# 1. Introduction

## 1.1 Content Based Image Retrieval (CBIR)

The content based image retrieval (CBIR) aims at retrieving visually similar images from image database for a given query image (or sketch). Retrieval of *required-query-similar* images from abundantly available / accessible digital images is a challenging need of today. The image retrieval techniques based on visual image content has been in-focus for more than a decade. Many search-engines, including state of the art web-search-engines retrieve similar images by searching and matching textual metadata associated with digital images. For quicker response time, association of metadata is carried out as an off-line process known as image-annotation. The image search results, appearing on the first page for fired text query *rose black*, are shown in Figure 1 for leading web search engines – Google & yahoo.

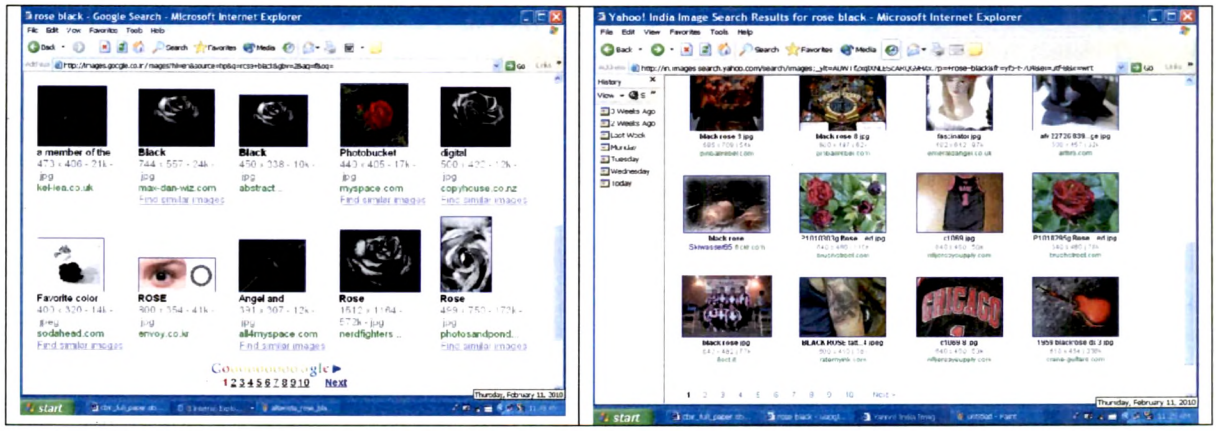


**Figure 1.** Image search results for query – rose black. a) Google b) Yahoo

As can be seen, many resultant images of Figure 1 lack semantic matching with the meaning of the text-query, showing vast scope of research leading to improvements in the state-of-art-techniques for image retrieval.

The need for image retrieval evolved two solutions – image annotation (or image tagging) and content based image retrieval. The annotation of images is in the form of textual description, carried out either automatically or manually e.g. Google image labeler (http://images.google.com/imagelabeler/). The automatic image annotation / tagging analyses the image content for producing and associating textual description with images under considerations. The textual query is then matched with annotations for image retrieval. The content based image retrieval techniques aim to respond to a query image (or sketch) with query-similar resultant images obtained from the image database, as shown in Figure 2.

