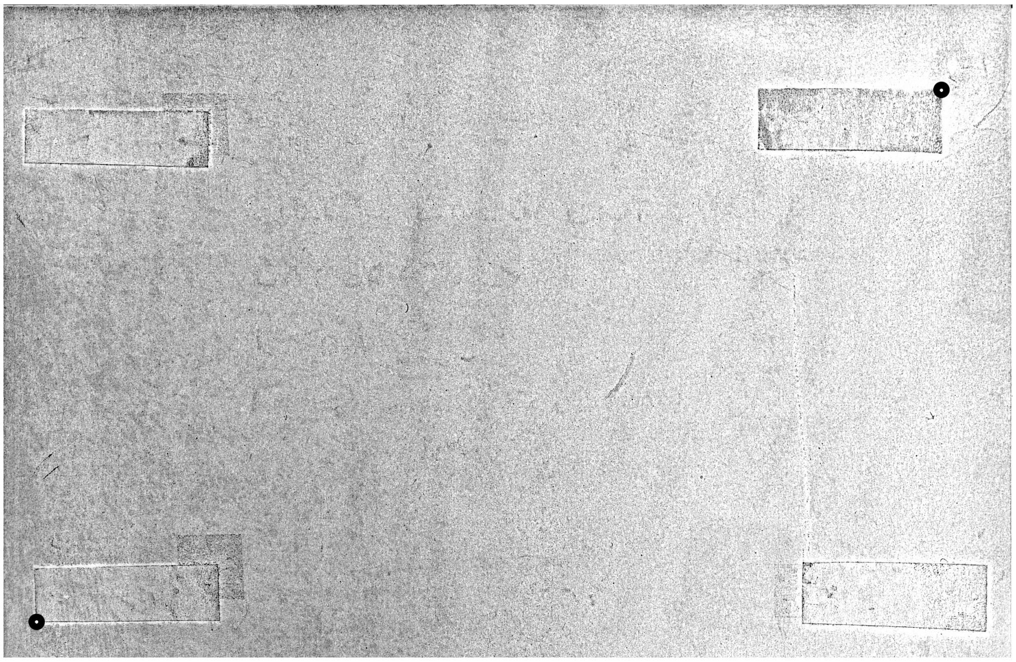

Figure 2. A single ESDA lift of the test document showing the images of the 4 Post-it Notes, the "alignment stars," and the faint impressions which are presently barely visible.

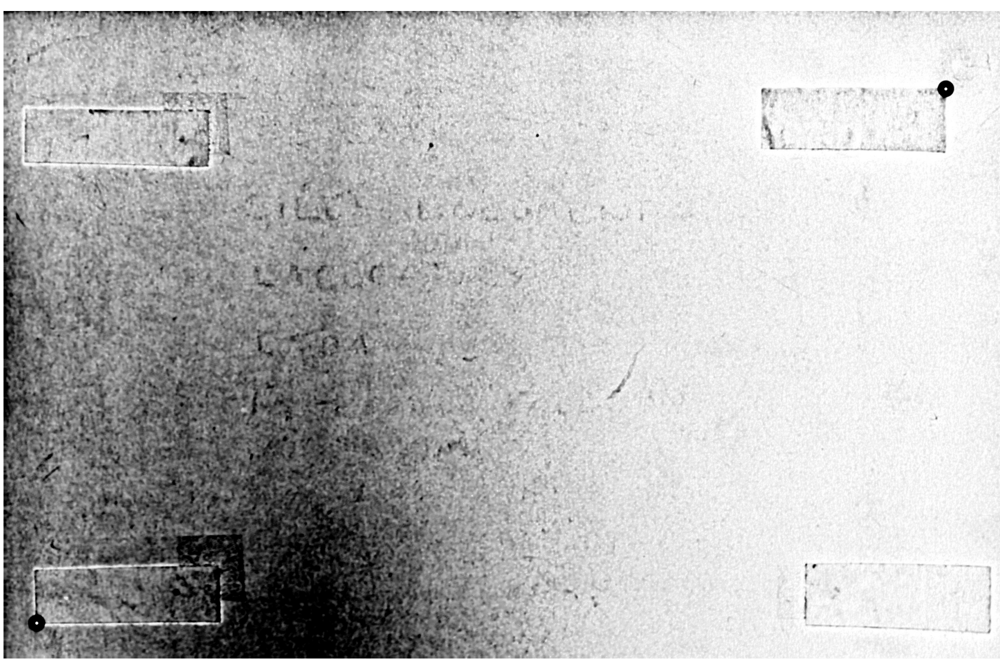

Figure 3. The stacked image of the 5 ESDA lifts from the test document and after subsequent image enhancement revealing the impressions.

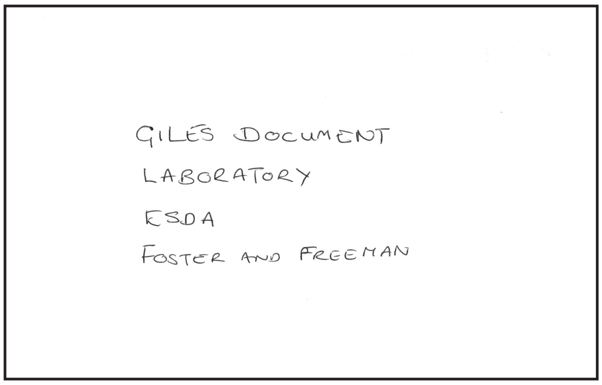

Figure 4. The writings which gave rise to the impressions revealed in Figures 2 and 3.

