Image Retrieval using Graphs

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***Abstract*—Content-Based Image Retrieval has been a fast advancing area since the 1990s decade, with the Internet growth and the technology available that provides an easy access to acquire images. Hence, image data requires to be organized so that image database queries can result as fast as possible, even though the many possible topics are available now a days. In this paper, we introduce a novel technique based on global image features by interest point detection and using graph theory, particularly Delaunay triangulations to obtain a graph that can be measured for comparison. The technique shows promising results and can be regarded as flexible in the sense that parts can be adapted or upgraded to achieve better performance.**

***Keywords*—Content-based image retrieval; interest point detection algorithms; graph theory; delaunay triangulations**

I. Introduction

Content-Based Image Retrieval (CBIR) refers to techniques of automatic retrieval of images from a database based on its contents, namely, visual features that describe the image contents [1]. In CBIR two different main approaches can be considered, discreet and continuous. The first one is inspired by textual information retrieval and uses such metrics for retrieval. On the other hand the second approach represents the images as feature vector, so these features are compared using different distance measures [2].

As a result, the use of visual features is a key component for the representation. Common features include colour, shape and texture and are called low level features, meanwhile high level features recall for a combination of low level features and a predefined model [3]. An open question here is then, which features are more suitable for image retrieval tasks. Part of the answer can be determined by the use of global or local image description features, that rely on the objects in images consisting of parts that can be modelled or not with varying degrees of independence [4].

Here, we introduce a novel technique for Content-Based Image Retrieval that works with the image in a global fashion using interest point detection algorithms and graph theory, in particular, Delaunay triangulations and graph measurements. Fig. 1 summarises the procedure.

Some of the previous works similar to our approach (either in the use of interest points or graph theory) include the work in [5], where two methods to find interest points and a Gabor filter are used to create descriptions based on textures for image indexation that generate good results according to the authors over different image data bases. In [6], the image is divided in a series of subregions with a different area according to the distribution the interest points so local features are obtained, so using multiple instances the method improves the image retrieval precision. In [7] a scientific-cultural collection of hebraic tombstones is used to evaluate the performance of different interest point algorithms (SIFT-SIFT, SIFT-BRISK, SURF- SIFT, SURF-SURF, SURF-BRISK and CenSurE-SIFT) to implement CBIR techniques. These systems seek to classify images the way the human being does, but in a different fashion, in [8] a method is described were they convert of a given video or multidimensional imaging (MDI) into time series, followed by the conversion of it into a network, and finally analysing the network metrics they are able to identify specific topological metrics which can be regarded as discriminators for different inputs.

The remainder of this paper is organized as follows. Section 2 gives details of the proposed method, in Section 3 the experiments are shown, and finally, in Section 4 some conclusions are given along with future work extensions.

II. Proposed Method

The first step is to select a query image, then the dominant RGB channel of the image is obtained in order to create a first filter for the images, remaining the ones from the data base with the same dominant colour as the query (Fig. 1(a)). After that, we proceed to extract image features, in this case and as mention before, global image features are considered.

The concept of feature descriptors refers to methods that aim to calculate abstractions of information in an image, in addition to making decisions at each point in the image if there is a characteristic of a given type at that time [9]. In this case image interest points detection algorithms are applied in order to obtain a set of meaningful points (Fig. 1(b)). Interest points can be regarded as points that have a well-defined position in image space, stable under local and global perturbations and include an attribute of scale, to make it possible to compute interest points from images at different scales [10]. Five different descriptors were used in this work, in order to answer which feature is better for this task. First we have the Brisk feature detector, which relates key points in cases without sufficient a priori knowledge of the scene and angle of the camera. Fast, which is a corner