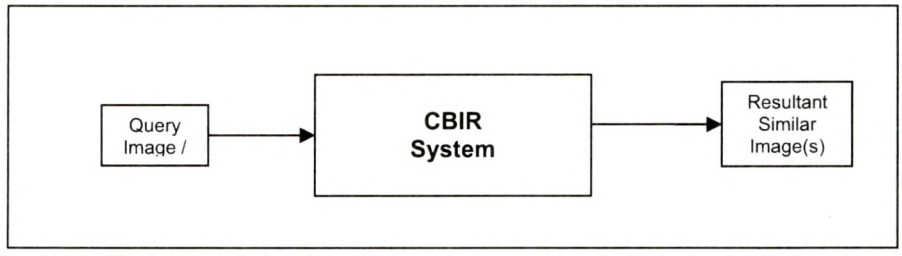


**Figure 2.** Block diagram of a CBIR system.

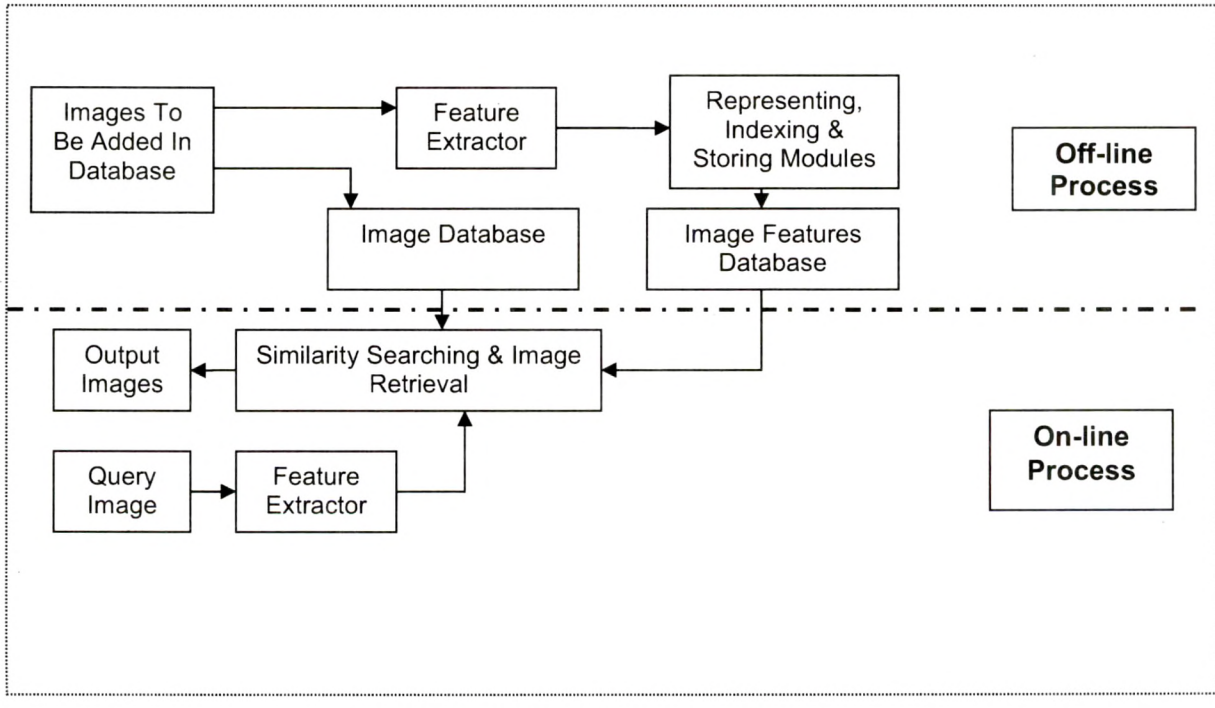


**Figure 3.** Detailed block diagram of a CBIR system.

The detailed block diagram of a CBIR system available in the literature is shown in the Figure 3. The system consists of two databases – image database and feature

database. The image feature database is a collection of the image features on which image search is to be carried out. While adding a new image in the image database, image features are extracted and stored in the feature database. The features are represented in a convenient format before storing them appropriately for faster search. Features of the query image are extracted and compared with the features of the images, available in feature database. The similarity comparison and search are carried out with the image feature database for finding similar-featured-images. The corresponding images are retrieved and displayed as a result on the basis of similarity measures.

## 1.2 Application Areas

Typical areas involving content based image retrieval [Gudivada, 1995] are

- Art galleries and museum management
- Architectural and engineering design
- Interior design
- Remote sensing and management of earth resources
- Geographic information systems
- Scientific database management
- Weather forecasting
- Retailing
- Fabric and fashion design
- Trademark and copyright database management
- Law enforcement and criminal investigation
- Picture archiving and communication systems.