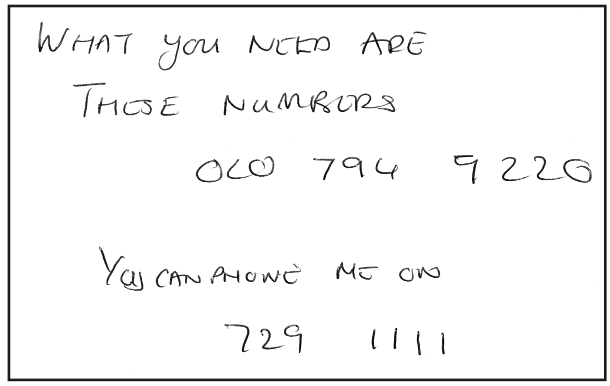

Figure 5. The writings which gave rise to the impressions revealed in Figures 6 and 7.

Stacking of the 5 ESDA greyscale images was carried out using the *Multi-Image | Autoprocess | Deep Sky* routine which allowed for different stacking routines, Sum, Average, Median and K-sigma. The program can handle image rotation and alignment automatically; but in view of the non-astronomical nature of these images, we preferred to carry out the process manually, assisting the software to achieve greater alignment accuracy. For 5 images with only 2 "reference stars," this was not onerous.

The Image Math routines within AIP4Win allowed for addition, subtraction, and more complicated routines for images.

Final image enhancement in AIP4Win or Photoshop CS3 was carried out using the curves, histogram, and blurring techniques similar to those described by Sperry and Tolliver (2001).

(Note: Astronomical images shown in this paper were taken rough a Celestron CPC 925 GPS [XLT] Schmidt-Cassegrain telescope [235 mm mirror] with a Meade Deep Sky Imager II CCD Camera running Meade Envisage software v 5.2.)

Results

Figure 2 is an image of a single ESDA lift of Sheet 4 showing the images of the 4 Post-it Notes, the "alignment stars" (bottom left and top right), and the faintest hint of the impressions between them.

All 4 stacking routines of the AIP4Win software (Sum, Average, Median and K-sigma) gave improved images. Sum and Average were the best, and Sum was the better of those 2.

Figure 3 shows the result of stacking 5 images using the Sum stacking routine, followed by histogram adjustment and background smoothing. Impressions of much of the writings can now be visualised.

Figure 4 shows the original writings which gave rise to the impressions shown in Figures 2 and 3.

Five images of the blank document were stacked and then subtracted from the stacked images of the fragmentary impressions on Sheet 4; no improvement resulted. Such a technique is routinely used in astronomical imaging to compensate for noise that results from using a CCD camera. A so-called "Dark Frame" is produced by taking an image with the front of the telescope covered up. Any "image" resulting is the noise from the camera; it is statistically predictable and can safely be subtracted from the image being taken at the time. The nature of the noise in an ESDA lift (the generally grey background one always observes) may not be the same type of phenomenon, and perhaps we were naïve in expecting this to help.

In a further experiment, 4 sheets of 80 gsm office-quality paper were stacked over a laser-printed letter. The sheets were slightly offset so that when writing with a Cross medium ballpoint pen on the topmost sheet to create impressions on the letter, the first 2 lines of writing were made over only 3 sheets of paper, whilst the 3 bottom lines were made over 4 sheets. Figure 5 shows the writings made on the topmost sheet.

Figure 6 shows the impressions developed in a single ESDA lift (note the use of only 2 Post-it Notes for creating reference points); the upper impressions made through 3 sheets are reasonably legible, whereas those made through 4 sheets are

