ABSTRACT

The aim of this chapter is to provide the reader with a Content Based Image Retrieval (CBIR) system which incorporates AI through ant colony optimization and fuzzy logic. This method utilizes a two-stage fuzzy modified ant colony algorithm employing in parallel low-level features such as color, texture and spatial information which are extracted from the images themselves. The results prove the system to be more efficient compared to popular and contemporary methods such as the histogram intersection, joint histograms and the scalable color histogram of the MPEG-7 standard. However, due to the high computational burden of the AI methods the system is quite slow when implemented in software. Thus in order to speed up the whole process the reader is also provided with the hardware implementation analysis of the whole system. The increase in speed is phenomenal.

INTRODUCTION

Due to the increase in usage and production of digital images and large volume image databases, a need has risen for organizing them according to their content so that they can easily be retrieved. A simple though effective way to index and retrieve images is through query by example, which means that the user has to present an image to the system and the latter searches for others alike by extracting features from the query image and comparing them to the ones stored in the database. The extraction of meaningful features as well as the actual retrieval of image data based on illustrative content queries is a challenging issue actively confronted by a large number of scientists (Del Bimbo, 1999). Effective retrieval of image data is important for general multimedia information
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management. For an image to be retrievable, it has to be indexed by its content. Color can provide significant information about the content of an image. Among the methods that use color as a retrieval feature, the most popular one is probably that of color histograms (Del Bimbo, 1999; Swain & Ballard, 2001). The color histogram is a global statistical feature which describes the color distribution for a given image (Gonzalez & Woods, 2002). Other low-level features widely used by researchers for indexing and retrieval of images, except color are texture and shape (Del Bimbo, 1999). In order to exploit the strong aspects of each of these features while constructing an optimum and robust CBIR system, a plethora of methods, introduced over time, have been based on combinations of these features (Cheng and Chen, 2003; Pass & Zabih, 1999).

In this chapter the synergy of such features, specifically color, texture, and spatial information is performed by use of a modified artificial ant colony. This specific type of insect was selected since studies showed that when in groups, the ants show self-organization as well as adaptation which are desirable attributes in image retrieval. Artificial ant colonies have previously been used in text based search engines (Kouzas et al, 2006) but also in texture classification (Ramos et al, 2002) and color matching (Huang et al, 2006). Here, a modified ant colony algorithm is applied in order to optimize the process of the retrieval of general interest images. The main thrust of the proposed method is a two stage modified ant colony algorithm employing in parallel color, texture and spatial information which are extracted from the images themselves.

The study of ant colony behavior and of their self-organizing abilities (Bonabeau et al, 2000) inspired the algorithm, although in this chapter they are approached in a more unorthodox (modified) way. Normally the ants exit their nest searching for the shortest path to the food. In this approach the nest is regarded to be the most similar image to the query one while the ants search for the closest food surrounding the nest, which are actually the images in the database. Unlike other methods which employ ant colony optimization techniques, in this case we try to establish which few, from a plethora of food, are closest to the nest by altering the position of the nest in two separate consecutive stages. In the first stage, the synergy of the low-level descriptors is considered to be a swarm of ants, seeking for the optimal path to the surrounding “food”, whilst settling pheromone on each of the paths in a “high similarity” area of 1,000 images. The terrain on which the ants move is predefined through three low-level features extracted from the query image. In the second stage the terrain changes as additional queries are made by using the highest ranked images from the first stage as new nests. In each of the queries in the first and second stages the ants disperse pheromone on the paths to the food that is supposedly closest to the nest. A Mamdani inference fuzzy system (Mamdani & Assilian, 1999) is employed in order to extract the aggregate amount of pheromone in respect to each query since none of them is considered to be of the same importance to the next.

In comparison to other popular and contemporary methods such as the histogram intersection (Swain & Ballard, 1991), joint histograms (Pass & Zabih, 1999) and the scalable color descriptor of the MPEG-7 standard (Manjunath et al, 2001), the proposed system exhibits better results. In this chapter, performance is presented in the form of Precision vs. Recall graphs (Muller et al, 2001) averaged over numerous queries using two large databases which contain images of general interest, as is the case with the LabelMe database (Russel et al, 2005) and a portion of the Corel database.

One way for rendering the complex image retrieval algorithms more applicable to real-time systems is by accelerating them through hardware implementation. As an application, image retrieval belongs to the field of processing and analyzing images. Consequently, the hardware implementation of a retrieval system and in fact a Field Programmable Gate Array (FPGA) (Ali, 1996; Hamid, 1994), offers benefits to the wider field of image processing, where circuits of this kind may be used in a broader spectrum of applications such as robot vision (Chen & Li, 2004), image retrieval (Yang et al, 2007) etc. However, very little has been done in this direction. Three such cases include an FPGA image retrieval system based on the color histogram (Kotoulas & Andreadis, 2003), an FPGA application for the retrieval of a sub-image from an image database (Nakano & Takamichi, 2003), and a method for the efficient retrieval in a network of imaging devices (Woodrow & Heizelman, 2002).

In this chapter we present the design and hardware implementation of a specialized processor for image retrieval which combines three different descriptors with the use of an ant colony algorithm (Konstantinidis et al, 2007). It constitutes a tentative approach from the point of view that in the field of image retrieval, even for databases with millions of images, the process followed is more offline rather than online. This means that the descriptor extraction process usually takes place during the initial classification of the database. Subsequently, every time a