International Journal of Innovative
Computing, Information and Control
Volume **7**, Number **10**, October **2011**

 ISSN 1349-4198
pp. 5939–5946

FPGA-BASED HOUSEHOLDER IMPLEMENTATION FOR EFFICIENT EIGENVALUES CALCULATION

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Received May 2010; revised September 2010

Abstract. *In most of the digital signal and image processing applications, eigenvalues are an integral but computationally intensive part. Recently, coordinate rotation digital computer (CORDIC) based Jacobi algorithm (CJA) has been used for the evaluation of eigenvalues on FPGA. It uses trigonometric functions, counterpart of square root, for the evaluation of eigenvalues. However, its accuracy is poor even for a small symmetric matrix because CORDIC computes trigonometric functions by using vector rotation approximation. In this paper, we present a new FPGA-based architecture to implement Householder method (HHM) for the evaluation of eigenvalues by employing non-restoring square root algorithm. Our proposed architecture demonstrated an improvement up to 30% in time, 28% in power and 10% in accuracy than CJA. The validity of the proposed architecture is checked by using five data sets for a real-time face recognition system.*
Keywords: Householder, Eigenvalues, FPGA, CORDIC

1. **Introduction.** Most of the image and signal processing applications, where a decision is to be made, can be envisaged as a pattern recognition problem [1]. Principal component analysis (PCA) is one of the best techniques used in pattern recognition applications, which offers reduced time complexity for features extraction [2,3]. However, PCA performance is dependent upon the size of a training set, number of eigenvectors and illumination condition [2,4]. In the last few years, numerous variants of PCA have been proposed to improve its performance and make it reliable under varying illumination condition [5].

It is an established fact that areal time pattern recognition system cannot afford time delay, usually observed in algorithm's computation [6] and thus requires a time-efficient embedded system [7,8]. In a pattern recognition solution, meaningful data are required by evaluating eigenvalues, which is one of the most computationally intensive parts of a pattern recognition system [1].

For hardware evaluation of eigenvalues, coordinate rotation digital computer (CORDIC) based Jacobi algorithm (CJA) is one of the best reported implementations on FPGA [9]. Basically, CORDIC implements trigonometric functions in order to evaluate eigenvalues [9,10]. During this process, it employs approximation in vector rotation to estimate trigonometric functions. On the other hand, Householder method (HHM) uses square root instead of trigonometric function for the evaluation of eigenvalues and in principle, the technique is more accurate than CJA [11,12]. Furthermore, HHM is considered an efficient method for eigen solutions, because it terminates definitely after $n-2$ iterations, where n is the size of an input symmetric matrix [11].