

Using Adobe Photomerge™ for Demonstrative Evidence

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Demonstrative evidence is of utmost importance to forensic document examiners (FDEs). This paper describes the use of Adobe Photomerge™ as a means of producing large charts from a combination of smaller images. The paper gives a step-by-step description, including caveats, and gives a case example where the technique was used in court.

Introduction

Forensic document examiners (FDEs) have found several uses for imaging systems and software (Tytell 1992). Of the software packages, Adobe® Photoshop® is 1 of the more popular in use. The uses for Photoshop, as Elements or the full version, to perform examinations and as a means of providing demonstrative evidence as well as the potential for abuse were described by Hicks (1995). Additional techniques using Photoshop were described for the preparation of electronic typewriter grids (Hicks 1999), deciphering indented impressions on plastic (Brown and others 2003), and ink examinations (Hammond 2007, Bodziak 2000). Further uses for Photoshop and plugins were described for color separation (Berger and others 2006, Chaikovsky and others 2003), and reconstruction of torn paper (Hammond 2002). Several step-by-step techniques for using Photoshop in the examination of documents have been described (Herbertson 2002).

The use of demonstrative evidence is of utmost importance to FDEs. One writer succinctly said, "what cannot be demonstrated is not evidence" (Harrison 1964). Traditionally, FDEs have used enlarged photographs to make demonstrative court charts (Nelson and Hicks 1998, Hicks and others 2006). However, many courtrooms now routinely incorporate the use of computer projectors, and this enables the FDE to display charts with annotations which can be animate or inanimate. FDEs have also made the transition from film to digital cameras. Digital images can be used

to prepare court charts and other demonstrative exhibits more easily than film. It is also possible to actively demonstrate the use of software packages to replicate the image processing function used to produce an image.

A photo montage can be defined very simply as a composite image created from multiple smaller images. A common use of this technology is to produce panoramic views from multiple overlapping images. This use of a composite image montage has been described for the depiction of a crime scene (Reis 2007). Beginning with Photoshop CS, a useful built-in tool called Photomerge™ became available specifically for this purpose.

The Photoshop manual describes Photomerge as a method that "...combines several photographs into one continuous image" in a (semi-)automated process that aligns the different images according to common image elements at the edges of the images. The primary application for this tool is the creation of wide field-of-view (FOV) panoramic images from several adjacent images.

This article reviews the steps involved in creating a montage using a manual process versus doing so automatically via Photomerge. An example drawn from the FDE domain is discussed, together with discussion of pros and cons. Finally, a casework example is provided.

Photo Montages in Forensic Document Examination

One appeal of this type of composite montage is the ability to combine several lower resolution

images to produce a single image having an overall higher effective resolution. Some of the imaging equipment used by FDEs, such as spectral lighting systems or cameras mounted on a microscope, capture digital images with a relatively low spatial resolution and/or show only a restricted FOV. For example, systems based on video camera technology often capture images having 640x480 or similar image resolution. If an original document is an 8-inch (approximately 20 cm) wide piece of paper, this translates into an actual image resolution of only $640 \div 8$ or 80 pixels per inch (ppi) across the image. This resolution may be acceptable for some purposes, but it is often too restricted to be of much value. One solution to this problem is to increase the magnification, which results in a smaller FOV but a higher spatial resolution.

If that same imaging system is used to capture an area that is only 1 inch wide (approximately 2.54 cm) from the original document, then the image resolution would be 640 ppi across the image. This is a significant increase and capable of characterizing and resolving many of the more subtle features present in an ink line, for example. Every increase in optical magnification will produce a higher image resolution. The problem with this approach is that several separate images are required to digitize the entire page width. Of course, those images would then have to be combined in some manner if the examiner wants to show the entire page width as a single, high-resolution image.

Another use for a composite montage is to combine images taken under differing lighting conditions. The decipherment of obscured, erased, or obliterated information often requires the use of multiple settings or lighting arrangements for different parts of a single document. On occasion, the best way to demonstrate the final decipherment is to combine different sub-images into a single composite montage.

How Does Photomerge Work?

