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Color reduction based on ant colony

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Abstract

In this article a method for color reduction based on ant colony algorithm is presented. Generally color reduction involves two steps: choosing a proper palette and mapping colors to this palette. This article is about the first step. Using ant colony algorithm, pixel clusters are formed based on their colors and neighborhood information to make the final palette. A comparison between the results of the proposed method and some other methods is presented. There are some parameters in the proposed method which can be set based on user needs and priorities. This increases the flexibility of the method.

Keywords: Color reduction; Clustering; Ant colony; Optimum palette; Image processing

1. Introduction

Researchers in the field of artificial intelligence have been inspired by the nature for many years. We can point to neural networks, evolutionary algorithms and artificial immune systems as well-known examples. Also some algorithms have been introduced based on swarm behavior studies (Dorigo et al., 1996; Deneubourg et al., 1990). Ant colony optimization, ACO (Dorigo et al., 1996), is a metaheuristic proven to be successful in solving NP-hard optimization problems. ACO is a distributed solution which uses pheromones as a positive feedback to enable the ants to communicate. On the other hand, ant-based clustering uses positive feedback and local information. It should be considered that ACO and ant-based clustering have many differences. The most important difference is that pheromones are not used in ant-based clustering.

The first clustering method based on ant colony was introduced by Deneubourg et al. (1990). They modeled ants as simple agents which move randomly in a square grid. Data items are scattered randomly on this grid and can be picked up, moved and dropped by ants. In this model ants are likely to pick up the items which are surrounded by dissimilar items and have tendency toward dropping them near similar items. Picking up and dropping down possibilities are calculated through simple formulas. By iterating these actions, the distribution of items on the grid will change. This distribution is used as a feedback and by repeating these operations, the items are clustered on the grid.

Several studies proceeded different aspects of Deneunbourg's model like straight movements. Lumer and Faieta (1994) expanded it for data analysis. They presented a modified method on numeric data and improved convergence time. They described data items through numeric vectors and used Euclidean distance to calculate the distance between them. Generally this algorithm can be used on any data set to which a function can be declared as a measurement of dissimilarity. Also they deployed a short-term memory to memorize last transmitted items and the position they were dropped. After picking up an item, the ant identifies the most similar item in its memory and move

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towards its position. Indeed they introduced the heterogeneous populations of agents for the first time which are the agents with different individual initialized parameters.

After Lumer and Faieta, Kuntz et al. proposed a method using ant-based clustering for graph partitioning (Kuntz and Snyers, 1994; Kuntz and Snyers, 1999; Kuntz et al., 1998). Also other studies proceeded ant-based clustering applicability in document retrieval and visualization. In (Handl et al., 2003; Handl and Meyer, 2002) Deneunbourg's basic algorithm was deployed on web page categorization and visualization. Handl and Meyer used ant-based clustering to create topic maps dynamically (Handl and Meyer, 2002). Handl's approach starts with randomly scattering the data items on a grid. In the next phase, each ant randomly selects a data item from the grid and then the ant is randomly placed on one of the empty cells on the grid. By the end of this phase each ant has picked up an item so the main loop starts. In the main loop, at first an ant is randomly selected then it moves one step of a given step size. The ant probabilistically decides whether to drop its carried data item. If it drops the item, it immediately searches for a free item to pick up probabilistically. Then the main loop is repeated for another randomly selected ant. More detailed information on Handl's approach can be found in (Handl et al., 2003; Handl, 2003).

Other approaches combine ant colony with other methods like C-means. The aim of this hybridization is to cover the disadvantages of one method with the advantages of the other. Ant-based clustering makes initial clusters for C-means instead of having no primary information. On the other hand C-means easily handles misplaced or free items and improves quality (Steinberg et al., 1998; Monmarché, 1999). In another approach real ants' behavior is simulated by a hybridization of ant-based clustering and fuzzy if-then rules (Kanade and Hall, 2003). Labroche et al. (2003) proposes a new model based on ants' chemical recognition system to cope with unsupervised clustering problems.

Image color reduction or quantization is one of the basic image processing techniques. Color reduction has two main steps: (1) K colors are chosen from the original ones to form the color palette. (2) The output image is reconstructed using this palette. Obviously quality of the output image depends on the first step, palette design. Palette design methods are divided into two main categories: (1) Palette design with pre-determined number of colors. (2) Designing the best palette without specifying the number of its colors. Many techniques have been proposed in each category (Scheunders, 1997; Papamarkos et al., 2002; Bing et al., 2004; Dekker, 1994).

In this article a method for palette design with pre-determined number of colors using ant-based clustering is introduced (Ghanbarian and Kabir, 2006). The rest of the paper is organized as follows. Section 2 presents the principal characteristics of the proposed method and also introduces the color reduction algorithm. A discussion on parameter analysis and experimental results on our method and five other methods is presented in Section 3. Finally Section 4 draws the conclusion.

2. The proposed method

In this section the general arrangement, the block diagram and the algorithm of the proposed method is introduced. Fig. 1 shows the block diagram of the proposed method. In the first phase, a modified ant-based clustering algorithm is applied to image pixels. The second phase is dedicated to choosing a representative for each cluster. In the third phase, pixels are mapped to the formed palette and color reduction is completed. The simplest method is used for mapping pixels to the palette. In this method closest item to each pixel in the palette replace it in the final reconstructed image. Modified ant-based clustering algorithm is discussed in the following.

2.1. Ant-based color clustering

This method is based on the algorithm presented by Handl (Handl and Meyer, 2002). Handl's algorithm has been proposed for data clustering applications. In these applications, the data items are randomly spread on a grid. However in the proposed method, for color clustering problem, the algorithm is directly applied on the image grid itself. In this way the color and adjacency information are considered simultaneously in the clustering process. The neighbourhood function, $f(i)$, used in our method is as follows:

$$f(i) = \max\left(0, \frac{1}{\delta^2}\sum_j\left(1 - \frac{d(i,j)}{\alpha}\right)\right) \quad (1)$$

$d(i,j)$ defines the dissimilarity between pixels i and j. Parameter α determines the influence of dissimilarity function on $f(i)$. δ is the radius of perception. In this method, δ is set to 1 so that 8 pixels around each pixel are considered in calculating $f(i)$. The experiments showed that larger radius of perception extends the execution time while has very low impact on the quality of the results.

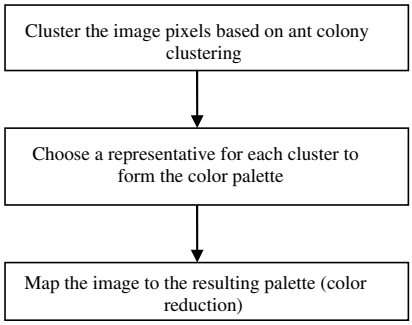

Fig. 1. The proposed color reduction method.