Chapter XXXVI
Visualisation of Large Image Databases

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ABSTRACT

Following the ever-growing sizes of image databases, effective methods for visualising such databases and navigating through them are much sought after. These methods should provide an "overview" of a complete database together with the possibility to zoom into certain areas during a specific search. It is crucial that the user interacts in an intuitive way with such a system in order to effectively arrive at images of interest. In this chapter, we look at several techniques that have been presented in the literature and allow for browsing and navigation of large image databases.

INTRODUCTION

Content-Based Image Retrieval (CBIR) is increasingly playing a major role in image retrieval systems, such as those provided by stock photo companies. Initially, concept-based methods were adopted where each image is individually annotated and categorised before keyword or free text searches can be performed. This approach is still extensively used in many image database systems but the need for more automated indexing techniques has led to the adoption of CBIR, which is based on features computed directly from images and a defined similarity between these features resulting in a computed resemblance between images that ideally corresponds to the visual similarity humans would assign. Both paradigms are useful for different reasons and are combined in some cases to increase the effectiveness of a retrieval system.

While content-based retrieval systems typically allow the formulation of query-by-example searches where a query image is provided by the user and the system retrieves the closest matches from the database, this type of search is often not very useful. Rather, a possibility to effectively and efficiently browse the whole database is sought. Often, images are displayed in a one-dimensional linear fashion, either in rank order after a query or in the order they were read in from the database. Clearly, this gives no indication to the user of where a certain image can be found unless queried. When visualising larger datasets, the number of images is simply too large to be realistically viewable on a single screen. Drawbacks like this have, therefore, led to the research and development of how to arrange the images in such a way that they are positioned on the screen in relation to all other images. While this may cause significantly more images to be displayed at once the advantage is that all images are visualised at once and clusters of related images will appear which can then be investigated further. With the images positioned relative to their similarity with other images, the display gives structure, as zooming into an area will mean that all neighbouring images will be alike.

Displaying an entire dataset on a single screen and allowing the user to localise specific areas to explore further, creates the option of browsing the database whilst also giving an indication of the size of the collection. Navigation can be accomplished through a top-down hierarchical approach by zooming into an area of interest, and thus gives more visual information on the entire range of the database to the user. Using this approach to visualisation is a widely desired feature by both users with personal image albums and businesses that manage larger image compilations.

In this chapter, we review six methods that have been used to visualise image datasets and introduce their ability to browse through them. Besides explaining the underlying techniques, advantages, and disadvantages of each method will be highlighted and a recommendation for a useful visualisation system provided.

PRINCIPAL COMPONENT ANALYSIS (PCA)

Principal component analysis transforms a number of high dimensional correlated variables into a smaller number of uncorrelated variables called principal components and allows to reduce the dimensionality whilst preserving the "essence" of the data. High dimensional data is normally vast in size and ungraspable by the human mind, making some form of representation necessary.

In order to calculate the principal components, the mean vector of the data (which also defines the first principal component) is calculated and subtracted from the samples (hence, resulting in a distribution centred around the origin). Using singular value decomposition (SVD), the remaining components are obtained by producing a diagonal matrix with eigenvalues in descending order. Each singular value is proportional to the square root of the variances and the corresponding eigenvectors are the principal components. Once these have been calculated, all samples (i.e., images) in the database can be projected onto the principal components and the projection weights be used for assigning coordinates for the display of each image thumbnail (i.e., for the display in a two-dimensional space, such as a monitor the first two principal components would be used).

Using this linear strategy is more limited than their nonlinear counterparts, but has advantages. Results shown are reliable, with genuine properties of the original data if image similarity is based on an L_2 norm (Euclidean distance). If distances between images are based on another norm (e.g., L_1 norm—"Manhattan" distance) or indeed any other distance function, the results will not be as reliable which follows from the fact that PCA maximises the captured variance in a least-squares Euclidean way. Hence, if accuracy of thumbnail positions is of primary interest, further configuration re-arrangements should be considered as any nonlinear correlation between variables is not captured. On the plus side, the mapping of

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