Other applications reported in the literature are

- Web image searching
- Education and training
- Home applications like digital photograph cataloging and retrieval
- Medical image database maintenance and medical diagnosis
- Military applications
- Pornography detection & elimination

## 1.3 Need & Motivation

Advances in processor speed & digital sensor technology, expansion & availability of internet have tremendously increased volume & accessibility of digital images. This has caused a need to have a system that returns images based on the given query considering visual similarity among them to facilitate image searching / cataloging. The conventional image search techniques involves search on metadata comprises of textual annotation associated with images, having severe drawbacks and limitations as illustrated in Figure 1. The CBIR system aims to overcome these limitations. The vast application areas (Section 1.2) and lack of availability of general purpose CBIR system imply huge research potential on the subject.

## 1.4 CBIR System Modules

Various modules of a CBIR system shown in Figure 3 can be described as under.

- **Input / output interface**:

  This module provides Graphical User Interface to user to give or select input query either in a form of an image within or outside of the image database. It may also provide GUI for giving sketch as an input query. The output interface displays images based on the similarity measures. It may also provide a mechanism to give positive or negative relevance feed back to refine search results.

- **Image database and its interface:**

  The image database is an unorganized collection of images. The corresponding interface provides accessibility to image database.

- **Image features database and its interface:**

  The image feature database is an organized collection of image features of corresponding images of image-database. The corresponding interface provides accessibility to image feature database.

- **Feature extractor:**

  It is the most important module of any CBIR system. The relevant-image-retrieval performance of the CBIR system is directly proportionate to the performance of the feature extractor module. The module extracts required image features listed in Section 1.6 by meeting challenging issues specified in Section 1.5. These image features are compared to determine similarity.

- **Representing, indexing & storing modules:**
  The extracted features are represented appropriately to facilitate storing and indexing.
- **Similarity searching & image retrieval:**
  The extracted features of the query image are compared with the stored image features of the feature database by applying similarity criterions for retrieving content-similar-images.

## 1.5 Challenges

Following issues make development of versatile techniques for image feature extraction and hence retrieval difficult and challenging.

- **Semantic gap:**
  It is a most crucial factor affecting the relevant-image-retrieval performance of the image retrieval. The semantic gap - as defined in [Smeulders, 2000], is the lack of coincidence between the information that one can extract from visual data and the interpretation that the same data have for a user in a given situation. It is also described in the literature as a gap between human perception for the image content description and its feature representations.
- **Subjectivity:**
  The subjectivity of human being for the content analysis and description, which is characterized by human psychology, emotions and imaginations, is a second most crucial factor affecting the relevant-image-retrieval performance of the system.
- **Inter tuning of various phases:**
  The feature extractor module generally consists of a series of operations / phases whose proper tuning is important for better over-all performance of the system. Inter tuning of phases plays very important role for example in CBIR systems incorporating relevance feedback or hierarchical frame work for feature extraction & representation.
- **Variety of image categories & characteristics:**
  Different image categories & varieties of image characteristics add to the difficulty levels for development of versatile image feature extraction algorithms. Few of them are summarized here.

- Image resolutions and resizing of images
- Image categories
- Intra-image illumination variations
- Non- homogeneity of intra-region and inter-region textures
- Multiple and occluded objects
- Affine transforms of objects

- **Parameter tuning and threshold value selection:**

  A large variety in the image characteristics and image categories require parameter tuning and threshold value selection for meeting required scale of feature extraction.

- **Time performance related issues:**

  The optimization of feature processing time and query response time may become crucial for a large image database. The issue of feature dimensionality reduction is equally important for a large image database.

- **Application domain specific issues:**

  The selection of algorithms, parameters, scale of segmentation etc. are many a times application specific, e.g. the segmentation algorithm used for natural images may not be suitable for X-ray or histopathological images.

