Effect of polarization filters on hand vein sample image quality

Christof Kauba and Andreas Uhl
Department of Artifical Intelligence and Human Interfaces
University of Salzburg
5020 Salzburg, AUSTRIA
{ckauba,uhl}@cs.sbg.ac.at

Abstract

This is work about using (polarization) filters in hand-vein biometric recognition. Experiments clearly demonstrate that the respective application of linear polarization, circular polarization, and band pass filters on the capturing lens improve hand-vein sample image quality across a considerable range of specific vascular image quality metrics. In case the illumination source is additionally equipped with a linear polarization filter (in relative perpendicular direction), further quality improvement could not be demonstrated.

1 Introduction

Biometric authentication systems are well established today as they exhibit many advantages over traditional password and token based ones. The most prominent examples are fingerprint and face recognition systems. In recent times, authentication based on finger- and hand-veins gains more attention as it provides advantages over the well established fingerprint techniques (Uhl et al. [2019]). Over the past few years, pioneered by Fujitsu's PalmSecure palm vein authentication technology, major technology companies including Tencent (i.e. Tencent PalmAI – Weixin/WeChat Pay) and Amazon (i.e. Amazon One) have released palm vein scanning-based payment systems, which have been applied to various scenarios such as grocery shops, subway stations, and sports venues, reaching tens of millions of registered users (Kuang et al. [2024]).

Hand-vein recognition utilizes the pattern of the blood vessels inside the hand of a human, which is captured using near-infrared (NIR) illumination. The vein patterns are neither susceptible to abrasion nor to skin surface conditions. However, the vein images have low contrast and quality in general and the vein structure may be influenced by temperature, physical activity and certain injuries and diseases (Kirchgasser et al. [2019]). NIR illumination is the key to finger- and hand-vein recognition. The positioning of the light source with respect to the camera and the subject's finger or hand plays an important role. We distinguish between reflected light, where the light source and the camera are placed on the same side of the hand and the light is reflected from the skin surface and deeper tissue layers and trans-illumination, where the light source and the camera are located on the opposite side of the hand and the light passes through tissue.

One way to deal with the low quality and low contrast of hand-vein imagery is to consider polarized NIR light to better cope with reflections and scattering light. In two keynote talks given at the IEEE/IAPR International Joint Conferences on Biometrics (IJCB) in 2023 and 2024, the Amazon One team postulated the usage of polarized NIR in their system, while hardly any details have been disclosed. On the other hand, the WeChat Pay group published work in this direction: In (Sun et al. [2023]) they report on the usage of polarization in a traditional hand-vein imaging system (however, only providing visual examples on the effects of doing so) while in (Kuang et al. [2024]) they suggest a polarization-selective metalens, a highly specialized imaging system, for hand-vein acquisition.

The Third Austrian Symposium on AI, Robotics, and Vision (AIROV26).

In this work, we extend a traditional hand-vein acquisition system (Kauba and Uhl [2018]) by employing a set of filters including circular and linear polarization filters. Instead of only considering visual examples as a “proof” of improved sample quality (as done in (Sun et al. [2023])), we apply a set of vascular image quality metrics to the data, which have been introduced to predict the suitability of sample data in a subsequent recognition process. In Section 2, we describe the experiments conducted in terms of the acquisition setup and the vascular image quality metrics employed. In Section 3, we present the results of applying the image quality metrics to the acquired data while providing conclusions and an outlook to further work in this direction in the Conclusion.

2 Experimental Setup

2.1 Hand-Vein Capturing Device

The hand-vein samples for the experiments were acquired using a custom built capturing device introduced earlier (Kauba and Uhl [2018]), with modified reflected light emitters. This capturing devices uses a NIR enhanced industrial camera, IDS Imaging UI-1240ML-NIR with a maximum resolution of 1280x1024 pixels together with a 9 mm wide-angle-lens. The used polarization filters can be screwed on the front of the lens. The device has two illumination sources, located at the top left and top right side wall, each targeting the wooden inside wall rather then directly targeting the hand surface. Each illumination source consists of two rows of 8 NIR-LEDs, one row with 850 nm LEDs, the other one with 950 nm LEDs – the former was used in data acquisition for the experiments. The brightness of the LEDs can be controlled to achieve an optimal contrast.

