Development of Descriptors for Color Image Browsing and Retrieval

Report Submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology
In
Computer Science and Engineering

By
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To

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It was due to Mr. Verma's toiling efforts that we worked towards submission of a research paper in an international conference. He encouraged us to gather the professional knowledge and material for the completion of this project. He helped us with his invaluable and finest suggestions to give shape and finesse to the work done.

I sincerely hope that users will find this project useful. Whatever intellectual effort may be reflected from this report is the direct result of the informative and stimulating discussions that I have had in the course of this internship. Given the time constraint and continuous nature of a research activity, there is always a scope to ameliorate image retrieval techniques.

Sahil Narang

Defence Research and Development Organization

I. About DRDO

DRDO was formed in 1958 from the amalgamation of the already functioning Technical development Establishment (TDEs) of the Indian Army and the Directorate of Technical Development and Production (DTDP) with the Defence Science Organization (DSO). DRDO was then a small organization with 10 establishments or laboratories. Over the years, it has grown multi directionally in terms of the variety of subject disciplines, no. of laboratories, achievements and stature.

Today, DRDO is a network of 51 laboratories which are deeply engaged in developing Defence technologies covering various disciplines, like aeronautics, armaments, electronics, combat vehicles, engineering systems, instruments, missiles, advanced computing and simulation, special materials, naval systems, life sciences, training, information systems and agriculture. Presently, the organization is backed by over 5000 scientists and about 25,000 other scientific, technical and supporting personnel. Several major projects for the development of missiles, armaments, light combat aircrafts, radars electronic warfare systems etc are on hand and significant achievements have already been made in several such technologies.

II. About DTRL

A. Historical Background

Terrain evaluation activities were initiated in Defence Research and Development Organization (DRDO) with the creation of Terrain Evaluation Cell (TEC) in Feb. 1964 with the objectives of development of techniques for terrain evaluation, and assessment of mobility potential of inaccessible areas. TEC over a period of 17 years completed a number of assignments. In view of the potential and vitality of terrain information, TEC was expanded and accorded to the status of a full fledged laboratories in December, and was renamed as Defence Terrain and Research Laboratory (DTRL).

B. Areas of work

- Development of a reliable system for assessment of terrain characteristics through modern techniques of terrain evaluation.
- Development of infrastructure, competence and instrumentation in the latest techniques of terrain evaluation.
- Development of terrain information database.
- Ground water study, landslide and hazard zonation, and geo-environmental studies.

C. Achievements

- Improvement in mapping by using better resolution data (5.6m in PAN Mode and 23.5m in LISS III mode) from IRS_IC and IRS_ID satellites.
- Use of digital information data of satellite imagery for preparation of different thematic maps.
- Use of geographic information system (GIS) to achieve automation of information mobility maps.

Synopsis

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<u>Degree</u>: B.Tech. (C.S.E.)

<u>Department</u>: Defence Terrain Research Laboratory (DTRL)

<u>Organization</u>: Defence Research and Development Organization (DRDO), Ministry of Defence, Delhi

<u>Project Title</u>: "Development of Descriptors for Color Image Browsing and Retrieval"

<u>Name of Project Supervisor</u>: Mr. D. N. Verma, Scientist 'E', DTRL, DRDO

<u>Month and Year of Project Completion</u>: July, 2011

<u>Project Description</u>:

Content Based Image Retrieval (CBIR) provides efficient and effective means to extract most similar images stored in the database based on image contents. It is a technique which aims at retrieving images which are perceptually and semantically meaningful by making the best use of a single or combination of visual content descriptors. The major steps are feature extraction and similarity comparison.

This research based project expands along the four approaches. An overview of the entire work done is presented here.

- **Texture Based Image Retrieval using Correlation**

Texture analysis is one of the widely used operations for feature extraction. The first method computes the features by calculating weighted standard deviation on Haar Discrete Wavelet Transform of image along with correlation between the bands. The texture features thus extracted are subjected to similarity comparison and few images with higher similarity value are retrieved. It depicts the improved precision of the proposed texture approach over the previously tested WSD, GLCM and Gradient methods.

- **Image Retrieval based on Multi-feature Fusion**

Computer-assisted search for an image can be done by extracting one or more salient characteristics like shape, colour, texture, and pattern. It is done through a search of exactly or relatively similar images considering a fusion of two prominent descriptors namely, texture and colour as search criteria.

An image is searched for given query image on the basis of collaborated similarity of colour and texture features. Experiments have shown that search results were accurate and impressive on all types of images. Concluding, this approach is practically useful in searching for similar images.

A rigorous and in-depth exploration of color and texture feature descriptors is performed to attain desired performance accuracy in image browsing. The project can be further extended to include other visual descriptors such as shape to further enhance the quality of Content based Image Retrieval System.

- **Image Browsing based on Multi-feature Fusion**

Object/region identification and search form challenging tasks in image interpretation which is itself a hot research area under the broad spectrum of CBIR.

Thus, this is a novel distributed approach for searching parts of images. An image is searched for given small image on the basis of collaborated similarity of color and texture features. Experiments have shown that search results were accurate and impressive on all kinds of images. Concluding, this approach is practically useful in searching and highlighting multiple occurrences of some given object anywhere in the image along with the near similar regions.

A rigorous and in-depth exploration of color and texture feature descriptors is performed to attain desired performance accuracy in image browsing. The project can be further extended to include other visual descriptors such as shape to further enhance the quality of Content based Image Retrieval System.

Table of Contents

Introduction

I. DIGITAL IMAGE PROCESSING

A. Introduction

An image may be defined as a two dimensional function f(x, y) where x & y are spatial coordinates and the amplitude of function f at any pair of coordinates (x, y) is called intensity of image at that point (also known as a pixel). When x, y, f(x, y) are all finite discrete quantities we call the image a digital image. Digital image processing encompasses processes whose inputs and outputs are images and processes that extract attributes from images, up to and including the recognition of individual objects. These processes fall under three broad categories:

1. *Low Level:* These involve primitive operations such as image manipulation to reduce noise, contrast enhancement and image sharpening.
2. *Mid Level:* It involves tasks such as segmentation, description of objects to reduce them to a form suitable for computer processing and classification of individual objects. Mid-level processes are characterized by the fact that their inputs generally are images, but outputs are attributes extracted from those images.
3. *High Level:* It deals with making sense of an ensemble of recognized objects extracted from the mid-level processes.

The mid-level and high level operations can be exploited for extracting useful information from a digital image which opens the way to *Content Based Image Retrieval.*

B. Image File Formats

Image file formats are standardised means of organising and storing images. The digital image formats are used to store photographic and other images. Image files are composed of either pixel or vector (geometric) data. The pixels that compose an image are ordered as a grid (columns and rows); each pixel consists of numbers representing magnitudes of brightness and color. Major graphic file formats are:

Raster Formats: JPEG, TIFF, BMP, RAW, PNG, GIF.

Vector Formats: CGM, SVG.

C. Image File Size

It is expressed as the number of bytes that increases with:

1. The *number of pixels* composing an image- the greater the number of rows and columns, the greater the image resolution and the larger the file
2. *Color depth* of pixels- each pixel of an image increases in size when its color depth increases-an 8-bit pixel (1 byte) stores 256 colors, a 24-bit pixel (3 bytes) stores 16 million colors, the latter known as true color.

II. CONTENT BASED IMAGE RETRIEVAL

The term CBIR can be properly studied by focusing on two aspects.

A. Text based Image Retrieval

As the term image retrieval denotes, it deals with searching images from a vast database fulfilling a user specified criterion. A traditional way of specifying search criteria is Query by Text (QbT). In QbT, queries are texts and targets are images. To access the desired image data, the seeker can construct queries using homogeneous descriptions, such as keywords while the images in the database have to be annotated with words, such as time, place, or photographer. Such retrieval is known as annotation/text based image retrieval. This annotation scheme comes with certain inherent disadvantages which cannot be overlooked as the size of image database increases. The disadvantages are:

1. Since automatically generating descriptive texts for a wide spectrum of images is not feasible, most text-based image retrieval systems require manual annotation of images which is a cumbersome and expensive task for large image databases, and is often subjective, context-sensitive and incomplete. As a result, it is difficult for the traditional text-based methods to support a variety of task-dependent queries.
2. The efficient management of rapidly expanding visual information poses an urgent problem.

B. Content Based Image Retrieval

The disadvantages mentioned above formed the driving force behind the emergence of CBIR. Content-based image retrieval (CBIR) uses visual information of the images to retrieve them from large image databases according to user's interest. The approach where user's interest can be expressed by an example image is called Query by Example (QbE). Here, both query and targets are images. In this type of retrieval, the image database can be efficiently managed by using the properties of the visual information.

B.1) *Steps followed in CBIR:*

1. The visual contents of the images in the database are extracted and described by multi-dimensional feature vectors. The feature vectors (Image Content Descriptors) of the images in the database form a feature database.
2. Users provide the retrieval system with example images, which are changed into internal representation of feature vectors.
3. The similarities/ distances between the feature vector of the query example and those of the images in the database are calculated.(Similarity Metric)
4. Indexing scheme is used to retrieve images according to the similarity values by providing an efficient way to search the image database.(Indexing Schemes)
5. User's relevance feedback can be incorporated to modify the retrieval process in order to generate perceptually and semantically more meaningful results. (Relevance Feedback)

C. Image Content Descriptors

The purpose of image content descriptors is to transform human perceptible qualitative features (content) of an image into an approximate quantitative measure. For example, if we consider the color content of an image, we wan well distinguish a red rose from a white one by calculating the amount of redness or whiteness present in them. The content of an image can be categorically divided as shown in the diagram below.