Photomerge is an example of a software “stitching” program. Stitching programs take several overlapping source images and create a single composite image from them using pattern recognition to identify corresponding elements in the various images. The process is quite complex and involves repositioning, rotation, and/or warping of the source images to achieve proper alignment of the common elements.

It is beneficial to understand the process of manually producing a montage using a program like Photoshop. The manual process involves placing

each of the individual images into a single blank image, followed by manual repositioning, rotation, and/or rescaling to properly align the sub-images to reflect their location and orientation in the original item or scene. Each image should be placed onto a separate layer so that it can be adjusted individually. Adjusting the opacity of each overlaying layer lets users see image features from each layer so that they can locate and align common elements. The only tricks or difficulties with manual composition are 1) ensuring proper alignment of the images in terms of horizontal position, vertical position, and rotation and 2) merging or blending the images seamlessly.

The main advantage of a program like Photomerge is that the program can automatically find and match overlapping elements in the sub-images while taking care of both position and rotation so long as the latter is not too extreme. However, this process does not always work perfectly. For example, when a large number of images are opened for processing, the program may not find reasonable matches due to the sheer number of comparisons that must be made. The problem is exacerbated if the image content does not provide much structure or tonal variation.

It is important to remember that humans are generally very good at the kind of pattern matching required for the alignment problem; in fact, humans are often much better and faster than software when dealing with a limited set of images or for images lacking distinctive features. The computer software will handle less difficult matching problems very well, and it is always superior for tedious or repetitive tasks. As a result, a good approach is to allow the software to perform easy matches first. After this has been done, any problematic matches can be dealt with using direct user interaction.

One of the most critical issues affecting the operation of the software is the quality of the original images. There are several important guidelines that should be followed if a user wants Photomerge to work well. The following are taken from the Photomerge Help information:

1. *Overlap images:* Images should have an overlap of 15% to 40% of the image area. More is not better, and less doesn't usually work well. At the same time, part of the issue is the nature of information in the image. Unusual image detail does seem to help the matching algorithm. Finally, sub-images that are distinctive are easier to match than a series of images that all look the same.

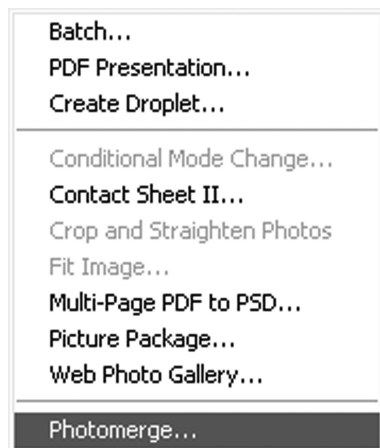


Figure 1 Photoshop submenu showing Photomerge option.

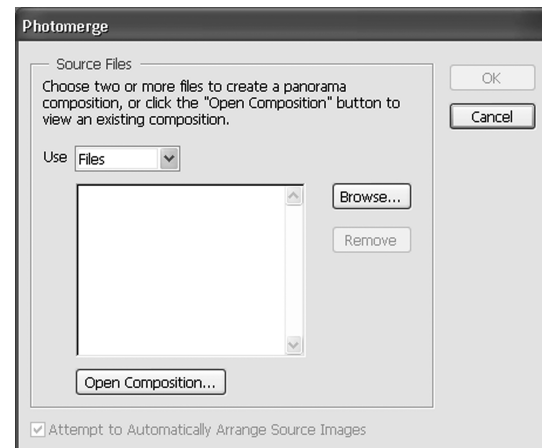


Figure 2 Initial Photomerge dialog box.

