SURVEY ON CONTENT-BASED IMAGE RETRIEVAL (CBIR) SYSTEM

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ABSTRACT

Content-Based Image Retrieval (CBIR) has emerged as a prominent method of effective image retrieval based on visual image features, i.e., shape, texture, and color, rather than text-based information. Traditional CBIR systems are plagued by issues such as the semantic gap between low-level image features and high-level human perception, computationally expensive operations in handling large amounts of data, and ineffectiveness in real-time performance. Recent advances in deep learning, particularly Convolutional Neural Networks (CNNs), have revolutionized CBIR by promising more accurate and scalable feature extraction. The present survey paper reviews a range of CBIR methods from traditional feature extraction methods to deep-learning-based techniques. The paper also presents similarity matching methods, indexing methods, and system architectures that enable retrieval efficiency. Further, the paper presents ongoing challenges confronting CBIR and future research directions, namely, cloud-based deployments, AI-based personalized searching, and enhanced security features. These advances are resulting in robust, intelligent, and scalable image retrieval systems that can discover widespread applications across a broad range of applications ranging from healthcare to security to e-commerce.

Keywords: content-based image retrieval *(CBIR), Feature Extraction, Deep Learning, Convolutional Neural Networks (CNNs), Semantic Gap, Similarity Matching, Image Indexing, Locality-Sensitive Hashing (LSH), FAISS, Computational Complexity, Real-Time Image Retrieval, Scalable Search Systems.*

1. INTRODUCTION

In the modern era of digital information, with visual information increasing exponentially, the need for effective and intelligent image retrieval systems is more pressing than ever before. Conventional methods relying on text descriptions, metadata, and human annotation are limited by inaccuracy and human dependence. Content-Based Image Retrieval (CBIR) overcomes these limitations by examining intrinsic visual features like color, texture, and shape for automatic retrieval.Automatic features were utilized in CBIR previously, created by humans, but these were hindered by the semantic gap—the difference between low-level image data and human perception. Deep learning, particularly through the utilization of Convolutional Neural Networks (CNNs), has considerably improved feature representation and retrieval performance. Methods like Locality-Sensitive Hashing (LSH) and Facebook AI Similarity Search (FAISS) have enhanced performance further by rendering it scalable and efficient in similarity searches.This survey offers an overview of conventional and deep learning-based CBIR techniques, comparing their methodologies, advantages, and disadvantages. It also discusses main challenges like real-time processing, scalability, and semantic understanding. With applications in healthcare, security, e-commerce, and multimedia search, CBIR is continually evolving towards providing smarter and more intuitive image retrieval systems.

2. MILESTONES

The paper "Advancements in Content-Based Image Retrieval: A Comprehensive Survey of Relevance Feedback Techniques" by Hamed Qazanfari, Mohammad M. AlyanNezhadi, and Zohreh Nozari Khoshbreig covers a wide range of relevance feedback (RF) techniques in Content-Based Image Retrieval (CBIR) systems in an endeavor to bridge the semantic gap as well as constraints on retrieval inefficiency. The conventional CBIR systems are built upon low-level visual features such as color, texture, and shape, often incapable of comprehensively describing users' high-level semantics, causing erroneous and dissatisfying retrieval results.To bridge this semantic gap, researchers examine how relevance feedback—i.e., repeatedly marking images as relevant or irrelevant by the users—can adaptively modify the retrieval process. RF techniques can be categorized under Short-Term Learning (STL) that modifies retrieval responses within a session, and Long-Term Learning (LTL) that retains user preferences across various sessions to facilitate better personalization.The work highlights new directions that integrate low-level features with high-level semantic indications, making use of deep learning methods such as convolutional neural networks (CNNs), and adaptive feature weights methods to boost performance. The enhancements lead to more accurate retrieval output, enhanced user intent matching, and enhanced scalability in handling enormous collections.The authors conclude that the integration of relevance feedback, and more so by deep learning and smart learning techniques, significantly enhances the effectiveness of CBIR. Not only does this extensive review solve the current issues but also foretells a roadmap for future advancements in closing the semantic gap and enhancing user-centric image retrieval systems.

The paper, "A Decade Survey of Content Based Image Retrieval using Deep Learning" by Shiv Ram Dubey provides a comprehensive review of deep-learning-based methods in Content-Based Image Retrieval (CBIR) and advancements in image retrieval methods in the last decade. The conventional CBIR methods used handcrafted features extracted from visual features such as color, shape, and texture to find similarity between images. These models suffered from the lack of accurate representation of high-level semantics of images and generalizing to a vast range of datasets.To overcome these shortcomings, the author offers a ten-year evolution of deep learning methods that automatically learn image features from data with better performance and scalability. The work proposes a wide-ranging taxonomy that categorizes current CBIR methods according to supervision type (supervised, unsupervised, semi-supervised, etc.), network structure (CNN, autoencoders, attention-based, etc.), descriptor type (global, local), and retrieval type (sketch-based, text-based, etc.).The article also gives a summary of some of the well-known large-scale datasets used in CBIR research, i.e., CIFAR-10, ImageNet, and NUS-WIDE, and their features such as the image resolution, the number of classes, and annotations. Deep learning techniques such as CNNs, Siamese networks, GANs, and transformers are explained in terms of their performance in feature learning and similarity computation.During the survey, the author presents some recent methods such as supervised CNN-based methods, distance metric learning methods (contrastive loss, triplet loss, etc.), and unsupervised methods based on autoencoders and GANs. These methods improve feature discrimination and retrieval performance over what is problematic in conventional methods. The analysis and evaluation suggest that deep learning enhances retrieval precision to a significant degree and is able to process large-scale data better than traditional feature engineering techniques. The author is of the opinion that deep learning, with the recent availability of self-supervised and transformer models, has transformed the field of CBIR and still offers robust solutions for real-world applications. The results discussed in the survey try to guide future research and development towards image retrieval using deep learning.

