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Portable hyperspectral imager with continuous wave green laser for identification and detection of untreated latent fingerprints on walls

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ABSTRACT

Untreated latent fingerprints are known to exhibit fluorescence under UV laser excitation. Previously, the hyperspectral imager (HSI) has been primarily evaluated in terms of its potential to enhance the sensitivity of latent fingerprint detection following treatment by conventional chemical methods in the forensic science field. In this study however, the potential usability of the HSI for the visualization and detection of untreated latent fingerprints by measuring their inherent fluorescence under continuous wave (CW) visible laser excitation was examined. Its potential to undertake spectral separation of overlapped fingerprints was also evaluated. The excitation wavelength dependence of fluorescent images was examined using an untreated palm print on a steel based wall, and it was found that green laser excitation is superior to blue and yellow lasers' excitation for the production of high contrast fluorescence images. In addition, a spectral separation method for overlapped fingerprints/palm prints on a plaster wall was proposed using new images converted by the division and subtraction of two single wavelength images constructed based on measured hyperspectral data (HSD). In practical tests, the relative isolation of two overlapped fingerprints/palm prints was successful in twelve out of seventeen cases. Only one fingerprint/palm print was extracted for an additional three cases. These results revealed that the feasibility of overlapped fingerprint/palm print spectral separation depends on the difference in the temporal degeneration of each fluorescence spectrum. The present results demonstrate that a combination of a portable HSI and CW green laser has considerable potential for the identification and detection of untreated latent fingerprints/palm prints on the walls under study, while the use of HSD makes it practically possible for doubly overlapped fingerprints/palm prints to be separated spectrally.

1. Introduction

Since the first demonstration of fingerprint detection with inherent fluorescence [1], fluorescent detection of fingerprints has been studied [2–4]. Ultraviolet (UV) lasers are typically used as excitation sources, because fingerprint residues such as amino acids absorb light in the UV to deep UV wavelength region. However, it should be noted that excitation wavelengths shorter than 310 nm damage the degraded DNA contained in fingerprint residues. Fingerprint residues also include components that absorb light in the blue-green wavelength region and fluoresce in the green-red or yellow-red wavelength region [3,5]. It is also known that the components of deposited fingerprints suffer photochemical and thermal degeneration [4,6–11]. Therefore, it is to be expected that the inherent fluorescence also changes. This has been demonstrated in terms of the photochemical degeneration process by Akiba et al. [4], who observed the red shift of the fluorescence spectrum peak after continuous UV-laser irradiation. This suggests a possibility that fluorescence spectra are measures of the degree of degeneration of the corresponding fluorescence components.

The hyperspectral imaging technique [12–17] is an outstanding method that measures a large data cube consisting of a series of optical images recorded at each wavelength, which is determined by the spectral resolution, in the wavelength region of interest [13], called hyperspectral data (HSD), within a short time. The equipment used to measure HSD is generally called a hyperspectral imager (HSI). The potential of this device to detect latent

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fingerprints treated by chemicals has been evaluated [18–21]. In this article, we examine the potential usability of a combination of a continuous wave (CW) visible laser and a portable HSI in order to visualize and detect untreated latent fingerprints on walls that were previously excluded as investigation objects in a crime scene. We also devise an approach to separating overlapped fingerprints based on HSD.

A part of the present study was presented at the 66th Annual Scientific Meeting of AAFS on Feb 19, 2014 and at the 22nd International Symposium on the Forensic Sciences of ANZFSS on Sept 3, 2014.

2. Materials and methods

2.1. HSI

A portable HSI was developed and is shown in Fig. 1, while details of its design concept and mechanisms have been given elsewhere [13–15,20]. Briefly, light passing through a 30-μm-wide slit is dispersed by an imaging spectrograph (ImSpector V10E; Specim, Oulu, Finland) and detected by an electron-multiplying charge-coupled device (EMCCD) camera (Luca, DL-658M-OEM; Andor Technology PLC, Belfast, UK). A HSD is obtained by rotating the unit consisting of the imaging spectrograph and EMCCD camera. The rotation is controlled by a computer, which maintains the distance from the target through the use of an auto-focusing module [15]. To aid measurements, another CCD camera (IVC-400B, Mu TEC Co., Ltd, Tokyo, Japan) monitors the target, capturing the segment that is undergoing hyperspectral imaging.