2. *Use a consistent focal length:* All images in the composition should be acquired using the same camera settings. Do not adjust or change the focus or zoom settings. Technically, it is possible to re-adjust the images after the fact; but this is quite difficult, and it is best to avoid this type of problem. One advantage FDEs have is complete control over the imaging process. Normal imaging setups, in a lab at least, are generally under the control of the examiner, so this should be an easy goal to achieve.
3. *Move the item in a horizontal plane (while keeping the surface level):* Photomerge will only rotate sub-images a few degrees, so it is best to avoid rotation entirely, if possible. If more rotation is required to align sub-images, automatic processing will not work properly. Minimizing rotation effects in FDE applications usually means sliding the item across the camera FOV in a horizontal plane. Alternatively, the camera may be the moving component in some situations. Certainly, for non-FDE applications, it is normal to pan the camera across the scene in a horizontal plane, keeping it level all the time, i.e., using a tripod with a swivel base.
4. *Avoid moving the camera position:* If the camera position relative to the item changes, the perspective of the images will vary, as will the continuity of the sequence.
5. *Do not use distortion lenses or polarizing lenses:* Photomerge does not work well for images that are noticeably distorted.

6. *Maintain consistent exposure and lighting:* Photomerge can compensate for slight tonal variations between sub-images, but it can't handle extreme differences. Additionally, any automatic processing used by the camera may produce unusual and unexpected tonal patterns. For example, some cameras adjust exposure settings automatically. It is best to find the correct, optimal settings and then switch the camera to manual control.

Using Photomerge

The operation of Photomerge is very straight forward, and the detailed instruction provided in the program's Help function are very easy to understand and follow. The descriptions provided here apply to Photoshop CS2, and there will be slight differences in other versions. The main function can be found under File > Automate submenu. All the user really has to do is identify the source files. After that, the assembly of the composition will be automatic most of the time. If fine tuning is required, the program allows the user to do that after the basic alignment has been achieved.

To start Photomerge, use 1 of the following methods:

1. Click on File > Automate > Photomerge (Figure 1).
2. From the File Browser, select the desired image and then choose Automate > Photomerge from the File Browser menu bar.

Using option 1, for example, a dialog box will appear (Figure 2) to allow file selection. Click on the Browse button and find the source files to

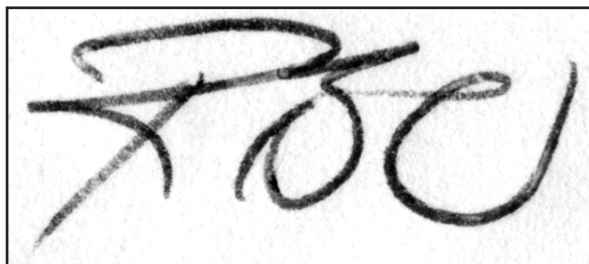


Figure 3 Set of test initials written in ballpoint pen on paper shown at 4X original size.

be processed. Alternatively, the user can process files that are already open in Photoshop. To do this, ensure the images have been saved to disk and then change the "Use" drop-down selection to "Open Files."

The "Attempt to Automatically Arrange Source Images" check box is selected by default, and most of the time it can be left checked. The "Open Composition" button allows a user to reopen a saved composition for reprocessing.

Once the files have been selected, click OK and Photomerge will proceed to generate the montage as best it can. A new dialog box will appear; and, if the program is able to match and align the images, the user can simply accept the results.

To demonstrate the process, 1 of the authors wrote a set of test initials on a piece of paper (Figure 3), and a total of 8 lower resolution images were captured from this signature (Figure 4). The lower resolution images were then processed using Photomerge to create a composite montage image of the initials. The resulting composite image was compared to the high-resolution scan of the test initials.

The main Photomerge window layout shown in Figure 5 has several elements. Along the left

side of the dialog box there are a number of tools for manipulating the composition of the images. At the top of the dialog box there is a "light box" for storing images not in use.

The main window in the centre of the dialog box is the work area for assembling the composition, in this example displaying the initial results of an automated assembly process. There are various options for viewing and editing the composition, using the controls to the right of the main window. Also on the right side is a Navigator window that can be used to zoom in and out for better interactive viewing of the results.

Sometimes, as in this instance, the initial result (Figure 5) from the automated processing was not acceptable and manual intervention was required. User interaction was needed to help the program arrange the sub-images into a good composite image. This is an easy process where the user places individual sub-images in approximately the correct location. The easiest way to do this is to temporarily separate all of the sub-images by placing them into the light box area (click and drag each image). Then 1 image is selected as a starting point. Each of the sub-images is then manually dragged and dropped into the approximate location adjacent to the image(s) already in place. As each sub-image is positioned, it is outlined in red and becomes semi-transparent as it moves over another image. This makes it quite easy to estimate the correct location.