## 1.6 Image Features

Various image features and variants of there of, found in the literature for content description of the images are as under.

- Histograms
  - Local , global and cumulative
- Colors, Color layouts and color distributions
- Edges
- Contours
- Boundaries & regions
- Textures
- Shapes

## 1.7 Various Approaches

The CBIR algorithm issues are addressed by various approaches in the literature, viz.

- Iterative relevance feed back from user
- Fuzzy, evolutionary and neural network
- Hierarchical approaches
- Focusing on improvements on processing of low level cues so as to precisely extract features
- Semantic domain based image retrieval systems, comparing *meaningful* concepts

## 1.8 CBIR Systems

Various CBIR systems reported in **[Thakore, 2010, 1]** are summarized below:

- **QBIC**: Query By Image Content system [QBIC, on line] [Flickner, 1995], developed by IBM, a pioneer commercial product
- **Ultimedia Manager Product:** developed by IBM [Barber, 1994], based on QBIC technology.
- **VisualSEEk**: Developed at Columbia University [Smith, 1996] [VisualSEEk, on line].
- **Photobook:** Developed at Media Laboratory, Massachusetts Institute of Technology – MIT [Photobook, on line], incorporating a unique feature of interactive learning agent, named *FourEyes* for selecting & combining feature-based models
- **MARS:** Multimedia Analysis and Retrieval Systems [MARS, on line]
- **FIRE:** Flexible Image Retrieval Engine [Fire, on line]
- **PicSOM:** (Picture & Self-organizing Map) [Laaksonen, 1999] implemented using tree structured SOM
- **NeTra** [Ma, 1997]

The elaborative survey on CBIR system can be found in [Veltkamp, on line].

## 1.9 Scope of the Work

**The work carried out includes:**

1. **Literature survey – CBIR algorithms and CBIR systems [Thakore, 2010, 1].**
2. **Development and implementation of a novel algorithm for edge detection and edge thinning & qualitative comparison of results with those of Adobe Photoshop, ACD photo editor, MS photo editor for color images [Thakore, 2010, 2].**
3. **Development and implementation of a novel algorithm for prominent boundaries detection and qualitative comparison of results with those of standard databases of color images [Thakore, 2010, 3].**
4. **Development and implementation of a novel algorithm for foreground object revealing by separating background for prominent boundaries detected color images [Thakore, 2010, 4].**
5. **Development and implementation of novel algorithms for image retrieval, based on:**
   - **color code attributes of whole image**
   - **color code attributes of separated foreground**
   - **foreground shape correlation coefficients**
   - **combination of foreground color codes and shape correlation**

   **5.1 Development and implementation of prominent boundaries & foreground separation based algorithm for extracting human-face and retrieving similar face images containing complex backgrounds.**

   **5,2 Performance evaluation and analysis of results of above image retrieval algorithms at various selectable similarity-cut-offs.**
6. **Integration of various modules and development of Graphical User Interface for the CBIR system comprising of above algorithms.**

## 1.10 Overview of the Work & Organization of the Thesis

CBIR being the most demanding and challenging need of the recent years, the work emphasizes on development and implementation of algorithms for achieving content based image retrieval. A complete GUI based CBIR system having selectable multimodal image retrieval with selectable cut-offs of (dis)similarity for selectable input-query image have been developed, implementing novel algorithms. The perspective

of query image processing for feature extraction & image retrieval given as the block diagram in Figure 4 gives *the overview of the work* and the relationship / dependency of various phases of the developed CBIR system / algorithms.

