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DEALING WITH DATA COMPLEXITY: ON NEURAL NETWORKS AND FUSION IN BIOMETRIC RESEARCH

The area of biometric, without a doubt, is one of the most dynamic areas of interest, which recently has displayed a gamut of broader links to other fields of sciences. Among those are visualization, robotics, multi-dimensional data analysis, artificial intelligence, learning, data fusion and data synthesis. The topic of this keynote is reviewing state-of-the-art in multi-modal data fusion, fuzzy logic and neural networks and its recent connections to advanced biometric research. Application examples are provided.

1. INTRODUCTION

The area of biometric originates from biometry – a field of biology that deals with human characteristics. Some early uses of biometrics are attributed to Middle East merchants stamping their clay pots with the imprint of their thumb. Early classification methods were later developed in criminology, specifically in Scotland Yard, to classify criminals based on “soft” (hair color, eyes color, height, weight) as well as “hard” biometric (fingerprint, handprint, face image). The rapid development of massive databases and image processing techniques has led over the past ten years to the significant spur in biometric research and relevant industrial product development. Typical applications include banking, border control, law enforcement, e-commerce and restricted access to certain resources.

Over the recent decade, the variety of issues related to biometric system performance and analysis has been addressed in literature. The high number of biometric samples, data variability, error-rates, data acquisition device performance, dealing with noise, and the need for improved precision and reduced error rates has influenced an increased attention to this area. However, even with the most computationally sophisticated techniques, and advanced algorithms, no single biometric can authenticate a person with hundred percent confidence in results. Thus, a new approach based on multi-modal biometric system has recently emerged as a more reliable way of person identification and authentication (Dunstone and Yager, 2009). The advantages of multimodal systems stem from the fact that there are multiple sources of information. The most prominent implications of this are increased security, fewer enrolment problems and enhanced accuracy. All multimodal biometric systems need a fusion module that takes individual data and combines it in order to obtain the authentication result: impostor or genuine user. This keynote speech briefly reviews current trends related to information fusion in multimodal biometric system and considers using neural networks for learning as one of new approaches.

2. STATE-OF-THE-ART REVIEW

A typical biometric system typically consists of four main components, namely, sensor module, feature extraction module, matching module and decision module. The sensor module is responsible for acquiring the biometric data from an individual. The feature extraction module processes the acquired biometric data and extracts only the most important information to form a new data representation. Ideally, this new representation should be unique for each person and also relatively invariant with respect to changes in the different samples of the same biometric collected from the same person. The matching module compares the extracted feature set with the templates stored in the system database and determines the degree of similarity (dissimilarity) between the two. The decision module either verifies the identity claimed by the user or determines the user’s identity based on the degree of similarity between the extracted features and the stored template(s).

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The functionalities provided by a biometric system can be categorized as verification and identification (Ross et al. 2006). In verification mode, the user claims an identity and the system verifies whether the claim is genuine. In this scenario, the query is compared only to the template corresponding to the claimed identity. If the user's input and the template of the claimed identity have a high degree of similarity, then the claim is accepted as ‘genuine’. Otherwise, the claim is rejected and the user is considered an ‘impostor’.

The most common performance metrics of biometric systems are false accept rate, false reject rate and failure-to-enroll rate (Dunstone and Yager, 2009). False accept rate (FAR) is the percentage of the likelihood that an impostor will be accepted by the biometric system due to large inter-user similarity. False reject rate (FRR) is the percentage of the likelihood that the genuine individual will be rejected by the system due to large intra-class variations. A FRR of 5% indicates that on average, 5 in 100 genuine attempts do not succeed. Similarly, A FAR of 0.1% indicates that on average, 1 in 1000 impostor attempts are likely to succeed. Genuine Acceptance Rate (GAR) is the percentage of the likelihood that a genuine individual is recognized as a match and computed as GAR = 1- FRR.

3. METHODOLOGY

Multimodal biometric system has emerged as a new popular trend in current and future real-world biometric system deployment, where the system utilizes more than one biometric identifier, physical or behavioral, for biometric recognition. For example, a multimodal biometric system may use face recognition, iris recognition and ear recognition to confirm the identity of a user. These systems address some of the problems faced by single biometric system through the utilization of multiple information sources. One of the emerging areas of research is information fusion in multi-modal biometric system, and this area is at the focus of this keynote.

It is easy to see that the most immediate advantage of multimodal biometric system is recognition accuracy. As the combination of each of the biometric identifiers offers some additional evidence about the authenticity of an identity claim, one can have more confidence in the result. For example, two persons may have the similar signature patterns, in which case, the signature verification system will produce large FAR for that system. Addition of face recognition system with the signature verification system may solve the problem and reduce the FAR. Multimodal biometric systems can also address the problem of non-universality. In case of unavailability or poor quality of a particular biometric data, other biometric identifier of the multimodal biometric system can be used to capture data. For example, a face biometric identifier can be use in a multimodal system (involves fingerprint of general labors with lots of scars in the hand). Multimodal biometric systems increase resistance to certain type of vulnerabilities. Thus, an attacker would have to spoof three different biometric identifiers which would be more challenging.

Several approaches have been proposed in literature for multimodal biometric authentication system with different biometric traits and with different fusion mechanism. One of the leaders of the field is A. Jain, who started to work in the area in late 1990 and introduced one of the first PCA-based face and a minutiae-based fingerprint identification system with a fusion method at the match score level (Hong and Jain 1998). It was followed by 2000 Frischholz and Dieckmann commercial multimodal approach, BioID, for a model-based face classifier, a VQ-based voice classifier and an optical-flow-based lip movement classifier for verifying persons (Frischholz and Dieckmann 2000). Lip motion and face images were extracted from a video sequence and the voice from an audio signal. Weighted sum rule and majority voting approaches of decision level fusion method were used for fusion.

