

A Model of Semantic-Based Image Retrieval Using C-Tree and Neighbor Graph

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ABSTRACT

The problems of image mining and semantic image retrieval play an important role in many areas of life. In this paper, a semantic-based image retrieval system is proposed that relies on the combination of C-Tree, which was built in the authors' previous work, and a neighbor graph (called Graph-CTree) to improve accuracy. The k-Nearest Neighbor (k-NN) algorithm is used to classify a set of similar images that are retrieved on Graph-CTree to create a set of visual words. An ontology framework for images is created semi-automatically. SPARQL query is automatically generated from visual words and retrieve on ontology for semantics image. The experiment was performed on image datasets, such as COREL, WANG, ImageCLEF, and Stanford Dogs, with precision values of 0.888473, 0.766473, 0.839814, and 0.826416, respectively. These results are compared with related works on the same image dataset, showing the effectiveness of the methods proposed here.

KEYWORDS

C-Tree, Graph-CTree, Image Retrieval, k-NN, Ontology, SBIR_grCT, Semantic-Based Image Retrieval, Similar Images, SPARQL

INTRODUCTION

The problems of image mining, image retrieval, and image semantics are becoming more popular among researchers. Identifying the desired image from a large and diverse image dataset is a challenging task. Therefore, it is essential to develop high-precision image retrieval systems for large datasets. However, the low-level content of images, including color, shape, and texture, cannot define the user's high-level semantics (Allani et al., 2017; Cevikalp et al., 2018). Therefore, it is essential to have a structure for mapping low-level features to high-level semantics based on ontology (Filali et al., 2017; Sarwara et al., 2013). Thus, high-level semantics of images can classify and retrieve high-level semantics of images based on SPARQL (Hogan, 2020).

Our ontology-based model is proposed to support two main features for semantic retrieval in image datasets: (1) searching for a set of images that are similar to a given image; and (2) mapping low-level features onto the high-level semantics of the image based on ontology. The result of using SPARQL query on ontology is the set of descriptive semantics of the dataset and the set of similar images according to the semantic of the input image. A balanced clustering tree structure, called

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C-Tree, was published in Nhi et al. (2020) to automatically archive indexed images from low-level features of the image. C-Tree has many advantages, such as a multi-branch tree and clustered feature vectors, so it can store large amounts of data and retrieve images rapidly. However, image retrieval on C-Tree is conducted by finding the branch with the closest similarity measure to the input image. Therefore, it may not be possible to find all feature vectors that are similar to the input image because, when splitting the node, it may have split through another cluster or even another branch.

This paper proposes a combination model of C-Tree and a neighbor graph, Graph-CTree, to limit the omission of similar elements that have split into another branch and to improve the accuracy of image retrieval. For semantic-based image retrieval, a semi-automatic ontology framework is built upon the Resource Description Framework (RDF; Furche et al., 2006; Haase et al., 2004) for a multi-object ImageCLEF dataset. An input image is queried on Graph-CTree to find a similar set of images. From there, the k-Nearest Neighbor (k-NN) algorithm is performed on this set of images to classify and create a set of visual words. SPARQL query is generated based on these visual words and is queried on the ontology. The experiment was implemented on the COREL, WANG, ImageCLEF (IAPR TC-12 benchmark), and Stanford Dogs datasets and compared with the previous results of related works to evaluate the efficiency of the proposals offered here.

The contributions of the paper include: (1) proposing a model combining C-Tree and Graph-CTree to improve the efficiency of image retrieval; (2) proposing a model for building a semi-automatic ontology framework; and (3) proposing a semantic-based image retrieval model combining machine learning method (Graph-CTree) and ontology.

RELATED WORK

There are many techniques of semantic-based image retrieval that have been implemented in many digital systems. The state-of-the-art techniques for reducing the ‘semantic gap’ can be broadly categorized into two main categories: (1) using machine learning methods to associate low-level features with visual concepts to describe image objects (Jui et al., 2017; Barz et al., 2020); (2) using ontology to define high-level semantics (Allani et al., 2017; Gonçalves et al., 2018; Bouchakwa et al., 2020). Many systems use one or a combination of different techniques to perform high-level semantic-based image retrieval.

Jiu Mingyuan and Hichem Sahbi (2017) used deep multi-layer networks based on nonlinear activation functions for image annotation (Jiu & Sahbi, 2017). The Support Vector Machine (SVM) technique was applied to layering images at the output layer to extract a semantic level according to visual information for similar pocket-based images from BoW (Bag-of-Words). Extensive experiments and analysis of the ImageCLEF and COREL5k datasets validated the effectiveness of the proposed method. The precision of image retrieval for each dataset was 0.597 and 0.8867, respectively.

Hakan Cevikalp et al. (2018) proposed a method for image retrieval using a class binary hierarchical tree and trained with a low-level feature-based transductive SVM (TSVM) technique to separate labeled and unlabeled data samples at each node of the binary hierarchy. The method was tested on the ImageCLEF, CIFAR100, and NUS-WIDE datasets with precision values of 0.4678, 0.7235, and 0.7621, respectively.

Barz Bjorn and Joachim Denzler (2020) proposed a method to integrate semantic relationships between classes. This approach has been mentioned as a classification into deep learning by deep neural networks. The hierarchy-based semantics preserve the semantic similarity of the classes in the common space of the images and classes. The proposed method has been implemented on the CIFAR-100, CUB-200, and Oxford Flowers-102 datasets, showing significant improvement in the semantic consistency of image retrieval results. At the same time, the precision of image retrieval for each dataset was 0.775, 0.68, and 0.711, respectively.

Jalila Filali et al. (2017) proposed to build ontology based on visual annotations of the ImageCLEF dataset. The image retrieval process is accomplished by integrating both low-level features and

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