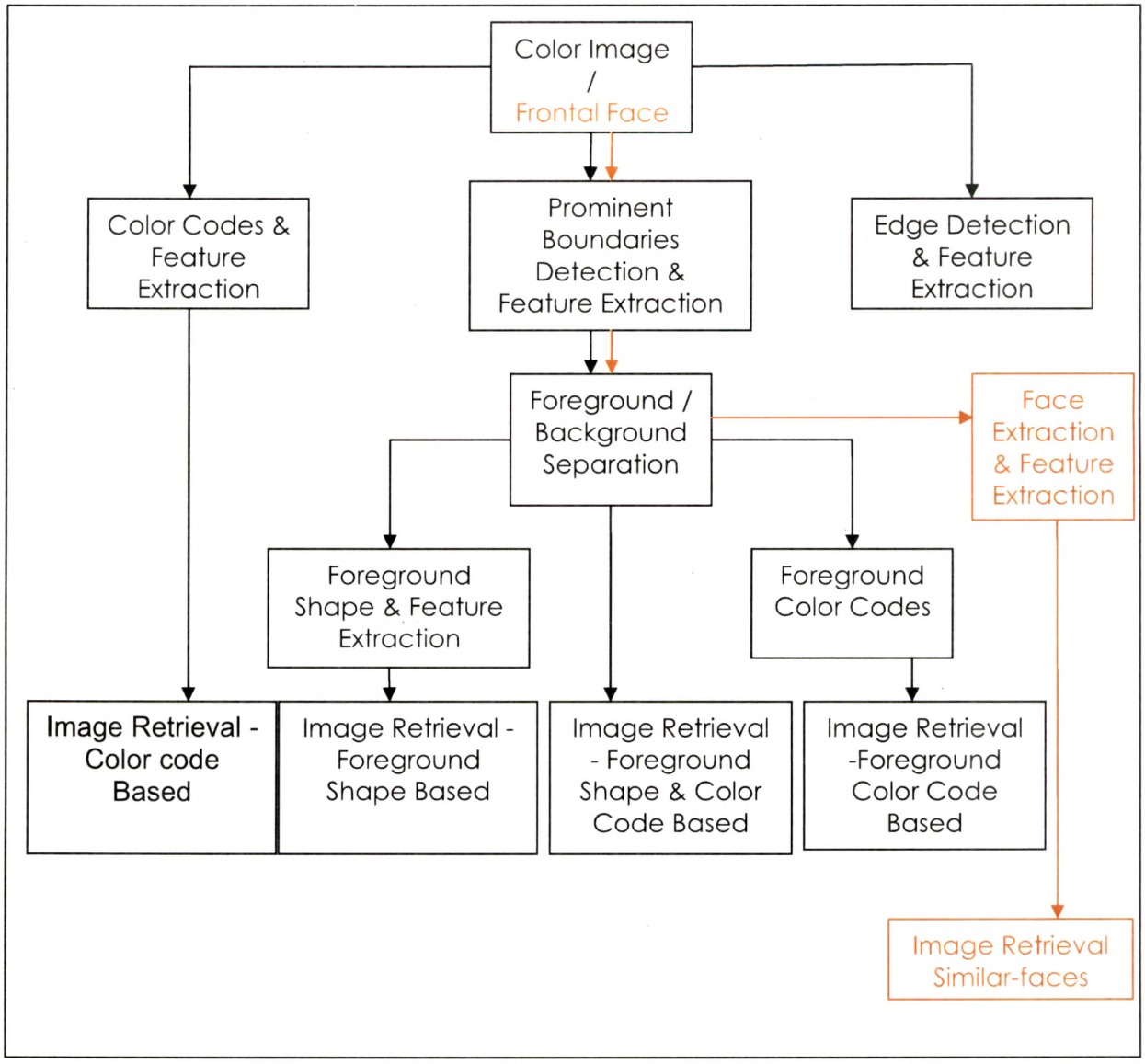


**Figure 4.** Block diagram – Perspective of query image processing for proposed system.

Our approach is based on two streams of features – prominent boundaries based features and Color code based features. These features and combination of them have been used for image retrieval. The color codes are broadest descriptors of colors whereas prominent boundaries are well localized boundaries detected due to reliable processing of low level cues. One of the most fundamental requirements for better performance of CBIR is the 'proper' image segmentation needed for precise and

reliable image-feature extraction. A novel approach based on detection of prominent boundaries for image segmentation & image feature extraction has been developed. The versatility and suitability of prominent boundary based image segmentation has been proved by testing various categories of images of various standard databases listed in Section 1.11. The qualitative comparison of results with human segmented images available at standard image database BSDB [Fowlkes, on line] [Martin, 2001] shows effectiveness of the method.