The article "Content Based Image Retrieval Using Deep Learning Convolutional Neural Network" by Arshiya Simran, Shijin Kumar P.S, and Srinivas Bachu discusses the advancement of image retrieval systems using the application of deep learning, that is, Convolutional Neural Networks (CNNs). The article is towards overcoming the disadvantages of traditional CBIR (Content-Based Image Retrieval) systems, which rely on low-level hand-crafted features such as color, texture, and shape, and do not perform adequately in representing the high-level semantic meaning of images. To rectify this limitation, the authors propose a CNN-based model by the name DConNet that is designed to learn and abstract deep visual features from images in an automatic fashion.The architecture receives a query image and applies it to a five-layer convolutional and three-layer fully connected

neural network, transforming the image into a feature vector. Vectors are matched on similarity measures, e.g., Euclidean distance, to retrieve visually and semantically similar images from the database. The authors highlight the ability of CNNs to capture high-level image semantics and overcome the semantic gap between machine and human vision. Experimental evaluations, such as performance comparison with traditional methods, confirm that the CNN-based technique significantly improves retrieval accuracy and robustness. The authors add that while training of CNN models is computationally expensive, the performance of the models justifies the expense. The results confirm that deep learning methods have the potential to transform CBIR systems with improved feature generalization, scalability, and user satisfaction. The study concludes by offering that CNN-based CBIR systems like DConNet have the potential to unleash intelligent image retrieval applications in surveillance, healthcare, and digital media management applications.

The article titled “Content based image retrieval by ensembles of deep learning object classifiers” by Safa Hamrerras, Bachir Boucheham, Miguel A. Molina-Cabello, Rafaela Benítez-Rochel, and Ezequiel López-Rubio explores the effectiveness of ensemble deep learning models in improving the accuracy and robustness of Content-Based Image Retrieval (CBIR) systems. The study aims to enhance image search capabilities by combining outputs from multiple Convolutional Neural Networks (CNNs), thereby bridging the semantic gap between low-level visual features and high-level image understanding. The authors propose an ensemble model composed of several CNNs trained either on different bags of images or with different configurations to generate class probability vectors. These vectors are aggregated and used as compact image representations for retrieval.The proposed system is evaluated based on retrieval metrics such as precision, recall, and mean average precision (mAP). The ensemble method demonstrates superior performance compared to individual CNNs, achieving higher retrieval accuracy and better generalization. Experimental results show that the ensemble learning approach outperforms traditional single-network methods by providing more discriminative and semantically rich image representations. The study highlights that ensemble models are more effective in identifying relevant images across diverse datasets and visual categories. The authors conclude that combining CNNs through ensemble learning significantly boosts CBIR performance, offering a scalable and accurate solution for intelligent image search systems in various real-world applications.

The article titled “Content based image retrieval using deep learning process” by R. Rani Saritha, Varghese Paul, and P. Ganesh Kumar presents a modern approach to retrieving images based on their visual content, aiming to overcome the limitations of traditional text-based and manual feature extraction systems. The authors introduce a framework that utilizes deep learning—specifically Deep Belief Networks (DBNs)—to automatically extract and analyze meaningful image features for effective and accurate Content-Based Image Retrieval (CBIR).The core idea of the proposed system is to simulate human-like understanding by using deep neural networks to learn complex representations of images. These networks extract high-level features such as shape, texture, and patterns directly from raw image data, eliminating the need for handcrafted descriptors. This deep learning approach helps bridge the semantic gap, which is the difference between how computers perceive visual content and how humans interpret it.The system follows a structured pipeline, beginning with input image data that is processed through the deep learning model to generate feature vectors. These features are then compared using similarity measures to retrieve the most relevant images from the database. By focusing on learned features rather than predefined ones, the system becomes more adaptable and robust across various image types and datasets.The authors evaluate the system's performance using experimental analysis, showing that the deep learning-based CBIR system outperforms traditional methods in terms of accuracy and relevance. It demonstrates improved retrieval times and a higher capability to detect semantically similar images, even under varying conditions and complex visual structures.In conclusion, the study offers a scalable and intelligent solution for CBIR that leverages deep learning to enhance retrieval performance. By automatically learning and interpreting visual data, the system can be applied in diverse fields such as digital libraries, e-commerce, surveillance, and multimedia search. The approach marks a significant step forward in making image retrieval more efficient, accurate, and aligned with human visual understanding.

