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New off-line Handwritten Signature Verification method based on Artificial Immune Recognition System

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ABSTRACT

Natural Immune System offers many interesting features that inspired the design of Artificial Immune Systems (AIS) used to solve various problems of engineering and artificial intelligence. AIS are particularly successful in fault detection and diagnosis applications where anomalies such as errors and failures are assimilated to viruses that should be detected. Thereby, AIS seem suitable to automatically detect forgeries in signature verification systems. This paper proposes a novel method for off-line signature verification that is based on the Artificial Immune Recognition System (AIRS). For feature generation, two different descriptors are proposed to generate signature traits. The first is the Gradient Local Binary Patterns that estimates gradient features based on the LBP neighborhood. The second descriptor is the Longest Run Feature, which describes the signature topology by considering longest suites of text pixels. Performance evaluation is carried out on CEDAR and GPDS-100 datasets. The results obtained showed that the proposed system has promising performance and often comfortably outperforms the state of the art.

1. Introduction

Biometrics is the science which identifies persons on the basis of their biological or behavioral features. Currently, various identification systems employing fingerprints, hand geometry, retina, iris, or faces provide very interesting performances. Nevertheless, in some specific applications using paper documents such as bank checks and contracts, handwritten signature remains the oldest and the main identification tool. Many successful studies have been reported on this subject. However, because of speed and robustness requirements, signature verification remains an open research issue (Impedovo, Modugno, Pirlo, & Stasolla, 2008). There are two approaches for developing such systems, the on-line verification and the off-line verification (Impedovo et al., 2008; Plamondon & Srihari, 2000). In the former, signatures are acquired via an electronic device such as tablets and an instrumented stylus that captures temporary information such as the *x*–*y* coordinates, velocity or acceleration (Plamondon & Srihari, 2000). In the off-line verification, such information cannot be recovered since signatures are prewritten on a paper. Consequently, it is less accurate but it has more practical application areas. On the other hand, the verification itself may be attempted in either writer-dependent or writer-independent context. In the writer-dependent case, the system is trained by using genuine signatures or both genuine and forgeries of a specific writer (Rivar, Granger, & Sabourin, 2013). This means that the training process should be repeated each time a new signer is presented to the system. The writer-independent scenario develops a generic system that can be tested on any new writer (Kumar, Sharma, & Chanda, 2012). Precisely, the system is developed using dissimilarities between genuine and forged signatures of some writers and tested on dissimilarities of other writers.

Note that since signatures are strong variable entities, even for human experts, their verification is not a trivial matter (Vargas, Ferrer, Travieso, & Alonso, 2011). For this reason, the signature verification has been widely investigated during the past years. The literature reports a lot of research works using various feature generation and verification methods (Impedovo et al., 2008; Plamondon & Srihari, 2000). Presently, we are focused on the writer-dependent off-line signature verification. In this approach, the best off-line signature verifiers (when tested on publicly available databases and against skilled forgeries) deliver error rates of approximately 9–10% (Kovari & Charaf, 2013). Such scores reveal that more theoretical advances should be done in the signature verification field in order to reach real-life verification systems.

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In this work, a new off-line signature verification method based on the Artificial Immune Recognition System (AIRS) is proposed. Artificial immune systems are a new computational research area inspired by simulated biological behavior methods like neural networks and genetic algorithms. Recall that to protect the bodies, biological immune system develops adaptive mechanisms (white blood cells) that allow the detection of foreign substances such as viruses. This process includes the detection of both unchanging organisms as well as un-encountered organisms (Bayar, Darmoul, Hajri-Gabouj, & Pierreval, 2015). These characteristics attracted researchers on pattern recognition who suggested that this principle can help to solve various expert and intelligent systems issues such as fault or anomaly detection. Then, several artificial immune algorithms such as the AIRS, which was developed by (Watkins, 2001), achieved high performance in various pattern recognition problems. AIRS was successfully used for thyroid diagnosis (Kodaz, Ozsen, Arslan, & Gunes, 2009), fault detection (Laurentys, Palhares, & Caminhas, 2011) and watermarking (Findik, Babaoglu, & Ulker, 2011).

Keeping in mind that a verification system should efficiently discriminate forged signatures that are seen as dangerous invaders to the verification mechanism, we suggest that AIRS can give an interesting solution for off-line signature verification. Recall that AIRS has been used in various handwriting recognition applications, such as handwritten character recognition (Chen, Liang, Yang, Peng, & Zhong, 2010), handwritten Russian uppercase letter recognition (Yang, 2011), as well as Arabic word recognition (Nemmour & Chibani, 2013a).

The contribution of this paper is twofold. First, the AIRS is used for solving the off-line signature verification where it is trained according to the writer-dependent approach. For each writer, an AIRS is developed by considering genuine and forged signature classes. Second, to obtain a robust signature characterization, a combination of topological and gradient features, is proposed. For the topological characterization, the Longest Run Feature, which highlights the pixel distribution in various directions is proposed. Then, gradient information based on Local Binary Neighborhood is extracted by using the so-called Gradient Local Binary Pattern. This paper is arranged as follows: Section 2 presents the background to signature verification methods. Section 3 provides a brief review of AIRS. Section 4 introduces the proposed signature verification system. Experimental results are reported and discussed in Section 5. The last section gives the main conclusions of this work.