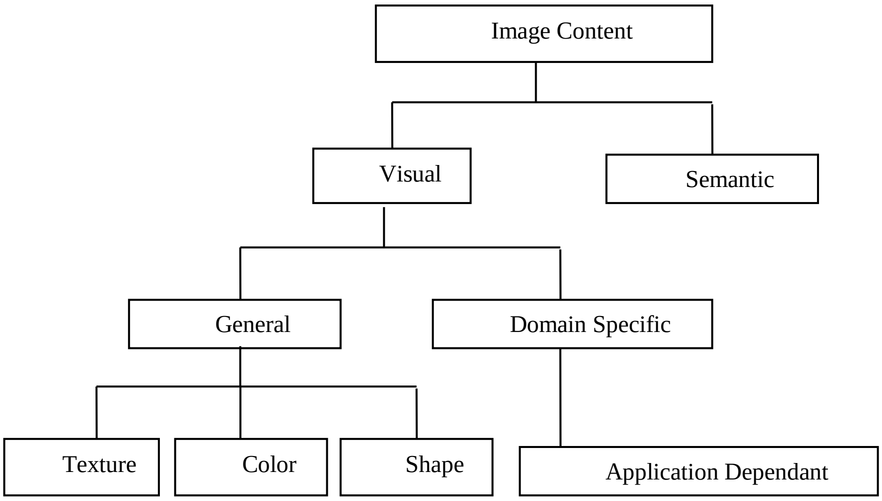


Fig.1. Categories of Image Content Descriptors

C.1) ***Color***

Colors that human perceive in an object are determined by the nature of light reflected from the object. Color is the most widely used visual content for image retrieval. Its extensive use can be attributed to the following factors:

1. It is a descriptor that simplifies feature identification and extraction.
2. Its 3 dimensional values make its discrimination potentially superior to the single dimensional gray values of images.

To facilitate the representation of colors in some standard, generally accepted way, color models are used. A color model is a specification of a coordinate system and a subspace within that system where each color is represented by a single point. Commonly used color space for image retrieval include RGB, Munsell, CIE L*a*b*, CIE L*u*v*, HSV and opponent color space. RGB color space corresponds closely with the way humans describe and interpret color.

Color descriptors: Color Histogram, Color Coherence Vector, Color Correlogram, Color Moments

C.2) ***Texture***

Texture can be defined by certain constant, slowly varying or periodic local statistical properties computed over different regions of an image. This descriptor, intuitively, provides measures of properties such as smoothness, coarseness, and regularity of an image. Three principal approaches used in image processing to describe the texture of a region are:

1. Statistical Approach characterizes texture as smooth, coarse, grainy and so on.

   Statistical descriptors: Fourier power spectra, co-occurrence matrices, Tamura features (coarseness, contrast, directionality, regularity, roughness, line likeness), Markov random field, Wold features (harmonic, evanescent, indeterministic), fractal model, multi-resolution filtering techniques such as Gabor and Wavelet transform.

2. Structural techniques deal with the arrangement of image primitives such as the description of texture based on regularly spaced parallel lines

   Structural descriptors: morphological operator, adjacency graph.

3. Spectral techniques are based on properties of the Fourier spectrum and are used primarily to detect global periodicity in an image by identifying high-energy, narrow peaks in the spectrum.

C.3) *Shape*

Shape features are usually described after images have been segmented into regions or objects. Since robust and accurate image segmentation is difficult to achieve, the use of shape features for image retrieval has been limited to special applications where objects or regions are readily available. The state-of-art methods for shape description can be categorized into boundary-based (rectilinear shapes, polygonal approximations, etc.) and region-based (statistical moments) methods.

Shape descriptors: Moment Invariants, Turning Angles, Fourier descriptors, Circularity, Eccentricity and Major Axis Orientation.

D. Similarity/Distance Measures

Image content descriptors describe the image content in terms of multi-dimensional feature vectors. A comparison of feature vectors of two different images gives the degree of similarity between them. Instead of exact matching of descriptors, content-based image retrieval calculates visual similarities of a query image with images in a database. Accordingly, the retrieval result is not a single image but a list of images ranked by their similarities with the query image. Many similarity measures have been developed for image retrieval based on empirical estimates of the distribution of features in recent years. Different similarity/distance measures will affect retrieval performances of image retrieval system significantly.

Similarity Metrics: Minkowski-Form distance, Quadratic Form distance, Mahalanobis Distance, Kullback-Leibler Divergence and Jeffrey-Divergence.

E. Performance Evaluation

The performance of a retrieval system should be evaluated to determine the efficiency of retrieving relevant images according to the query given by the user.

Performance Measures: Recall, Precision (retrieval accuracy), Average Normalised Modified Retrieval Rank (ANMRR),

Software Requirements Specification

I. INTRODUCTION

A. Purpose

The SRS is a technical specification of requirements for the software products. The goal of software requirement definition is to completely and consistently specify the technical requirements for the software product in a concise and unambiguous manner.

Thus, the purpose of this document is to describe the external requirements for the research and development of color, texture and shape (visual content) descriptors for content based image retrieval. It is a culmination of requirements that arose at the various phases of development.

B. Scope

The scope of this SRS document encompasses the following: -

1. It serves as a good reference to study, analyze and understand the need for the development of low-level descriptors for CBIR.
2. It acts as a verification tool for the final specification.
3. The functionalities derived from the requirement analysis and mentioned in this document are further refined in the design phase.

The scope of the application to be developed expands over research area of CBIR. It concentrates on exploration of the already accomplished research work on image content descriptors, focussing mainly on color and texture. Also, contribution to the enhancement of efficiency of such techniques is to be made for improved content based image retrieval. The application of the work to be done covers the following fields:

1. *Military:* locating and recognizing remotely sensed objects, interpreting satellite data.
2. *Crime prevention and Security Check:* Automatic face recognition systems, finger print or retina scanning for access privileges.
3. *Medical Diagnosis:* Using CBIR in a medical database of medical images aid diagnosis by identifying similar past cases.
4. *Intellectual Property:* Trademark image registration, where a new candidate mark is compared with existing marks to ensure no risk of confusing property ownership.

C. Definitions, Acronyms and Abbreviations

See Appendix

D. References

See Appendix

E. Overview

An in-depth research on CBIR has to be done keeping in mind the objective of proficiently retrieving digital images or parts of digital images from a huge image database. Also a study on application of visual content-based descriptors has to be carried out to find certain desired regions within an image. Owing to the well known fact that such tasks consume a considerable amount of time and memory, there arises an obvious requirement of working towards minimizing such constraints. A specification of all the requirements from the user's as well as developer's perspective has been made in the following sections of the document.

II. PROBLEM/ OVERALL DESCRIPTION

A. Product Perspective

In the early 1990s, as a result of advances in the Internet and new digital image sensor technologies, the volume of digital images produced by scientific, educational, medical, industrial, and other applications increased dramatically. The difficulties faced by text-based retrieval became more and more severe. The efficient management of the rapidly expanding visual information became an urgent problem. This need formed the driving force behind the emergence of content-based image retrieval techniques. The content of a color image can be analyzed by extracting its low level features such as color, texture, shape.

- The conversion of color images to gray level is a good start for determining texture of an image. There are many ways for extracting textural properties of an image. One of them is to first transform an image from spatial domain to frequency domain and then apply appropriate statistical tools on it. The theory of Multi-resolution Analysis which includes Discrete Wavelet Transforms can be useful in this task.
- An insight into color content of an image can be gained by working in a certain color space. Thereafter color information can be obtained by using the standard color moments or experimenting with some novel approaches or aptly combining both.
- Images are displayed to the user on the basis of similarity of features.
- In military applications, there often arises a requirement of searching out satellite imagery for objects or regions with certain characteristics. Similar requirements may also arise in other application domains. The above stated strategy can be modified to perform a pixel by pixel search on an image thus fulfilling the mentioned requirement.
- Since search on a pixel by pixel basis takes computation time of the order of hours, a time reduction scheme such as multitasking comes into picture. Further reduction in time can be obtained by implementing this scheme for a large digital image collection in a distributed environment.
- In certain cases, a single content descriptor may not suffice for correct retrieval rather a fusion of two or more descriptors can prove to be a good choice.
- The computation of the features for images comprising the database can be done either offline or online. Offline computation requires feature computation to be done and stored prior to query submission by the user. Online computation is time consuming and is done for every new query submitted.

A.1) *Software Interfaces*

- A database management system
- Image processing package in Java with the specifications as given below:

  Name: Java Advanced Imaging (JAI)

  Version: 1_1_2 or higher
- Java Runtime Environment (JRE)

A.2) *User Interface*

GUI

B. Product Functions

According to user's perspective, the product should provide two facilities:

1. Searching and Retrieval of whole images
2. Browsing and Retrieval of parts of images(especially from satellite imagery)

The facilities are detailed in the block diagram presented in **Fig.2**.in the next page.

A thorough research and analysis of existing image content descriptors coupled with the exploration and experimentation of some novel and efficient low level descriptors is a prerequisite to the development of product functions.

C. User Characteristics

The users are categorized into the following three constituencies: -

- Researchers – people interested in research on CBIR.
- Defence Personnel – people interested in developing projects for defence use.
- Geologists and people working on satellite data.

D. Constraints

Performance and extensibility must be taken care of while developing the system.

E. Assumptions and Dependencies

For testing and development purposes, the following should be considered:

- *Image size:* Image width must be equal to its height; images of even (or in powers of 2) dimensions are to be taken.
- *Color space:* RGB color space should be considered for images.
- *Color Depth:* 24-bit True color images must be taken into account.
- *Image Format:* Images stored in BMP and TIFF formats should be taken up for analysis and testing.

