An Examination of Image Mining: Approaches, Techniques, and Application

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Abstract:- Image mining, encompassing Image processing, Databases, Data mining, Machine learning, and artificial Intelligence, is primarily focused on the extraction of patterns from extensive collections of images. Despite the considerable amount of research conducted in these domains, challenges persist within the field of image mining. For example, data mining techniques are unable to automate the extraction of information from large sets of images. Within this paper, we explore a comprehensive approach to extract data based on the existing body of research. This paper aims to assist readers interested in gaining insights into current image mining techniques and advancing their knowledge extraction from substantial image datasets within this domain.

Keywords:- *Data Mining, Image Processing, Neural Network, Machine Learning, Image Mining, Image Classification, Image Clustering, Image Pre-Processing, And Content-Based Image Retrieval (CBIR).*

I. INTRODUCTION

Image mining represents an interdisciplinary field that draws upon Image processing, data mining, machine learning, databases, and artificial intelligence. With the expansion of the global network and the exponential growth of social networking, there is an increasing demand for extracting meaningful images from the vast pool of online content. Image processing primarily focuses on comprehending specific characteristics of images, while data mining employs algorithms to extract data (in this case, images) with greater accuracy and efficiency.

In contrast, machine learning plays a crucial role in enabling networks to learn patterns and features, reducing errors in output, and classifying images based on specific features identified during image processing. This paper provides a concise overview of the image mining process and reviews relevant literature from various sources. It highlights research gaps, discusses the application of image mining techniques, and concludes with insights on the subject.

Image mining can be performed through manual data manipulation involving cutting and fragmenting data to achieve specific patterns or automatically using software programs for data analysis.

II. CONTENT-BASED IMAGE RETRIEVAL (CBIR)

In the context-based image retrieval system, the image's color, texture, and existing shapes serve as the primary descriptors.

Similar images can be identified and retrieved from a large image database using primary descriptors. Manual extraction of images from such a vast dataset is challenging due to its sheer size [11].

Additionally, context-based image retrieval (CBIR), also known as Query by Image Content (QBIC) and content-based visual information retrieval (CBVIR), involves the use of machine vision to retrieve digital images from extensive image databases [11]. Traditional image retrieval methods like indexing are recognized as time-consuming and inefficient. These methods involve associating an indexed image with a keyword or a number related to its categorized descriptions, but they do not rely on CBIR content.

In CBIR, each image in the database possesses unique characteristics that are extracted and compared with those of the query image. This approach draws upon various fields of knowledge, including pattern recognition, object matching, machine learning, and microwave filtering, among others. CBIR aims to recognize and explore the visual attributes of images without the need for descriptive text.

CBIR is designed to identify database images that closely resemble the query image. It also seeks to develop techniques that can automatically extract images based on their features. CBIR places a significant emphasis on image features, which can be categorized as low-level features or high-level characteristics. It retrieves images from the database based on attributes such as color, texture, edges, and shape [12]. In contrast, in a text-based image retrieval system (TBIR), images are retrieved based on descriptions, indexing, and attributes such as size, type, date, time of capture, owner identification, keywords, or other explanatory text associated with the image [12].

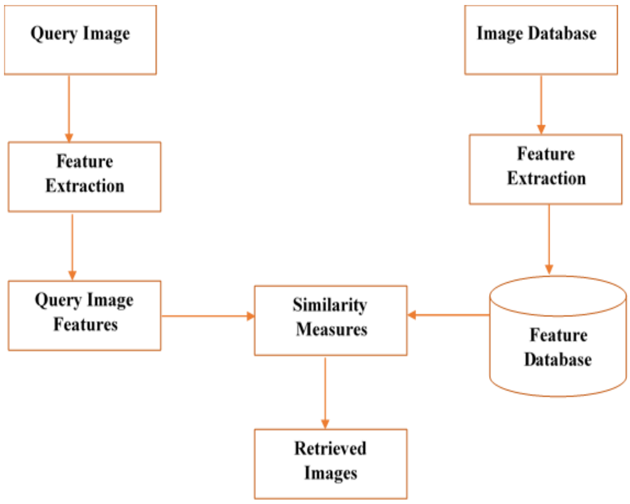

Fig 1. The system architecture of CBIR

III. IMAGE MINING PROCESS

In an image mining system, various tasks are undertaken to obtain the desired images. Many of these tasks rely on image processing methods and pattern recognition. The primary goal of image mining is to extract valuable knowledge from extensive image databases. Image mining takes on various forms depending on factors like queries, similarity search methods, and the type of learning employed, including supervised and unsupervised learning.