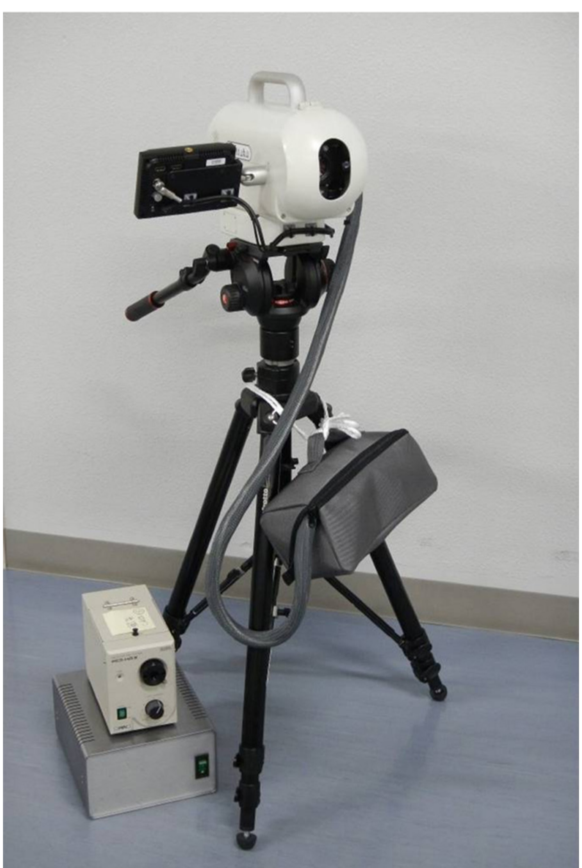

Fig. 1. Snapshot of the portable HSI developed for identifying and detecting untreated latent fingerprints.

The principal specifications of the HSI are as follows: Minimum field of view: 30 × 30 mm; spatial resolution: 46 μm; effective wavelength range: 440–800 nm; wavelength resolution: 2.0 nm; HSD: 658 (line pixels) × 638 (scan pixels) × 248 (spectral pixels); and HSD acquisition time: 13–42 s, depending on the exposure time per line. For the reflection measurements, illumination was provided by a 100-W halogen lamp (PCS-HRX; Nippon P/I Co., Ltd. Tokyo, Japan) through an optical fiber. For the following fluorescence measurements, a sharp-cut long-pass filter of ϕ30 mm with an appropriate cut-off wavelength was used.

2.2. Fluorescence measurements

In this study, portable CW lasers oscillated at 460, 532, and 577 nm (TracER 460NM2W, 532NM8W, and 577NM5W; Coherent Corporation, Santa Clara, USA) were used as excitation sources and operated in the diffusion mode. When the excitation wavelength dependence of fluorescent images was examined using all the CW lasers, an output power was maintained at 1.98 W for each laser. Otherwise, the CW green laser was used alone and operated at an output power of 4 W. The fluorescence from each target was measured by the HSI, to which an appropriate sharp-cut long-pass filter (SCF-50S-56O and SCF-50S-60R; Sigma Koki, Tokyo, Japan) was attached according to the excitation lasers, so as to reject the laser spectra.

2.3. Samples

We prepared not only intended samples but also samples presenting a situation close to a crime scene.

2.3.1. A latent palm print sample on a steel wall

The background wall was made of steel sheeting, to the surface of which a polyethylene resin was applied and baked at 190–200 °C. Neither fingerprint nor palm print on the wall was visible to the naked eye under ordinary lightning of fluorescent lamps. In order to look for latent fingerprints/palm prints on the wall, the CW green laser was used. The palm print whose area was the largest was selected as a sample close to a criminal scene, for which the excitation wavelength dependence was examined.

2.3.2. Doubly overlapped fingerprints/palm prints samples on a plaster wall

Overlapped fingerprint/palm print samples were prepared on a plaster wall. Six Japanese male, whose age ranged from 31 to 48 years old (averaged age: 39.5 years old), took part in preparing the samples. They were in good health and their eating habit was normal. The nature of secretion of all donors was natural. In depositing finger marks, forefront touching was used. Keeping a situation close to a real crime scene, no specific protocol was used. The time lag between the first and second depositions was varied. The sample preparation method is summarized in Table 1. The samples 1 to 11 (12 to 17) correspond to the intended samples (the samples representing a situation close to a criminal scene). For the samples 12 to 17, the first fingerprint/palm print, which existed from the beginning, was looked for using the CW green laser as in the case of the sample on the steel based wall.

No sample was visible to the naked eye under ordinary lightning of fluorescent lamps. For these samples, fluorescence measurements were performed under the CW green laser excitation. The time period between the fluorescence measurement and the first (second) fingerprint deposition was treated as a parameter for the intended samples (the samples close to a criminal scene). Note that multiply overlapped samples were outside the scope of the present study. Digital color images of all overlapped fingerprint/palm print