

Fingerprint Detection and Analysis Using Talbot Interferometry

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Abstract In the present communication, a full field technique for mapping latent fingerprint using Talbot interferometry has been proposed. Collimated light from He–Ne laser illuminates a specimen comprising of a fingerprint implanted onto a reflecting surface. Reflected light carries information regarding the depth and orientation of furrows and ridges in the fingerprint. The topological information of the fingerprint is retrieved using phase shifting interferometric technique. The slope of the phase provides the information regarding variation in ridges of latent fingerprint. The proposed technique does not require any kind of chemical or physical treatment.

1 Introduction

Fingerprint is a unique and distinguishable pattern of curves, which makes its detection one of the biometric parameter of importance in forensic science [1]. A fingerprint impression is obtained on a surface due to friction of ridge skin with the surface. The fingerprint is composed of ridge lines and valleys. The ridge lines are mainly parallel but bifurcations as well as terminations also appear. The pattern in a fingerprint can be basically classified as arch, loop and whorl. Wide ranges of techniques have been developed for detection and analysis of finger prints. The important things of concern in choosing a technique are the time taken in analyzing the results, simplicity of the setup and portability. Based on the time consumption, the techniques can be classified as based on the physical and chemical processing of a sample and those based on real-time analysis. The techniques based on physical

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and chemical processing of a sample, are time consuming and use hazardous chemicals. Also they are relatively older techniques. Real-time techniques are comparatively safer and faster. Optical Coherence Tomography (OCT) is one such technique. OCT methods have been reported [2–10] to recognize genuine fingerprints by providing in-depth information of the finger. Huang et al. [2] presented fringe projection based technique to obtain 3D fingerprint with color texture information in real time by projecting color sinusoidal fringe patterns onto a finger surface. Dubey et al. [9, 10] described full field swept source OCT based technique to detect latent fingerprint. The authors used super-luminescent diode and acousto-optic tunable filter as wavelength tuning device for non-mechanical scanning. Interferometric systems including the OCT based systems have relatively high sensitivity to the environmental perturbations and are difficult to align at locations outside the laboratory. Also, relatively high cost of tunable laser source increases the overall system cost.

In present communication, we report application of Talbot interferometer (TI) for fingerprint detection and mapping. To increase the sensitivity and reliability in detection and identification process, a four-step phase shifting technique has been incorporated. The phase profiling of the latent fingerprint can be achieved by visualization of the 2D and 3D phase plots obtained by mapping the phase profile of fingerprints. The technique is full field and incorporates amplitude and phase profiling of the latent fingerprints. Amplitude profiling can be attained by analyzing the light reflected from the specimen. The phase profiling can be achieved by visualization of the 2D and 3D phase plots. The experimental arrangement is simple, inexpensive and flexible.

2 Basic Theory

Figure 1 shows the schematic of experimental setup based on TI. TI involve two gratings with a separation equals to Talbot distance. When a plane wave is incident upon a diffraction grating, its image is repeated at regular distances away from the grating plane and is given by $d = 2p^2/\lambda$, where p is the period of the grating and λ is the wavelength of the light used. The regular distance is called the Talbot length, and the repeated images formed at regular intervals are called as self images or Talbot images. Various applications of the TI have been reported in the literature [11, 12].

The intensity distribution, formed at a point (x, y) on the CCD chip, is a co-sinusoidal function which can be expressed as:

$$I(x, y) = A(x, y) + B(x, y)\cos[\psi(x, y) + \delta] \quad (1)$$

where, $A(x, y)$ is average intensity, $B(x, y)$ is intensity modulation, $\psi(x, y)$ is the desired phase information and δ is the known phase shift. In the experimental setup as shown in Fig. 1, the reflected beam from the specimen, carrying information