The second technique for image feature extraction is based on *color codes* - a technique to map a set of colors to a specific color code leading to image segmentation based on broad color descriptors. Though the method may sometimes under-segment the image, the computationally inexpensiveness and broad color description of regions are two great advantages of the method.

The prominent boundaries and watershed algorithm have been utilized for region feature extraction and foreground / background separation. The incorporation of Stationary Haar wavelet decomposition at various levels makes the method suitable for hierarchical approach. The results of the proposed method are also qualitatively compared with those of JSEG [Deng, on line] [Deng, 2001] for the effect of texture and illumination variations and suitability of the algorithms for foreground – background separation.

The developed algorithms extract image features like contours, edges, boundaries & thin boundaries, regions & region attributes, color & color distribution, derived features of foreground & background regions, shape of foreground region, color & color distribution of foreground object. The edge-features are not incorporated for image retrieval purpose. It may be utilized for further reduction in number of over-segmented regions – *a suggested future enhancement of the work*. The edge detection results are compared qualitatively in **[Thakore, 2010, 2]** with edge detection performance of leading DTP and image processing software packages – Adobe Photoshop, ACD photo-editor and MS photo-editor. The results of the proposed method outperform others for i) detection of significant perceptual edges ii) elimination of insignificant edges corresponding background and foreground textures iii) better preservation of continuity.

Image retrieval methods based on (i) color codes of entire image (ii) Foreground color codes (ii) Foreground shape correlation (iv) Combination of foreground color codes and shape correlation have been developed and implemented. The image query responses for various images at different similarity cut-off along with precision and recall for various images of standard database SIMPLIcity [SIMPLIcity, on line] and ALOI [ALOI, on line] [Geusebroek, 2001] have been presented for aforesaid retrieval techniques.

The prominent boundaries and foreground detection based method for extracting face and face region attributes from images containing complex background and illumination variations have been developed. The application specific CBIR for retrieving similar-face-images has been implemented. The method measures similarity of normalized face regions based on correlation coefficients. The effectiveness of prominent boundaries and foreground detection techniques for face extraction has been shown for 115 images of standard database Caltech [Caltech, on line] [Fei-Fei, 2004].

The algorithms are tested on vast set of images inclusive of standard image databases listed in Section 1.11, consisting of various categories of images. The implementation has been carried out on Intel® dual core T 2050, 1.6 GHz processor with 1.5 GB of RAM using Matlab R14.

The thesis is organized as follows. Chapter 2 includes review and evaluation of various CBIR algorithms and CBIR systems. The relevant technical background is covered in the chapter 3. The chapter 4 deals with the developed novel techniques for edges & prominent boundaries detection. It also covers analysis and qualitative comparison of the results of prominent boundaries with human segmented images of standard database BSDB [Fowlkes, on line] [Martin, 2001]. The edge detection results are qualitatively compared with edge detection response of Adobe Photoshop, ACD photo-editor and MS photo-editor in the same chapter. The next chapter 5 covers prominent boundaries based novel technique for foreground object detection and background separation, results and qualitative comparison of them. It also includes qualitative comparison of results of the proposed method of segmentation / foreground detection with that of segmentation algorithm JSEG [Deng, on line] [Deng, 2001]. The chapter 6 includes the details of the image features, proposed novel method for image retrieval based on (i) color codes of entire image (ii) Foreground color codes (ii)

Foreground shape correlation (iv) Combination of foreground color codes and shape correlation. It also covers results and performance evaluation and analysis with precision-recall & precision recall curves. The method and results of face extraction and similar-face-image retrieval are also covered in the chapter. And finally, conclusions & future enhancements are covered in the last chapter 7.

