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A comparative study of image low level feature extraction algorithms

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Abstract Feature extraction and matching is at the base of many computer vision problems, such as object recognition or structure from motion. Current methods for assessing the performance of popular image matching algorithms are presented and rely on costly descriptors for detection and matching. Specifically, the method assesses the type of images under which each of the algorithms reviewed herein perform to its maximum or highest efficiency. The efficiency is measured in terms of the number of matches founds by the algorithm and the number of type I and type II errors encountered when the algorithm is tested against a specific pair of images. Current comparative studies asses the performance of the algorithms based on the results obtained in different criteria such as speed, sensitivity, occlusion, and others. This study addresses the limitations of the existing comparative tools and delivers a generalized criterion to determine beforehand the level of efficiency expected from a matching algorithm given the type of images evaluated. The algorithms and the respective images used within this work are divided into two groups: feature-based and texture-based. And from this broad classification only three of the most widely used algorithms are assessed: color histogram, FAST (Features from Accelerated Segment Test), SIFT (Scale Invariant Feature Transform), PCA-SIFT (Principal Component Analysis-SIFT), F-SIFT (fast-SIFT) and SURF (speeded up robust features). The performance of the Fast-SIFT (F-SIFT) feature detection methods are compared for scale changes, rotation, blur, illumination changes and affine transformations. All the experiments use repeatability measurement and the number of correct matches for the evaluation measurements. SIFT presents its stability in most situations although its slow. F-SIFT is the fastest one with good performance as the same as SURF, SIFT, PCA-SIFT show its advantages in rotation and illumination changes.

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1. Introduction

Feature detection and image matching represent two important tasks in computer vision, computer graphics, photogrammetric and all images' applications. Their application continues to grow in a variety of fields day by day. From simple photogrammetric tasks such as feature recognition, to the development of sophisticated 3D modeling software and image's search engine, there are several applications where image matching algorithms play an important role. Moreover, this has been a very active area of research in the recent decades and as indicated by the tremendous amount of work and documentation published around this. More than a decade ago, the applications associated with 2D and 3D models and object reconstruction were mainly for the purpose of visual inspection and robotics. Today, these applications now include the use of 2D and 3D models in computer graphics, virtual reality, communication and others. But achieving highly reliable matching results from a pair of images is the task that some of the most popular matching methods are trying to accomplish. But none have been universally accepted.

It seems that the selection the adequate method to complete a matching task significantly depends on the type of image to be matched and in the variations within an image and its matching pair in one or many of the following parameters: (a) *Scale*: At least two elements of the set of images views have different scales. (b) *Occlusion*: Is the concept that two objects that are spatially separated in the 3D world might interfere with each other in the projected 2D image plane. (c) *Orientation*: The images views are rotated with respect to each other. (d) *Affine Transformation*: Whether is a planar, textured or edgy object. (e) *Blurring*: is the apparent streaking of rapidly moving objects in a still image or a sequence of images. (f) *Illumination*: Changes in illumination also represent a typical problem for accurate feature matching [1,2,3].

Comparative studies have been published and available assessing the performance of the image matching algorithms methods without other aspects like (time, cost and power consumption) but this study overcomes some of the limitations of the current comparative studies by incorporating the analysis of the algorithms using different scenes to determine under which circumstances they will provide optimum results. In [4], they showed how to compute the repeatability measurement of affine region detectors also in [5] the image was characterized by a set of scale invariant points for indexing.

2. Related work

During the process of searching for documentation on 2D modeling, a lot of work was found that addresses the early feature detection and the posterior image matching. Most of the early implementations developed seemed to work well under certain limited image condition. The real challenge for those authors was to achieve true invariant feature detection under any image such (a) Consistency, detected positions should be insensitive to the noise, scale, orientation, cluttered, illumination. (b) Accuracy, should be detected as close as possible to the correct positions and features; (c) Speed, should be faster enough.

Some researches focused on the application of algorithms such as automatic image mosaic technique based on SIFT [6,7], stitching application of SIFT [8–11] and Traffic sign recognition based on SIFT [10]. Ke and Sukthankar [12] gave some comparisons of SIFT and PCA-SIFT. PCA is well-suited to represent keypoint patches but observed to be sensitive to the registration error. In [13], the author used Fast-Hessian detector which is faster and better than Hessian detector. Section 3 will show more details of the three methods and their differences.

The first attempt towards digital image recognition was the color-based algorithm (color histogram or color distributive features). This practice although effective had many limitations. Color histogram was successful and faster in detecting color distribution features in any given images meeting basic requirements. But it was unsuccessful in matching large set of images and no satisfies the following criteria (Consistency, Accuracy) [14].

The second attempts towards digital image recognition were limited to the identification of corners and edges. The beginnings of feature detection can be tracked with the work of Harris and Stephen and the later called *Harris Corner Detector*. Harris was successful in detecting robust features in any given image. But since it was only detecting corners, his work suffered from a lack of connectivity of feature-points which represented a major limitation for obtaining major level descriptors such as surfaces and objects. Almost a decade after the Harris Detector was published; a new corner detector algorithm called FAST (*Features from Accelerated Segment Test*) was presented.

The third attempt towards digital image recognition was limited to achieve reliable image matching from textured image with cluttered backgrounds. Before this, it is important to know that feature-based algorithms have been widely used as feature point detectors because colors, corners and edges correspond to image colors and locations respectively with high information content, meaning this that they can be matched between images. But the feature-based detectors only perform accurately when the objects to be matched have a same color or a distinguishable corner or edge. Furthermore, the feature-based algorithms do not perform as good as expected when images are subjected to variations in color's distribution, scale, illumination, rotation or affine transform.

To overcome these limitations, a new class of image matching algorithm was developed simultaneously. These algorithms are known as texture-based algorithms because of their capability to match features between different images despite of the presence of textured backgrounds and lack of planar and well-defined edges. One of the first attempts towards this novel approach was undertaken by David Lowe.

Lowe [15] presented SIFT (*Scale Invariant Feature Transform*) for extracting distinctive invariant features from images that can be invariant to image scale and rotation [10,15,16]. Then it was widely used in image mosaic, recognition, retrieval and etc. After Lowe, Ke and Sukthankar used PCA (*Principal Component Analysis-SIFT*) to normalize gradient patch instead of histograms [12]. They showed that PCA-based local descriptors were also distinctive and robust to image deformations. But the methods of extracting robust features were still very slow. Bay et al. SURF (*speeded up robust features*) and used integral images for image convolutions and Fast-Hessian detector [13]. Their experiments turned out that it was faster and it works well.