An Adaptive-Sampling Algorithm for Object Representation

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Abstract

We present a novel adaptive-sampling algorithm for spectral signature generation. This algorithm is designed to increase inter-object discrimination and reduce feature-vector dimensionality. Our algorithm is applied to a Gabor-feature based multi-resolutional object detection and recognition scheme. In this context we study and analyze the detection and identification of unknown objects in a complex background. Iterative, off-line optimization methods are employed to reduce computational demands during the learning phase. Our representation scheme takes into account all items in a given object library. It selects sample-point sets that maximize the inter-object distance. Thus, the presented method increases identification robustness and can reduce the size of signature vectors.

1 Introduction

This paper describes an algorithm for object representation that can be applied to several transform domains. Objects are sampled in order to extract signature vectors containing highly discriminant data. These vectors are then used to represent each item in a local object library. Such feature sets are required to be as unique to the sampled object as possible to allow for maximum differentiation from other items. Several face-recognition methods make use of *fiducial* points, located at face landmarks that have been found to provide effective characterization, e.g., the eyes and the ears [13]. However, for the more general problem of object recognition we do not know in advance what object points carry more significant information than others for the purpose of distinguishing between items. These points have to be determined without human intervention.

Due to the high time and space costs associated with processing high dimensionality data, it is neccessary to reprsent transformed objects by as short as possible feature vectors. Typically, this reduction is performed by taking a few samples from each object. However, the research literature does not provide optimal or efficient methods for sample selection.

In this paper we present results obtained for the Gabor transform. However, other transforms/filters can be applied for extracting spectral-signature information, e.g., the Fourier transform and derivatives of the Gaussian [2].

Two classes of object representation methods are mentioned in the literature: Statistical representation of local-image data and fixed-grid sampling [12]. Statistical representation methods typically represent objects by low-order statistics of a portion of their transform. In [1] Gabor filtered images are represented by the average and the standard deviation computed for all pixels. Fixed-grid sampling is described in [8], where Gabor filters are used for handwritten numeral recognition. A grid of 64 points at regular intervals is used to sample Gabor-filtered objects. The grid size is dynamically adjusted to ensure it contains the entire object circumference. Dailey and Cottrell [7] use a 29x36 fixed grid to sample faces filtered with 40 different Gabor kernels for a total of 41760 features. Principle Component Analysis is then applied in order to reduce the dimensionality to 109 features. Gabor filters are used for facial expression recognition in [16], where feature vectors are created by sampling Gabor-filtered faces at predetermined fiducial points e.g., the eyes and chin.

Ben-Arie and Pandit use five scales and four orientations for object detection. They represent objects by a single sample point in Gabor space [3]. Chung et al [6] use 12 predefined fiducial points at five central frequencies and eight orientations for face recognition. PCA is later used for dimensionality reduction. Wiskott et al sample the Gabor transform magnitude at various face landmarks and store them in a graph [13].

Increasing the separation between object representations is of prime importance. Even an infinitesimal variation between feature vectors can make the difference between a correct and incorrect recognition where nearest-neighbor classification is employed. The sampling method presented in this paper is unique because it determines preferred sampling points by considering all objects in a given library. Sample points are automatically selected so that they increase inter-object differentiation and thus can reduce required feature-vector lengths.

2 The Gabor Transform

Gabor filters can efficiently localize frequency and orientation properties of an analyzed image. The general form of the complex Gabor filter is presented below [9]. It consists of a two-dimensional Gaussian function with standard deviation σ, that modulates a spatial sinusoid,