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Content-based image retrieval tools and techniques

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Content-Based Image Retrieval Tools and Techniques

In the beginning was an image.

To my mother
who inspired me
to develop intellectually

Contents

10 A glimpse at where we can find CBIR

10.1 Introduction

CBIR in different forms can be found wherever image collections exist and the user needs to find information. Easy availability of all kinds of mobiles, laptops and PC computers has been turning us more and more into an "image" society. CBIR systems in very professional applications, e.g., forensic, are becoming increasingly popular, especially thanks to the Google image search engine offered to all users.

Therefore, these systems have recently been one of the most vivid research areas in the field of computer vision.The abundance of types of images results in constructing adequate systems to process and retrieve them effectively. Additionally, at present images and videos are globally used on TV and You Tube.

10.2 Application Areas of CBIR

Application areas of CBIR are varied and virtually unlimited, the most important being:

- Geographic Information Systems (GIS) – These are computer-based tools which allow us to link databases and digital maps to create a dynamic, spatial analysis. They provide applications to visualize, query, and overlay databases in ways not possible with traditional spreadsheets. These abilities distinguish GIS from other information systems, and make them valuable to all using them for predicting outcomes, planning strategies or preventing damages.
- Weather forecasting – Multimodal (from infrared through visual up to the ultraviolet wave length) meteorological satellite images are applied to predict future temperatures, relative humidity, rainfall, wind speed and atmospheric pressure [250]. Additionally, nowadays, there are several free web-based

services that provide environmental information in the form of maps showing the extent, type and location of pollution usually encoded numerically or in colour [251]. These environmental data analyses and information forecasting relate to health issues and directly affect a variety of everyday activities.

- Film and video archives – Categorization and indexing of videos mainly on TV news, for instance, sports news. In case of films the user needs to recognize standard video units, such as shots and scenes [252].
- Entertainment – We can include holiday photo albums, home videos and scenes from favourite TV programmes and films. This area offers a great market for developing CBIR technology products. The new trend in high-tech consumer imagery is 360° still photography and video used in virtual reality (VR). In the nearest future cloud technologies will offer popular tools enabling us to create our own CBIR system instead of a family album.
- Crime prevention and investigation – connected very closely with face recognition because many security agencies maintain large archives of visual evidence, including suspects' mug shots, fingerprints, etc. When a new serious crime is committed, a lot of new evidence is added to the records of crime archives. Later, they are searched by many security services around the world. Additionally, when an arrest warrant is issued, all the passport control services check video records to retrieve the suspect's face.
- Electronic retailing - CBIR systems help search for clothes in electronic retailing applications by using colour and texture matching techniques. They are applied to electronic retailing, and supply chains of e-commerce, such as design synthesis, predicting customer requirements, inventory management, etc. Moreover, these systems simplify business-to-consumer e-commerce by computer aided sales [253].
- Identification
  - Biometric authentication – Modern image analysis systems enhance an observer's ability to make measurements and run a statistical analysis of people's physical and behavioural characteristics from a large or complex set of images, by improving accuracy, objectivity, or speed [254]. Computational technologies accelerate and automate the process of people identification based on large amounts of high-information content biomedical images [255] or video scenes.
  - Face recognition – is a process of identifying or verifying a person from a digital image or a video frame. Recognition systems are being very intensively developed and installed at all transportation hubs. Among the different biometric techniques, face recognition is coming to the fore as the most reliable and efficient [205].
- Medicine [256]
  - Medical diagnosis – Most kinds of modern diagnoses rely on imaging techniques, such as: X-ray radiography, magnetic resonance imaging (MRI), medical ultrasonography, endoscopy, elastography, tactile imaging, thermography, medical photography and nuclear medicine functional

imaging techniques, etc. [257]. The practitioners are generously supported by image processing equipment which helps in measuring, region of interest (ROI) determination, boundary finding, and so on [258]. Most imaging techniques, although non-invasive, offer more efficient diagnoses to the patient and might save their time, money or even life.

- Patient documentation - There are strict rules of confidentiality for such sensitive information. The images should be kept in special DBs, whereas visual information for scientific use should be provided only anonymously.
- Telemedicine - is the use of telecommunication and information technologies to help eliminate distance barriers between the patient and the doctor. It improves access to medical services that are not consistently available in distant communities. Telemedicine is also used to save lives in critical care and emergency situations because it allows us to transmit medical imaging and health data between the patient at home and a medical centre.

  Advanced diagnostic methods supported by distributed client/server applications with tele-medical devices permit in-home care support.