III. SPECIFIC REQUIREMENTS

A. External Interfaces

TABLE I
MAJOR INPUT, OUTPUT OF THE SYSTEM

Item Name	Category	Format	Source
Image File Name	Input	Text	Keyboard/ Mouse (GUI)
Input Image	Input	Digital Image (BMP,TIFF)	Hard Disk
Feature Extraction Method (for Searching function)	Input	Text	Keyboard/ Mouse (GUI)
Image features computed offline (for Searching function)	Input	Numeric	Database stored on hard disk
Retrieved Images	Output	Digital Image (Internal Representation)	Monitor (GUI)

B. Functions

The product shall perform two key functions:

B.1) ***Searching and Retrieval of whole images***

The product function of searching and retrieval of whole images shall be viewed as a sequence of following sub tasks:

- Inserting images and their offline computed features in a database
- Accepting a query image from the user
- Preprocessing of query image
- Computation of features of query image using a method depending on the color or texture feature being extracted
- Ranking of database images according to similarity/ distance measure between the query image features and features of each image present in the database
- Presenting few images of higher ranks(most similar ones) to the user

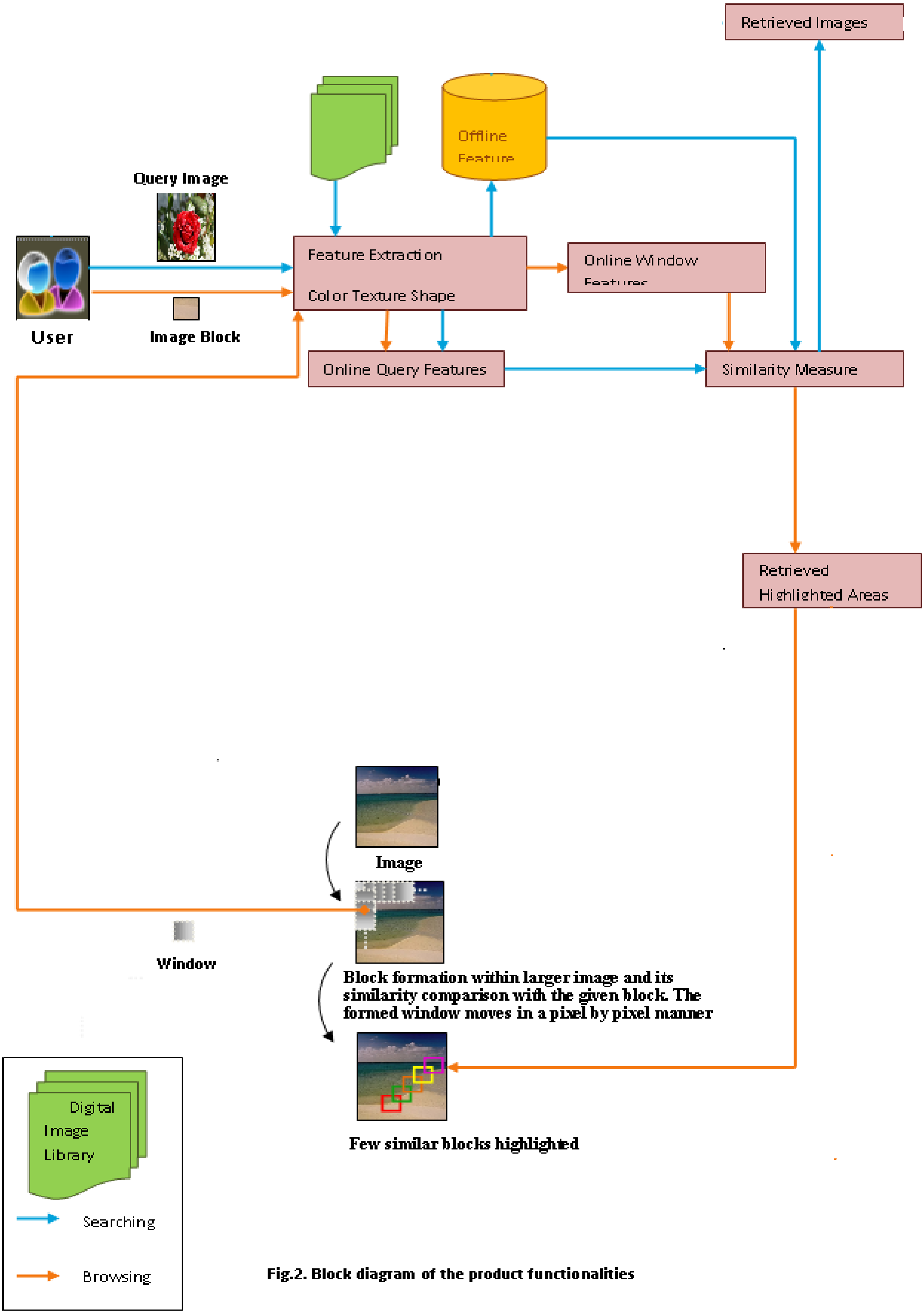


Fig.2. Block diagram of the product functionalities

B.2) ***Browsing and Retrieval of parts of images***

The product function of browsing and retrieval of parts of images shall be accomplished by following the steps listed below:

- Accepting a small block of query image containing an identifiable object/ region from the user
- Preprocessing and computation of low-level features of the query image
- Browsing the smaller image over a large image or a collection of images by traversing in a pixel by pixel manner
- Highlighting and displaying the most similar objects/ regions found according to the small block of image to the user.

B.3)***Validity Checks on Inputs***

TABLE II
VALIDATIONS

Input Item	Validation Required
Input Image	Image file must exist on the hard disk Image format should be BMP or TIFF Image height and width must be equal and even

C. Logical Database Requirements

A database of image features computed offline shall be maintained to be used for image search function. Its characteristics are:

TABLE IV
CHARACTERISTICS OF DATABASE

Parameters	Value
Type of information stored	Text - The absolute path of images residing on the hard disk Numeric - Image features computed offline
Data Entity	Digital image's Visual Content
Integrity Constraints	Duplicate entries for an image shall not be allowed The paths of an image should be in a consistent format
Frequency of use	Each record of the database shall be accessed frequently

C.1) ***Entity Relationship Diagram***

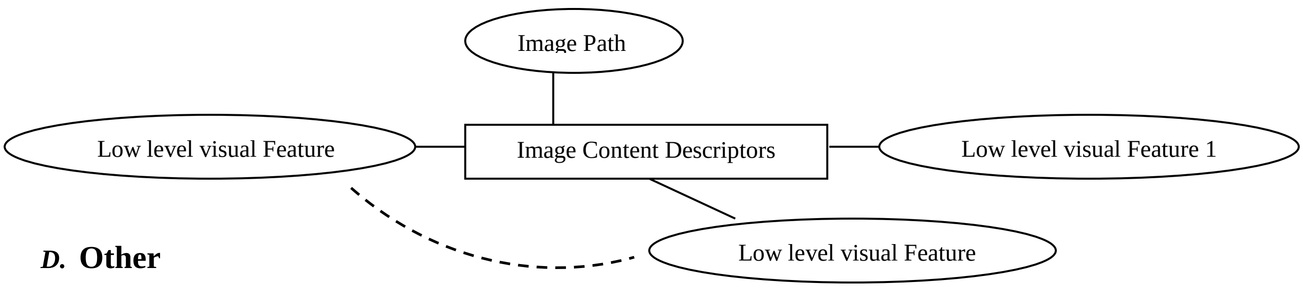


Fig.3. ERD

D. Other

D.1) ***Research***

The exploration and experimentation on a wide range of concepts which fall under the broad spectrum of CBIR shall be undertaken to make this project result-oriented. Some of the areas are:

- Development of efficient texture descriptor
- Development of efficient color descriptor
- Fusion of texture and color descriptors
- Determining base of Fuzzy Triangular Function for Similarity Metrics
- Basic knowledge of remote sensing through satellites
-

D.2) ***Test data***

The selection and arrangement of test data must be done keeping the following points in mind.

- A database containing images of varying texture and color properties must be taken up for experimentation. For e.g.: Brodatz Texture Album can be a good choice for analyzing texture descriptors. VisTex Album can be used for analyzing texture and color fusion functionality.
- For browsing function, images captured by IKONOS and IRS shall be used along with non-satellite images

Research & Exploration

I. INTRODUCTION

A. Purpose

The purpose of this document is to summarize the research work done at each phase of the development of the software.

B. Scope

The scope of this SRS document encompasses the following: -

1. It serves as a reference to study, analyse and understand methodologies to be designed, programmed and documented.
2. It acts as a tool for the development of test cases which would exercise small conditions of the program.

C. Audience

Designers, Programmers, Testers, Researchers and any fellow interested in studying image processing especially CBIR.

D. Definitions, Acronyms and Abbreviations

See Appendix

E. References & Formulae

See Appendix

II. TEXTURE

A. Understanding Texture Analysis

In biological vision, texture is an important cue allowing humans to discriminate objects. This is because the brain is able to decipher important variations in data at scales smaller than those of the viewed objects. In order to deal with texture analysis in digital data, many techniques have been developed by image processing researchers.

Texture analysis refers to the characterization of regions in an image by their texture content. Texture analysis attempts to quantify intuitive qualities described by terms such as rough, smooth, silky, or bumpy as a function of the spatial variation in pixel intensities. In this sense, the roughness or bumpiness refers to variations in the intensity values, or gray levels.

Statistical tools, when applied on these gray levels, can characterize the texture of an image because they provide information about the local variability of the intensity values of pixels in an image. For example, in areas with smooth texture, the range of values in the neighborhood around a pixel will be a small value; in areas of rough texture, the range will be larger. Similarly, calculating the standard deviation of pixels in a neighborhood can indicate the degree of variability of pixel values in that region.

Texture analysis is used in a variety of applications, including remote sensing, automated inspection, robotics, defence, the geo-sciences and medical image processing. Texture analysis can be helpful when objects in an image are more characterized by their texture than by intensity, and traditional threshold techniques cannot be used effectively.

B. Illustrations

Some images which can be characterized by their texture are shown in Fig.4:

Fig.4 Sample images taken from Brodatz Album

C. Texture Analysis Methodologies for Color Images

The procedure followed for texture analysis in this project is outlined below:

C.1) *Conversion of Color Image to Gray Scale Equivalent*

Since the texture depends on the variations in the intensity values, conversion of a color image into its gray level equivalent is commendable. There are many methods for this purpose which can be used depending on the color space. For RGB color space, two such conversion methods were preferred for good results:

- Each pixel is assigned the highest intensity value out of its red, green and blue color values. Mathematically, this can be written as:

$$I_{ij} = \max \{C_{ij} (R, G, B)\}$$

- Each pixel of image is assigned an intensity value according to the formula given below:

$$I_{ij} = (11* Cij (R) + 16* Cij (G) + 5* Cij (B)) / 32$$

Here, *I_{ij} is the intensity assigned to pixel (i,j) of Image C, C_{ij} (R, G, B) denotes the red, green and blue color values of (i, j) pixel of image C*

Fig.5 Gray scale conversion of color images

An illustration of conversion using both the methods is depicted in the figure above. The first column displays the original color image, and the second, third columns demonstrate the converted images for the first, second methods respectively.

C.2) *Conversion of Gray Scale Image from Spatial Domain to Frequency Domain using Wavelets & Multi-resolution processing*

In numerical analysis and functional analysis, a **discrete wavelet transform**(DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it captures both frequency *and* location information (location in time). The first DWT was invented by the Hungarian mathematician Alfréd Haar. For an input represented by a list of 2^n numbers, the Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to provide the next scale: finally resulting in $2^n - 1$ differences and one final sum. A standard decomposition of a two dimensional signal (image) is easily done by first performing a one dimensional transformation on each row followed by a one dimensional transformation of each column. The 2D Haar transform is used extensively in image compression.

