Dual-Channel Digital Holographic Imaging for Fingerprint Biometrics

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Abstract: We introduce a dual-channel, polarization-sensitive holographic phase imaging system for fingerprint biometrics. From two orthogonal polarization channels, we extracted fingerprint phase images, showing unique features that are detectable only in one of the polarization channels.

OCIS codes: (090.1995) Digital Holography; (260.5430) Polarization.

1. Introduction

Biometric authentication methods take advantage of intrinsic individual behavioral or physical characteristics such as: DNA, voice, iris and fingerprints. Among these, fingerprint recognition is one of the oldest and most widely used biometric method [1]. There are two main types of fingerprint recognition methods, where classification is determined by the process of the fingerprint formation. "Latent prints" are fingerprints which were left unintentionally, and their detection is highly difficult to the bare eye. "Exemplar prints" refers to a high-quality fingerprint samples that were directly acquired by applying ink on the finger and pressing it against a surface such as a paper or a coverslip. Nowadays, in the evolving digital-based reality, where smartphones, which contain personal and confidential information, are largely consumed, and where wireless network communication becomes part of our everyday routine, we are forced to discover new reliable, easy-to-use, low-cost authentication devices.

Here, we introduce a novel, wide-field, transmission digital off-axis holography system. The system, shown in Fig. 1, is based on single, tilted cube beamsplitter, and enables simultaneous recording of two twin interferograms in orthogonal polarization states, using a single exposure of a single digital camera. We hypothesize that due to the fingerprint organized line morphology, a certain degree of birefringence may appear in local areas [1-3]. Hence, in addition to the three dimensional structure of the fingerprint, which is extracted by quantitative phase measurement [4], it is possible to derive birefringence properties which may be regarded as a new, unique, biometric parameters.

2. Sample Preparation and its Imaging

A thin layer of ultrasound gel (AquaSonic Clear) is speared on the experimenter's finger, and pressed against half of a microscope cover glass. The sample is place on a mount and the twin interferograms are recorded using a CMOS camera.

3. Experimental Setup

In the proposed system, illustrated in Fig. 1, a HeNe laser, linearly polarized at 45 degrees, is spatially filtered by a 25µm pinhole P, and expanded twice by lenses $L_{0\text{-}3}$. Then, half of the illuminating beam (1" in diameter) passes through the fingerprint pattern and serves as the interferometric sample arm.

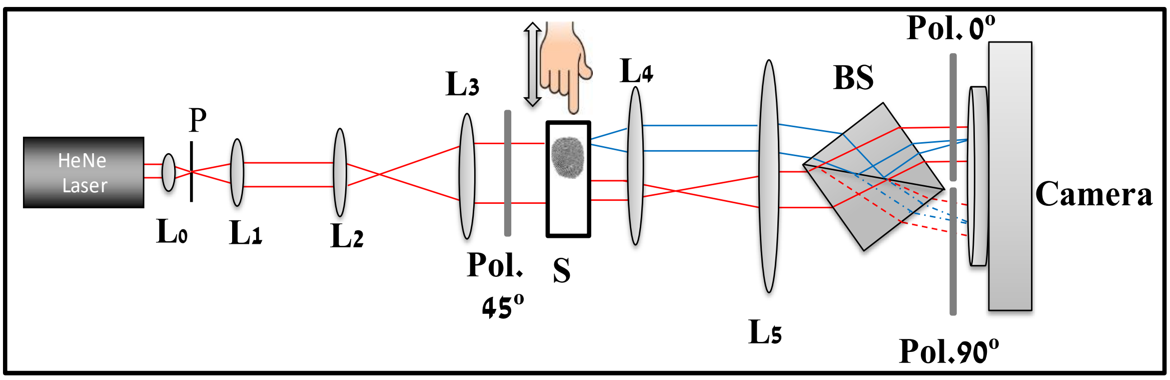

Fig .1. Dual-channel holographic phase imaging system for fingerprint biometrics. $L_{1\text{-}5}$ lenses, P - pinhole, S - sample, BS - cube beamsplitter, Pol. - polarizer. Blue lines - sample arm, red lines - reference arm.