This semi-manual process is simple and easy because precision in placement is not required. The program attempts to align the layers when commonality is detected so long as the Snap to Image option is checked (see checked box on bottom right in Figure 5). If this option is not selected, the user has manual control over the alignment of the sub-images. Complete manual control may be useful when the program is experiencing



Figure 4 Three of 8 low-resolution images of the test initials.

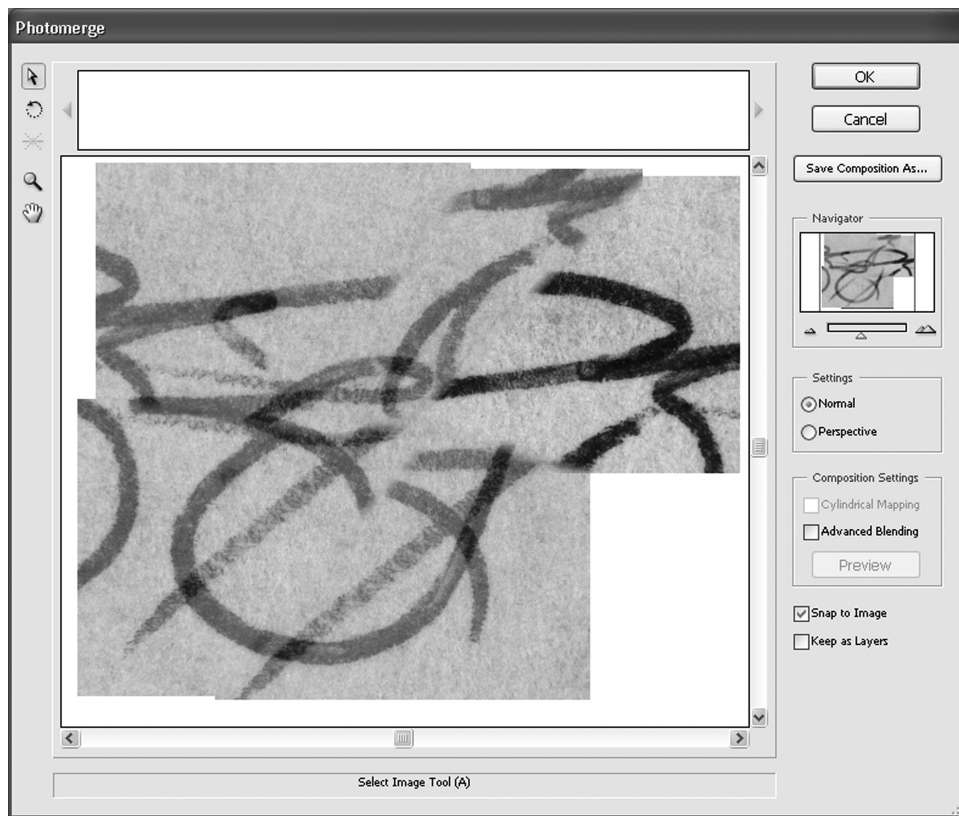


Figure 5 Photomerge processing window showing results of the automated processing.