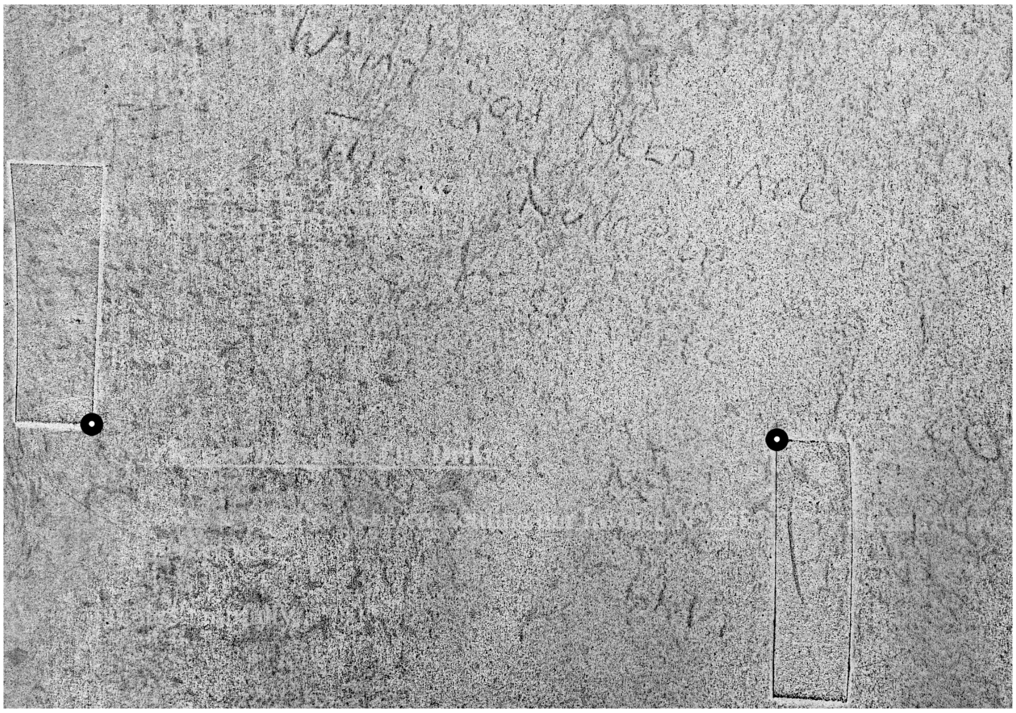

Figure 6. Impressions revealed from writings shown in Figure 5 on a single ESDA lift. The upper 2 lines of writing made through only 3 sheets of paper show reasonably clearly, whilst the 3 lines below, made through 4 sheets, are more elusive.

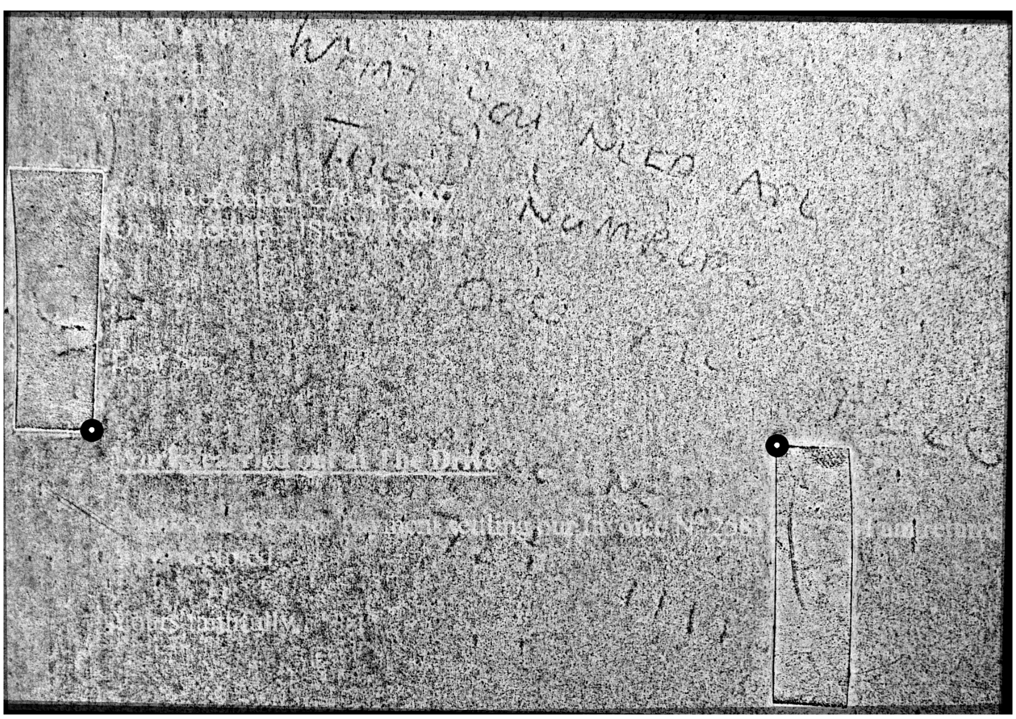

Figure 7. The stacked image of 6 separate ESDA lifts as shown in Figure 6. Now the upper 2 lines of writing made through 3 sheets of paper are clearly visible; and 3 lines below, made through 4 sheets, are also becoming apparent.

much less so. Figure 7 shows the result of stacking 6 ESDA lifts from the same letter. Now the upper 2 lines of impressions are clearly visible, and some detail of the lower 3 lines are apparent.

Discussion

We have shown that the stacking technique borrowed from astronomers can be applied to ESDA lifts to enhance otherwise faint or illegible impressions. We used astronomical software, but other image handling software such as Photoshop can achieve the same thing, though alignment and rotation of images to get an exact stack is more difficult. One could, of course, place the actual ESDA lifts 1 on top of the other to achieve the same result. However, physically manipulating 5 or more slippery ESDA films and holding them together is tricky, especially if one wanted to photocopy them to produce demonstration material for court or scan them so that electronic manipulation of the background and Brightness/Contrast/Curves can be carried out.

It also occured to us that any graphic evidence in the form of an image could be stacked in such a manner; for example, weak autoradiographs of DNA analyses, gel electrophoresis images, chromatography images, etc.

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