2.2 Polarization Filters

Several different filters, including one circular and three linear polarization filters, have been applied to the lens:

Lens without any filter: No filter was applied to the lens.
BN850: narrow band-pass filter with a center frequency of 850 nm.
PR032: linear polarisation filter from MIDOPT with a wavelength band of 400 - 700 nm.
PR120: linear polarisation filter (high contrast version) from MIDOPT with a wavelength band of 400 - 750 nm.
PR1000: linear polarisation filter (high contrast version) from MIDOPT with a wavelength band of 400 - 2000 nm.
PC052: circular polarisation filter from MIDOPT with a wavelength band of 450 - 650 nm.

In addition, the following filter has been applied to the illumination sources optionally:
PS1000: linear polarizing film from MIDOPT with a wavelength band of 400 - 2000 nm. In case of its application, the polarization direction is perpendicular to that of the lens mounted linear polarization filters. Fig. 1 illustrates the illumination and capturing principle with linear polarisation filters. Details and datasheets for the filters can be found at: https://midopt.com/filters/polarizing/

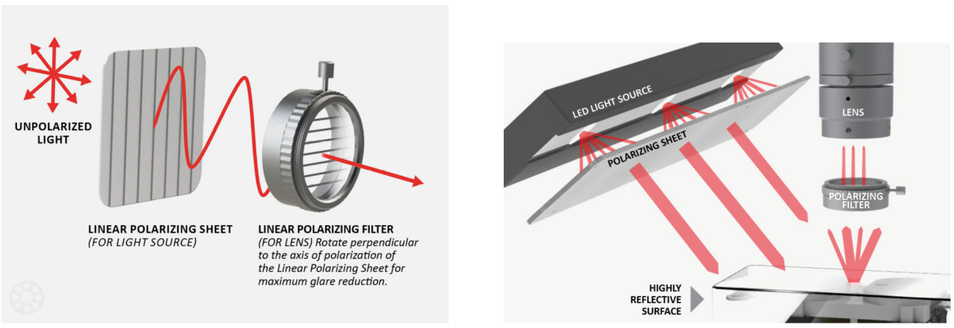

Figure 1: Linear polarisation filter applied to illumination source and camera lens. Pictures from: https://midopt.com/filters/polarizing/

2.3 Capturing Protocol

Hand-vein sample data from a single subject have been captured in different illumination and polarization filter settings, respectively:

- Outdoor (with direct sunlight or with cloudy sky)
- Indoor (with artificial ceiling light or with light shining through window only)
- Frontal lid closed or frontal lid open

The frontal lid of the capturing device is meant to protect the imaging process from incident light. Per default it is closed, but to study the effect of even more challenging acquisition, we have added settings with this frontal lid being removed (i.e. “frontal lid open”). For each of those settings, all of the aforementioned polarization filters have been applied. In addition, the polarization filter on the illumination source has been applied as well in selected settings. For each configuration, 5 dorsal and 5 palmar hand-vein samples have been acquired, and their quality values have been averaged for the experimental results provided. Figure 2 displays three dorsal example images as captured for the experiments, overall, roughly 1600 samples have been taken.

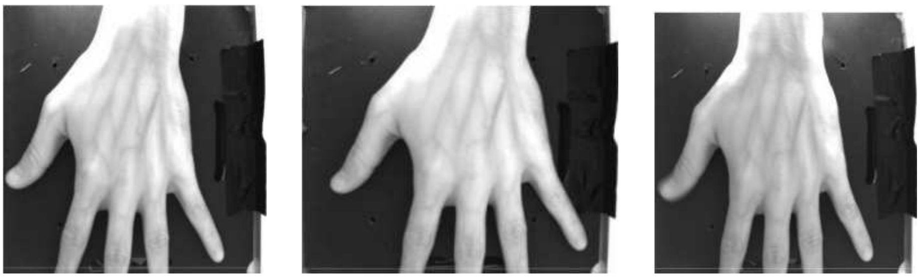

Figure 2: Example dorsal sample images captured with sensors PC052, PR032 and PR1000 (from left to right): Capturing in direct sunlight with lid of capturing box open.

