Development of a vein imaging system with minimum value operation and scanned stripe pattern projection for contactless vein authentication

Sota Nakazawa[1], Keiichiro Kagawa[2], Takashi Komuro[3], Kazuya Nakano[4], Hiroyuki Suzuki[5]
1 Graduate School of Integrated Science and Technology, Shizuoka University
3-5-1 Johoku, Hamamatsu, 432-8011 Japan
2 Research Institute of Electronics, Shizuoka University
3-5-1 Johoku, Hamamatsu, 432-8011 Japan
3 Graduate School of Science and Engineering, Saitama University
255 Okubo, Saitama, 338-8570 Japan
4 Department of Science and Technology, Faculty of Science and Technology, Seikei University
3-3-1 Kita, Musashino, 180-8633 Japan
5 Gunma University Center for Mathematics and Data Science
4-2 Aramaki, Maebashi, 371-8510 Japan
E-mail: kagawa@idl.rie.shizuoka.ac.jp

Abstract: There are several issues in conventional vein imaging such as saturation of pixel values at the finger edges in the transmissive configuration and low contrast due to large reflection at the skin surface in the reflective configuration with uniform illumination. We propose a reflective vein imaging system with minimum value operation and a scanned stripe pattern projection to solve these issues. The proposed method enables us to image venous patterns at a high contrast although it is based on the reflective configuration. In the experiments, we obtained clearer venous images compared to the conventional methods.

Keywords: vein imaging, non-line of sight imaging

1. Introduction

Vein authentication has become an important authentication method because it is noninvasive and unaffected by external factors such as masks and makeup. Reflected-light and transmitted-light vein imaging systems using LEDs have been proposed[1][2].

However, because the general reflected-light system uses uniform irradiation, the contrast of the vessel pattern is reduced due to a large amount of reflected light on the skin surface. In addition, in a transmitted light system, strong transmission light at the finger edges causes the pixel values to saturate, resulting in a decrease in the recognition accuracy of the finger shape.

In this study, we propose a reflected-light vein imaging system using multi-line scanning to solve these problems. The proposed method is the non-line of sight imaging. With the constructed imaging system, the images of palm are taken, and the vein patterns are visualized by applying a minimum value operation to the captured images.

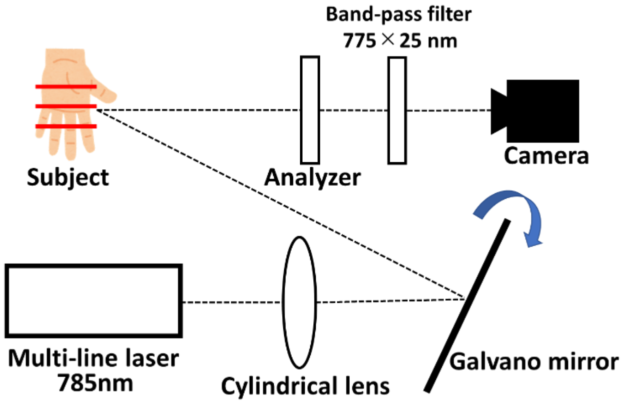

Fig. 1. Imaging system with scanned strip-pattern projection

2. Reflected-light vein imaging system with multi-line scanning

Fig. 1 shows the optical setup of the proposed method. A linearly polarized multi-line laser module (Osela, SL-785-120-S-A-30-19L0.9) emits multiple parallel lines. After adjusting the radiation angle with a cylindrical lens so that the illuminated area and the observation target (palm) are almost the same size, the multi-line pattern is projected onto the target with scanning it vertically using a Galvano mirror whose scanned angle is controlled by a periodic triangular wave voltage. An analyzer to remove surface reflection components and a bandpass filter (center wavelength: 775 nm, transmission wavelength width: 25 nm) to reduce ambient light are placed between the camera and the object to be observed.

The scanning area of the multi-line light matches to the interval of the multiple lines, and *N* images are captured in a half period of the scanning[3][4]. When N = 4, the images are taken as shown in Fig. 2.