The article titled “Content Based Image Retrieval System Using CNN based Deep Learning Models” by Anita Khanna and Giriraj Gautam presents a deep learning-based framework for improving image search accuracy within Content-Based Image Retrieval (CBIR) systems by utilizing Convolutional Neural Networks (CNNs). Traditional CBIR systems rely on low-level features such as color, texture, and shape for image retrieval. However, these features often fail to capture the high-level semantic understanding of images, leading to irrelevant search results and limited user satisfaction.To overcome these challenges, the authors propose the integration of CNNs for automated and hierarchical feature extraction. Unlike hand-crafted features, CNNs are capable of learning deep representations of image content that align more closely with human visual perception. The system accepts a query image, processes it through a pre-trained CNN model to extract feature vectors, and compares these vectors with those in a stored image database using similarity measures such as Euclidean distance.The paper emphasizes the advantages of CNN-based models in capturing semantic content, enhancing retrieval precision, and reducing the semantic gap between visual data and human interpretation. Experiments conducted using standard datasets demonstrate improved accuracy and efficiency in retrieving visually and semantically similar images compared to traditional methods.The study concludes that incorporating CNNs into CBIR systems significantly enhances retrieval performance, scalability, and user experience. The work lays a foundation for future advancements in intelligent image retrieval, particularly through the integration of deep learning techniques, hybrid models, and scalable architectures for real-world applications in areas such as medical diagnostics, surveillance, and digital asset management.

The article titled “CBIR Using Features Derived by Deep Learning” by Subhadip Maji and Smarajit Bose investigates the enhancement of Content-Based Image Retrieval (CBIR) systems through the use of deep learning-derived features. The study addresses the limitations of traditional CBIR techniques, which often rely on hand-crafted features that fail to capture the semantic content of images, resulting in a semantic gap between user queries and retrieval results.Through a comparative analysis, the authors examine the effectiveness of features extracted from pre-trained deep neural networks, particularly convolutional neural networks (CNNs), for representing image content. These features are shown to outperform classical methods such as color co-occurrence matrices (CCM), support vector machines (SVM), and bag-of-visual-words (BoVW) in both accuracy and semantic relevance.The study further explores the efficiency of retrieval by proposing a pre-clustering approach. By clustering the image database based on deep feature similarities, the search space is significantly reduced, leading to faster retrieval times without compromising result quality. The experiments demonstrate that this method achieves better retrieval performance while being computationally efficient.The authors conclude that deep learning-based features provide a more robust and semantically meaningful representation of images, effectively narrowing the semantic gap. The combination of deep feature extraction and clustering techniques results in a powerful CBIR framework capable of delivering more accurate and relevant image search results. The study emphasizes the potential of deep learning in advancing CBIR systems and highlights the importance of integrating intelligent feature representation with scalable retrieval strategies.

The article titled “Content-Based Image Retrieval and Feature Extraction: A Comprehensive Review” by Afshan Latif, Aqsa Rasheed, Umer Sajid, Jameel Ahmed, Nouman Ali, Naeem Iqbal Ratyal, Bushra Zafar, Saadat Hanif Dar, Muhammad Sajid, and Tehmina Khalil provides a detailed survey of the techniques and methodologies used in the field of Content-Based Image Retrieval (CBIR). The study focuses on the extraction and use of visual features such as color, texture, shape, and spatial layout to improve the retrieval of relevant images from large-scale databases. The authors emphasize the growing need for efficient and intelligent image search systems, driven by the massive increase in digital image content across various platforms. The paper systematically reviews traditional feature extraction techniques along with recent advances involving machine learning and deep learning. It categorizes image features into low-level (e.g., color histograms, texture patterns, and shapes) and high-level semantic features, highlighting their respective roles in representing image content. The authors explore how these

features are used in similarity comparison and image indexing to support accurate and scalable retrieval. They also discuss the role of hybrid and fused approaches, combining multiple types of features to enhance CBIR effectiveness.Evaluation metrics such as precision, recall, and retrieval time are used to compare the performance of different CBIR methods. The study notes that while traditional approaches provide a foundation for image retrieval, modern methods—particularly those based on deep learning—offer superior results by narrowing the semantic gap between machine-extracted features and human interpretation. The review includes comparisons of popular datasets and benchmarking techniques used to validate CBIR systems.The authors conclude that although significant progress has been made in the CBIR field, challenges remain, particularly in terms of semantic understanding, feature fusion, and system scalability. They suggest that future research should focus on integrating deep learning with intelligent feature selection and multimodal data to further improve retrieval performance and adaptability in real-world applications.