- Biological applications – Here there are two separate aspects: (i) CBIR systems in which matching methods are inspired by biological achievements, for instance, gene or genetic algorithms [259], and (ii) retrieval biological images like microscopic images or different DBs supporting bio-laboratories in dedicated CBIR systems for particular kinds of images, for example, US patent No. 7 502 519 covering methods of image pattern recognition using vector quantization (VQ) [260] or a CBIR system applied in the collection of biological specimen images [261]. In the latter situation success is possible only in the case of close cooperation between the engineering and biological communities.
- Journalism and advertising - Journalists and news agencies maintain archives with millions of images and video shots to illustrate their articles in newspapers and magazines. Keywords indexing these sets are extremely expensive and almost impossible to use without some degree of automatic assistance [262]. Advertising campaigns rely heavily on still and moving imagery to promote products or services. The growth of commercial stock photograph libraries, reflects the profitable nature of the industry.
- Remote sensing - offers services including making measurements of the earth's surface using sensors on airplanes or satellites. These sensors collect multimodal images and provide specialized tools for manipulating, analysing, and visualizing such images. Remote sensed imagery is integrated within a GIS for different purposes, including, among others, geological and agricultural ones [263].
- Scientific database – Visualization and image analysis are becoming more and more important methods for the scientists. Applications need to be adapted to the salient features of particular images, for example, in astronomy where many hours of pre-recorded sky surveys are automatically searched for interesting objects (SOM), images are blurred and mostly in the grey scale. [226]. From the macro scale to the molecular structure, all the combinations of the state-of-

the-art optical techniques are used. Additionally, in the micro scale the complementing method for visualization is the electron diffraction which opens new possibilities for structural research in chemistry and material science.

- Architectural real estate and engineering design - Generally, design applies numerous 2D and 3D modelling techniques and uses different visualizations for the client. Sometimes, instead of preparing a stereoscopic presentation, it is easier to show some images, especially for finished projects, including interior and exterior shots of buildings. When the client is looking for their dream real estate, an agent rarely has a stereovision model to hand, especially that describing the shape of a building and the subtle aspects of architecture need to be projected at least in a sketchy way. However, in the designing process Computer Aided Design (CAD) is used extensively.
- Stereovision - Nowadays, CBIR systems are being constructed in order to recognize 3D objects. Modern applications use 3D models more frequently. Two cameras building stereo-pairs are being substituted by a plenoptic camera (SPC) which consists of an array of micro lenses. Thanks to multiple image overlap with proper disparity we can estimate the distance and depth of refocused images. Applying the SPC and the light field is an alternative to the traditional depth map acquisition by disparity analysis [264], [265].
- Art galleries and museum management - Computers have become and will continue to be developed as the primary medium for learning and education, and, last but not least, for archiving all historical and cultural materials in digital form in the years to come.

  The importance of CBIR technology in the aiding of preservation and analysis of our history in digital media was appreciated by the journal *IEEE Transactions on Image Processing* which published a special issue to discuss the state-of-the-art in image processing applications for cultural heritage [266]. The main focus of this issue is on modelling, retrieval, and authentication of cultural legacy images. Additionally, an introduction of statistical methods can sometime capture subtle characteristics of art which can be easily overlooked by a human observer [179], [267], [268].

  Archaeologists also rely heavily on images, for example, pottery pattern data bases are being created for different time periods.
- Digital shopping - There are three types of support in shopping: one type is product catalogues which are used to convey information in e-mail-order shopping. It is becoming a more and more popular shopping method in the era of the Internet boom. The choice is made by selecting the product name, so image content retrieval is less exploited.

  The second type is barcode readers (as an application on a mobile) which aid the buyer in collecting his/her order from home or from a shop. When, for instance, impaired or handicapped individuals want to do bigger shopping, they have a serious problem because of the weight of the goods, in which case they can collect the barcodes of the products they have at home to reorder them or walk around the shop, bring each product and eventually read its barcode and send that information to the client service point. Then, after the payment is made, the purchased goods are packed and sent to the client's address.

The third type of shopping support is taking a photograph of products on shop shelves or fridge shelves to identify the shortage of a product, and send the list of missing products to the owner.

