Accepted Manuscript

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PII: S2405-9595(18)30104-8
DOI: https://doi.org/10.1016/j.icte.2018.04.009
Reference: ICTE 155

To appear in: *ICT Express*

Received date : 15 February 2018
Accepted date : 9 April 2018

Please cite this article as: M. Farouk, A. Sutherland, Principal component pyramids for manifold learning in hand shape recognition, *ICT Express* (2018), https://doi.org/10.1016/j.icte.2018.04.009

ICT Express
Information & Communications Technology

Principal Component Pyramids for Manifold Learning in Hand Shape Recognition

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ABSTRACT
This paper presents two algorithms using data pyramids for hand shape recognition in Irish Sign Language. Principal Component Analysis (PCA) is used as a feature extraction and dimensionality reduction method. Originally, the problem is nonlinear and it is hard for PCA to extract the underlying structure of the data. The proposed PCA pyramids provide an alternative to nonlinear PCA as they depend on dividing the space into subspaces which are approximately linear using the appropriate eigenspace in each level. They are used to accelerate the search process to approximate the nearest neighbour search problem. The first algorithm uses unsupervised multidimensional grids to cluster the space into cells of similar objects. The second algorithm is based on training a set of simple architecture multilayer neural networks. Experimental results are given to measure the accuracy and performance of the proposed algorithms in comparison with the exhaustive search scenario. The proposed algorithms are applicable for real time applications with high accuracy measures.

I. INTRODUCTION

Hand shape recognition using appearance-based methods provides a natural mode of interaction between humans and computers. Hand shapes hold the information about the meaning of the gestures. As the hand is a deformable object, it is a challenging task to build a recognition system that can classify the same hand shape under different orientations or different viewpoints of the camera. [1].

There are different techniques used to build classifiers for gesture and posture recognition where PCA is one of them. In [2], a dynamic gesture recognition system is proposed based on Gabor features which suffers from high dimensionality and PCA is applied to reduce it. A Support Vector Machine (SVM) is used to carry out the classification process. In [3], the PCA technique is used to extract the features from human shape silhouettes to analyze and classify human body posture. The classification is based on two categories, either human standing posture or human non-standing posture. SVM is used for the recognition task. In [4], the visual appearance of hand movements is used to implement a Human Computer Interaction system based on Hidden Markov Models. PCA is used for dimensionality reduction and feature extraction from the input sequence.

Example-based approaches use a large training set of computer generated hand images that densely sample the space. All possible orientations and variations in the appearance can be created in a short time and can be labelled according to the pose parameters which is hard for a real signer to do. These methods provide a powerful mechanism for estimating the pose by mapping a new image to pose space and comparing it with a dataset of rendered samples. In [5], a specially designed coloured glove is used where the system maps hand shapes to the closest rendered images for the application of virtual reality. In [6], a large database of 107,328 synthetic images, for 26 shapes uniformly sampled at different viewpoints, is used for 3D hand pose estimation. The problem is considered as an indexing problem to efficiently retrieve the closest match. In [7], an example-based classifier is presented for 3D human body pose estimation using 150,000 synthetic images. Hashing is used to solve the nearest neighbour search problem.

II. RELATED WORK

PCA can be used as a feature extraction and dimensionality reduction method. However, it usually works well only if the embedded manifold is linear. Studying nonlinear manifolds using a manifold learning technique is an important issue in pattern recognition. A nonlinear phenomenon is characterised by a curve in the original data space. Nonlinear Principal Component Analysis (NLPCA) is a nonlinear generalisation of standard PCA. It helps in visualising the nonlinear data as an aspect of data analysis by mapping the data from the original space to a component space using an artificial neural network based on learning a multilayer perceptron with an auto-associative topology known as a bottleneck network [8]. Kernel Principal Component Analysis (KPCA) is a nonlinear PCA that is computed by applying linear PCA after using a kernel function to map the original inputs into a high dimensional feature space. The linear PCA in the high-dimensional feature space corresponds to a nonlinear PCA in the original input space [9].

In[10,11], data pyramids are used for hand shape recognition in Irish Sign Language as a coarse-to-fine search technique to provide a fast estimate for the hand shape and pose parameters in terms of rotation and translation. Image blurring is used for flattening the