The Haar wavelet function

Let $\psi : R -> R$ be defined by:

$$\psi(t) = \begin{cases} 1 \to t \in \left[0\ \tfrac{1}{2}\right) \\ -1 \to t \in \left[\tfrac{1}{2} 1\right) \\ 0 \to t \notin [01) \end{cases}$$

Probably the simplest useful energy compression process is the HAAR TRANSFORM. In one dimension, this transforms a 2-element vector

$((x(1)\ \ x(2))^T$ is transformed into $((y(1)\ \ y(2))^T$ Using

$$\begin{pmatrix} y(1) \\ y(2) \end{pmatrix} = T \begin{pmatrix} x(1) \\ x(2) \end{pmatrix}$$

$$\text{Where T=}\ \tfrac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

Thus y(1) and y(2) are simply the sum and differences of x(1) and x(2), scaled by $1/\sqrt{2}$ to preserve energy.
Note that it is an orthonormal matrix because its rows are orthogonal to each other(their dot products are zero) and they are normalized to unit magnitude .Therefore

$$T^{-1} = T^T$$

(In this case T is symmetric i.e $T^T = T$)

In two dimensions x and y becomes 2*2 matrices. We may transform the first column of x ,by pre-multiplying by T,and then the rows of the result by post multiplying by T^T .
Hence: $y = TxT^T$
If $x = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$
Then

$$y = \begin{pmatrix} a+b+c+d & a-b+c-d \\ a+b-c-d & a-b-c+d \end{pmatrix}$$

These operations correspond to the following filtering process.:

- Top left=a+b+c+d= 4-point average or 2d low pass filter. This is also known as approximation image.
- Top right=a-b+c-d=Average horizontal gradient or horizontal high pass filter and vertical low pass filter. This is also known as horizontal difference of the image.
- Lower left=a+b-c-d=Average vertical gradient or horizontal low pass filter and vertical high pass filter. This is image is also known as vertical difference of the image

- Lower right= a-b-c+d=Diagonal curvature or 2d high pass filter. This image is also known as diagonal difference image.

Fig.6 1-level and 2-level haar operation on a gray scale image

C.3) *Formation of texture feature vector*

- **Correlation Technique**

In statistics, **dependence** refers to any statistical relationship between two random variables or two sets of data. **Correlation** refers to any of a broad class of statistical relationships involving dependence.

The most familiar measure of dependence between two quantities is the Pearson product-moment correlation coefficient, or "Pearson's correlation." It is obtained by dividing the covariance of the two variables by the product of their standard deviations

$$\rho X,Y = corr(X,Y) = \frac{\mathrm{cov}(X,Y)}{\sigma x \sigma y} = \frac{E[(X-\mu x)(Y-\mu y)]}{\sigma x \sigma y}$$

where *E* is the expected value operator, *cov* means covariance, and, *corr* a widely used alternative notation for Pearson's correlation.

The Pearson correlation is +1 in the case of a perfect positive (increasing) linear relationship (correlation), −1 in the case of a perfect decreasing (negative) linear relationship (**anticorrelation**), and some value between −1 and 1 in all other cases, indicating the degree of linear dependence between the variables. As it approaches zero there is less of a relationship (closer to uncorrelated). The closer the coefficient is to either −1 or 1, the stronger the correlation between the variables.

Suppose X and Y are NXM matrices containing the pixel intensity values of images A and B respectively. Then the correlation of A and B can be given as

$$\mathbf{R_{xy}} = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N}(xij-\bar{x})(yij-\bar{y})}{\sqrt[2]{\sum_{i=i}^{N}\sum_{j=1}^{N}(xij-\bar{x})\sum_{i=1}^{N}\sum_{j=1}^{N}(yij-\bar{y})}}$$

Where $\bar{x}$ and $\bar{y}$ represent the mean of X and Y respectively,

The decomposed gray level image obtained after applying the Haar transform is subjected to feature extraction procedure by using statistical tools as discussed below. The output of this procedure is a vector containing quantitative values that describe the texture content of the image.

1. An image after L-level DWT contains 3*L+1 sub bands. The standard deviation of 4*L bands (4 of each level) along with the mean of the approximation image obtained at each level are calculated.

2. Since these high frequency sub bands lose information at higher levels of decomposition, the standard deviation (SD) of each high frequency sub band image at i^{th} level is weighted by the factor $½^{(i-1)}$, thus assigning higher weights to lower level bands.
3. The correlation of the LL band with HL , LH bands and the correlation of LH with HL band was computed for each level. So there were 3*L correlation features.
4. The energy of the approximation image of each level was computed thereby providing L energy features (1 for each level).
5. The 9*L sized feature vector is defined as follows:-

The Texture Feature(TF) for two level haar image is:

$TF = \{ \sigma_1^{LL}, \sigma_1^{LH}, \sigma_1^{HL}, \sigma_1^{HH}, \mu_1^{LL}, E_1^{LL}, \sigma_2^{LL}, ½\, \sigma_2^{LH}, ½\, \sigma_2^{HL}, ½\, \sigma_2^{HH}, \mu_2^{LL}, E_2^{LL}$

,corr(LL1-HL1),corr(LL1-LH1),corr(HL1-LH1),corr(LL2-HL2),

corr(LL2-LH2),corr(HL2-LH2) }

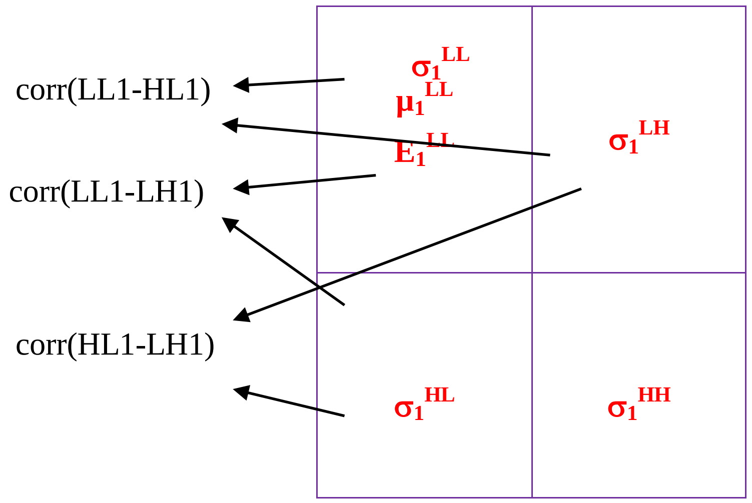


Fig.7 Correlation method 2-level haar

.

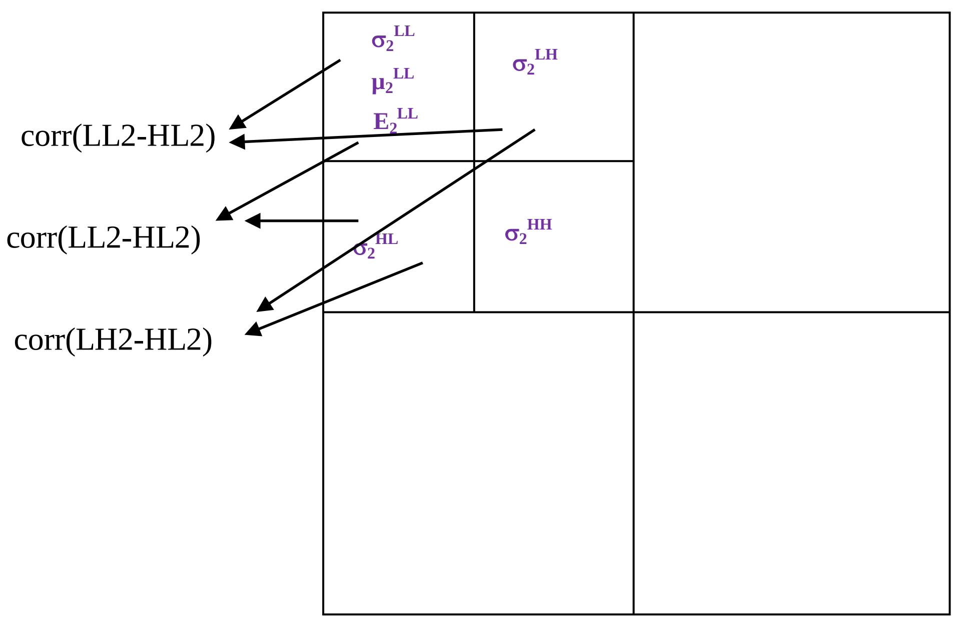


Fig.8 CORRELATION method on 2-level haar

where

TF stands for Texture Features

σ_i*MM is the SD of the MM (stands for LL, LH, HL, or HH sub bands) at decomposition level i*

μ_i*LL is the mean of the approximation image (i=1,2 corresponding to level1 or level2)*

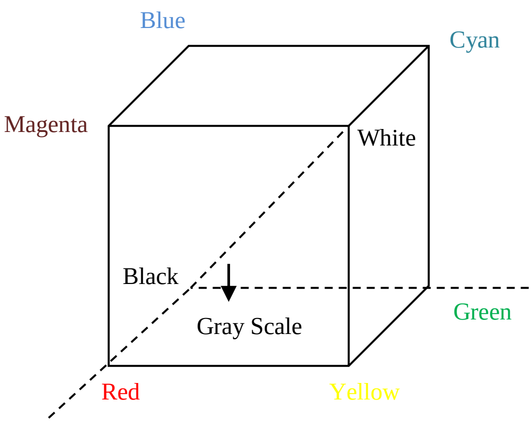
E_i^{LL} is the energy of the *approximation image (i=1,2 corresponding to level1 and level2 respectively)*

Corr(mmi-nni) stands for the correlation of subband mmi and nni (mm,nn Ɛ {LL,HL,LH} and i Ɛ {1,2} corresponding to level 1 and level2 respectively)

III. COLOR

A. Understanding Color Analysis

The color analysis of an image starts with determining an appropriate color space. RGB is a widely used color space. It is composed of three color components red, green and blue called additive primaries since a color in RGB space is produced by adding them together. Images represented in RGB color model consist of three component images, one for each primary color. The number of bits used to represent each pixel in RGB space is called pixel depth. In an RB image, in which each of RGB color pixel [that is, a triplet of values (R, G, B)] is said to have a depth of 24 bits (3 image planes times the number of bits per plane).



B. Illustration

Some color images are shown below:

Fig.10 Sample of color images

C. Color Analysis Methodologies for Color Images

The procedure followed for color analysis in this project is outlined below:

C.1) ***Conversion to RGB Space***

The images are converted to RGB color space.