The article titled “Content-based Image Retrieval and the Semantic Gap in the Deep Learning Era” by Björn Barz and Joachim Denzler critically examines how deep learning has impacted the traditional challenges in content-based image retrieval (CBIR), particularly the semantic gap. The semantic gap refers to the disconnect between low-level visual features extracted by machines and the high-level semantic concepts understood by humans.The authors review the evolution of CBIR systems, highlighting how early methods relied on hand-crafted features that poorly captured image semantics. With the advent of deep learning, especially Convolutional Neural Networks (CNNs), systems can now learn rich feature representations directly from data, significantly narrowing the semantic gap.However, the paper argues that while deep learning has improved CBIR performance, it has not completely resolved the semantic gap. The authors explore various issues such as the limitations of supervised learning (which depends heavily on labeled data), the challenges of interpretability, and the difficulty in aligning learned features with human concepts. They also discuss the role of unsupervised and self-supervised learning methods as promising alternatives to further reduce this gap.Through an in-depth analysis of recent literature and techniques, the article sheds light on the progress made and the challenges that remain in bridging the semantic gap. The authors advocate for more human-centered evaluation methods and hybrid approaches that combine deep learning with semantic knowledge representations.The paper concludes that although deep learning has transformed CBIR, achieving true semantic understanding remains a complex challenge that requires continued innovation in learning methods, interpretability, and evaluation techniques.

The article titled “Content Based Image Retrieval” by Mustafa Salah Shareef, Hadeel Adnan Mohammed, and Israa Raid Noor Alkhafaji investigates the development of a Content-Based Image Retrieval (CBIR) system that enhances the accuracy and efficiency of retrieving relevant images from large databases based on visual content rather than textual metadata. The main objective of the study is to bridge the gap between low-level image features and high-level semantic understanding by combining multiple image processing techniques and machine learning methods.The proposed CBIR system follows a structured pipeline that includes preprocessing, segmentation, feature extraction, and classification. The preprocessing stage improves image quality through noise removal and histogram equalization. Image segmentation is then performed to isolate important regions, often using techniques like K-means clustering. Key image features such as texture, shape, and color are extracted using methods like GLCM (Gray Level Co-occurrence Matrix) and Hu moments.For classification and retrieval, the study incorporates a Support Vector Machine (SVM) classifier, which enhances the system’s ability to accurately categorize and retrieve images. The system is trained and tested using a dataset of medical images, particularly focusing on brain MRIs, and performance is evaluated using metrics like accuracy, precision, recall, and F1-score.Experimental results demonstrate that the proposed method achieves high retrieval accuracy and efficient performance. The integration of multiple feature types and machine learning improves the semantic matching of images, enabling more precise and relevant search results.The authors conclude that their CBIR system offers a

robust solution for intelligent image retrieval, with potential applications in medical imaging and other domains requiring fast and accurate visual content analysis.

The article titled “Content-Based Image Retrieval: A Survey on Local and Global Features Selection, Extraction, Representation, and Evaluation Parameters” by Divya Srivastava, Shashank Sheshar Singh, B. Rajitha, Madhushi Verma, Manjit Kaur, and Heung-No Lee provides a comprehensive survey of the techniques and challenges involved in content-based image retrieval (CBIR) systems. The paper focuses on the selection and extraction of both local and global features, which play a critical role in improving the accuracy and efficiency of image retrieval.The authors categorize CBIR systems based on the types of features used. Global features, such as color, texture, and shape, describe the entire image, while local features, like SIFT, SURF, and ORB, focus on key points and regions within images. The survey compares these features in terms of their discriminative power, robustness, and suitability for various applications.Additionally, the article discusses feature representation methods including Bag of Visual Words (BoVW), Vector of Locally Aggregated Descriptors (VLAD), and deep learning-based embeddings. It highlights the evolution from traditional hand-crafted features to deep neural networks that learn hierarchical feature representations directly from image data.The paper also reviews the evaluation parameters and performance metrics commonly used in CBIR, such as precision, recall, and mean average precision (mAP), providing a benchmark for comparing different systems. Various datasets and retrieval scenarios are discussed to demonstrate the applicability of the methods.The authors conclude by identifying ongoing challenges in CBIR, including the semantic gap, scalability to large datasets, and the need for real-time performance. They advocate for hybrid systems that combine local and global features with deep learning to achieve better retrieval accuracy and efficiency.

The article titled “Content-Based Image Retrieval: A Review of Recent Trends” by Ibtihaal M. Hameed, Sadiq H. Abdulhussain, and Basheera M. Mahmmod presents a comprehensive review of the recent advancements and methodologies in content-based image retrieval (CBIR) systems. The authors aim to address the growing need for efficient image retrieval techniques that rely on the actual visual content of images rather than metadata.The paper categorizes CBIR approaches based on feature extraction techniques, including low-level features (such as color, texture, and shape), mid-level features, and high-level semantic features. It discusses traditional hand-crafted features alongside modern deep learning-based methods, emphasizing the shift towards neural networks for automatic feature learning and representation.The study further explores the role of feature descriptors like SIFT, SURF, and ORB, and the integration of machine learning models including Convolutional Neural Networks (CNNs) for improving retrieval accuracy. It highlights how deep learning has helped bridge the semantic gap—the disconnect between machine-learned features and human-understood semantics—although challenges still remain.The article reviews various similarity measurement techniques, indexing methods, and evaluation metrics used in CBIR, such as precision, recall, and F1-score, providing insight into the effectiveness of different models and algorithms across benchmark datasets.The authors conclude by identifying key challenges in CBIR, including scalability, real-time performance, and semantic understanding. They advocate for further research into hybrid systems that combine hand-crafted and learned features, as well as the use of large-scale annotated datasets to support deep learning approaches.