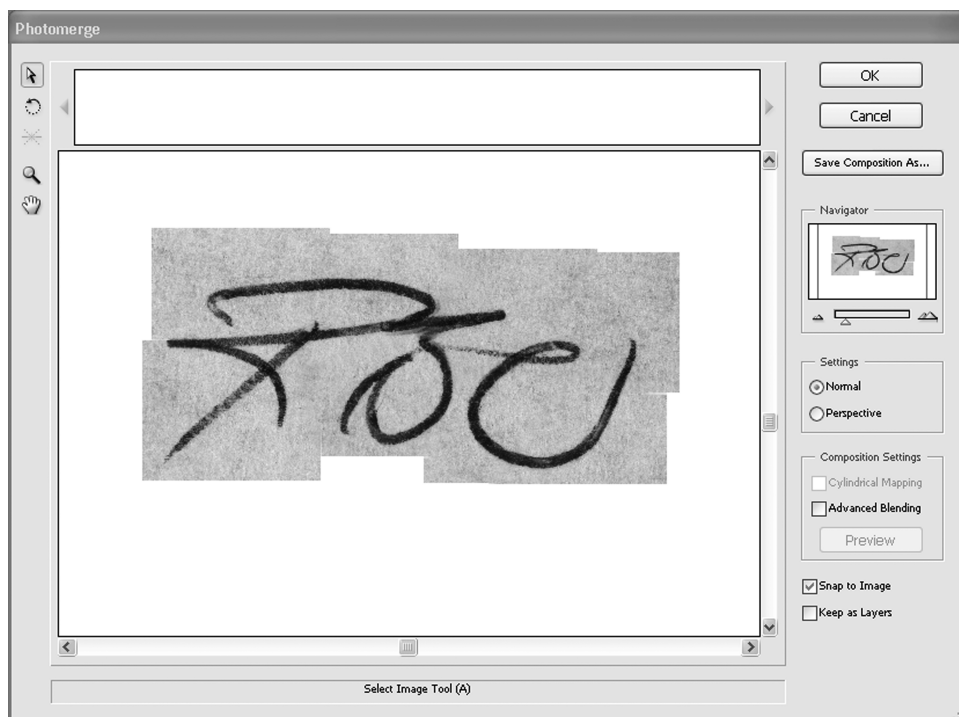
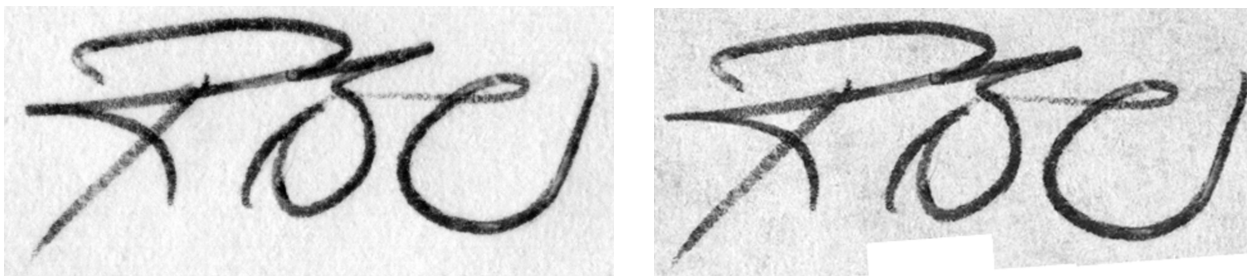


Figure 6 Results after semi-automated processing (i.e., manual repositioning).



Figures 7 Original test initials (left) versus Photomerge results (right).

extreme difficulties in making the correct adjustments automatically. After each adjustment, the program blends the images displayed in the work area to give the user a reasonable idea of the final montage appearance. By using this method, a much better composite montage was created in about 30 seconds (Figure 6).

It should be noted that changing the sequence in which the sub-images are adjusted can result in slightly different blended results. In other words, it is a good idea to record the sequence in which the sub-images are adjusted whenever a manual adjustment process is used.

The Rotate tool found on the left side of the main dialog box is very useful for those instances when 1 sub-image has been captured at a slightly different rotation than the other sub-images. When this happens, the program attempts to fit the images together, but the result is generally a distortion in the image. The user should then rotate the sub-image manually to optimize alignment.

There are a couple of additional options available that appear on the right side of the dialog box. These include perspective correction and composition settings. The latter composition settings permit advanced blending and cylindrical mapping. These settings affect the way the images are adjusted to match and how they blend in the final composition.

In general, perspective correction should not be required when dealing with normal FDE-type problems. It is used to adjust all of the sub-images to a common vanishing point that may be in any 1 of the images or outside the entire composition.

To adjust perspective, the Vanishing Point tool, the 3rd symbol down in the tools along the left edge, is used. Please refer to the Photoshop Help function for additional information.

