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TECHNICAL NOTE

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John Albanese,[1] *Ph.D. and Ronald Montes,*[1] *H.B.A.*

Latent Evidence Detection using a Combination of Near Infrared and High Dynamic Range Photography: An Example Using Bloodstains

ABSTRACT: In this paper, we use bloodstains to illustrate an approach for identifying latent evidence on dark cloth using near infrared (NIR) photography combined with high dynamic range (HDR) photography techniques. NIR photography alone has been used to capture latent evidence that cannot be seen in normal ambient light. HDR techniques combine multiple bracketed photographs of the same image to increase the dynamic range of the photograph which can provide greater contrast. Using NIR photography alone, we were able to detect a bloodstain up to a 1/16 dilution, an improvement over previous studies. Combining NIR photography with the HDR process resulted in a noticeable increase in visibility up to 1/16 dilution when compared to NIR photographs alone. At 1/32 dilution, we were able to detect bloodstains that were not visible using NIR alone. NIR is a useful tool for imaging latent evidence, and combining NIR with HDR consistently provides better results over NIR alone.

KEYWORDS: forensic science, forensic photography, near infrared photography, latent evidence detection, high dynamic range photography, bracketing photographs

The detection of latent evidence on black or dark mottled cloth can present specific challenges to crime scene investigators. In this paper, we investigate the utility of combining near infrared (NIR) photography with high dynamic range (HDR) photography techniques for the detection of latent evidence using bloodstains on black cloth.

Digital cameras record a scene by capturing light either transmitted or reflected into the light capture device, normally a charged couple device (CCD) or silicone equivalent (CMOS). Camera brands such as Nikon and Fuji use CCDs while Canon uses the CMOS variant. The instant preview function and the capture of images onto memory cards have increased the ease of use of photography in many fields including forensics (1,2). Tethering a digital camera to a laptop computer takes the on-site preview and analysis of images to a whole new level.

Traditional infrared (IR) photography used IR-sensitive film that needed to be loaded in the dark. Focus and exposure was estimated by the photographer and results could only be observed after development. Thus, the costly and inaccurate procedures made IR photography too cumbersome for practical use in many forensic contexts. With the advent of digital cameras, focusing and exposure can be compensated on-site by reviewing each image in real time on the preview screen or a tethered laptop computer. In most digital cameras, a "hot" filter or IR/UV cut filter is installed in front of the CCD or CMOS capture device to filter out any IR/UV that degrades the quality of normal visible spectrum photographs. When used for IR photography, the hot filter must be removed and replaced by a clear glass cover to allow full spectrum sensitivity (1,3) (http://www.lifepixel.com/forensics/, accessed January 15, 2010). Filters are then fitted in front of the lens to block specific wavelengths of light.

The NIR spectrum commonly used in forensic photography is *c.* in the 700–900 nm range (1). The Wratten rating system denotes the spectrum range which is blocked, and the 89B filter is the most common IR filter available which blocks light below 680 nm wavelength. Using NIR photography can provide greater contrast to visually separate latent evidence such as a bloodstain from the background material (4). Lin et al. (5) demonstrated the utility of NIR photography for detecting latent evidence, including gunshot residue, ink, and bloodstains on dark cloth. They were able to identify dilutions of up to 1/8 for bloodstains.

Previous studies have used image fusion to combine images with differing flash exposures (6,7). In contrast, HDR tone mapping consists of creating an 8-bit image from the 32-bit image using the HDR process. HDR photography is a proven technique that has been used extensively in landscape and architectural photography. The HDR process involves combining three or more photographs of the same scene but with differing exposure. Usually underexposed (−1), normal, and overexposed (+1) photographs are taken. Variations in this method include taking up to five photographs or exposures ranging from −2 to +2. The photographs can be easily combined using available software such as Adobe Photoshop CS3© (San Jose, CA) or Photomatix© (Montpellier, France). Combining the three images results in a 32-bit image that exhibits an HDR compared to each individual image. Tone mapping must then be performed to reduce the photograph back to an 8-bit image as most displays can only output the detail of an 8-bit image.

[1]Department of Sociology, Anthropology, and Criminology, University of Windsor, 401 Sunset Avenue, Windsor, ON N9B 3P4, Canada.

