Gabor kernels for affine-invariant object recognition

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ABSTRACT – We present an approach for affine-invariant object/target recognition by iconic recognition of image patches that correspond to object surfaces that are roughly planar. Each surface is recognized separately invariant to its 3D pose, employing novel Affine-Invariant Spectral Signatures (AISSs). The 3D-pose invariant recognition is achieved by correlating the image with a novel configuration of Gabor kernels¹ and extracting local spectral signatures. The local spectral signature of each image patch is then matched against a set of iconic models using multi-dimensional indexing in the frequency domain. Affine-invariance of the signatures is achieved by a new configuration of Gabor kernels with modulation in two orthogonal axes. The proposed configuration of kernels is Cartesian with varying aspect ratios in two orthogonal directions. The kernels are organized in subsets where each subset has a distinct orientation. Each subset spans the entire frequency domain and provides invariance to slant (foreshortening), scale and translation within the region of support of the kernels. The union of differently oriented subsets is utilized to achieve invariance in two additional degrees of freedom, i.e. swing and tilt. Hence, complete affine-invariance is achieved by the proposed set of kernels. The indexing method provides robustness in partial distortion, background clutter, noise, illumination effects and lower image resolution. The localized nature of the Gabor kernels allows independent recognition of adjacent shapes that correspond to object parts which could have different poses. The method yields 100% correct recognition rates in experiments over a wide range of slant, scale, swing, and tilt² with a dataset of 26 gray-level and infra-red models, in the presence of noise, clutter and other degradations.

¹We use the terminology “Gabor Kernels” to refer to modulated Gaussian kernels. Other people may use it with other meaning. Also, this configuration can be interpreted as multi-window Gabor scheme. A theoretical analysis of multi-window Gabor schemes can be found in Chapter 12.
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Object Analysis of Object Using Gabor Kernels at Different Scales and Orientations

Localized Signature at orientation $\theta_0$

Multi-dimensional Indexing for Affine Invariant Recognition and Pose Estimation

FIGURE 13.1.1. Block diagram of iconic recognition scheme.

13.1 Introduction

One could classify image understanding into two general approaches. The first approach involves preprocessing the image and further analysis deals with abstract information in the form of features such as lines, junctions, interest points, etc. Such simplified pictorial information is then used for interpretation and understanding of the image. However, in practical imagery, feature extraction necessitates prior segmentation that commits subsequent interpretation stages into analyzing information that might be incomplete and might also include a large amount of irrelevant clutter. Also, the large number of small features most often leads to a combinatorial explosion in the complexity of algorithms required for matching image data to stored models.

The method presented in this paper belongs to the second approach called iconic (or pictorial) representation. Here, the given image is directly projected onto a set of kernel functions. This approach is also equivalent to linear shift-invariant filtering (correlation) of the image with a set of filters represented as kernels. The coefficients obtained from this linear operation form a signature (feature vector) that yields a rich and localized representation of the image shape. In addition to describing the local shape, the signatures can also contain local frequency characteristics, which represent texture and other image attributes. In the frequency domain, our kernels divide the whole frequency range into exponentially increased subbands.