*Toeplitz matrices, multibiometrics,
feature extraction, image description,
security in biometric systems,
spoofing in biometrics*

Khalid SAEED*

A NOTE ON TÖEPLITZ MATRIX-BASED MODEL IN BIOMETRICS

This paper presents a summary of the work presented as an invited paper at MIT 2008 International Conference. The work comprises a general note on the problems we meet in our everyday contact with biometrics and their different systems. A particular attention is paid to the anti-spoofing approaches in having a safe and convenient system of human verification for personal identification. A conclusion is drawn that neither stand-alone nor multi-system Biometrics are ideal and convenient to people for their daily necessity of being identified. The author suggests a system that may seem practical in banks and cash machines, for example, in which a biometric system is used (fingerprint or face identification for example) in conjunction with the popular means of account securing, the PIN code.

1. INTRODUCTION

Biometrics and their different systems of biometric testing are not effective in their performance in an absolute way as they are supposed to be. They are not perfect or secure enough to play the role of automatic personal identifiers. This problem is faced by us in our everyday life. Biometric systems are not rather accurate or quite reliable either. They are sometimes helpless against the growing systematically spoofing methods [1]. It is obvious that almost all biometric systems involve user's writing on paper, stamping their fingerprints, showing their eye open to a camera, pressing their hand to show its geometry, uttering to a microphone, and the most common way of identifying the user by their recalling a code or a password to enter the identifying machine with (PID - Personal Identifying Number, for example). Until now, there is no perfect and a 100% reliable biometric system. None has proved to be spoof proof. That is why the process of searching new biometric systems for human identification is still under steady examination and improvement. Recently, the devices used in preprocessing stages of biometric systems are available and almost standard and cheap, whereas still more precise and fast methods for image and signal feature extraction and description, before classification, are desired.

On the other hand, research is being done on applying multi-system biometrics, which have also successfully proved their reliability to meet the system performance requirements for personal identification [2, 3]. The identity established by integrating face and fingerprints recognition systems is more reliable than the identity established by a face recognition system in meeting the response time as well as the accuracy requirements. However, we must ask ourselves the following question: Who would accept to be photographed or to give his fingerprints in order to have an access to his own account? Sooner or later, this will prove to be inconvenient to people and hence impractical. More, some researches have proved really high accuracy and rate success in verifying the user, but with three biometric sources. The model integrates face, fingerprints and voice identification biometric systems in one complex system [3]. Although this could really be a secure system, it cannot be accepted as a solution to the problem of finding a reliable but practical human identification system.

2. POSSIBLE SOLUTIONS TO THE PROBLEM

The idea of multi-model biometrics is a very good trial to solve the problem of reliability in biometric models but not when the system comprises three sources of biometrics, and when two, then not both inconvenient to users. The system should not involve more than one of the undesirable methods like eye photographing, face filming, fingerprints taking, or uttering. A system with fingerprints and signature or PIN code and face photographing may seem acceptable to us in our daily use, particularly in banks and bank machines. The signature recognition systems [4-6] are the most acceptable biometric feature-taking methods to people as they never relate to crime. This may seem convenient and appreciated by cash machine users, they should not complain and would show tolerance to the additional test in exchange for more reliable, secure and more effective system [7].

Now, complex systems involve huge data and hence are subject to large computations, but this is the problem many researchers are working on. The data reduction in all aspects of computer systems and networks is a serious problem although the today's computers are capable of computing and saving large amount of operations and data in a short time, but of course with higher cost.

Then, we remain with the problem of data reduction and a tool that decreases the data size would be searched for. In this presentation, the author uses Töeplitz Forms to suggest a mathematical model for a new technique, easy to implement, to evaluate the data representation stages in biometric systems for human identification. The technique has been developed to use the unique characteristics of Töeplitz matrices and their minimal eigenvalues to describe and classify images in both

* Faculty of Computer Science, Bialystok Technical University, Wiejska 45A, 15-351 Bialystok, Poland.
Grant no. W/WI/10/07.; ksaeed@wi.pb.edu.pl; http://aragorn.pb.bialystok.pl/~zspinfo/eng/zsp_sae.html

physiological and behavioural biometrics. The description leads to a feature vector carrying unique information about the image by introducing the relations between the characteristic points rather than their geometric positions and their huge number of features. This model is particularly practical when integrating it with a suitable classifier in conjunction with another appropriate source of biometrics like signature identification.