The Annexure 1 contains the list of the publications made so far. The Annexure 2 describes various components of Graphical User Interface (GUI) for the developed CBIR application. The Annexure 3 contains typical miscellaneous results.

## 1.11 Image Databases

Proposed novel algorithms have been tested on various images including following standard image databases.

- **BSDB** [Fowlkes, on line] [Martin, 2001] - The Berkeley Segmentation Dataset and Benchmark (BSDB).
  Available: http:/www.cs.berkeley.edu/projects/cs/vision/grouping/segbench/
  The standard data set consists of variety and vast range of images, segmented images and human segmented images of medium size and resolutions.
- **SIMPLIcity** [SIMPLIcity, on line] [Wang, 2001]- The SIMPLIcity web site:
  Available: http://wang14.ist.psu.edu/cgi-bin/zwang/regionsearch_show.cgi
  A data set consists of images of 10 different image categories and 100 images per category (Table 6). Images are of small size and medium resolution.
- **Amsterdam Library of Object Images (ALOI)** [ALOI, on line] [Geusebroek, 2001]–
  Available: http://staff.science.uva.nl/~aloi/
  A collection of images of small objects with dark background. Multiple images of objects captured with varied and controlled illumination conditions viewing angle, illumination angle, and illumination color.
- **Caltech** [Caltech, on line] [Fei-Fei, 2004] - Caltech 101 face dataset. Available:
  http://www.vision.caltech.edu/Image_Datasets/Caltech101/Caltech101.html
  A data set consisting of 101 objects, of which 437 face images of 27 different people with various indoor-outdoor complex background and different illumination conditions. Images are of medium size and medium resolution. The same face images of larger size and higher resolution are available as Caltech frontal face images 1999.

- **PASCAL challenge 2008 image database** [Everingham, on line] - Available: http://pascallin.ecs.soton.ac.uk/challenges/VOC/voc2008/workshop/index.html
  A data set of image segmentation competition – consisting of various challenging images.
- University of Washington, Image database [University of Washington, on line]. Available:
  http://www.cs.washington.edu/research/imagedatabase/demo/seg/
  A collection of images used for segmentation.
- **MedPics** [MedPics, on line] – An Image Library for Medical Education, UCSD – School of Medicine.
  Available: http://medpics.ucsd.edu/
  A collection of medical images.

The images of PASCAL challenge 2008 image database [Everingham, on line], University of Washington, Image database [University of Washington, on line] and MedPics [MedPics, on line] have been used only for edge detection, prominent boundaries detection & foreground extraction. Rest all have been used for testing of all proposed algorithms.

## 1.12 Specifications of the Developed CBIR System

- **Query**
  - By example - single image
  - Selectable from image database
  - GUI based
- **Results**
  - Retrieved similar images in order of decreasing similarity
  - Presented in multiple windows & 16 thumbnails (images) / window
- **Supported Image types**
  - jpeg
  - png

- **Image Features**
  - Color Codes
  - Histograms
  - Regions & region attributes
  - Foreground & background regions and region attributes
  - Shape correlation coefficients
- **Image Retrieval**
  - Based on
    - Color codes of entire image
    - Foreground color codes
    - Foreground shape correlation
    - Combination of foreground color codes and shape correlation
      - With selectable percentage proportion of weight of foreground color codes and foreground shape correlation for composite similarity measure
  - Similar face – images containing complex background
- **Selectable similarity cut-offs**

  The feature of the CBIR system allows user to specify the cut-off level for similarity measurement, helpful to specify the maximum permitted inexactness in the retrieved images

***The GUI of the CBIR system and its description are shown in Annexure 2.***

## 1.13 Concluding Remark

*A successful endeavor of development of CBIR algorithms and the CBIR system...*