This section provides an overview of the activities involved in the image mining process and highlights some of the techniques used in each step. It's important to note that the sequence of these activities may vary depending on the specific image-mining model that has been designed.

A. Pre-processing and De-noising

It is essential to enhance the image quality before utilizing it for feature extraction purposes. Pre-processing of images is performed to generate high-quality images, which subsequently leads to more transparent categorization. The pre-processing of an image is also critical for eliminating any noise present in the images that could lead to undesired outcomes. Filtering is a method employed to modify or improve an image. It is applied when there is a need to emphasize specific aspects within an image. To eliminate any existing noise in an image, both linear and nonlinear filtering techniques are employed. Some of the techniques used to eliminate noise from images include low-pass filters, high-pass filters, and band-pass filters [9]. Various techniques, including both linear and non-linear image filters, can be employed to eliminate noise from the image. In the pre-processing phase, tasks such as Image thresholding [1], edge detection [1], border tracing [1], and wavelet-based segmentation [2] can be applied. Additionally, low-pass filters, high-pass filters, and band-pass filters [1] may be utilized to effectively eliminate noise from the images.

B. Feature Extraction

The characteristics present within an image are pivotal in the differentiation and classification of sets of images into their respective categories. These features encompass aspects such as color, edges, texture, shape, and boundaries, all of which can be derived from the image. Multiple techniques are available for the extraction of these features, and these methods will be elaborated upon in the following sections.

- *Image thresholding*

This represents the most basic approach to image segmentation. By performing extreme contrast stretching, we achieve the result of thresholding. When applied to a grayscale image, thresholding transforms it into a binary image. Put simply, this process involves replacing all the image pixels denoted as I(i,j) which indicates the intensity values of the pixel located in the i^{th} row and j^{th} column whose intensity falls below a predetermined or constant threshold value.

- *Edge detection*

Variations in scene characteristics, such as changes in brightness, lead to the emergence of edges. These edges represent instances of abrupt shifts in the intensity function of an image. The primary objective of identifying sharp discontinuities in image brightness is to capture significant and valuable alterations in the properties of the depicted scene. It can be demonstrated that, under general assumptions regarding an image, discontinuities in image brightness correspond to breaks in-depth, shifts in surface orientation, alterations in material attributes, and fluctuations in scene lighting conditions. Various techniques exist for detecting these discontinuities in the form of edges. These methods all rely on derivatives and can be categorized into two main groups, as detailed below.

The first-order method - Prewitt and Sobel operators [1] represent tools commonly employed for edge detection. These operators take the form of 3x3 dimensional masks, which are applied to the entire image to obtain edge information.

Second Order Method - The Laplacian operator [1] is utilized in the second derivative technique to accentuate sharp edges. These operators are also known as isotropic filters. However, they exhibit a high sensitivity to noise. In cases where an image includes noise, the application of the Laplacian operator can adversely affect the entire image.

- *Contour tracing*

It is alternatively referred to as boundary tracing of a binary digital area, and it can be viewed as a segmentation method aimed at detecting the boundary pixels within a digital image. This process entails tracing all the pixels of the image from top to bottom and from left to right, with the outcome often encoded using Run-Length [1] coding.

- *Color Extraction of Image*

It serves to extract color as an image feature. The color histogram feature in an image is employed to portray the distribution of colors within that image. By applying histogram equalization, one can manipulate the distribution of red, green, and blue colors in the image. During the equalization process, all the red, green, and blue pixels in the image are assessed and redistributed to achieve a global balance in image contrast. This enables regions with lower contrast to attain higher contrast.