The article titled “Web Image Search Reranking Using CBIR” by V. Vinitha, J. Jagadeesan, and R. Augustian Isaac explores the enhancement of image retrieval accuracy through the integration of Content-Based Image Retrieval (CBIR) techniques into the search reranking process. The study addresses the limitations of conventional text-based image retrieval systems, which depend heavily on associated metadata such as file names, keywords, and descriptions. These methods often produce imprecise results, as they fail to account for the actual visual content of the images.To overcome this issue, the authors propose a reranking system based on low-level visual features including color, texture, and shape. The core methodology involves using an image as the input query

rather than a textual keyword. The system extracts key visual features from this query image and compares them with the feature sets of images stored in the database. This comparison is carried out using a similarity matching process to retrieve visually similar images.The authors construct meta rerankers that utilize multi-feature analysis to reorder the initial search results, ensuring that the most visually relevant images are ranked higher. This process significantly reduces the noise (irrelevant images) in the final output. An architectural framework is proposed wherein the system combines feature extraction, similarity matching, and reranking strategies to produce improved image search results. The study concludes that incorporating CBIR techniques into web image search reranking increases both the accuracy and relevance of the results. The work underscores the effectiveness of using actual image content for retrieval rather than relying solely on textual annotations, and it sets the groundwork for further research into visual reranking systems in image mining and search engines.

The article titled "An Overview of Content-Based Image Retrieval Methods and Techniques" by M.H. Hadid and colleagues presents a comprehensive review of the principles, methods, and challenges associated with Content-Based Image Retrieval (CBIR) systems. The paper emphasizes the growing demand for efficient retrieval methods due to the rapid growth of digital image databases across sectors such as healthcare, security, and multimedia. The study categorizes CBIR approaches based on the visual features they use—primarily color, texture, and shape. It explains how these features are extracted using various algorithms and how similarity is measured using distance metrics such as Euclidean and Mahalanobis distances. The authors also explore feature representation techniques, including color histograms, co-occurrence matrices for texture, and edge-based descriptors for shape. In addition to basic CBIR frameworks, the paper discusses modern advancements such as relevance feedback mechanisms and the application of machine learning, particularly deep learning, to bridge the semantic gap—the disconnect between low-level visual data and high-level human interpretation. The review further addresses performance evaluation metrics like precision, recall, and F-measure, which are used to assess the accuracy and effectiveness of CBIR systems. It highlights the ongoing challenges in CBIR, including computational complexity, scalability, and semantic understanding. The article concludes by advocating for hybrid models that combine multiple visual features and deep learning techniques to improve the efficiency, scalability, and semantic relevance of image retrieval systems. The authors recommend future research directions focused on enhancing semantic interpretation and optimizing search performance for large-scale image databases.

The article titled "Recent Developments of Content-Based Image Retrieval (CBIR)" by Xiaoqing Li, Jiansheng Yang, and Jinwen Ma presents a detailed overview of the advancements in CBIR technologies, emphasizing the integration of deep learning methods for improved performance in visual information retrieval tasks. The authors analyze the evolution of CBIR from traditional feature-based systems to modern approaches that leverage deep neural networks.The study categorizes CBIR techniques into two major stages: early systems that relied on handcrafted features such as color, texture, and shape, and newer systems that utilize Convolutional Neural Networks (CNNs) to extract high-level semantic features from images. These deep learning-based features help bridge the semantic gap between low-level pixel data and human image understanding, enhancing the system's ability to retrieve visually and contextually similar images. The article also discusses the importance of feature representation and similarity measurement in CBIR. It explores how deep embedding vectors generated by neural networks improve the accuracy and efficiency of image matching. Additionally, the authors examine various datasets and benchmarks used for evaluating CBIR systems, highlighting how new methods have significantly outperformed traditional approaches in precision and recall metrics. To illustrate progress, the paper reviews recent frameworks that combine deep feature extraction with techniques like hashing, re-ranking, and relevance feedback, aiming to address challenges such as scalability, robustness, and query variation. The article concludes by emphasizing the growing role of deep learning in CBIR and the potential for further research in areas like unsupervised learning, multi-modal retrieval, and efficient indexing strategies. The authors advocate for continued innovation in feature learning and retrieval techniques to support the demands of large-scale, real-world image databases.