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HDR images represent a more accurate luminance that corresponds to values in the real world. Therefore, HDR images are known as "scene referred" images, while the more common limited dynamic range images are outputted on devices such as monitors or printers and are known as "output referred" images. HDR images typically contain 16 bits or 32 bits of data per color channel, while traditional digital images contain 8 bits of data per color channel, as in most output displays such as monitors (http://www.anyhere.com/gward/hdrenc/hdr_encodings.html, accessed January 15, 2010; http://http.developer.nvidia.com/GPUGems/gpugems_ch26.html, accessed January 15, 2010). Tone mapping is used to reduce the dynamic range back to an "output referred" level, while retaining the contrast between neighboring pixels. Various tone mapping methods can be used to obtain the optimum contrast (http://www.mpi-inf.mpg.de/resources/hdr/datmo/mantiuk08datm.pdf, accessed January 15, 2010). This increased contrast should provide an improvement over NIR alone for identifying latent evidence.

Materials and Methods

A Nikon D50 digital camera was converted to a full spectrum camera by replacing the hot filter with a clear filter. The procedure was performed by Lifepixel. A 28–105 Nikon Nikkor macro lens (Tokyo, Japan) with an 89B IR filter was used on the camera. Black fabrics, cotton/polyester, cotton/lycra, and cotton/acrylic were cut into *c.* 7.5 × 7.5 cm square. Sheep's blood was used in the experiment following a variation in the process used by Lin et al. (5), with sample preparations of undiluted, and 1/4, 1/8, 1/16, and 1/32 dilutions of blood. For all dilutions, a micropipette was held perpendicularly to the fabrics at a height of 15 cm and 20 μL was dropped onto the different fabrics (cotton/polyester, cotton/rayon, and cotton/lycra). All dilutions of blood were also dropped on a 7.5 × 23 cm fabric, in a 20-μL and 80-μL droplet in a row to mimic a pattern that could be found at a crime scene. The blood droplet was allowed to dry for 24 h.

To photograph the blood stain, the Nikon D50 camera was placed 15 cm above the 7.5 × 7.5 cm square of fabric with the blood droplet. Manual focus was used because the 89B filter blocks the light needed for autofocus to function. After a few test photographs, we found that bracketing the normal exposures with +2 and −2 displayed a wider dynamic range than +1 and −1 bracketing sequence, which was expected with HDR as greater exposure bracketing captured a wider exposure range. These exposures were taken under normal tungsten lighting that was positioned at a 45° angle *c.* 30 cm away from the fabric. The 7.5 × 23 cm fabric strips were photographed at a distance of 30 cm and 180 cm from the fabric to simulate an overall crime scene photograph.

On the cotton/rayon and cotton/lycra fabric, the blood droplets were not absorbed by the fabric. The blood beaded and dried in a concentrated point. Therefore, the detection of the bloodstain on the cotton/rayon and cotton/lycra material was visible with the naked eye under normal conditions and was not suitable for this study. On the cotton/polyester blend, the 20-μL blood droplets were completely absorbed and this fabric was used to test the utility of the method.

The bracketed images were processed into HDR images using both Adobe Photoshop CS3© and Photomatix©. Each image was tone mapped to create the greatest amount of contrast.

Results

Both Adobe Photoshop CS3© and Photomatix© produced similar HDR images after tone mapping. The bloodstains in the resulting images were detectable with greater contrast than the visible spectrum images (Table 1 and Fig. 1). NIR photographs produced images with greater contrast than the visible spectrum images. Additionally, the NIR combined with HDR-processed images resulted in noticeably greater contrast and an increase in visibility of the stains of all dilutions when compared to NIR alone. In contrast to other studies, we were able to detect stains at 1/16 dilution using only NIR, and the stain was more visible with greater contrast when the NIR was combined with the HDR process (5). At the distance of 30 cm and 180 cm, we were able to detect up to a 1/32 dilution for the 80-μL droplet on the 7.5 × 23 cm fabric (Fig. 1). However, the 20-μL droplet was not visible at this distance.

TABLE 1—*A Summary of the results using various dilutions of blood on black cloth.*

Blood	Visible Spectrum	NIR Only	NIR + HDR
Undiluted	2	3	4
1/2 Dilution	1	3	4
1/4 Dilution	1	3	4
1/8 Dilution	0	2	3
1/16 Dilution	0	2	3
1/32 Dilution	0	1	2

Results were consistent for several trials on cotton–polyester cloth. See Fig. 1 for an illustration of the results. (0 = Undetectable, 1 = Very Faint, 2 = Somewhat Detectable, 3 = Detectable, 4 = Detectable with greater contrast.)