- Education and training - Increased availability of powerful computers gives greater opportunity for students to work with dynamic models and simulations [269]. From the teacher's point of view, the plethora of good teaching materials to illustrate key points in a lecture could reduce preparation time and improve teaching quality. The accessibility of static images or video collections helps to illustrate the presented subject and to support theoretical lessons, seminar problems, practical seminars, as well as to evaluate students' knowledge and skills.
  Additionally, remote learning, characterised by the physical distance between the teacher and the student, is becoming increasingly popular. Moreover, given the explosion of modern mobile devices, the e-learning process can be moved away from standard locations. This fact is closely connected with the researches on mobile multimodal user's interfaces [270].
- Fabric, fashion and interior design – Fashion and interior designers need to work with different materials, especially with a collection of fabrics with a variety of colours and textures. The ability of matching the proper material is very useful for the design process.
- Intellectual property – Trademark image registration, as well as image copyright protection are really vital areas, given the deluge of unauthorized copies of such images, especially when they have been altered in some way. Moreover, during the trademark registration the new mark image is compared with the existing ones to avoid repetition or any confusion due to similarities to other trademarks.
- Image archiving and management – For non-professional use an automatic image downloader for individual photo collections is applied and it can store each batch of shots in a separate folder, labelled with the date on which the files have been saved. It is a natural way to catalogue pictures for a camera but very inconvenient for the user because you have to remember when pictures were taken. A better option then is adding keywords and times to the file name. Some applications allow photographers to tag image files with keywords that represent favourite people, places, or events. This makes it easy to find all the pictures you have taken. But the best method in such a situation is an automatic retrieval system.
- Surveillance - is the monitoring of activities, mainly by observation from a distance by means of electronic equipment (especially by CCTV cameras), or interception of electronically transmitted information.
  Biometric surveillance is any technology that measures and analyses human physical or behavioural characteristics for authentication, identification, or screening purposes. Facial recognition is the use of a person's unique facial features to identify them, usually from a video footage. Many international and national security services are intensively funding research into facial surveillance systems effective, even from the distances up to 500 ft.

Another form of behavioural biometrics is an analysis of people's emotional state based on their facial expressions, how fast they are talking, the tone and pitch of their voice, their posture, and other behavioural traits. This might be used, for instance, to see if any individual's behaviour is suspicious (looking around furtively, 'tense' or 'angry' facial expressions, waving arms, etc.).

- The military – military applications of imaging technology are probably the earliest and best developed but generally kept in secret. Surveillance, recognition of enemy's weapons, identification and designation of targets by means of satellites, drones or micro-aerial vehicles, tracking missile trajectories are only the tip of the iceberg of a whole spectrum of military tools already in use and just developed.
- Mobile multimodal user's interfaces - Emerging ubiquitous mobile devices support access to the Internet with its Web applications nearly everywhere [271]. All the devices use graphical user's interfaces (GUI) which are mainly based on trigger-action rules. The next generation of GUIs needs to be more user-friendly, adaptive, effective and efficient. The possible procedure could be as follows: the user submits a picture taken with a mobile phone camera and tagged with the user's GPS location that is to be used to perform a search for explanatory information [272]. For this purpose, the GUI can be considered in terms of three elements: the user (the tasks, the preferences, the emotional state, etc.), the devices (their interaction resources, connectivity, multimedia support, etc.), the environment (noise, light, temperature, and so on) [270].
- Tourist information - closely connected with mobile devices because the scenario is similar to the above-mentioned application. The important point is the fact that image DBs offered for the user need to contain information about landmarks, monuments, tourist services, etc [273].

10.3 The CBIR User

In contrast with many CBIR systems already described or just being developed, the CBIR users and their needs have so far been subject to little systematic analysis. Most reported research has focused either on specific collections or on specific user types or professions, for example, journalists or art historians.

Generally, we can identify professional users and the inexperienced ones whose needs are quite disparate. The needs of the former are indirectly presented in the previous section in connection with particular domains and, as a matter of fact, their requirements are strictly adapted to the specificity of professional images. The inexperienced users' awareness of image retrieval, especially with regard to the most popular field, such as entertainment or tourism, has dramatically increased through the use of video games, Internet browsers, Google's image search engine, etc. which have all caused CBIR research to concentrate on semantic recovery. In Chapter 8 and sect. 7.2 we signalised the approach of CBIR designers to the users who are treated as an objective rather than subjective.

Nowadays, the most urgent issue is to understand the way in which the user of the system searches for images in order to design the strategy of developing modern systems. The typical user is reluctant to operate a CBIR system, unless the interaction is simple and intuitive. Hence, a user-friendly and simple interface is crucial for the system. It is an apparent paradox because the human brain functions well in a complex environment which provides it with a spectrum of multimodal clues. So far, entities that comprise artificial intelligence cannot function properly in such an environment. Consequently, the user's attitude causes a change in research perspective in terms of CBIR from computer vision, image processing and pattern recognition to other disciplines, such as cognitive science or psychology.

For instance, Markkula and Sormumenn [274] divided journalist requests into four categories:

- particular objects (people's names, buildings or other places);
- background information on the image (film fragments, television programmes and documentaries, or specific news events);
- some abstract information from photographs;
- well-known photographs.

The authors recommended a kind of hybrid system which, on the one hand, offers a classical form as a user interface permiting browsing DB thematically, and on the other hand, it supports traditional concept-based indexing and classification methods.

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