The article titled "Content-based image retrieval by classification with reinforcement optimisation evolutionary machine learning with applications" by Anandh Sam Chandra Bose, Laxman Singh, Shamimul Qamar, S. Uma, L. Sherly Puspha Annabel, and Sanjay Singla presents an innovative approach to enhance content-based image retrieval (CBIR) systems by integrating classification models with reinforcement learning and evolutionary optimization strategies. The proposed model focuses on improving both the accuracy and efficiency of retrieving similar images from large datasets by using an advanced neural network framework called Ker_RadBAEFNN (Kernelized Radial Basis Auto Encoder Function Neural Network).The study introduces a classification-based retrieval strategy, where images are first classified into relevant categories before the retrieval process. This allows for more focused and relevant searches. The core of this method is the combination of reinforcement learning for adaptive learning, evolutionary optimization for tuning model parameters, and the Ker_RadBAEFNN for robust classification. Together, these components improve feature representation and retrieval performance.A significant aspect of the paper is its optimization strategy using reinforcement signals and fitness functions to guide the training of the neural network. This reduces the computational cost and enhances learning speed. The model is validated on multiple benchmark datasets including MNIST, METU, and COCO, where it demonstrates superior performance compared to traditional techniques like PSO-ANN, IRB-CNN, and FAGWO.To address typical CBIR challenges such as the semantic gap and low retrieval accuracy, the authors leverage intelligent learning and optimization. By doing so, the system not only improves precision but also achieves high generalization capability across varied domains and image types.The paper concludes that this classification-driven, reinforcement-optimized CBIR model holds strong potential for real-world applications such as medical imaging, forensics, remote sensing, and e-commerce. By integrating deep learning with adaptive learning strategies and optimization, the proposed model presents a significant advancement in the development of high-performance, scalable image retrieval systems.

The article titled "Content Based Image Retrieval with Machine Learning Classification for Reducing Computational Complexity" by Ramsha Pallawkar, Ujwal Harode, and Suchitra Patil presents a machine learning-enhanced framework for image retrieval, aiming to overcome the high computational cost of traditional CBIR systems. The authors propose two key improvements: feature dimension reduction and support vector machine (SVM) classification, to enable more efficient and semantically accurate image retrieval.The proposed system extracts both color and texture features from images, including HSV histograms, color moments, auto-correlograms, Gabor wavelets, and wavelet transforms. Using symmetric uncertainty (SU), irrelevant and redundant features are filtered out to reduce the dimensionality of the feature vectors. Images are then grouped into semantic categories, and an individual SVM classifier is trained for each category to differentiate relevant images from unrelated ones.At runtime, the system classifies the query image into a category using the trained SVM models, and then performs distance-based matching only within that category, significantly reducing the number of comparisons required. This hybrid approach of classification followed by selective matching accelerates the retrieval process without compromising accuracy.The system was tested using images from various categories and was shown to improve retrieval performance. Compared to traditional distance-based retrieval across the full dataset, the proposed method achieved a 14% reduction in retrieval time while maintaining high relevance in the returned images. The authors conclude that integrating machine learning classifiers and intelligent feature selection into CBIR systems enhances both efficiency and accuracy, making it a scalable solution for large-scale image databases. The approach offers practical value in fields like digital libraries, medical imaging, and surveillance, where quick and relevant image access is crucial.

The article titled "Image Ranking Based on Texture Feature Using Content-Based Information Retrieval Techniques" by S. Pratap Singh, Dr. Ch. Bindu Madhuri, and Dr. P. Satheesh presents a method for enhancing image retrieval systems by ranking images based on their texture features. The authors introduce a content-based image retrieval (CBIR) framework that leverages several texture-based feature extraction techniques to accurately

assess image similarity and improve retrieval precision.The paper investigates four key feature extraction methods: Local Derivative Radial Pattern (LDRP), Statistical Edge Detection (SED), Modified Scalable Descriptor (MSD), and Discrete Wavelet Transform (DWT). These techniques capture intricate texture details from images and convert them into numerical features used for comparison. A query image is analyzed, its features are extracted, and then compared with a database of images using similarity measurement techniques such as Euclidean Distance, Cosine Similarity, and Manhattan Distance.The process results in a ranked list of images, ordered by their visual similarity to the query image. Experimental results show that certain combinations of texture features and distance measures produce higher precision and more accurate rankings, confirming the effectiveness of the approach.The authors conclude that texture-based feature extraction significantly enhances image retrieval accuracy. Their CBIR framework demonstrates the potential for practical use in applications such as medical imaging, digital libraries, and surveillance systems. The proposed method not only improves retrieval quality but also provides a foundation for further research in intelligent image analysis and content-aware systems.

The article titled “Content-based Image Retrieval in Medical Applications” by T. M. Lehmann, M. O. Güld, C. Thies, B. Fischer, K. Spitzer, D. Keysers, H. Ney, M. Kohnen, H. Schubert, and B. B. Wein introduces an innovative framework for retrieving medical images based on their visual content, addressing the limitations of traditional text-based search systems. The authors propose a hierarchical model for semantic image analysis, forming the foundation of the IRMA (Image Retrieval in Medical Applications) system. This model extracts and analyzes features such as texture, shape, and structure from images to support more effective and accurate retrieval.The IRMA framework is based on a four-layered semantic structure that moves from raw pixel data to high-level medical knowledge, enabling a deeper understanding of image content. A key component is the automatic categorization of images by using medical knowledge to classify content by modality, anatomy, and pathology. The system incorporates processes like segmentation, registration, and feature extraction, and uses similarity measures to compare and retrieve relevant images from large databases.The authors tested the system on a dataset of 10,000 real-world medical images, implementing content-based search using distributed computing and machine learning algorithms. The evaluation demonstrated that the system could efficiently retrieve semantically similar images, which is especially valuable for diagnostic support and medical training. Results showed improved retrieval accuracy, with the system effectively distinguishing between images with different modalities or anatomical structures.The authors conclude that the IRMA framework offers a reliable and scalable solution for medical image retrieval, outperforming conventional approaches in flexibility and relevance. By leveraging visual features and structured medical knowledge, the system can be integrated into clinical workflows to assist in diagnosis, research, and education, ultimately contributing to better healthcare outcomes.