C.2) ***Formation of Color Feature Vector***

Formation of Feature Vector By F-Norm Theory

A vector norm is defined as a linear function $f : R^n \rightarrow R$ that satisfy the following property.

1. $f(\alpha x) = |\alpha| \, \| x \| \quad , \alpha \in R$
2. $f(x+y) \leq f(x) + f(y)$
3. $f(x) \geq 0$
4. $f(x) = 0$ *if and only if* $x = 0$ (the zero vector length of n)

We may also consider matrix norm. Here we discuss one type of matrix norm that is F-norm or Forbenious Norm.

F *norm* on $\mathbf{C}^{n \times n}$ is a mapping $\mathbf{C}^{n \times n} \rightarrow \mathbf{R}$ with the properties:

(i)

$$\|A\| \geq 0 \ \forall \ A \in \mathbf{C}^{n \times n}, \ \ \|A\| = 0 \iff A = 0$$

,

(ii)

$$\|\alpha A\| = |\alpha| . \|A\| \ \forall \ \alpha \in \mathbf{C}, \ A \in \mathbf{C}^{n \times n}$$

,

(iii)

$$\|A + B\| \leq \|A\| + \|B\| \ \forall \ A, B \in \mathbf{C}^{n \times n}$$

,

(iv)

$$\|AB\| \leq \|A\| . \|B\| \ \forall \ A, B \in \mathbf{C}^{n \times n}$$

.

F-NORM [3] theory can be used to decrease the dimension of image feature. The calculation of feature vector from F-NORM theory is done as follows:-

$$A = \begin{pmatrix} a_{11} \ldots a_{1N} \\ \ldots \ldots \ldots \\ a_{N1} \ldots \ldots a_{NN} \end{pmatrix} \quad A_i = \begin{pmatrix} a_{11} \ldots a_{1i} \\ \ldots \ldots \ldots \\ a_{i1} \ldots \ldots a_{ii} \end{pmatrix}$$

Suppose A is a NXN square matrix of any single color component of an image and Ai is its ith order sub matrix where

$1 \leq i \leq N$

The F-norm of Ai is given as:

$$\| A \|_F = \sqrt{\sum_{i=1}^{m} \sum_{j=1}^{n} | a_{ij} |^2} = \sqrt{tr(A^* A)} = \sqrt{\sum_{i=1}^{\min(m,n)} \sigma^2{}_i}$$

where A^* denotes the conjugate transpose of A, σ_i are the singular values of A, and the trace function is used.

An image can be represented as matrices of Red, Green, and Blue(R, G, and B) components. The F-Norm theory can thus be effectively used on these matrices to reduce the dimension of image features.

1. Suppose A is a NXN square matrix of any single color component of an image and A_i is its i^{th} order sub matrix where $1 \leq i \leq N$, then F-norm of A_i is given as:

$$\|A_i\|_F = \left(\sum_{k=1}^{i} \sum_{l=1}^{i} |a_{kl}|^2 \right)^{1/2}$$

2. The values of R, G and B color bands are normalized by dividing them by the highest color intensity value possible. The objective is to bring all the pixel values within the range [0,1] so as to reduce computation efforts for large values.
3. When F-Norm is separately applied on the normalized values of R, G, and B color bands, three N-dimensional feature vectors are obtained.

$$FNF_{AX} = \{ \|A_1\|_F, \|A_2\|_F, \ldots\ldots, \|A_i\|_F, \ldots\ldots, \|A_n\|_F \}$$

where, *$X \in \{R, G, B\}$, FNF_{AX} stands for F-Norm Features.*

4. The feature vector values are then assigned weights.

$$WF_{AX} = \{ w_1\|A_1\|_F, w_2\|A_2\|_F, \ldots, w_i\|A_i\|_F, \ldots, w_n\|A_n\|_F \}$$

where, *w_i are weights, WF_{AX} stands for Weighted Features.*

5. The averages of the weighted features of the three bands yield the final three-dimensional color feature vector.

$$CF = \{WAR/N, WAG/N, WAB/N\}$$

where, *CF stands for Color Features, WAR, WAG and WAB are the weighted 3-dimensional feature vectors for Red, Blue and Green colors respectively.*

IV. MULTI-FEATURE FUSION

A. Understanding feature fusion

Identification of features/objects in an image captured by any device is a specialized task since the captured image properties depend on objects present and its surroundings. Therefore, an object needs to be identified by segregating its low level descriptors from those of its background. While performing such computer assisted task, ambiguities may arise between the descriptive content of the required object/region and its surrounding area. For instance, sky appears blue, which can generate a conflict with water bodies. This ambiguity can be resolved by considering their texture features. Similarly, dry grass shows yellow area which differs from a petal of sun flower in having a relatively lighter tone and coarse texture. In such cases, using color or texture features separately is not good enough rather a fusion of both the features may prove to be beneficial. The same technique is applied in Image Retrieval.

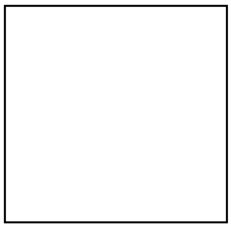
B. Methodology

The construction of low-level feature vector can be done by applying F-Norm (or other color feature descriptor) for color feature extraction and efficient Haar Discrete Wavelet Transform (or other texture feature descriptor) for texture feature extraction in sequence.

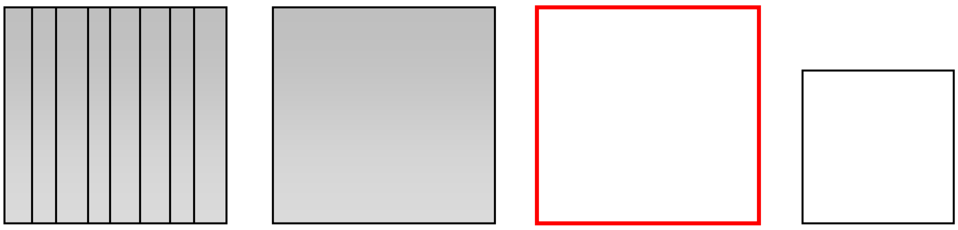
V. SIMILARITY MEASURE

A. Illustration

Let's say a transparent square is placed over four different squares to check the differences between them.



(a) Transparent square



(b) Textured square **(c) Colored square** **(d) Bordered square** **(e) Small size square**

On placing (a) over all the squares, the following conclusions can be drawn:

- The difference between (a) and (b) is 7 vertical lines and gray color. *(Similarity: very low)*
- The transparent square can be made similar to (c) by coloring it with gray or removing gray color from the colored square. *(Similarity: low)*
- (d) and (a) are almost similar except border. *(Similarity: high)*
- (e) and (a) are also similar except in their size. *(Similarity: high)*

Thus, it can be deduced that by comparing the features of the squares and adopting an additive or subtractive matching scheme, the similarity of the given squares with the query transparent square can be ordered as : *[(d), (e)]; [(c)]; [(b)]*. In the same way, similarity between the images can be found out by adopting a suitable methodology on their feature vectors.

B. Methodologies

B.1) *Similarity Measurement with Fuzzy Logic*

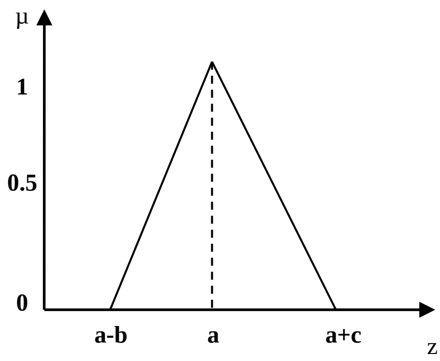
- ***Introduction***

In classical set theory, "crisp sets" whose membership can only be true or false in the traditional sense of bi-valued Boolean logic are dealt with. For e.g. Let Z denote the set of all days and A is a subset of Z called set of hot days. To form this subset we need a membership function that assigns a value of 0 or 1 to every element. This function simply defines a threshold at or above which a day is considered hot, and below which it is considered cold. This poses an immediate difficulty since a temperature of 30 degree is considered to be a hot day but a temperature of 29 degree is considered cold. This limits the use of classical set theory in many practical applications where we need to define the degree of membership of a set. In this example we need a gradual transition from hot to warm to cold and thus, an infinite valued function. This makes it possible to define degrees of hotness and we can now make statements like a day being hot, warm, warmer, cold, and very cold and so on. These types of vague (fuzzy) statements are more in line with what humans use when talking imprecisely about the temperature of a day. Thus, infinite valued membership functions can be viewed as the foundation of fuzzy logic and the sets generated using them as fuzzy sets.

- ***Membership Function***

A fuzzy set, A in a set of elements Z = {z} is characterised by a membership function, $\mu_A(z)$, that associates with each element of Z a real number in the interval [0,1]. The value of $\mu_A(z)$ at z represents the grade of membership of z in A. The grade of membership is usually found out by using membership functions like triangular, trapezoidal, Gaussian, etc. One particular membership function of interest is the triangular function.

$$\mu(z) = \begin{cases} 1-(a-z)/b & a-b \le z < a \\ 1-(z-a)/c & a \le z \le a+c \\ 0 & \text{otherwise} \end{cases}$$



- ***Relationship between Similarity Measure and Fuzzy Logic***

Fuzzy logic can be used as a similarity measure to handle the impreciseness inherent in the calculated features thus, leading to improved retrieval results and efficiency in comparison. The percentage of similarity between the feature vectors of any two images can be found out by using an appropriate triangular membership function where the parameters a, b and c can be decided by adjusting the length of the base of the triangle. The base can be expanded or contracted depending on the desired accuracy of retrieval results. The standard deviation or range of values of the feature vector can be used for deciding the expanse of the base. The reason behind the choice of triangular function for similarity measurement is that the values of similarity range from being dissimilar to exactly similar and thus the base set constitutes a continuum. Moreover, its simplicity and efficiency with respect to computability makes it an appropriate choice for the same.

B.2) ***Similarity Measurement with Minkowski-Form Distance***

If each dimension of image feature vector is independent of each other and is of equal importance, the Minkowski-Form Distance, L_p is appropriate for calculating the distance between two images. This distance is defined as:

$$D(I,J) = \left(\sum_i |f_i(I)-f_i(J)|^p \right)^{1/p}$$

When p=1, 2, and ∞, D(I,J) is the L_1, L_2 (also called Euclidean Distance), and L_∞ distance respectively. Minkowski-form distance is the most widely used metric for image retrieval. For instance, MARS system used Euclidean distance to compute the similarity between texture features.