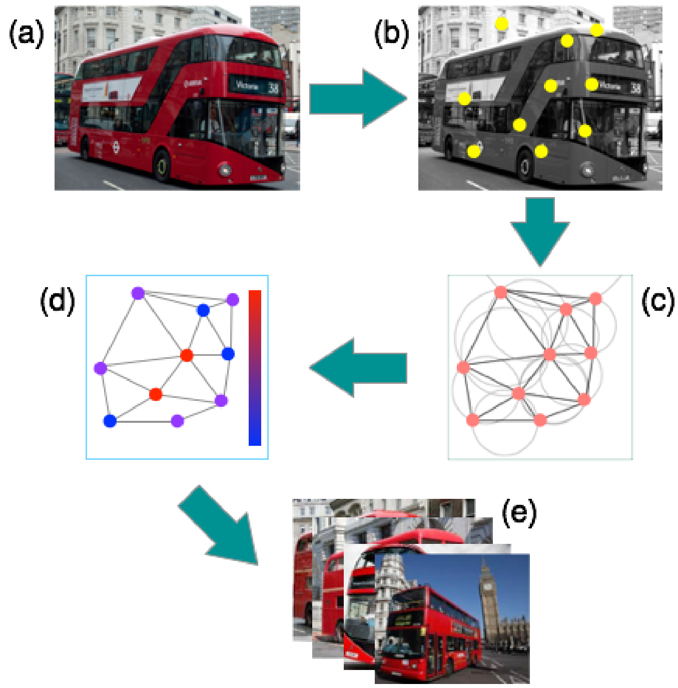

Fig. 1. Proposed method: (a) Selection of the target image for the query, (b) Calculation of interest points, (c) Delaunay graph calculation, (e) Graph measurements calculation and (f) Query results.

detector, is used to extract characteristic points as well as tracing objects in computer vision. In addition the well-known Harris method is used, that identifies similar regions between images that are related through related transformations and have different illuminations. SURF, another classic method, which is a detector and descriptor of characteristics that is usually used for tasks such as recognition, classification or registration of objects and finally we use MSERF, which extracts a number of regions that remain almost the same range through Wide thresholds.

Once a set of interest points is obtained by one of the aforementioned methods, a Delaunay triangulation is performed to generate a graph so that we can perform measurements to compare the query image with the rest of the data base (Fig. 1(c)). Delaunay's condition stays that a network of triangles is a Delaunay triangulation If all the circumscribed circumferences of all the triangles (created bu the graph nodes) of the net are empty, that is, the circumscribed circumference of each triangle in the network contains no vertices other than the three that define the triangle [11]. The reason why Delaunay's triangulation is used is to ensure that for every image we will obtain a unique graph representation [12].

Having the triangulation, then an adjacency matrix is obtained and from it so graph measures can be calculated (Fig. 1(d)). There are several measures that characterize a graph, within the most common and the ones used in this work are: shortest path that indicates the length of the shortest path between two nodes of a graph; density, which is a proportion of connected vertices; length, the number of edges of a path; centrality, a measure that determines the relative importance of a vertex in a graph and the degree or number of edges incident to a vertex [13].

The final step is to compare the obtained results from the measurements with the images of the database to obtain the similar ones to the query (Fig. 1(e)). An interface has been created to facilitate the selection of image interest points method and to visualise the performance of the method. On the upper left corner the query image is loaded and below it, information regarding the number of interest points generated by each algorithm is given, along with the dominant colour RGB channel and he number of resulting images to be displayed (Fig. 2).

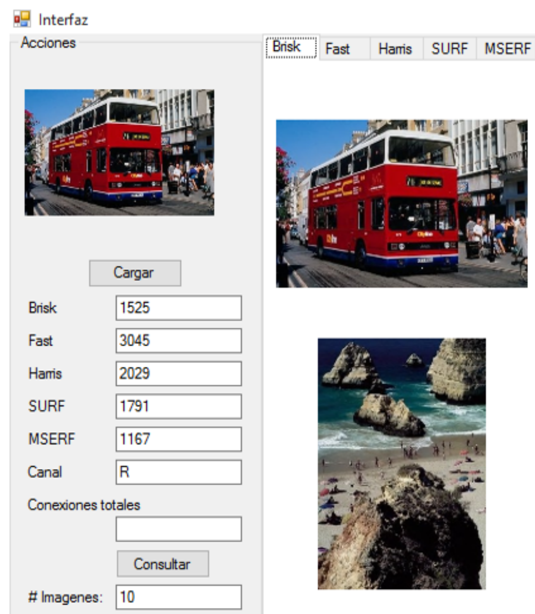

Fig. 2. Interface of the application, where the image query an the interest point method can be selected.