HDR, high dynamic range; NIR, near infrared.

Discussion and Conclusion

Locating and identifying individual bloodstains and their pattern of distribution is a key part of crime scene investigation (8). When viewing bloodstains on black cloth under normal lighting, bloodstains are undetectable by the naked eye after a 1/4 dilution. Using NIR photography alone, we were able to detect a bloodstain with a 1/16 dilution, an improvement over previous studies. Overall, combining NIR photography with the HDR process resulted in a small but noticeable increase in contrast, and we could detect bloodstains up to 1/16 dilution when compared to NIR photographs alone. At 1/32 dilution, we were able to detect bloodstains that were not

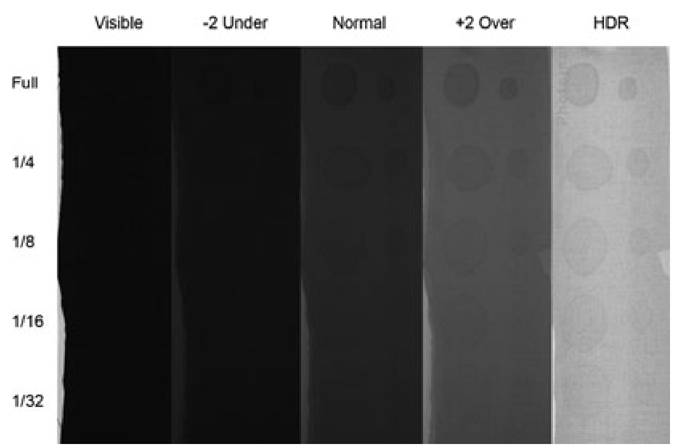

FIG. 1—*Comparison of (from left to right) visible spectrum, near infrared (NIR) −2 exposure, NIR normal exposure, NIR +2 exposure, and the high dynamic range-processed image. The larger droplet is 80 μL and smaller droplet is 20 μL.*

visible using NIR alone. The increase in the detection of the 1/16 blood dilution compared to previous study by Lin et al. (5) could be owing to the use of a different IR filter (89B) that allows for a wider range of the NIR spectrum to reach the camera sensor.

The underexposed (−2 exposure) images displayed the least amount of detail in the bracketing sequence. Therefore, a bracketed sequence of normal, +2 overexposed, and +4 overexposed could have resulted in more detail in the final HDR image. Other IR filters such as the 87C or 89B series could result in additional incremental improvements in contrast when imaging bloodstains or other latent evidence. Finally, the use of newer digital cameras with a wider dynamic range may increase the sensitivity of the NIR spectrum and combined HDR image. Newer digital cameras can also utilize five exposure bracketed images, which may also aid in detecting the stains. In addition to latent bloodstains, Lin et al. (2005) demonstrated the utility of IR imaging for the detection of various types of latent evidence including ink and gunshot residue. We present these preliminary results using bloodstains as a proof of concept for combining NIR spectrum photography with HDR techniques in a forensic context. Similar results should be expected for other latent evidence such as gunshot residue, and the analysis of questioned documents. Additionally, the NIR and HDR techniques can be used to enhance the visibility of faint bite marks on skin.

The combined NIR–HDR approach can be used for forensic purposes either at the crime scene or off-site. With the camera tethered to a laptop computer, the bracketed images can be uploaded and easily processed into HDR images using readily available software such as Adobe Photoshop CS3© or Photomatix©. Then, each image can be tone mapped to create the greatest amount of contrast. At a crime scene, this approach can be used to locate bloodstains or other latent evidence on any dark cloth such as carpeting or upholstery that cannot be easily removed from the scene. Once the stain is located, only that piece of the material needs to be excised and taken off-site for further analysis. In a laboratory setting, dark clothing, fabrics, etc., can be photographed using this technique to locate stains that can be subject to further analysis. With a photographic approach, evidence is not directly or indirectly affected, destroyed, or degraded (8). A full suite of additional tests is possible including additional NIR photography from other angles and perspectives.

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Additional information and reprint requests:
John Albanese, Ph.D.
Department of Sociology, Anthropology, and Criminology
University of Windsor
401 Sunset Avenue
Windsor
ON N9B 3P4
Canada
E-mail: albanese@uwindsor.ca