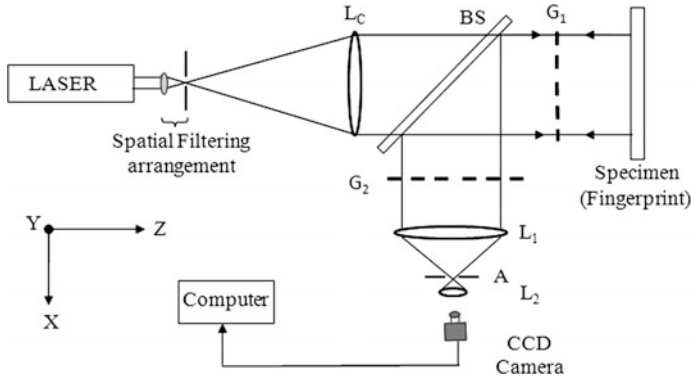


Fig. 1 Schematic of experimental arrangement used for fingerprint detection using Talbot interferometer

regarding the details in the finger print is analysed using the TI. The TI comprises of a pair of gratings of period p . One of the two gratings is shifted in four-steps such that the phase difference of $\pi/2$ results in each successive recording. Intensity profile of the grabbed fringe patterns is given by [12]

$$I_1(x, y) = A(x, y) + B(x, y)\cos[\psi(x, y)] \tag{2}$$

$$I_2(x, y) = A(x, y) + B(x, y)\cos\left[\psi(x, y) + \frac{1}{2}\pi\right] \tag{3}$$

$$I_3(x, y) = A(x, y) + B(x, y)\cos[\psi(x, y) + \pi] \tag{4}$$

$$I_4(x, y) = A(x, y) + B(x, y)\cos\left[\psi(x, y) + \frac{3}{2}\pi\right] \tag{5}$$

Phase at each point of the specimen can be determined from the above equations using the following relation

$$\psi(x, y) = \arctan\left[\frac{I_4 - I_2}{I_1 - I_3}\right] \tag{6}$$

The phase $\psi(x, y)$ is calculated using phase shifting algorithm and plotted against pixel position.

The deflection angle $\Phi(x, y)$ can be written as,

$$\Phi(x, y) = \frac{p}{2\pi d}\psi(x, y); \tag{7}$$

where p is the period of the grating. The deflection angle $\Phi(x, y)$ is related to $\psi(x, y)$ and is effectively the measure of the slope of the rays in the direction perpendicular

to the grating lines. The relative surface height $h(x, y)$ or depth of ridges can then be determined from the phase data by integrating [13]

$$h(x, y) = \frac{\lambda}{4\pi} \int \Phi(x, y) dx dy \quad (8)$$

3 Experimental Arrangement

Schematic of experimental arrangement for fingerprint detection using Talbot interferometry is shown in Fig. 1. Light from the laser of power 15 mW and wavelength 632 nm is spatially filtered and illuminates collimating lens L_C to obtain a collimated beam. The collimated beam after transmission through a beam splitter BS and grating G_1 , is incident on the specimen comprising of a fingerprint implanted on a plane reflecting surface. The collimated beam after transmission through the BS is incident on the specimen comprising of a fingerprint implanted on a plane reflecting surface. The back reflected light from the specimen has been diverted using beam splitter, towards a set of gratings G_1 and G_2 , each of pitch 0.08 mm and separated by a Talbot distance. The first self imaging plane is at 20 mm away from the first grating while the second grating was kept at fourth self imaging plane which was at 80 mm. The second grating was kept at fourth Talbot distance because it is not possible to keep the second grating at first Talbot plane due to small distance. The choice of grating pitch is according to their availability. The spatial filtering arrangement comprising of lens L_1 , L_2 and aperture A_2 was used in the setup. Focal lengths of lenses L_1 , L_2 are 250 mm and 40 mm respectively. The aperture A of variable size was used. One of the gratings was mounted on a precision translation stage. The grating has been shifted, in-plane, in four steps. Four subsequent patterns have been recorded using a CCD camera, and the phase shifting program in MATLAB environment was used to obtain 2D and 3D phase maps.

4 Results and Discussion

A plane reflecting surface with fingerprint implanted on it has been used as a specimen. When a light beam passes through or is reflected from the specimen under study, the beam acquires a phase change. This phase change exhibits the parameter of interest, in this case, the depth. The interferogram corresponding to this fingerprint is recorded and stored in computer memory for analysis. The image size has been chosen to be 800×1000 pixels. Figure 2a shows directly recorded fringe pattern without gratings of the right hand thumb. Figure 2b to Fig. 2e shows the recorded interference patterns with the grating G_1 shifted in steps of 0 , $\pi/2$, π , $3\pi/2$, and 2π , with respect to grating G_2 , respectively.