III. Results

To obtain the points of interest using feature detectors, Delaunay triangulation and mathematical calculations, Matlab was used. In this section we show results obtained on a subset of the image database of Dr. Wand at PennState (http://wang.ist.psu.edu/docs/related/) [14], in this case the used categories were buses, beach, horses, flowers, mountains, food, dinosaurs, buildings, elephants and tribes. As training, only 10 photographs of each category were taken giving a total of 100 test images.

Fig. 3. Query image for the experiments.

The bus query image for the experiments is shown in Fig. 3 and the 10 most similar resulting images from the data base are shown for each method: Brisk (Fig. 4), Fast (Fig. 5), Harris (Fig. 6), SURF (Fig. 7) and MSERF (Fig. 8). In each figure, images are ordered from left to right according to the results of the graph measure so the image on the left upper corner is the most similar to the query one. Important to mention that only results with the graph density measure are presented since it was considered the most successful one according to the obtained results.

Fig. 4. Results of the bus query of the image for the Brisk method and using the graph density measurement.

Fig. 5. Results of the bus query of the image for the Fast method and using the graph density measurement.

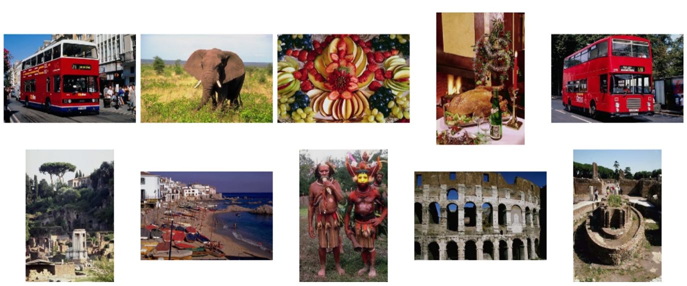

Fig. 6. Results of the bus query of the image for the Harris method and using the graph density measurement.

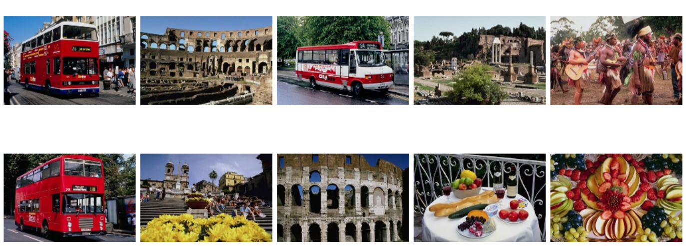

Fig. 7. Results of the bus query of the image for the SURF method and using the graph density measurement.

Fig. 8. Results of the bus query of the image for the MSERF method and using the graph density measurement.

IV. Conclusions and Future Work

We introduced a novel method for Content-Based Image Retrieval that works in a global manner using different interest point detection algorithms to generate a graph, in particular Delaunay triangulations, and from there find the most similar images from the data base using graph measurements. Method can be regarded as flexible since changing the point detection algorithms and the graph measurements we can enhance the performance as shown in the results.

Given the results generated by the different methods to obtain points of interest, we can considered a good start to continue working on the development of image recovery using measurements in graphs. Results might show a weak performance of the method only by giving a visual inspection, but in each case the query image was retrieved successfully. From the best result obtained using the MSERF method (Fig. 8) were buses occupy the first positions of resulting images, we strongly believe that using the right combination of methods to pre-filter images (by colour), interest points obtention and graph measurements, results can be improved.

Fig. 9. Some images contain objects with different colours, so the method should incorporate features to overcome this issue.

As an example, other methods to pre-filter the images and obtain the closest ones in terms of the dominant colour is using Colour Coherence Vectors [15] or in the case of new interest points, different approaches like a corner detector based on global and local curvature properties [16] can be implemented. Finally, other graph measures like spectral graph ones can be used instead of the simple ones we are currently using. Additionally, the method needs to be adapted so the colour feature can be assessed properly in the analysis since there are images with the same objects but with different colours (Fig. 9).

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