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Shoeprint retrieval: Core point alignment for pattern comparison

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ABSTRACT

Purpose: Shoeprint recognition has been widely used as forensic evidence in criminal cases. The purpose of this study is to propose a shoeprint retrieval method based on core point alignment for pattern analysis.
Method: The proposed method firstly detects contour points in a black-and-white shoeprint image. These reliable contour points are selected to simulate the left and right sidelines of the shoeprint by a curve fitting method. Subsequently, the most concave points along the left and right sidelines can determine the core point of the shoeprint, thereby partitioning the shoeprint into circular regions. Next, the Zernike moments of the circular regions are calculated for pattern descriptions of each region. Finally, the Euclidean distance is measured to match the shoeprints with the same pattern.
Result: The highest $A_{PR} = 0.726$ is obtained from the first four Zernike moments with a radius of 90 pixels and three baselines. The experimental results also show that the Zernike method in any order always outperforms the compared moment invariant and GLCM method. The experimental results also indicate that the core point is more stable than the gravity center in the both sets, because the standard deviation values of the core point are less than that of the gravity center.
Conclusions: This study has verified that the proposed method can effectively align shoeprints for pattern comparison.

1. Introduction

When a person takes a step his/her shoe exerts pressure on the surface of the floor, which leaves an impression on the floor. According to the literature, the first case of shoeprint identification dates back to year 1786 [1]. Since then, shoeprint recognition has been generally used by the police for investigative purposes and by the courts as forensic evidence in criminal cases [2]. Shoeprint analysis and recognition can also provide valuable information to police investigators, as a link between different crime scenes may suggest possible suspects [3–5]. If a suspect is eventually identified, his/her involvement in different offences can be further investigated. These criminal offences may be solved due to shoeprint evidence [6]. In some instances, the pattern detail left by a shoeprint may not enable the identification of a specific shoe, but may still be very valuable to the investigation. Due to the wide variety of shoes available on the market, and with most having distinctive outsole patterns, any model of shoe will be owned by a very small fraction of the general population. If the model of shoe can be determined from its mark, then this can quickly narrow the search for a particular suspect.

Digital image processing and pattern recognition techniques can be applied to retrieve the shoeprint from the massive shoeprint databases. AlGarni and Hamiane [7] applied Hu's moment invariant for shoeprint matching. Their experimental results show that this method is invariance to different orientations, but very sensitive to the existence of noise, resulting in the decrease of the accuracy. Chazal et al. [8] proposed the discrete Fourier transform to generate the power spectral density, which represents the levels of different spatial frequencies of the shoeprint pattern. Due to the characteristics of invariance to translation and rotation, this method is also utilized to retrieve partial shoeprints. Patil and Kulkarni [9] used the Gabor transform to extract multi-resolution features of a shoeprint because Gabor transform possesses the characteristic of invariance to intensity and rotation. Rathinavel and Arumugam [10] used redundant discrete Wavelet transform and support vector machine to conduct experiments on the Cambridge ORL Shoe print database. Su et al. [11] extracted shoeprint features based on a gray level co-occurrence matrix (GLCM). Their experiments report that the quality of the shoeprint images is closely related to the effectiveness of the GLCM features, thereby affecting the retrieval accuracy. Pavlou and Allinson [12] applied scale-invariant feature transform (SIFT) to encode the pattern of each shoeprint. They

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proposed codebooks to represent each shoe pattern, facilitating fast indexing. Nibouche et al. [13] combined the Harris detector and SIFT descriptor to determine the interest points of a shoeprint. Then, the orientation and magnitude of the interest points are used as the features of those points. Ramakrishnan et al. [14] used the probabilistic model of the conditional random field to match a shoeprint with the most similar pattern. This model exploits the inherent long range dependencies that exist in the latent print and hence is more robust than other compared approaches. Skerrett et al. [15] proposed a Bayesian approach for interpreting shoeprint evidence in forensic casework. This approach is still limited to sole pattern and wear characteristics because it does not account for cuts and other accidental damages.

To retrieve similar shoeprints, the main purpose of this study is to propose a method of core point alignment for pattern analysis of shoeprints. The four objectives include (1) to identify the contour of shoeprints and determine the core point; (2) to partition the circular regions based on the core point and extract features from these regions; (3) to analyze the textural patterns of the partitioned regions; and (4) to evaluate the retrieval performance among the different methods and settings.