In 2003, Ross and Jain proposed another multimodal system for face, fingerprint and hand geometry, with three fusion methods at the matching score level (Ross et al. 2003). Sum-rule, decision trees and linear discriminant function are used and by their experiments, they showed that the sum rule performs better than the decision tree and linear discriminant classifiers. In 2004, Feng et al. developed a system using face and palmprint using feature level fusion strategy (Feng et al. 2004). For feature level fusion, they use feature concatenation approach. They used two algorithms for classification –PCA and ICA.

More works have been introduced by Jain et al., proposing a multimodal approach for face, fingerprint and hand geometry, with fusion at the score level (Jain et al. 2005). The matching approaches for these modalities are minutiae-based matcher for fingerprint, which has similarity scores as output, PCA-based algorithm for face recognition, which has Euclidean distance as output, and a 14-dimensional features vector for hand-geometry, which also has Euclidean distance for output. Seven score normalization techniques and three fusion techniques on the normalized scores were tested in this study. In 2006, Li et al. introduced a new feature metric – handmetric, which is a combination of palmprint, hand shape and knuckle print (Li et al. 2006). They integrated the features of these three biometrics using feature level fusion based on Kernel Principle Component Analysis (KPCA), which is a combination of kernel projection and PCA dimension reduction. They used four fusion rules for combining feature – sum, product, min and max.

In 2008, Nandakumar et al. presented a multimodal biometric system using likelihood ratio based match score level fusion (Nandakumar et al. 2008). They proposed a framework for optimal combination of match scores that is based on the likelihood ratio test which models the distributions of genuine and impostor match scores as finite Gaussian mixture model. In 2009, Monwar and Gavrilova developed a multimodal biometric system utilizing face, ear and signature biometric identifiers (Monwar and Gavrilova 2009). They proposed rank fusion approaches for biometric fusion using fisherimage method as matching algorithm and logistic regression and Borda count for fusing rank information.

In 2010, Monwar and Gavrilova introduced Markov chain rank fusion for multimodal biometric system (Monwar and Gavrilova 2010). The method utilized face, ear and iris biometric identifiers for the multimodal system and examined various rank fusion methods including the novel Markov chain approach. The results demonstrated that the Marko chain approach for biometric rank fusion satisfies the Condorcet criterion which is essential for any fair rank aggregation process.

From the above discussion, it can be concluded that many multimodal biometric systems with various methods and strategies have been proposed over the last decade to achieve higher accuracy rate. One of the recent directions of research is in combining biometric fusion with recent advancements in chaotic neural networks (K. Ahmadian and M. Gavrilova, 2010). The methodology creates a set of biometric features, or classifiers, from various biometric sources, and then applies powerful chaotic neural network learning methods to identify patterns and improve resulting recognition rates. Overhead associated with training of neural network is minimal, as it could be done at pre-processing stage, and benefits of the specially designed set of strong biometric features is significant. The methodology extends ideas presented in the book "Computational Intelligence: A Geometry-Based Approach" (M.L. Gavrilova, 2009) and a book chapter "Computational Geometry and Image Processing in Biometrics: on the Path to Convergence" (M.L. Gavrilova, 2007), concentrating on power of intelligent and cognitive systems in current biometric research.

4. CONCLUSIONS

Multimodal biometric and information fusion recently emerged as promising new research direction. The design of a multimodal biometric system however is still a challenging task due to heterogeneity of the biometric sources in terms of the type of information, the magnitude of information content, correlation among the different sources and conflicting performance requirements of the practical applications. Powered by novel fusion methods, such as Markov Chain model, fuzzy logic and chaotic neural networks, the methodology found its place among some of the most powerful approaches to biometric fusion in multi-modal systems. The novel methods utilizing these approaches to biometric fusion find their place in the exciting field of multi-modal biometric research.

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BIOGRAPHY

Marina L. Gavrilova is an Associate Professor in the Department of Computer Science, University of Calgary. Dr. Gavrilova research interests lie in the area of computational geometry, image processing, optimization, spatial and biometric modeling. Prof. Gavrilova is a founder and co-director of two innovative research laboratories: the Biometric Technologies Laboratory: Modeling and Simulation and the SPARCS Laboratory for Spatial Analysis in Computational Sciences. Prof. Gavrilova publication list includes over 120 journal and conference papers, edited special issues, books and book chapters. Prof. Gavrilova acted as a Co-Chair of the International Workshop on Biometric Technologies BT 2004, Calgary, Alberta, Canada, 2004, an Overall Chair of the Third International Conference on Voronoi Diagrams in Science and Engineering and as Organizational Chair of WADS 09. Prof. Gavrilova is an Editor-in-Chief of the LNCS Transactions on Computational Science Journal, Springer-Verlag and serves on the Editorial Board for the International Journal of Computational Sciences and Engineering, CAD/CAM Journal and Journal of Biometrics. Marina L. Gavrilova has been invited to delivere keynotes and invited lectures at numerous internationally recognized venues, including Samsung Research Institute, Seoul, Korea; Microsoft Research, Redmond, USA; DIMACS Research Centre and Bell Labs; International Voronoi Diagram Centre, Hanyang University, Korea; MITACS Workshop on Remote Sensing, Calgary, Alberta; LSBU, London, UK as part of High Profile Research Series; 12th International Conference on Computer Graphics and Artificial Intelligence 2006, France; GRAPHICON, Moscow, Russia; ICBAKE 2009, Poland; INDIN 2003, Canada; PIMS Banff Research Station Workshop, Banff and CMS Summer Meeting, Edmonton, among others.