Chapter 2
Image Segmentation with Eigen-Subspace Projections

Jar-Ferr Yang and Shu-Sheng Hao

Abstract In this chapter, object segmentation algorithms dependent on the characteristics of eigen-structure are proposed. The eigen-subspaces are obtained from eigen-decomposition of the covariance matrix, which is computed from the selected color samples. Hence, the color space can be transformed into the signal subspace and its orthogonal noise subspaces. After statistical analysis of eigen-structure of target color samples, the color eigen-structure segmentation algorithms are then designed to extract the desired objects, which are close to the color samples. The principal component transformation (PCT) techniques, which only use the signal subspace can be treated as a subset of color eigenspace algorithms. The eigenspaces discriminated as signal and noise subspaces related to original color samples should be effectively utilized. The adaptive eigen-subspace segmentation (AESS) algorithm, which can save the computation of eigen-decomposition, is applied to adaptively adjust the eigen-subspaces. Finally, the Eigen-based fuzzy C-means (FCM) clustering algorithm has been proposed to effective segment color object. By jointly consideration of signal and noise subspace projections of desired colors, the separate eigen-based FCM (SEFCM) and coupled eigen-based FCM (CEFCM) are used to achieve effective color object segmentation. With these proposed algorithms, the color objects can be successfully extracted by using eigen-subspace projections.

2.1 Overview

Image segmentation has been treated as a key technology in many smart image and video related applications. To achieve effective coding, for example, the image segmentation is the most important kernel in construction of the MPEG-4 video object plane (VOP) [1, 2]. The four major features, including luminance, motion, color,
and depth information, have been used as indexes for segmentation of the scenes. If we can separate the video objects and encode them in the video bitstreams, we can achieve the goals such as content scalability, sprite construction, and depth map estimation [3]. Recently, there are many segmentation researches proposed by using motion [4, 5], edge [6, 7], shape [8], and textual [9, 10] information. In this chapter, we introduce the object segmentation algorithms by only using the characteristics of eigenstructure of the color space. After statistical analysis of eigen-structure of the color samples, the color eigen-structure segmentation algorithms, which consider characteristics of signal and noise subspaces, are suggested. By using color information only, simulations show that the proposed algorithm can successfully detect the desired objects from standard video test sequences. In Sect. 2.2, the object segmentation algorithm based on the color eigen-structure characteristics will be stated. In Sect. 2.3, color object segmentation using adaptive eigen-subspaces will be discussed. In Sect. 2.4, color object segmentation using fuzzy C-means with eigen-subspace projection will be described. Conclusions will be stated in Sect. 2.5.

2.2 An Object Segmentation Algorithm Based on Color Eigen-Structure Characterizations

As mentioned in Sect. 2.1, the principal component transformation (PCT) for image segmentation has been proposed [11–13]. The PCT essentially exhibits a color transformation to the signal subspace only. In this section, we propose a color eigen-structure algorithm to efficiently and effectively retrieve the desired objects. In Sect. 2.2.1, the theory of PCT will be introduced. In Sect. 2.2.2, we further analyze the properties of eigen-subspaces. In Sect. 2.2.3, we adopt the statistical analysis of the eigen-structure to design a color eigen-structure segmentation algorithm. The detailed procedures of the algorithm are also described. In Sect. 2.2.4, simulation results will be shown to verify the above theoretical development.

2.2.1 Principal Component Transformation (PCT)

The principal component transform (PCT) [17–19] is also called discrete Karhunen-Loève (KL) expansion. The KL transformation achieves optimal energy compaction and independent properties, which are commonly used for data compression. For the purpose of color object segmentation, the PCT could help to identify the most likely component. The proposed algorithms can also apply to other color coordinates, for example, YUV or \( Y_C, C_b \) as well. Without losing the generality, we choose RGB components to form the covariance matrix related to the selected color samples. First, using mouse clicks on the desired object to choose a few desired color samples. The \( k \)th sample in the RGB color vector is given by

\[
s_k = [r_k \ g_k \ b_k]^T ,
\]

(2.1)