The composition settings include advanced blending and cylindrical mapping. Again, neither of these functions should be required for normal FDE-type problems. Cylindrical mapping is used to reduce "bow-tie" distortion that may occur



Figure 8 Pseudo-color comparison of images 7a and 7b highlighting differences between the 2 images.

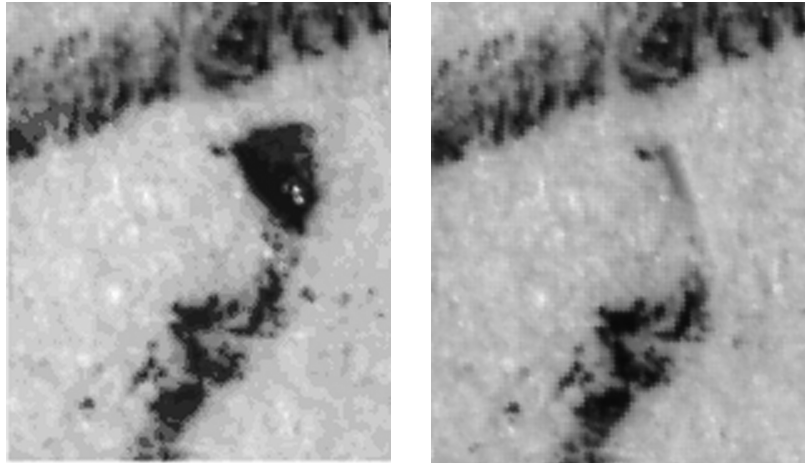


Figure 9 Ink deposition in original signature (left) and Photomerge results (right). Note the removal of ink gooping in the latter.

when a perspective correction has been applied to an image. Since perspective corrections are not normally required, cylindrical mapping should not be required either. Please refer to the Photoshop Help function for additional information.

Advanced blending can be used to minimize color inconsistencies caused by blending images with different exposures or tonal variation. Selecting the advanced blending option causes broad color or tones to be spread over a large area in the blending process. More detailed colors are blended over a smaller area so that discernible detail is not lost in the process.

It is enlightening to compare the composite montage image directly with a higher resolution image of the original to see what differences, if any, are present (Figure 7). The composite image shown here was also rotated slightly to align properly with the other image. The images appear to be similar, and the composite montage would be considered a fair representation of the original by most observers. However, it is far from being a perfect rendition of the original.

In fact, there are several very subtle differences between the 2 images. Figure 8 shows these differences using an enhanced pseudo-color overlay of the composite montage image (Figure 7, right) with the high-resolution scanned image (Figure 7, left). In the enhanced overlay, features common to both images appear as yellow-gray, while areas where there are differences between the images appear as a dark blue.

In general, the background of the images has many subtle differences, but these do not affect the image very much. Significant distortion is present along the edges of most of the image features, indicating a small but noteworthy difference in scaling and/or position. The most pronounced difference is in the buckle of the “R” movement which appears as a much thinner stroke in the composite image than in the original.

This type of distortion will not happen in every situation, but it is clear that significant distortion can sometimes occur. The nature of distortion cannot be easily predicted or anticipated. In another situation, the authors observed a type of “drop-out error” which appeared to be a by-product of the blending processing. When a feature of interest lies roughly on the seam between 2 sub-images and neither sub-image extends far enough beyond the feature, the blending function will sometimes blur out (i.e., remove) the feature partially or entirely. For example, consider the ink deposit that appears at the beginning of the descending ink stroke in Figure 9a (left), and compare this to the Photomerge result for the same area in Figure 9b (right). It is very clear from this example that the process may produce significant changes in the image content. To minimize this particular type of problem, it is important that sub-images overlap by the suggested 15% to 40%.