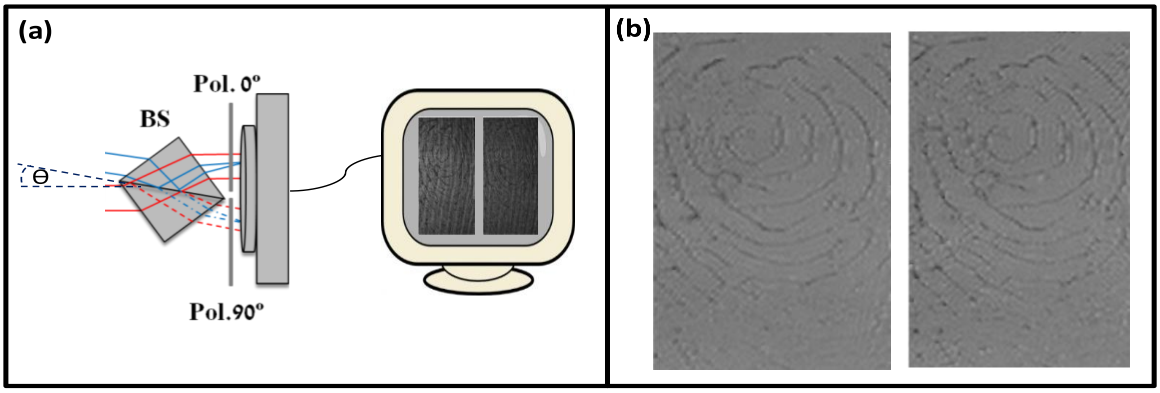

Fig.2. (a) Tilted-beamsplitter interferometer configuration. (b) Fingerprint phase images in two orthogonal polarization channels.

The second half of the beam does not interact with the fingerprint pattern on the sample and thus serves as the reference arm. The 4f lens system delivers spherical waves diverging from the fingerprint pattern to the upper half of the tilted beamsplitter cube, and plane waves from the empty lower part of the coverslip to the lower half of the beamsplitter cube.

The off axis configuration of the beamsplitter and the specific illumination technique enables creating two twin off-axis holograms (see Fig. 2(a)) on the same camera plane, where the angle θ determines the spatial frequency of the fringes. Two orthogonal polarizers are mounted close to the camera, dividing the beam into two orthogonal polarized beams reaching the camera simultaneously. Each of the hologram is processed to the quantitative phase profile of the sample using digital spatial filtering, followed by a phase unwrapping algorithm [4].

4. Results and Conclusions

In close comparison between the two orthogonally-polarized phase images, we have noticed that in certain areas, which are characterized by straight and organized line morphology, there are considerable differences between the phase channels (see Fig. 3). For example, vertical lines in these areas are clearly seen in the 90° polarization channel and invisible in the 0° polarization channel, and the other way around.

We attribute this phenomena, where the phase is overexpressed in one polarization state, to a local birefringence resulted from the fingerprint morphology. These initial results show the potential of phase-measured fingerprint birefringence as a new and unique biometric property.

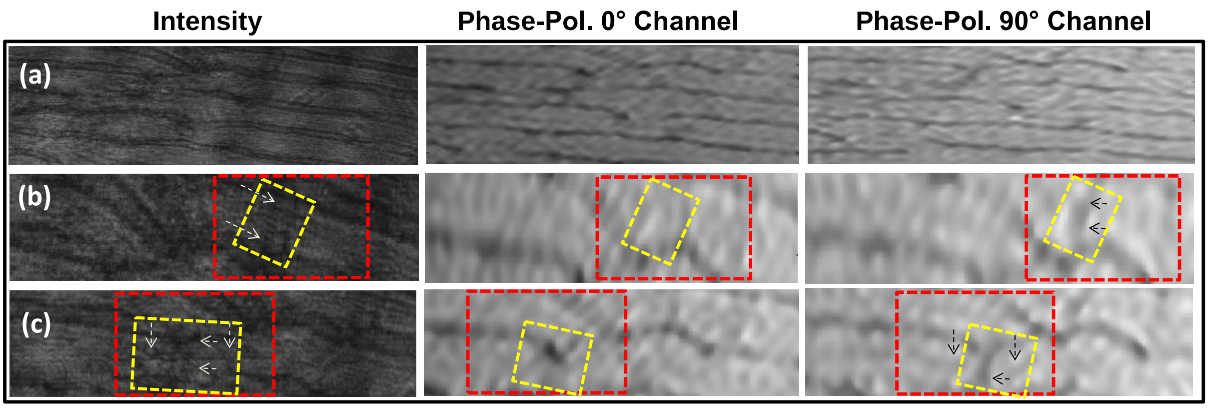

Fig. 3. Experimental results: (a) Intensity and phase images in the region of interest (ROI). (b)Morphological differences in the ROI. (c) Additional morphological differences in the ROI.

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