Toeplitz matrix has the form given in equation (1) with the elements being complex numbers [8] and $C_{-i} = C_i^*$ with the assumption that for the biometric image analysis applications the matrix elements are real and hence $C_{-i} = C_i$. These elements are obtained from some kind of transformation from the image geometric *x-y* coordinates into numbers that represent the coefficients of Taylor series [8]. Taylor series coefficients result from dividing two polynomials, the elements of which are the *x* and *y* coordinates, respectively.

$$C = \begin{bmatrix} c_0 & c_{-1} & c_{-2} & \cdots & c_{-n+1} \\ c_1 & c_0 & c_{-1} & \ddots & \vdots \\ c_2 & c_1 & c_0 & \ddots & c_{-2} \\ \vdots & \ddots & \ddots & \ddots & c_{-1} \\ c_{n-1} & \cdots & c_2 & c_1 & c_0 \end{bmatrix} \quad (1)$$

The minimal eigenvalues of Töeplitz forms λ_i for i =1, 2, ..., n are then computed by any known mathematical means (this step is usually performed in MATLAB). They furnish the characteristics shown in Fig. 1. They present a nonincreasing sequence with one of the shapes A, B or C of Fig. 1. All tend to a limit defined by and dependent on the values of the elements of Toeplitz matrix *C* in equation (1).

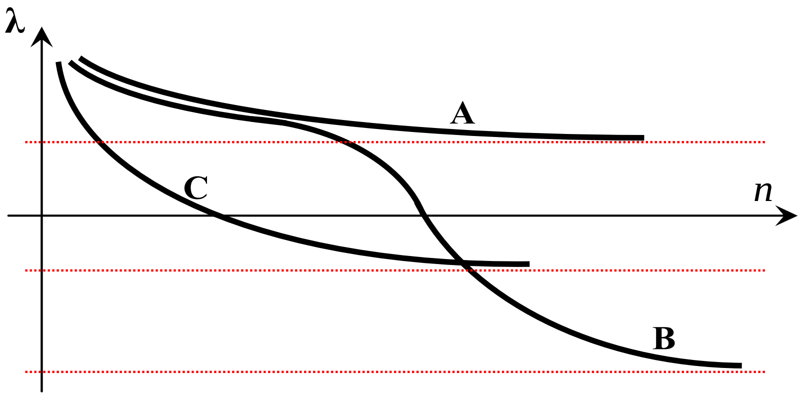

Fig. 1 The possible behaviour of the minimal eigenvalues of Töeplitz forms

The essential and basic information taken from the curves of Fig. 1 is the monotonous character that leads to the similarity of the curve behaviour in any interval. This in turn leads to the fact that we do not need to test the whole sequence but only a part in any interval, the best that approaches the limit of the sequence. It may seem worth to discuss the cases A, B and C. Curve B has a rather odd character. However, although theoretically it is a possibility, it has never appeared in practice over all of experiments made on the minimal eigenvalues. Nevertheless, as seen in Fig. 1, it also contains all the necessary information. Case C in similar to case A but with negative values of the minimal eigenvalues. Again this does not affect the capability of the sequence to describe the image. It is worthy mentioning that cases B and C may have significant meaning in some applications of Töeplitz matrices, but this is beyond the topic of this work.

ACKNOWLEDGEMENT

This work is the abstract of a keynote lecture presented at MIT'08 – XIII International Conference on Medical Informatics and Technologies. The author is grateful to Professor Piotr Porwik, the Chair of the Conference, for his kind invitation to submit this work and have the opportunity to discuss aspects of new approaches in Biometrics methods of analysis for data size reduction in single and multi-model.

BIBLIOGRAPHY

[1] SAEED K. (Editor-in-Chief), NISHIUCHI N., YAMAGUCHI T. (Guest Editors), International Journal of Biometrics (IJBM), Special Issue on Spoofing Issues and Anti-Spoofing, Vol. 1, No. 2, 2008.

[2] ROSS A., KULKARNI Y., JAIN A., Handbook of Multibiometrics, Springer Verlag, 2006.

[3] HONG L. , KULKARNI Y., ROSS A., JAIN A., Multibiometrics - Integrating Faces and Fingerprints for Personal Identification. http://biometrics.cse.msu.edu/multi_bio.html , September 2008.

[4] PARA T., PORWIK P., WRÓBEL K., On-line signature recognition method based on Linear Regression, Journal of Medical Informatics and Technologies, vol. 11, Medical Informatics and Technologies : 12th International Conf., Osieczany, pp. 97-103, 2007.

[5] SAEED K., ADAMSKI M., Experimental Algorithm for Characteristic Points Evaluation in Static Images of Signatures, Biometrics, Computer Security Systems and Artificial Intelligence, Springer, New York, pp. 89-98, 2006.

[6] KHOLMATOV A., YANIKOGLU B., Identity authentication using improved online signature verification method, Pattern Recognition Letters, Vol. 26, No. 15, pp. 2400-2408, November 2005.

[7] JAIN A. K., PANKANTI S., *A Touch of Money*, *IEEE Spectrum*, vol. 43, no.7, pp. 14-19, July 2006.

[8] GRENANDER U., SZEGÖ G., Toeplitz Forms and Their Applications," University of California Press, 1959

[9] SAEED, K.: *Image Analysis for Object Recognition*. Bialystok Technical University Press, Bialystok, Poland, 2004.