VI. PERFORMANCE EVALUATION

A. Methodology

To evaluate the performance of a retrieval system, two measurements, namely, recall and precision, are borrowed from traditional information retrieval.

A.1) ***Precision and Recall***

For a query q, the data set of images in the database that are relevant to the query q is denoted as R(q), and the retrieval result of the query q is denoted as Q(q).

- The precision of the retrieval is defined as the fraction of the retrieved images that are indeed relevant for the query:

$$\text{Precision}= |Q(q)\cap R(q)| \div |Q(q)|$$

- The recall is the fraction of the relevant images that are returned by the query:

$$\text{Recall}= |Q(q)\cap R(q)| \div |R(q)|$$

A.2) ***Interpretation of Precision and Recall***

Usually a tradeoff must be made between recall and precision since improving one will sacrifice the other. In typical retrieval systems, recall tends to increase as the number of retrieved items increases; while at the same time the precision is likely to decrease. In addition, selecting a relevant dataset R(q) is much less stable due to various interpretations of the images. Further, when the number of relevant images is greater than the number of retrieved images, recall is meaningless. As a result, precision and recall are only rough descriptions of the performance of the retrieval system.

VII. SATELLITE/ REMOTE SENSING

A. Remote Sensing

Remote Sensing is defined as the science and art of acquiring multi date, reliable and timely information about a material object by accessing it remotely (without physical contact). This information can be constructively exploited in the fields covering agriculture, forestry, geo-science and various other disciplines.

B. Satellites

Satellites illuminate us with vital information and visual imagery that cannot be captured in any other manner. One can ponder over the enormous amount of spectral and spatial information provided by a satellite which can be used selectively to identify and characterize the surface features, e.g., hills, rivers, trees, fields, forests, soils and land-use patterns.

A remote sensing satellite is designed according to its application for studying the earth's resources or for meteorology. An earth resource satellite carries sensors with a medium to high spatial resolution which look down to the earth and collect information. The multispectral scanner (MSS) is extensively used in such satellites (including IRS, IKONOS) for measuring more than one spectral band or wavelength region. The configuration of two satellites whose images are to be tested is summarized here:

B.1) ***Indian Remote Sensing Satellites***

A linear image self scanning sensor (LISS – III), as used in Indian Remote Sensing(IRS) satellites, IRS-IC and IRS-ID is one such MSS operating in four spectral bands shown in the table below:

TABLE V
IRS (LISS – III) SENSOR CONFIGURATION

Band	**Spectral Bands (in µm)**	**Resolution (in m)**
1	0.52 – 0.59 (Green)	23.5
2	0.62 – 0.68 (Red)	23.5
3	0.77 – 0.86 (Near Infra–red)	23.5
4	1.55 – 1.70 (Mid Infra–red)	70.5

B.2) ***IKONOS***

The IKONOS sensor system acquires data in four multi-spectral bands. The sensor details are tabulated below:

TABLE VI
IKONOS SENSOR CONFIGURATION

<table>
<tr><th>Sensor</th><th>Spectral Bands (in µm)</th><th>Resolution at Nadir (in m)</th><th>Resolution 26° off Nadir (in m)</th></tr>
<tr><td>PAN</td><td>0.45 – 0.90</td><td>0.82</td><td>1</td></tr>
<tr><td rowspan="4">MSS</td><td>0.45 – 0.52 (Blue)</td><td rowspan="4">3.2</td><td rowspan="4">4</td></tr>
<tr><td>0.52 – 0.60 (Green)</td></tr>
<tr><td>0.63 – 0.69 (Red)</td></tr>
<tr><td>0.76 – 0.90 (Near Infra–red)</td></tr>
</table>

A clear understanding of spectral reflectance or emittance characteristics which define shape, color, and texture is a prerequisite for interpreting distinctive features in an MSS image.

C. CBIR and Satellite Imagery

The application domain of CBIR generally excludes satellite images, but its usability can be explored on satellite imagery. One can ponder over the contribution of remotely sensed data towards diverse scientific and commercial purposes. Hence, it is reasonable to selectively identify objects such as buildings, aeroplanes, runways etc. and characterize the surface features, e.g., hills, rivers, trees, fields, forests, soils and land-use patterns. The interpretation and analysis of such objects and features is a major step in transforming the remotely sensed data into information that is intelligible and usable.

D. Illustrations

Images taken from IRS and IKONOS satellites are shown below. (a) is a picture of vegetation area whereas (b) depicts a part of an bonny terminal at Nigeria at 0.8m resolution.

Fig.11 (a) IRS image (b) IKONOS image

Software Design Specification

I. INTRODUCTION

A. Purpose

This document specifies the final system design for the system. It also gives some explanations on how the design evolved and why some design decisions were taken. It is a summary of the design decisions taken for each requirement as they came in during the development of the system.

B. Scope

It is the main document which gives the implementation guidelines of the project along with acting as a verification and validation tool for the testing phase.

C. Audience

Analysts, designers, programmers, testers

D. References of other pertinent documents

SRS, Research and Exploration, Research papers, Test& development plan.

E. Definitions, Acronyms and Abbreviations

See Appendix

F. References

See Appendix

II. SYSTEM OVERVIEW

This system is to consist of a graphical interface design to aid the development of efficient image content descriptors. A user interested in research area of CBIR can experiment with various texture and color descriptors for searching and browsing an image. It will also assist user to assess the accuracy of the image retrieval results and thus judge the efficiency of the descriptors used.

The goal of this project is to build a Content Based Image Retrieval system by developing efficient color and texture descriptors.

- It follows the QbE approach for image retrieval where inputs and outputs are images and the processing is related to searching or browsing images from a large image database according to the similarity of the contents like color, texture and shape of images with the query image given by the user.
- The main modules of the system are specified in the SRS. Rigorous research and exploration was done to devise efficient methodologies for the steps to be followed in the system. These have been compiled in chapter 2 (Research and Exploration).

III. DESIGN CONSIDERATIONS

A. Assumptions & Dependencies

- Java Advanced Imaging (JAI) package should be available for working with images in java.
- The software is mainly targeted for research purposes.
- It is assumed that the Research & Exploration documents have been studied thoroughly.
- Image sizes should be small, even (preferably, power of 2), and of equal height and width.

B. General constraints

- Memory requirements should be looked after. Images consume a lot of memory.
- Evaluation and changes (if required) of the results of the modules to be designed and implemented should be done on a regular basis.

C. Development Methods

The system is to be designed by using the following well known approaches:

1. *Structured Modeling:* Flowcharts and DFDs are used to represent the structure of the system. Since our system follows a modular structure, the mentioned methods are apt for the situation.
2. *Behavioral Modeling:* The behavior of a system (as referenced from the Block Diagram in SRS) can be examined by going through its states. Therefore, such a system can be modeled well with state diagrams.
3. *Object Based Modeling:* Certain data items share common usages and form a meaningful identity when clubbed together. It is always easy for class diagrams to depict such entities.

IV. System Architecture

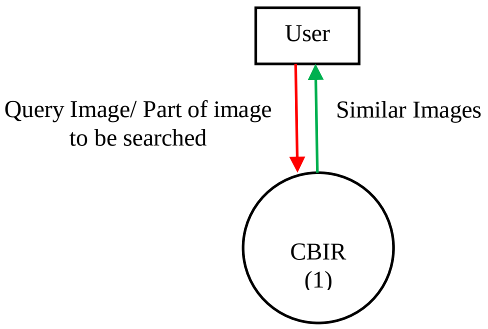


Fig.12 Context Diagram of CBIR System

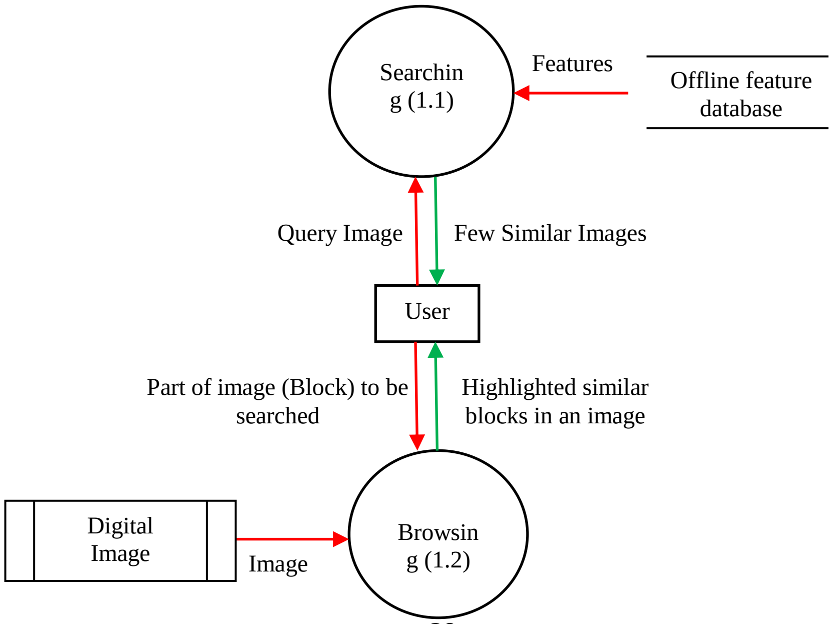


Fig.13 1-level DFD of CBIR System

As shown in the diagram above the system will provide two main functionalities:

1. **Searching of images in a digital image library (Module 1.1)**

The input to this function is a query image given by the user. The features of each image in the image library are computed and stored. After computing the feature of the query image, similar images are ranked and displayed according to the similarity of the features.

2. **Browsing of parts of images in a digital image library (Module 1.2)**

The input to this function is an identifiable object or a region block given by the user. The images in the library are browsed for searching similar object or region present in them. Features obtained by moving windows in a pixel by pixel manner over the large image are computed and compared with the features of the block to get the similar regions.

TABLE V11
MAJOR INPUT, OUTPUT OF THE MODULES

Functionality	Input	Output
Searching (Module 1.1)	Query Image of size NxN	K most similar images of sizes NxN
Browsing (Module 1.2)	Query Image of size SxS	A single of size NxN with L most similar regions highlighted.

A. *Subsystem Architectures*

Both the functionalities are further expanded into modules/functions and described in the 2nd level DFDs drawn below.

