7. Conclusions & Future Enhancements

7.1 Conclusions

A challenging task of development, implementation and integration of various novel algorithms to result into GUI based, selectable multi-modal processing of selectable single query image for retrieval of similar images has been achieved successfully.

These algorithms include:

- Edges and prominent boundaries detection
- Foreground separation
- 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
  - Extracted face region from images containing complex background for similar face-images retrieval

Other points of conclusions are:

- Well localized and well delineated thinned edges detected with proposed method outperform Adobe Photoshop, ACD Editor and MS Editor for i) detection of significant perceptual edges ii) elimination of insignificant edges corresponding background and foreground textures and iii) better preservation of continuity. These edges can be utilized for further reduction of artifacts produced due to watershed algorithm.
- Prominent boundaries, prominence measure, watershed algorithm with various levels of Haar wavelet decompositions are effectively incorporated together for proper segmentation and feature extraction by enforcing reliable processing of low level cues for avoiding breaks as well as under segmentation

by utilizing continuity preserving, well localized visually prominent boundaries for foreground – background separation. The problem of over segmentation is addressed by compositely considering proximity influence and watershed algorithm.

- High performance measures - $Precision_{fg}$ and $Recall_{fg}$, computed with respect to Ground Truth foreground for extracted foreground with proposed method endorses the uniqueness & effectiveness of the method & produced results.
- Prominent boundaries based approach for foreground-background separation is largely insensitive to illumination variations and inter region texture variations.
- *"Relaxed feature description for better Recall"* – the first half of the theme for the approaches has been accomplished with color codes and associated similarity measure for image retrieval.
- *"Simultaneous emphasizing of reliable processing of cues leading to precise feature extraction for better precision"* - the second half of the theme of approached has been accomplished with R,G,B and Gray channel processing for prominent boundaries and subsequent feature extraction.
- Image retrieval with similarity comparison of broader color descriptors - color codes for whole image is robust to illumination, pose and view point variations provides user an option of searching of similar images based on color distribution of whole image.
  - The method possesses conventional shortcomings due to ignorance of shapes and regional features.
  - The method is computationally efficient for feature extraction and similarity comparison.
  - The method provides high Recall and high ranking for nearly similar images.
- The retrieval technique based on foreground color code exploits reliable processing to precisely detect foreground and exclude background & related features to provide foreground color distribution based comparison of foreground objects.
  - The combination of stringent feature for prominent boundaries & foreground detection with broader color descriptor provides remarkable results for wide variety of images.
- Image retrieval with foreground shape correlation is very sensitive to the detected shape of the foreground. Attached shape altering regions adversely

affect the performance of the method. The method may not perform equally well on natural images.

- Foreground based methods are not suitable for images containing small foreground objects and objects spreading across image boundaries.
- The composite similarity measure constituted with selectable proportion of weights of foreground color codes and foreground shape correlation maps users need for proportionately emphasizing color code distribution and shape of foreground for retrieval of images. The stringent shape feature & broader color code features of foreground and their selectable proportion provide excellent combination for foreground object based image search with high Precision.
- High success ratio of 82% for precise face region extraction from 115 images of standard database Caltech [Caltech, on line] [Fei-Fei, 2004], which possess complex background and various illumination conditions infers the effectiveness of various proposed methods.
- The effectiveness & preciseness of various proposed algorithms have been exploited for development of application specific CBIR for similar face image retrieval on Caltech [Caltech, on line] [Fei-Fei, 2004] image database.
- All algorithms have been tested on variety of images, mainly of standard image databases, viz. BSDB[Fowlkes, on line] [Martin, 2001], SIMPLIcity [Wang, 2001] [SIMPLIcity, on line], PASCAL challenge 2008 [Everingham, on line], ALOI [ALOI, on line] [Geusebroek, 2001], Caltech [Caltech, on line] [Fei-Fei, 2004], MedPics [MedPics, on line] and University of Washington [University of Washington, on line], establishing suitability of methods for wide varieties and categories of images.
- Obtained P – R curves for query responses with proposed methods of retrieval are close to ideal for many cases and similar to practical P – R curves for the rest proving effectiveness of algorithms and validity of results.
- No method of image retrieval can be generalized to be concluded outperforming others for all queries because of
  - diversities in image characteristics and categories
  - subjectivity in image content description
  - semantic gap

7.2 Limitations

The limitations of the developed CBIR system are as under:

- The developed algorithms and application are resource hungry. Hence, processing of high resolution large sized images is possible only with machines possessing huge memory and computational resources.
- The prominent boundaries detection does not yield expected results for very low resolution images, particularly captured from web-cam.
- Lack of incorporation of indexing technique has caused higher query response time.

7.3 Future Enhancements

Suggested future enhancements are as under.

- Analysis of performance of prominent boundaries detection method with other wavelets.
- Utilization of well localized thin-edges to further reduce artifacts produced due to intrinsic characteristic of watershed algorithm.
- Extraction of texture feature and its incorporation in the CBIR algorithms.
- Incorporation of indexing technique(s) for faster query response.
- Incorporation of database management modules for image and image-feature databases.
- Incorporation of relevance feed-back from user to increase the retrieval performance of the system.
- Incorporation of multiple-queries to refine results for improved retrieval performance.
- Extending the query processing support to all file types.
- Testing of the CBIR algorithms for Precision and Recall performance measures - on very large image databases, of the order of tens of thousands of images. (This testing requires high-end machine(s) to meet computational needs of feature extraction and similarity comparison methods.)
- Testing of CBIR algorithms for databases consisting of transformed images with scaling, cropping, contrast alterations, brightness changes, changes in quality factor of JPEG compression and noise introduction.
- Testing of the CBIR algorithms for precision and recall performance on medical images – particularly X-ray images. The foreground shape based CBIR method should yield very encouraging results because of following reasons:

- The foreground detection should be well localized and precise due to X-ray image characteristics.
- The X-ray images are captured by skilled persons in a controlled illumination conditions eliminating associated challenges.
- The object shape variations due to affine transformations are limited.

- Exploiting regions and region attributes for development of CBIR application for histological and pathological images.
- Inclusion of face-geometric features for face detection & extraction for improvement in face-extraction success ratio.
- Enhancing the application for image annotation.
- Development of face recognition and face expression understanding algorithm/application based on proposed face extraction method.
- Development of application for video abstraction.
- Enhancing the developed application to web-based CBIR system.

7.4 Concluding Remark

A step forward on the road-map of continuous & endless technical evolution towards a perfect & versatile CBIR ...