The article titled “A smart content-based image retrieval system based on color and texture feature” by Chuen-Horng Lin, Rong-Tai Chen, and Yung-Kuan Chan presents an efficient image retrieval method by integrating color and texture features for improved search performance in large image databases. The system is developed to overcome the limitations of traditional keyword-based retrieval methods by analyzing the actual visual content of images.The study introduces three main feature extraction techniques: the Color Co-occurrence Matrix (CCM), which captures spatial relationships between colors in an image; the Difference Between Pixels of Scan Pattern (DBPSP), which identifies compact texture features based on pixel differences in defined scan patterns; and the Color Histogram for K-means (CHKM), which utilizes clustering to group similar colors and build a histogram for global color representation. These features are selected for their ability to characterize both color distribution and texture details effectively.The authors develop a smart retrieval system called TCTHIRS, which integrates the above techniques to perform feature extraction, selection, and image matching. A feature selection strategy is applied to determine the optimal combination of features that yields the highest retrieval accuracy while minimizing computation time. This adaptive approach improves the system’s scalability and robustness across various image types.Experimental results on three different image datasets show that the proposed method outperforms traditional single-feature approaches in both retrieval precision and computational efficiency. The system successfully identifies visually similar images with higher accuracy and faster response time,

demonstrating its effectiveness in practical applications. The study concludes that the integration of multiple visual features with an adaptive feature selection mechanism significantly enhances the performance of content-based image retrieval systems. The proposed method has potential applications in areas such as digital libraries, medical imaging, surveillance, and multimedia archives, where efficient and accurate image retrieval is essential.

The article titled “Content-Based Image Retrieval Using AutoEmbedder” by Md. Mohsin Kabir, Adit Ishraq, Kamruddin Nur, and M. F. Mridha presents a deep learning-based approach to improve image retrieval systems through the use of visual content analysis. The study introduces AutoEmbedder, a Deep Convolutional Neural Network (DCNN) architecture designed to automatically extract deep visual features from images and convert them into compact embedding vectors. These embeddings are clustered using the K-means algorithm, enabling more efficient and accurate image retrieval based on visual similarity.Through experimental analysis on benchmark datasets such as Corel10K and CIFAR-10, the authors investigate the retrieval performance of AutoEmbedder using precision and recall metrics. The results reveal that the model effectively identifies visually similar images, outperforming conventional Content-Based Image Retrieval (CBIR) techniques that rely on handcrafted features. The embeddings generated by AutoEmbedder capture high-level semantic features, and the clustering mechanism reduces search complexity while maintaining accuracy.The study further evaluates the generalization ability of the system, highlighting its robustness across different classes and image variations. The unsupervised learning approach in the embedding generation allows the model to adapt to unseen data without requiring labeled input. The findings indicate that the AutoEmbedder achieves high precision in image retrieval tasks, validating its potential for large-scale image database applications.The article concludes by emphasizing the effectiveness of the AutoEmbedder architecture in delivering a scalable, high-performance solution for content-based image retrieval. The authors advocate for the integration of deep learning and clustering techniques in future CBIR systems to replace traditional metadata-based methods and enhance user search experiences in visually rich environments.

The article titled “A review on content-based image retrieval system: present trends and future challenges” by Narendra Kumar Rout, Mithilesh Atulkar, and Mitul Kumar Ahirwal explores the development of CBIR systems that retrieve images based on visual content rather than text annotations. This approach addresses the limitations of traditional keyword-based methods, especially with the rapid growth of digital image databases.The study focuses on three key visual features: color, texture, and shape, using techniques such as color histograms, GLCM, LBP, and edge histograms. These features help in identifying and matching similar images more effectively.A major highlight of the paper is the discussion on feature weight assignment, which plays a critical role in retrieval accuracy. The authors review methods like individual, equal, and combined weight assignment, noting that these are often manually defined, which limits automation.To overcome this, the authors propose the need for automated feature weighting, making the system more adaptive and efficient. The paper concludes that combining multiple features with dynamic weighting cansignificantly improve CBIR performance, with potential applications in fields like medical imaging, security, and digital libraries.