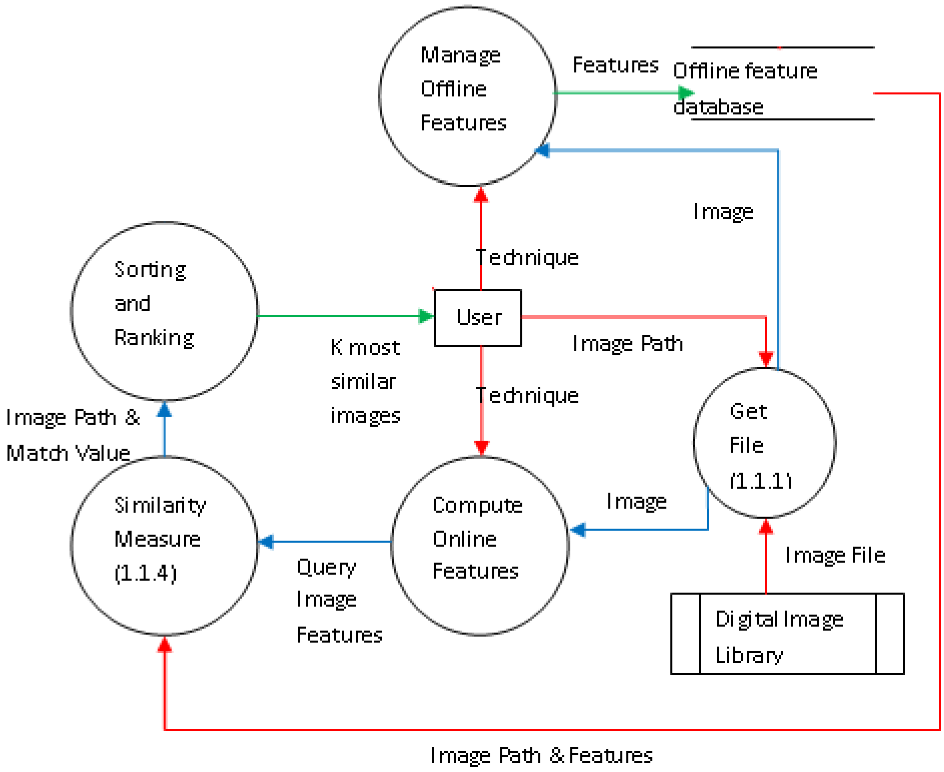


Fig. 17 2-level DFD of Searching Function

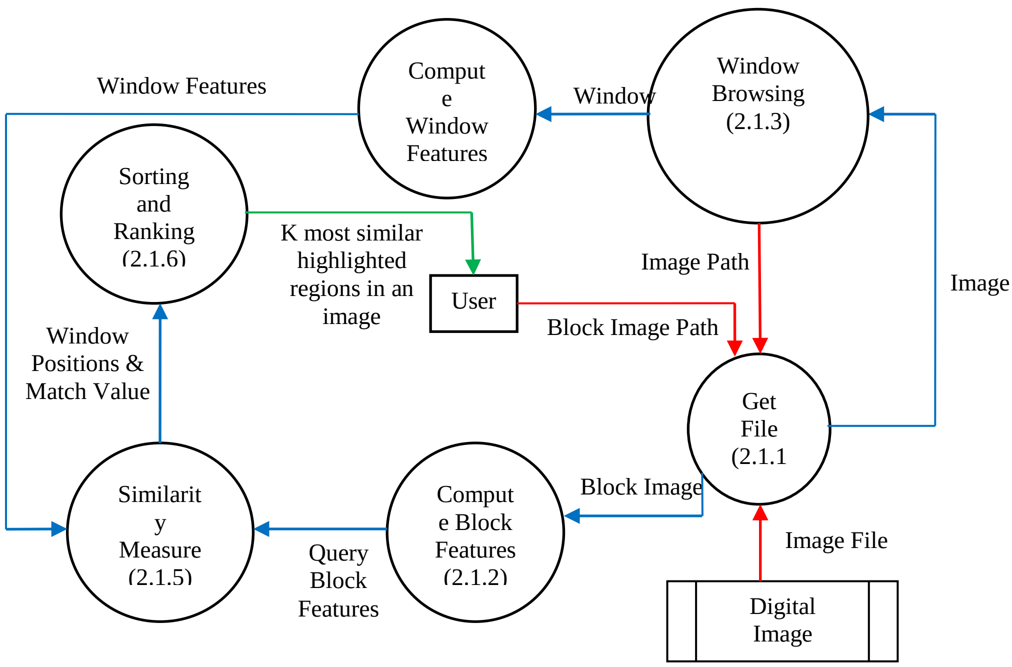


Fig.15 2-level DFD of Browsing Function on a single image

V. DETAILED SYSTEM & SUBSYSTEM DESIGN

A. Searching Module

A.1) *Get File (Function 1.1.1)*

Type: Function

Responsibilities: It loads an image stored in hard disk in a particular file format into RAM by converting into an internal representation used in Java.

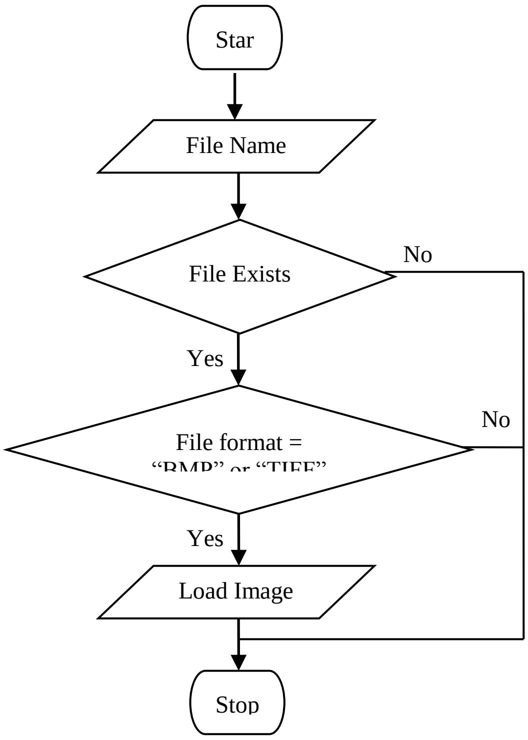
Parameters:

Data Item	Parameter Type	Data Type
Image Path	Input (as function argument)	String
Internal Representation of image	Output (as return data)	RenderedImage or 3D array representation of image

Constraints:

- The image must have equal height and width (NXN).
- The image size (NXN) should be an even number, preferably in powers of 2.
- Large sized images (greater than 1024X1024 pixels) may not be processed because of shortage of memory.

Processing:



Error Handling:

Condition	Entry			
Invalid query image path	Yes	No	No	No
File path variable does not contain extensions ".bmp" or ".tiff"	X	Yes	No	No
Internal representation of image in JAI does not have 3 bands	X	X	Yes	X
Large sized image	X	X	No	Yes
Action	**Entry**			
Image does not exist error	✓			
File format error		✓		
Number of bands error and hence cannot proceed			✓	
System stops due to shortage of memory				✓

A.2) *Compute Online Features (Module 1.1.3)*

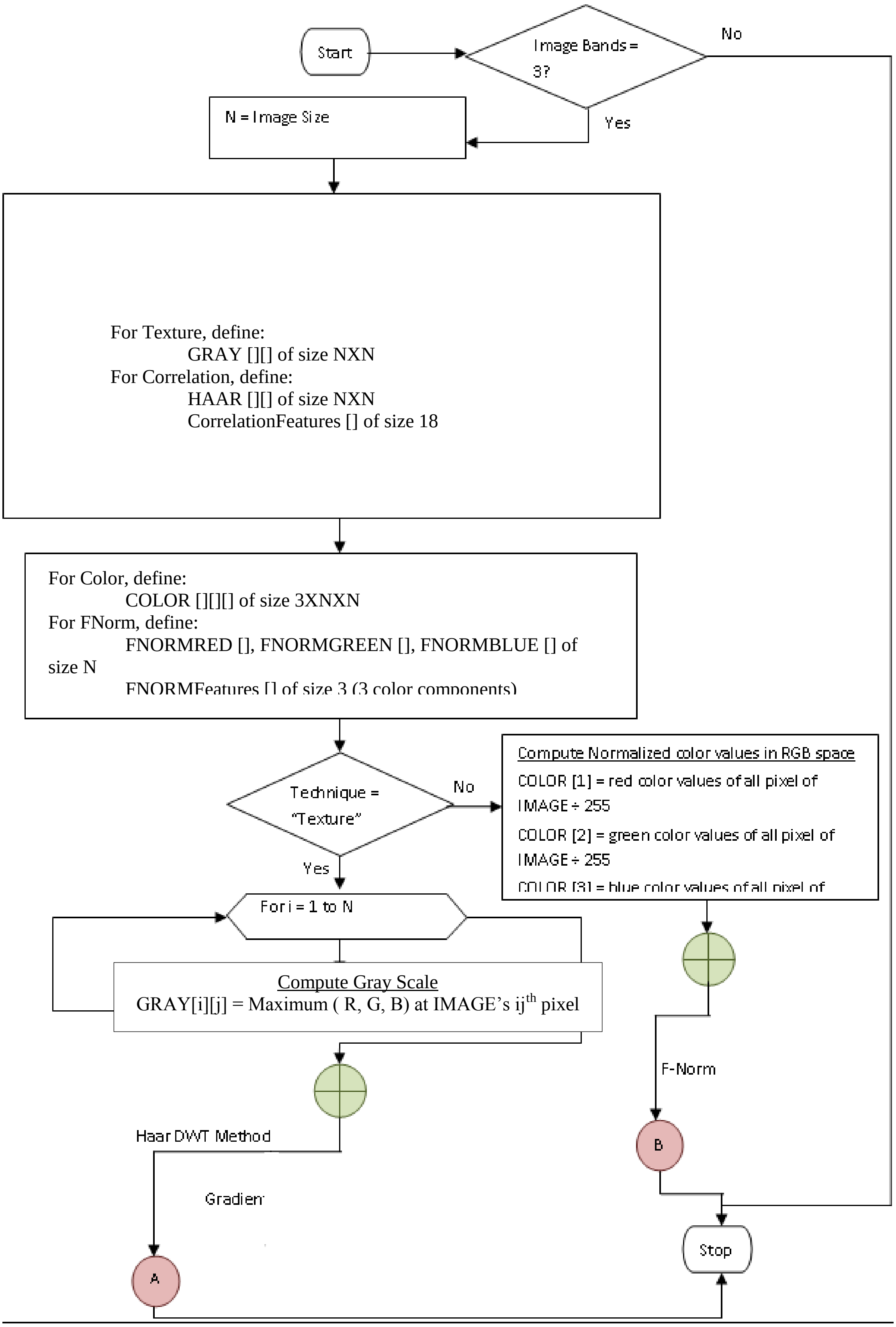
Type: Module

Responsibilities: It finds out the texture or color features of a query image.