2. Material and methods

2.1. Shoeprint dataset

In this study, shoeprints were obtained by inviting participants to tread on an inkpad and then stamp on a 210 mm × 297 mm piece of paper for each shoe. As seen in Fig. 1, each shoe was used to stamp and create five shoeprints of different qualities. The five shoeprints, which are regarded as the same pattern category, were of variable quality, with some prints clearly showing the full detail of the shoe mark while others only captured part of the shoe mark. This dataset includes 246 shoe categories, resulting in a total of 1230 shoeprints. This dataset of shoeprint images was generated by digitizing the paper shoeprints in 256-level gray scale.

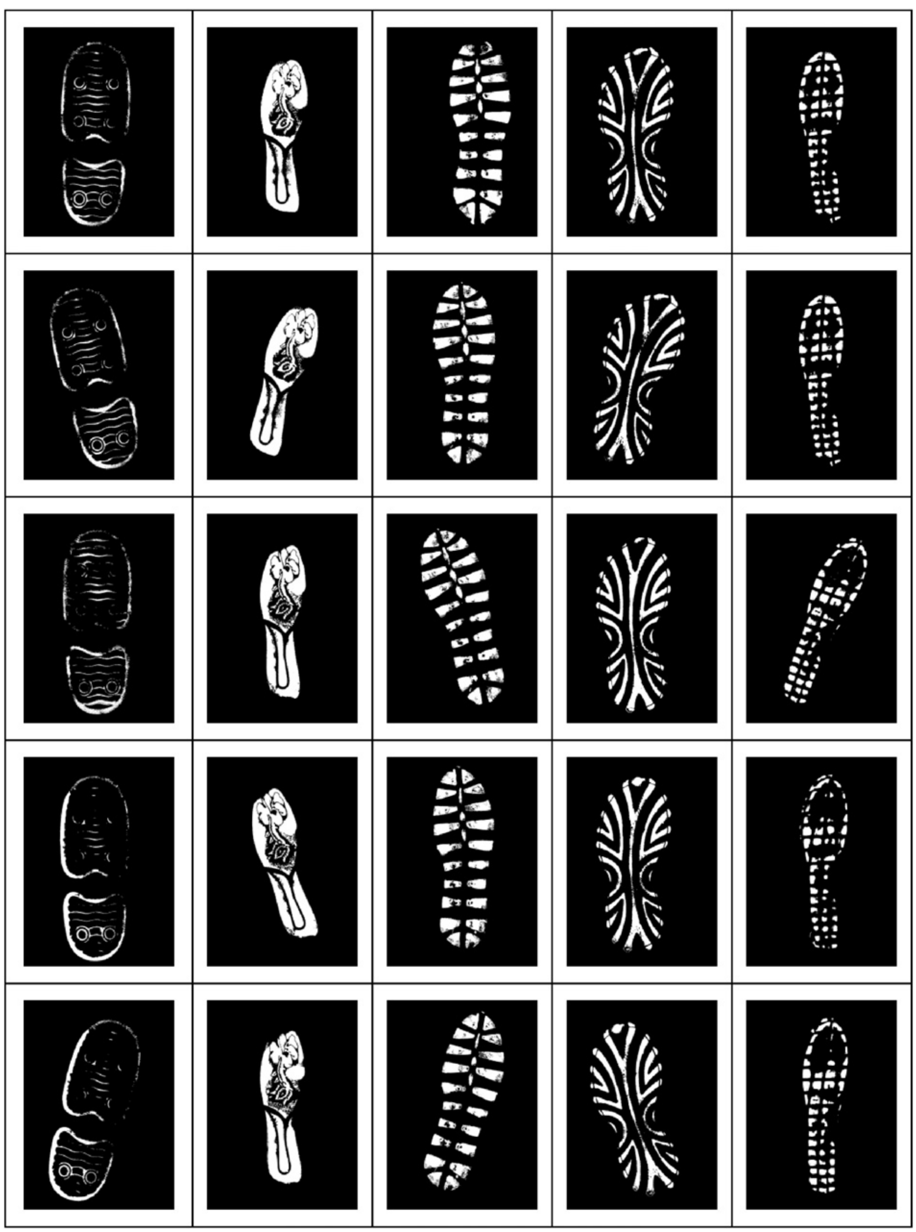

Fig. 1. Dataset of shoeprint images used for performance evaluation.