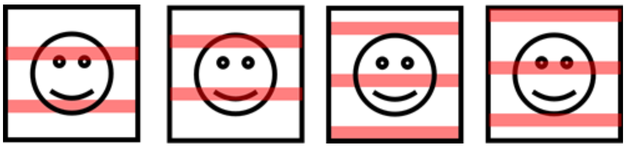

Fig. 2. Scanning of multiple lines (N = 4)

3. Minimum value operation

If the (source-detector) separation between the positions of light irradiation and detection is denoted by ρ, the measured depth in average, *z*, is represented by the following equations.

$$z = \frac{1}{2}\sqrt{\frac{\rho}{\mu_{eff}}} \qquad (1)$$

$$\mu_{eff} = \sqrt{3\mu_a \mu'_s} \qquad (2)$$

μ_a and μ'_s are absorptions and reduced scattering coefficients of skin. When we consider typical optical parameters of skin at a wavelength of 785nm such as $\mu'_s = 1.0\ \mathrm{mm}^{-1}$ and $\mu'_s = 1.0\ \mathrm{mm}^{-1}$, z becomes 2.686 mm for $\rho = 5.0$ mm.

This depth corresponds to that of venous blood vessels in the dermis. The pixel value is considered to be minimal when the pixel is in the center of two adjacent lines. Therefore, for the N images captured, an operation to find the smallest pixel value at every pixel is performed, which we call a minimum value operation. Thus, we obtain an image to enhance the vein vascular pattern by extracting the absorption at z and suppressing the surface reflection of the projected light.

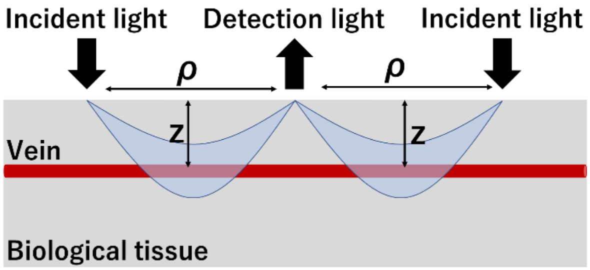

Fig. 3. Light propagation in biological tissues

4. Experimental Results

The specifications of the measurement system are shown in Table 1.

Table 1. Specifications of the imaging system.

Number of images(N)	8
Camera	ximea xiQ MQ022CG-CM
Exposure time	10 ms
Laser wavelength	785 nm
Line spacing [7]	10 mm
Frame rate	100 fps
Band-pass filter	775 × 25 nm

Fig. 4 shows the captured images for eight scanning steps. Fig. 5 shows a vein image reproduced by the minimum value operation. For comparison, the images captured by conventional transmitted-light type and a reflected-light type with uniform illumination are shown in Fig. 6. Overall, the proposed methods provide the best vein image in terms of contrast and saturation.

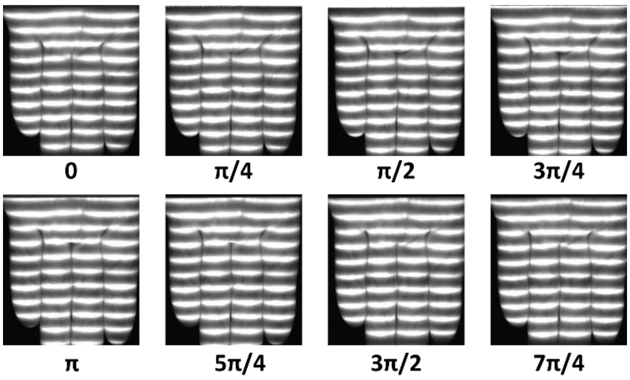

Fig. 4. Images captured by the proposed method (N = 8)

5. Conclusion

A vein imaging method using a scanned multi-line and the minimum value operation was proposed. The experimental results showed that the proposed method could alleviate the pixel value saturation at the finger edges and enhanced the contrast of the venous vascular patterns.

Acknowledgments

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Fig. 5. Stripe-light illumination & minimum operation

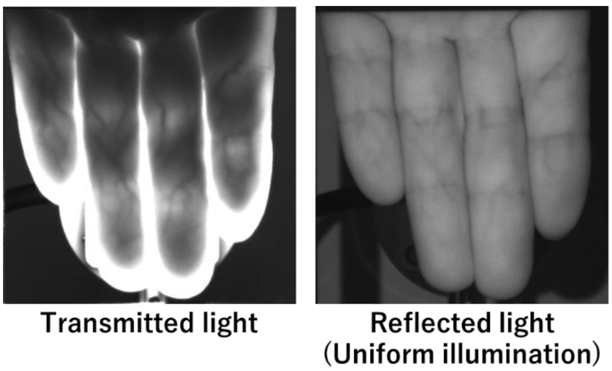

Fig. 6. Vein images captured by conventional method