➢ *Texture Extraction of Image*

Image texture provides insights into the spatial pattern of colors or intensities within an image or a specific image area. It constitutes a collection of metrics computed in image processing to measure the texture characteristics of the image. These image textures can be either manually designed or discovered in the natural environment.

C. Image Classification

Classification is a supervised technique for organizing data into groups. In this approach, a labeled set of images, known as a learning set, is provided for classification. Classification typically involves a two-step procedure, consisting of a learning phase and a test phase. The objective of the classification process is to categorize all the pixels within a digital image into distinct classes. This is accomplished through a supervised learning method that relies on known results to classify images. The primary task is to assign a label from a predetermined set of categories to an input image. All classification algorithms operate under the assumption that the image contains one or more features, and each of these features belongs to one of several unique and exclusive classes. Several classifiers are employed for this purpose, including the Bayes classifier, Neural Networks (such as MLP, RBF, SVM, among others), Decision Tree classifier, and Genetic Algorithms.

Image classification typically involves two key phases: the learning phase and the testing phase. In the learning phase, diverse images are utilized, and the learning process is based on the resultant output classes [2]. During the testing phase, image features and specifications are utilized to associate the image with an output class. Decision tree classification is one of the most significant methods, as it partitions the decision space into smaller regions based on decisions made while taking actions, effectively breaking down complex problems into more manageable ones.

D. Image Clustering

It is an automated unsupervised technique wherein samples are grouped into various categories based on shared characteristics. Each of these individual groupings is referred to as a cluster. Essentially, a cluster represents a collection of objects that possess some property or feature in common with at least one other object within that same cluster. Various methods exist for organizing data into clusters, including Partitioning methods, hierarchical methods, and Grid-based methods. Unlike classification, clustering does not require an output feature vector. Instead, it continually assigns new samples to a group based on their properties, closely matching them with existing samples in the group, thus expanding the cluster's size as more samples are added.

E. Histogram Equalization

Histogram equalization is a technique employed in image processing to adjust contrast. It achieves a more even distribution of contrast within the histogram, allowing regions with lower local contrast to exhibit improved contrast. This method enhances contrast significantly by emphasizing the highest contrast levels. Histogram equalization proves particularly valuable for images characterized by a black-and-white background and foreground, such as radiology images. Another histogram-based method in image processing involves generating a severity histogram. In this type of histogram, various features like average, variance, skewness, elongation, entropy, and energy are considered [13].

F. Interpretation and Evaluation

The assessment of retrieval plays a crucial role in the image mining process. Researchers have put forth a variety of methods to gauge the system's performance. However, the prevailing approach for evaluation remains Precision and Recall. Typically, these metrics are visualized through a precision vs. recall graph. The formulas used to calculate precision and recall values are as follows.

$$Precision = \frac{number\ of\ relevant\ images\ retrieed}{Total\ number\ of\ images\ retrieved} \quad (1)$$

$$Recall = \frac{number\ of\ relevant\ images\ retrieed}{Total\ number\ of\ relevant\ images\ in\ the\ database} \quad (2)$$

IV. APPLICATIONS OF IMAGE MINING

Medical image mining aims to obtain valuable insights and patterns that can aid in the identification of irregular conditions that do not conform to established patterns. This technique can be applied to categorize brain CT scan images into three distinct groups: normal, benign, and malignant. Additionally, image mining can be employed for the analysis of satellite cloud images. Utilizing neural networks, image clustering can be performed on diverse image collections, aiding physicians in achieving more efficient classification. Furthermore, the inclusion of multiple keywords per image can enhance accuracy in this process.

V. CONCLUSION

Every day, a wealth of valuable data is generated from sources such as satellites, space observations, medical imaging, and digital images. The sheer volume and complexity of this data make it impractical for humans to manually analyze it to extract useful information or discern relevant patterns for decision-making. While image mining is not a new field, there is still room for further exploration because defining image objects is a challenging task, and no definitive algorithm has been established to date. Every proposed methodology has encountered issues, whether they pertain to accuracy (comparing input and output images) or processing speed. This paper has discussed a range of strategies that have been previously employed and identified research gaps associated with these strategies. These research gaps can serve as a foundation for the development of new image-mining techniques.

COMPLIANCE WITH ETHICAL STANDARDS

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