2.4 Image Quality Metrics

To evaluate the impact of the polarization filters, the following hand-vein specific (all but the last) and general image quality metrics (NIQE) were employed (see Kirchgasser et al. [2025] for an overview):
Wang (Wang et al. [2017]): This palm-vein specific quality metric is based on clarity and brightness uniformity.
GCF (Matkovic et al. [2005]): The Global Contrast Factor (GCF) should correspond closer to the human perception of contrast. GCF uses contrasts at various resolution levels to compute the overall contrast.
HSNR (Ma et al. [2013]): The HSNR (signal to noise ratio based on the human visual system) finger-vein image quality evaluation index is based on both, the human visual characteristics and finger-vein image characteristics, by combining several features: contrast score, effective area score, finger shifting score and a noise level.
GLES (Yang et al. [2013]): The grey level entropy score is based on a discrete image entropy calculation.
ES (Yang et al. [2013]): The entropy score is also based on a discrete image entropy calculation, with only slight variation relative to GLES.
NIQE (Saad and Bovik [2012]): Is a general purpose no-reference opinion-unaware and distortion unaware image quality metric.
For all metrics but NIQE (where the opposite is true), larger values indicate higher sample image quality.

3 Experimental Results

Results in Tables 1 and 2 are sample-averaged quality metric values. In the “No Filter” row, samples are acquired by the sensor without any filter being mounted. For all other rows, filters denoted in the first column are screwed on the lens. The first metric value is obtained with plain illumination source, the second value originates from the additional application of polarizing film to the illumination source. In Table 1, we display the results for the most controlled acquisition environment, i.e. indoor capturing with artificial light from the ceiling and closed frontal lid.

Table 1: Controlled environment: Indoor capturing (artificial ceiling light) with closed frontal lid.

	Wang	GCF	GLES	ES	HSNR	NIQE
No Filter	0.32	1.54	0.94	5.92	86.4	8.02
BN850	0.47/0.52	2.23/1.51	1.00/0.98	7.66/6.49	87.8/95.6	8.22/10.2
PC052	0.34/0.41	1.68/1.65	0.98/0.98	6.31/6.81	87.9/88.9	10.7/8.56
PR032	0.55/0.42	1.63/0.98	0.98/0.99	6.08/7.24	90.2/91.9	13.0/7.98
PR1000	0.57/0.35	1.50/2.00	0.98/0.99	6.12/6.80	93.5/93.0	12.6/11.0
PR120	0.50/0.47	2.83/2.00	0.99/0.99	6.98/6.82	94.3/92.8	11.0/8.98

In green, we depict the overall best metric value per image quality metric. We notice that this value is inconsistently attained: With and without polarization film on illumination source and for different filters (only the circular polarization filter PC052 values never show up in green). In any case, for all quality metrics specific to vascular data, the metric values observed with filters on the lens are superior to those without filter being applied ("No Filter"; only for the GCF metric we observe one inferior value indicated in red). For the NIQE quality metric, all but a single value are worse in case of filters being applied, i.e. indicating better quality for the "No Filter" setting. In Table 2, we display the results for the most uncontrolled acquisition environment considered, outdoor capturing with cloudy sky and open frontal lid.

Table 2: Uncontrolled environment: Outdoor capturing (cloudy sky) with open frontal lid

	Wang	GCF	GLES	ES	HSNR	NIQE
No Filter	0.32	1.21	0.81	5.68	84.4	8.05
BN850	0.36/0.47	2.16/2.00	0.97/0.99	7.39/6.82	86.6/92.8	8.10/8.98
PC052	0.31/0.42	1.54/0.98	0.94/0.99	6.11/7.24	85.9/91.9	9.45/7.98
PR032	0.49/0.35	1.49/2.00	0.87/0.99	6.12/5.80	88.2/93.0	10.2/11.0
PR1000	0.42/0.41	1.20/1.65	0.84/0.98	6.12/6.81	90.5/88.9	10.4/8.56
PR120	0.41/0.52	2.63/1.51	0.87/0.98	6.18/6.49	91.3/95.6	9.18/10.2

Considering the "No Filter" setting, the quality metric values for the uncontrolled environment are consistently inferior as compared to the controlled environment (as it is expected; only for the Wang metric, the values are identical and for NIQE, the value for uncontrolled setting is slightly superior). In green, we again depict the overall best metric value per image quality metric. We notice that this value is still inconsistently attained, but not entirely random: In four out of six quality metrics green values are observed with polarization film on illumination source and the values of the linear polarization filter PR120 show up three times in green. In any case, again for all but two quality metrics specific to vascular data, the metric values observed with filters on the lens are superior to those without filter being applied ("No Filter"; exceptions where we observe inferior values are indicated in red: Wang & GCF for one filter and negligible decrease). Again, for the NIQE quality metric, all but a single value are worse in case of filters being applied.