Comments and Recommendation

Overall, Photomerge can be a very useful tool, but users **must** be aware of some caveats. First,

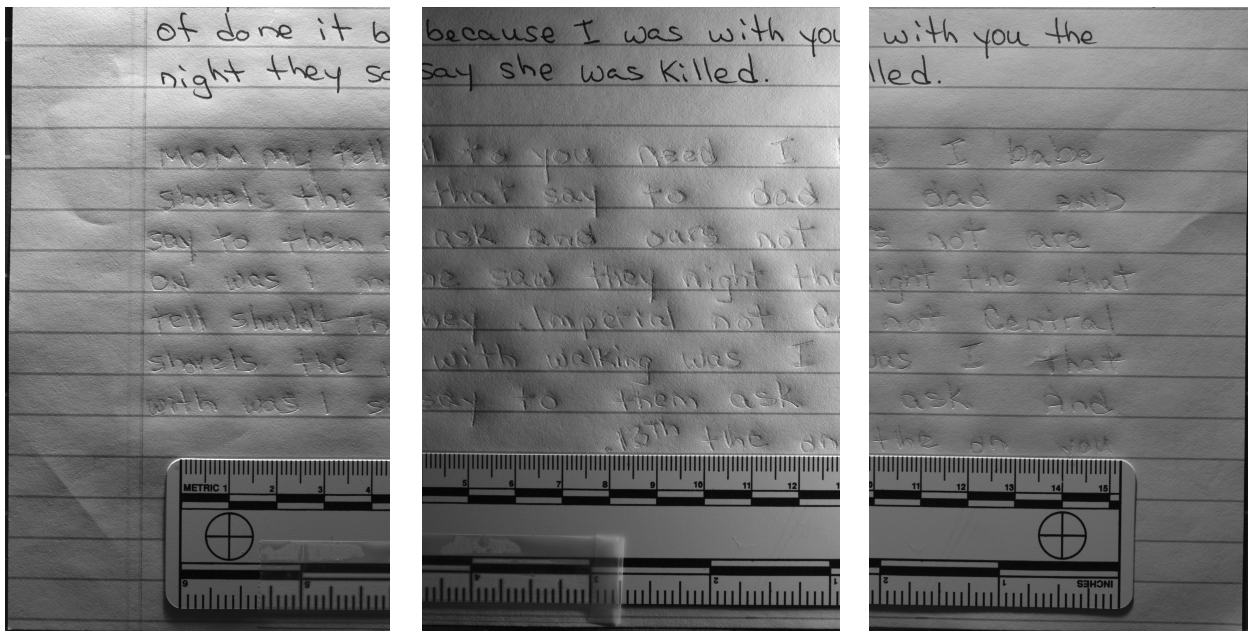


Figure 10 Three images of a questioned document each taken under differing illumination.