2. Background

In both on-line and off-line approaches, the verification system is composed of two main steps that are feature generation and verification. In the on-line verification, the feature generation is the key component since the verification itself can be carried out through similarity measures. With modern tablets, signatures are registered as a set of discrete points from which various basic dynamic features are captured, such as x-y coordinates, pen-top, pen-down, pressure, velocity, and acceleration. Thereafter, features can be locally computed for each point in the time sequence or global if they are calculated from the whole signature sequence (Doroz, Porwik, & Orczyk, 2015). In Doroz et al. (2015), authors employ ten of such dynamic features associated to various similarity coefficients. Also, several research works were focused on developing robust features from on-line signature sequences while employing the Dynamic Type Warping (DTW) or other similarity measures to achieve the verification task (Fischer, Diaz, Plamondon, & Ferrer, 2015). Furthermore, recent works based on SVM and random forest classifiers propose feature combination associated to time functions that parameterize pen pressure, coordinates and inclination angles (Parodi & Gomez, 2014).

In the off-line signature verification approach which constitutes the purpose of the present work, signatures are extracted from digitized documents using a scanner or a camera, and stored as two dimensional gray level images. To cope with the lack of dynamic information, complex image processing techniques are required to extract signature traits. For the feature generation, a large number of methods were utilized to extract pertinent information about signatures. First techniques were based on statistical features like geometric moments as well as global image transformations such as the wavelet transform, Radon transform, Ridgelet transform, Contourlet as well as the Curvelet transform (Deng, Mark Liao, Ho, & Tyan, 1999; Hamadene, Chibani, & Nemmour, 2012; Nemmour & Chibani, 2013b; Radhika, Venkatesha, & Sekhar, 2011; Soleymanpour, Rajae, & Pourreza, 2010). Also, in Kumar and Puhan (2014), authors propose the use of Chord moments for feature generation. Experiments conducted on CEDAR dataset by using SVM gave promising performance. Currently, attentions are focused on the use of local features, which are intended to be more robust to the global shape variation induced by ballistic and fast movement during the signature writing (Kiani, Pourreza, & Pourreza, 2009). In this respect, various structural, directional and curvature features provided satisfactory results (Huang & Yan, 2002; Justino, Bortolozzi, & Sabourin, 2005). In (Bertolini, Oliveira, Justino, & Sabourin, 2010) authors proposed a set of grid features including pixel density, pixel distribution, slant and curvature to train an ensemble of SVM classifiers. Experiments showed that distribution-based and slant-based systems can provide satisfactory discrimination between genuine and forged signatures. Also, satisfactory performance has been reported using grid-based Histogram of Oriented Gradients (Yilmaz, Yanikoglu, Tirkaz, & Kholmatov, 2011). In recent past years, textural features, especially Local Binary Patterns (LBP), gained an important interest for signature characterization (Vargas et al., 2011). Various forms of LBP, such as Center Symmetric LBP (CS-LBP), Local Derivative Patterns (LDP), Rotation Invariant Uniform LBP (LBPriu) and Orthogonal Combination of LBP (OC-LBP), were utilized for off-line signature verification (Ferrer, Vargas, Morales, & Ordonez, 2012; Serdouk, Nemmour, & Chibani, 2014; Vargas et al., 2011). Moreover, several research works present LBP-based verification, as one of the most powerful systems for off-line signature verification, where efforts are focused on developing approaches to strengthen such systems (Ferrer, Diaz-Cabrera, & Morales, 2015; Galbally et al., 2015).

Regarding the verification step, first techniques were based on similarity measures and template matching (Hunt & Qi, 1995). Thereafter, efficient classifiers and learning machines such as Bayes classifiers, artificial neural networks, Hidden Markov Models and SVM, were employed (Fang & Tang, 2005; Kalera, Srihari, & Xu, 2004; Shanker & Rajagopalan, 2007). Recent researches on signature verification reveal that similarity measures still remain very successful for on-line verification (Doroz et al., 2015), whereas SVM constitutes the best verifier for the off-line approach (Ferrer et al., 2015; Galbally et al., 2015; Guerbai, Chibani, & Hadjadji, 2015). Indeed, various works showed that SVM outperforms hidden Markov models and neural networks in terms of accuracy and efficiency (Justino et al., 2005; Martinez, Sanchez, & Velez, 2006).

Despite all these efforts, verification scores obtained on benchmark datasets are suboptimal and need to be improved (Justino et al., 2005; Martinez et al., 2006; Murshed, Bortolozzi, & Sabourin, 1995a; 1995b). Various references proposed hybrid systems as well as classifier ensembles to deal with the complexity of this task (Batista, Granger, & Sabourin, 2012). In Ferrer et al. (2015) and Galbally et al. (2015), authors propose an ink deposition model to produce synthetic images that help improving the off-line verification. Synthetic signature images aim at integrating on-line information that are not present in regular static signatures (e.g., pressure, speed or pen-ups trajectory). Different results obtained