4 Conclusion

Experimental results clearly indicate that applying polarization (and other filters) to the lens, improves hand-vein sample image quality across the considered range of specific vascular quality metrics. However, we have found no empirical evidence that equipping illumination source additionally with a linear polarization foil (in relative perpendicular direction to the lens filters if applicable) further enhances those quality values. Also, linear polarization does not turn out to be superior to circular polarization and band-pass filtering. NIQE behaves antithetic to the vascular sample quality metrics, which is not too surprising, as it is designed to work on natural images captured under visible light.

In future work we aim to confirm these findings in actual recognition experiments, confirming results in (Kuang et al. [2024]) for a standard hand-vein acquisition system.

Acknowledgments and Disclosure of Funding

We thank Latif Muhammad Ummar who has captured the analyzed hand vein sample data in the context of a Multimedia Technologies Seminar at the University of Salzburg (master's program on Applied Geoinformatics).

References

Andreas Uhl, Christoph Busch, Sebastien Marcel, and Raymond Veldhuis. *Handbook of Vascular Biometrics*. Advances in Computer Vision and Pattern Recognition. Springer Nature Switzerland AG, Cham, Switzerland, 2019. ISBN 978-3-030-27731-4. doi: 10.1007/978-3-030-27731-4.

Ying Kuang, Shuai Wang, Bincheng Mo, Shiyou Sun, Kai Xia, and Yuanmu Yang. Palm vein imaging using a polarization-selective metalens with wide field-of-view and extended depth-of-field. *npj Nanophotonics*, 1, 07 2024. doi: 10.1038/s44310-024-00027-4.

Simon Kirchgasser, Christof Kauba, and Andreas Uhl. Towards understanding acquisition conditions influencing finger-vein recognition. In Andreas Uhl, Christoph Busch, Sebastien Marcel, and Raymond Veldhuis, editors, *Handbook of Vascular Biometrics*, chapter 7, pages 177–199. Springer Nature Switzerland AG, Cham, Switzerland, 2019. ISBN 978-3-030-27731-4. doi: 10.1007/978-3-030-27731-4_7.

Shiyou Sun, Zheng'ao Wang, Fanglin Chen, and Kai Xia. Palm vein imaging enhancement in highly reflective hand scenarios. In *2023 8th International Conference on Image, Vision and Computing (ICIVC)*, pages 438–442, 2023. doi: 10.1109/ICIVC58118.2023.10270232.

Christof Kauba and Andreas Uhl. Shedding light on the veins - reflected light or transillumination in hand-vein recognition. In *Proceedings of the 11th IAPR/IEEE International Conference on Biometrics (ICB'18)*, pages 1–8, Gold Coast, Queensland, Australia, 2018. doi: 10.1109/ICB2018.2018.00050. URL `https://doi.org/10.1109/ICB2018.2018.00050`.

Simon Kirchgasser, Christof Kauba, Georg Wimmer, and Andreas Uhl. Advanced image quality assessment for hand- and finger-vein biometrics. *IET Biometrics*, 2025(1):8869140, 2025. doi: https://doi.org/10.1049/bme2/8869140.

Chunyi Wang, Xinhua Zeng, Xiongwei Sun, Wengong Dong, and Zede Zhu. Quality assessment on near infrared palm vein image. In *2017 32nd Youth academic annual conference of Chinese association of automation (YAC)*, pages 1127–1130. IEEE, 2017.

Kresimir Matkovic, László Neumann, Attila Neumann, Thomas Psik, Werner Purgathofer, et al. Global contrast factor-a new approach to image contrast. In *Computational Aesthetics*, pages 159–167, 2005.

Hui Ma, Feng Peng Cui, and Popoola Oluwatoyin P. A non-contact finger vein image quality assessment method. *Applied Mechanics and Materials*, 239:986–989, 2013.

Lu Yang, Gongping Yang, Yilong Yin, and Rongyang Xiao. Finger vein image quality evaluation using support vector machines. *Optical engineering*, 52(2):027003–027003, 2013.

Michele A Saad and Alan C Bovik. Blind quality assessment of videos using a model of natural scene statistics and motion coherency. In *2012 Conference Record of the Forty Sixth Asilomar Conference on Signals, Systems and Computers (ASILOMAR)*, pages 332–336. IEEE, 2012.