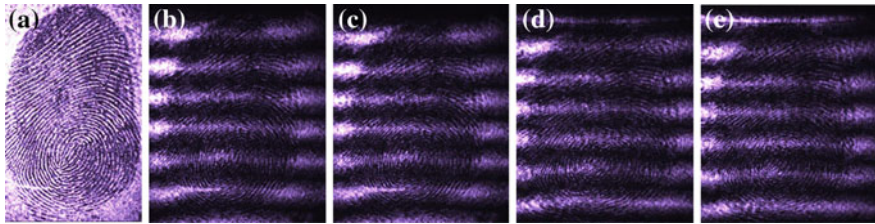


Fig. 2 **a** shows the directly recorded fingerprint, **b–e** show the fringe patterns recorded subsequently after a phase shift of $\pi/2$, π , $3\pi/2$, and 2π with respect to the directly recorded patterns

For determination of phase, the computation has been done in MATLAB environment. Phase shifting algorithm has been developed to evaluate the phase values at each point of the interferogram. Phase shifting interferometry (PSI) electronically records a series of interferograms while the reference phase of the interferometer is changed. The wavefront phase is encoded in variation in the intensity pattern of the recorded interferograms and a simple point by point calculation recovers the phase. Once the phase is determined across the interference field, the corresponding measurement variable can be measured. To introduce a phase shift, a suitable optical element is used in TI. In PSI, one of the two gratings is subjected to in-plane translation in direction perpendicular to the grating lines. Calibrated micrometer screw based translation stage and piezo-electric transducer (PZT) are used for introducing phase shifts in steps. (PZT) is a very precise device in which piezo-electric crystal expands or contracts with an externally applied voltage. During introduction of a phase shift, all physical parameters must necessarily remain fixed. In PSI is the lack of registration between the frames and noise due to speckles (in case of laser source is used) are presents. It seems that both of these are adding to the loss of resolution in the unwrapped phase map. These can be reduced by using an appropriate filtering scheme. Figure 3a shows the slope of the phase map for a small portion (300 pixels) which provides the information regarding inter-ridge distance. The small portion of the image is chosen to display the intensity variation in clearer

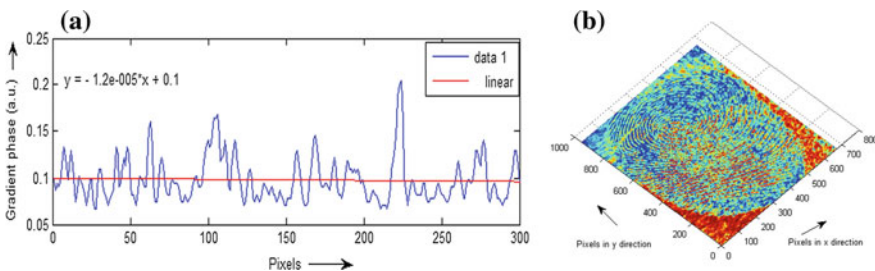


Fig. 3 **a** 2D phase map obtained using PSI technique. **b** Reconstructed 3D phase map obtained by applying PSI on the fringe patterns obtained with the specimen carrying a fingerprint

fashion. 3D reconstructed phase map for the fingerprint has also been plotted in Fig. 3b. The slope of the phase provides the information regarding variation in ridges of latent fingerprint. It has been estimated to be as 0.449 mm.

This inter ridge spacing calculated using 2D phase map is comparable to the value as reported in literature [14]. Thus phase map can be used for recognizing as well as matching fingerprints with finer details. The slope data obtained has been integrated using least square method to obtain the ridge height. Using the formula in (8) the depth information has been determined. The average depth has been determined to be 0.224 mm.

5 Conclusions

In this paper TI has been experimentally demonstrated for fingerprint detection and mapping. The results obtained using TI match well with the techniques reported till date. Local and global variations in the ridge lines and valleys have been successfully mapped. Highlight of the technique has been its extreme simplicity, low cost and ability for the technology to be transferred to the locations outside the laboratory. 2D and 3D phase map of grabbed fingerprint images provide finer details about the depth profile of fingerprint. Also, the technique does not require any chemical or physical processing. Hence, repeated tests may be performed without any degradation in the sample under test. The technique is simple, full field, low cost and fast.

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