The article titled “Efficient Framework for Content-Based Image Retrieval using CNN Classification Scores” by S. A. Angadi and Hemavati C. Purad proposes a deep learning-based image retrieval method that enhances search accuracy and efficiency by using CNN classification scores instead of traditional handcrafted features.The system employs pre-trained CNN models like AlexNet, GoogLeNet, and ResNet18, leveraging transfer learning to adapt these models to smaller image datasets. Rather than extracting raw features, the method uses the classification outputs (probability scores) as compact, high-level feature vectors.A Query-by-Image approach is used, where the system retrieves similar images based on similarity between classification scores using various distance metrics such as Euclidean and Cosine. This significantly reduces feature dimensionality while preserving semantic meaning. Experiments on the Wang database show that the method achieves 99.45% accuracy, outperforming

traditional techniques in both speed and precision. In conclusion, the integration of CNN classification scores and transfer learning offers a highly effective solution for image retrieval tasks, with potential applications in fields like digital libraries, surveillance, and medical imaging.

The article titled "A Novel Model for Visual Content Based Image Retrieval using Transfer Learning" by Amit Sharma, V. K. Singh, and Pushpendra Singh presents an approach to improve content-based image retrieval (CBIR) systems by using transfer learning techniques with pre-trained deep convolutional neural networks (DCNNs). This method aims to enhance the accuracy and efficiency of image retrieval by leveraging the knowledge of existing models, particularly in scenarios where large datasets or high computational resources are limited.The study emphasizes the use of pre-trained CNN architectures such as VGG19, ResNet50, and SqueezeNet for deep feature extraction from images. These deep features are more robust and descriptive than traditional low-level features. To further refine the extracted features, dimensionality reduction techniques and pooling layers such as Global Average Pooling are applied. This results in more compact and meaningful feature representations that can be used for effective classification and retrieval.A significant aspect of the paper is the modular two-step approach it follows—first extracting features using transfer learning, and then processing these features with various classifiers like SVM, decision trees, or random forests. This not only enhances retrieval performance but also simplifies adaptation to various domains.To tackle common challenges in CBIR systems, such as limited labeled data and time-consuming training, the authors highlight the advantages of transfer learning. By reusing the knowledge from large-scale datasets like ImageNet, the model can achieve strong generalization even with smaller datasets.The paper concludes that transfer learning-based CBIR systems show promising potential in various real-world applications such as medical diagnosis, forensic analysis, and biometric recognition. By combining deep learning with efficient feature processing, the proposed model marks a step forward in building more adaptive and high-performing image retrieval systems.

The article titled "Content-Based Image Retrieval for Traditional Indonesian Woven Fabric Images Using a Modified Convolutional Neural Network Method" by Silvester Tena, Rudy Hartanto, and Igi Ardiyanto presents a deep learning-based image retrieval framework specifically designed to recognize traditional Indonesian woven fabrics, particularly ikat textiles.To tackle challenges such as the absence of a comprehensive fabric database and the complexity of woven patterns, the authors propose a Content-Based Image Retrieval (CBIR) system utilizing a Modified Convolutional Neural Network (CNN). Unlike generic pretrained models, their modified CNN is tailored to effectively capture the distinctive visual characteristics of ikat fabrics, including intricate motifs, textures, and color arrangements.A custom dataset named TenunIkAtNet was developed, comprising 4800 images across 120 fabric classes. These images were captured under diverse lighting and background conditions to reflect real-world variability. The retrieval system employs a Query-by-Image mechanism, comparing deep features derived from the modified CNN to find visually similar fabric images.Experimental evaluations demonstrate that the modified CNN significantly outperforms widely used pretrained models such as ResNet101, VGG16, Inception-V3, and DenseNet201. The system achieves excellent retrieval performance, with 99.96% accuracy (Top-5), 99.88% (Top-10), and 97.60% (Top-50), indicating its effectiveness in preserving semantic understanding of the woven patterns.In conclusion, this study introduces an efficient and culturally meaningful CBIR framework. By combining a purpose-built CNN and a specialized dataset, the system shows strong potential for use in digital heritage archiving, fabric cataloging, and support for the traditional textile industry.

3. CONCLUSIONS

Content-Based Image Retrieval (CBIR) has emerged as a transformative approach to image retrieval, leveraging visual features rather than relying on traditional text-based methods. Over the years, CBIR systems have evolved significantly, with advancements in feature extraction, similarity matching, and indexing techniques. However, challenges such as the semantic gap, high computational complexity, and scalability constraints continue to hinder their widespread adoption.The integration of deep learning, particularly Convolutional Neural Networks (CNNs), has substantially enhanced the accuracy and efficiency of CBIR systems by enabling high-level feature representations. Additionally, modern indexing techniques like Locality-Sensitive Hashing (LSH) and FAISS have optimized retrieval performance for large-scale image databases. Despite these improvements, challenges related to real-time processing, privacy concerns, and adaptive learning models remain open research areas.Future advancements in CBIR will likely focus on AI-driven personalization, cloud-based architectures, and secure retrieval frameworks to improve accessibility, efficiency, and security. By addressing these challenges, CBIR will continue to play a crucial role in diverse applications, including healthcare, security, e-commerce, and multimedia analytics, paving the way for more intelligent and scalable image retrieval solutions.

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