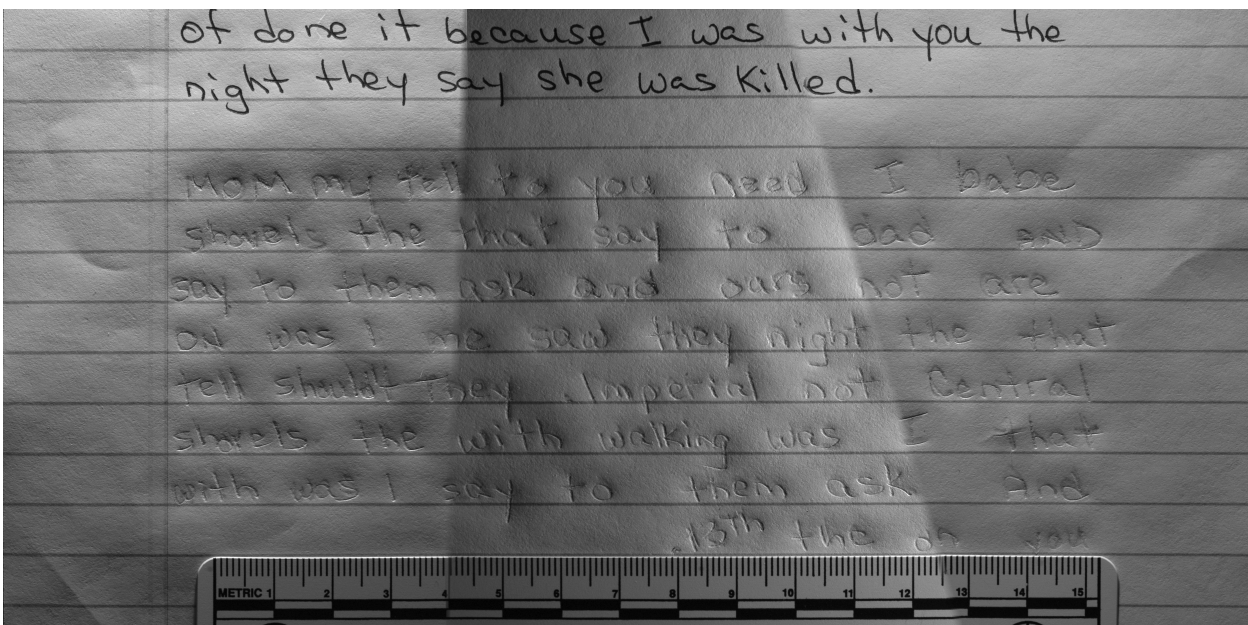


Figure 11 Photomerge composite image created from images in Figure 10.

stitching programs rotate and/or warp sub-images to achieve acceptable alignment. This is usually a very subtle effect, but it does involve data interpolation. Furthermore, as seen in the example used above, the effect can be very dramatic, with significant changes in the resulting image data. It is very important to always review the final montage with a critical eye to ensure that it is, in fact, a reasonable representation of the original item. Second, blending of layers will generally produce a relatively smooth transition between sub-images; but the process also modifies the image data, at least in the area along the seam. To minimize the effects, it is important to have good overlap in the adjacent sub-images. Third, if the advanced blending option is selected, it can produce pronounced tonal artifacts. Finally, depending upon the imaging system used to generate the original sub-images, the final composition may have some distorted elements such as "curved" lines when the original lines were straight. It should also be noted that most of these same issues can arise when creating entirely manual compositions (i.e., when not using Photomerge).

In the end, if the user is aware of the limitations of the software and takes steps to avoid the problem areas noted above, there is no reason to avoid using Photomerge in FDE work. Photomerge can and will produce good results with very little time or effort. However, due to the potential for distortion of the image, this type of montage image should be considered an approximate representation of the original item and be treated accordingly. The user should not assume that the result is an accurate representation of the original; rather he should assess the results to be sure that this is the case. If and only if he feels the image is an accurate representation of what he personally observed should he present it as such to the courts.

Case Example

The defendant in a homicide case was accused of killing his 18-year-old girlfriend and her teenage friend. While in prison on another charge, he wrote a 4-page letter in pencil on lined, yellow note pad paper to his new girlfriend. On the middle of the reverse side of page 1 there was a sentence which gave instructions to erase the writing or destroy the page after reading it. The writing was erased. The document was seized during a search warrant and brought to the laboratory, and the examiner was asked to decipher the erased writing. After several hours of examination, the examiner

deciphered the majority of the entries using side lighting, infra-red reflectance, and ESDA.

After a preliminary hearing during which the examiner testified to the decipherment, the defendant was remanded to stand trial. Just before the trial, the defense asked for a motion-in-limine hearing to keep the decipherment out. After the 2 motions in limine (1 of which involved an "expert" critic), the examiner was allowed to testify; but the judge ruled that the examiner would have to demonstrate the decipherment to the court.

After pondering the best method to demonstrate the evidence, the examiner decided to use photographs of the areas of the document which showed up best under different lighting. The best digital photographs were selected and stitched together using Photomerge. A very large chart was produced showing the stitched photo. This chart was placed before the jury. The photograph was also placed into a Powerpoint slide which was shown in the courtroom. Each juror was given an 8½x11-inch photograph mounted on a card. However, the jurors were not allowed to take these cards into the jury room. Figure 10 shows images of a recreated document similar to the questioned document in the case described. Each image was created using different lighting to enhance the features of interest. Figure 11 shows the images stitched with Photomerge. The lines visible in the composite image indicate where the stitching occurred, and these were left in to show where the stitching was done.

The defendant had written from right to left, probably to get by the attention of the jailers, as all jail mail is copied and screened. The photo montage made it easy for the jurors to see this aspect of the note, together with the content. The defendant was convicted of double homicide and sentenced to life without parole. The document evidence proved to be very incriminating.

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