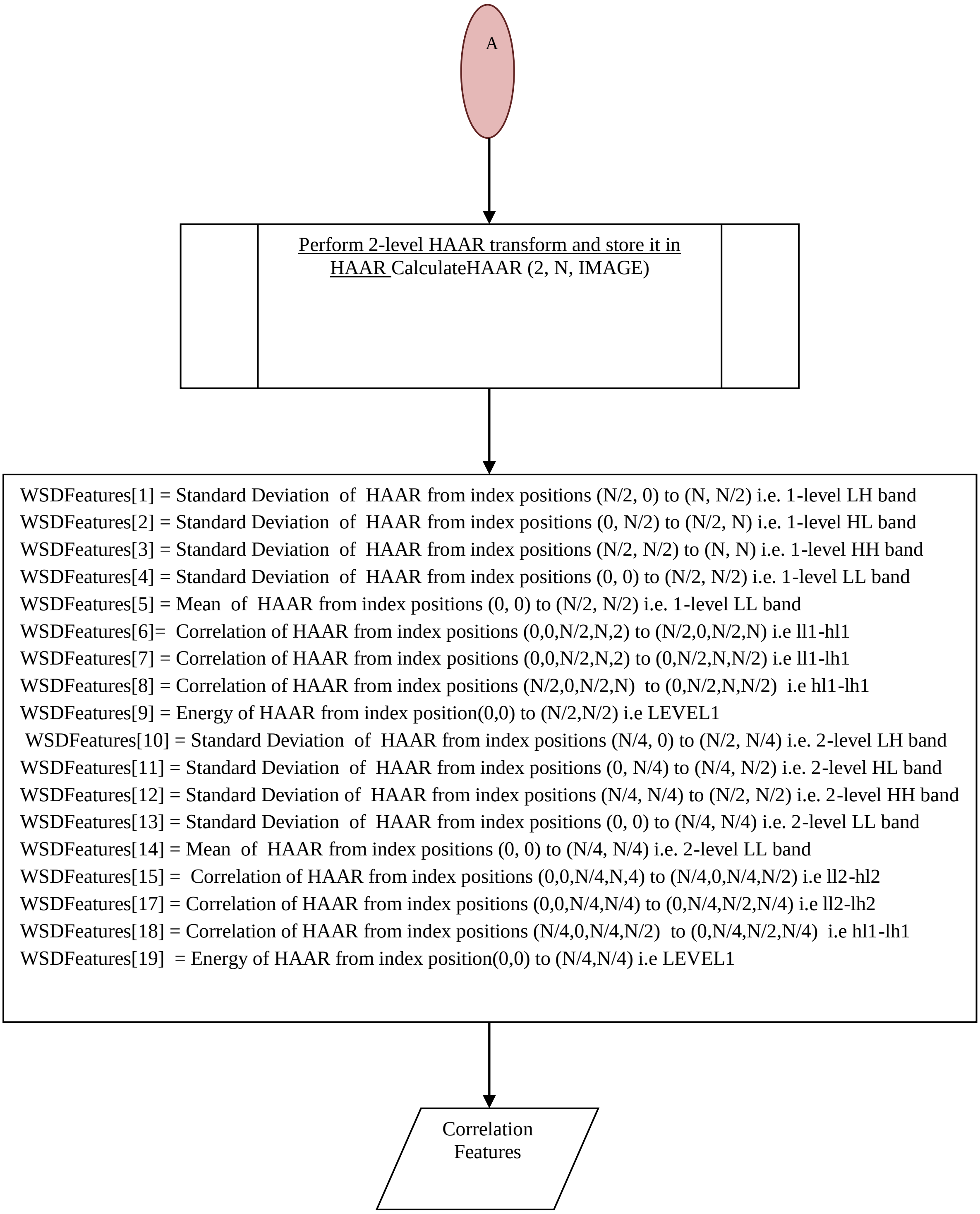
Parameters:

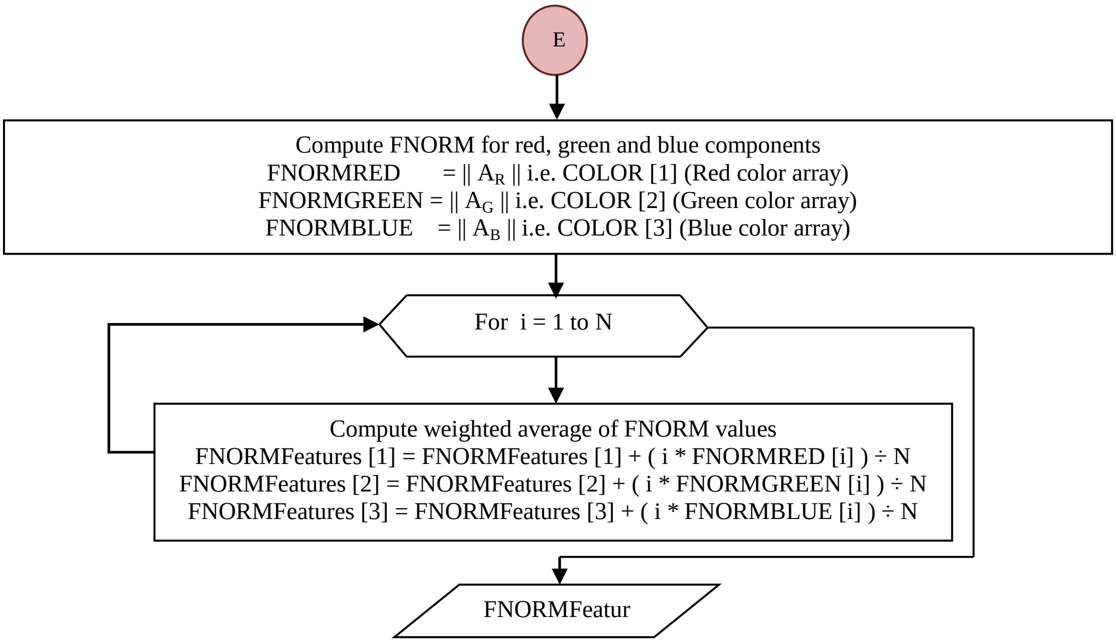
Data Item	Parameter Type	Data Type
Image	Input (as function arguments)	RenderedImage or Image in the form of 3D array
Feature Extraction Technique	Input (as function arguments)	String
Feature Vector	Output (as return data)	Float array

Processing:



Start
Image Bands = 3?
No
Yes
N = Image Size
For Texture, define:
GRAY [][] of size NXN
For Correlation, define:
HAAR [][] of size NXN
CorrelationFeatures [] of size 18
For Color, define:
COLOR [][][] of size 3XNXN
For FNorm, define:
FNORMRED [], FNORMGREEN [], FNORMBLUE [] of size N
FNORMFeatures [] of size 3 (3 color components)
Technique = "Texture"
No
Yes
Compute Normalized color values in RGB space
COLOR [1] = red color values of all pixel of IMAGE ÷ 255
COLOR [2] = green color values of all pixel of IMAGE ÷ 255
COLOR [3] = blue color values of all pixel of
For i = 1 to N
Compute Gray Scale
GRAY[i][j] = Maximum (R, G, B) at IMAGE's ij^th pixel
F-Norm
Haar DWT Method
Gradien
B
A
Stop


A
Perform 2-level HAAR transform and store it in HAAR CalculateHAAR (2, N, IMAGE)
WSDFeatures[1] = Standard Deviation of HAAR from index positions (N/2, 0) to (N, N/2) i.e. 1-level LH band
WSDFeatures[2] = Standard Deviation of HAAR from index positions (0, N/2) to (N/2, N) i.e. 1-level HL band
WSDFeatures[3] = Standard Deviation of HAAR from index positions (N/2, N/2) to (N, N) i.e. 1-level HH band
WSDFeatures[4] = Standard Deviation of HAAR from index positions (0, 0) to (N/2, N/2) i.e. 1-level LL band
WSDFeatures[5] = Mean of HAAR from index positions (0, 0) to (N/2, N/2) i.e. 1-level LL band
WSDFeatures[6]= Correlation of HAAR from index positions (0,0,N/2,N,2) to (N/2,0,N/2,N) i.e ll1-hl1
WSDFeatures[7] = Correlation of HAAR from index positions (0,0,N/2,N,2) to (0,N/2,N,N/2) i.e ll1-lh1
WSDFeatures[8] = Correlation of HAAR from index positions (N/2,0,N/2,N) to (0,N/2,N,N/2) i.e hl1-lh1
WSDFeatures[9] = Energy of HAAR from index position(0,0) to (N/2,N/2) i.e LEVEL1
WSDFeatures[10] = Standard Deviation of HAAR from index positions (N/4, 0) to (N/2, N/4) i.e. 2-level LH band
WSDFeatures[11] = Standard Deviation of HAAR from index positions (0, N/4) to (N/4, N/2) i.e. 2-level HL band
WSDFeatures[12] = Standard Deviation of HAAR from index positions (N/4, N/4) to (N/2, N/2) i.e. 2-level HH band
WSDFeatures[13] = Standard Deviation of HAAR from index positions (0, 0) to (N/4, N/4) i.e. 2-level LL band
WSDFeatures[14] = Mean of HAAR from index positions (0, 0) to (N/4, N/4) i.e. 2-level LL band
WSDFeatures[15] = Correlation of HAAR from index positions (0,0,N/4,N,4) to (N/4,0,N/4,N/2) i.e ll2-hl2
WSDFeatures[17] = Correlation of HAAR from index positions (0,0,N/4,N/4) to (0,N/4,N/2,N/4) i.e ll2-lh2
WSDFeatures[18] = Correlation of HAAR from index positions (N/4,0,N/4,N/2) to (0,N/4,N/2,N/4) i.e hl1-lh1
WSDFeatures[19] = Energy of HAAR from index position(0,0) to (N/4,N/4) i.e LEVEL1
Correlation Features



A.3) *Similarity Measure, Sorting & Ranking (Function 1.1.5)*

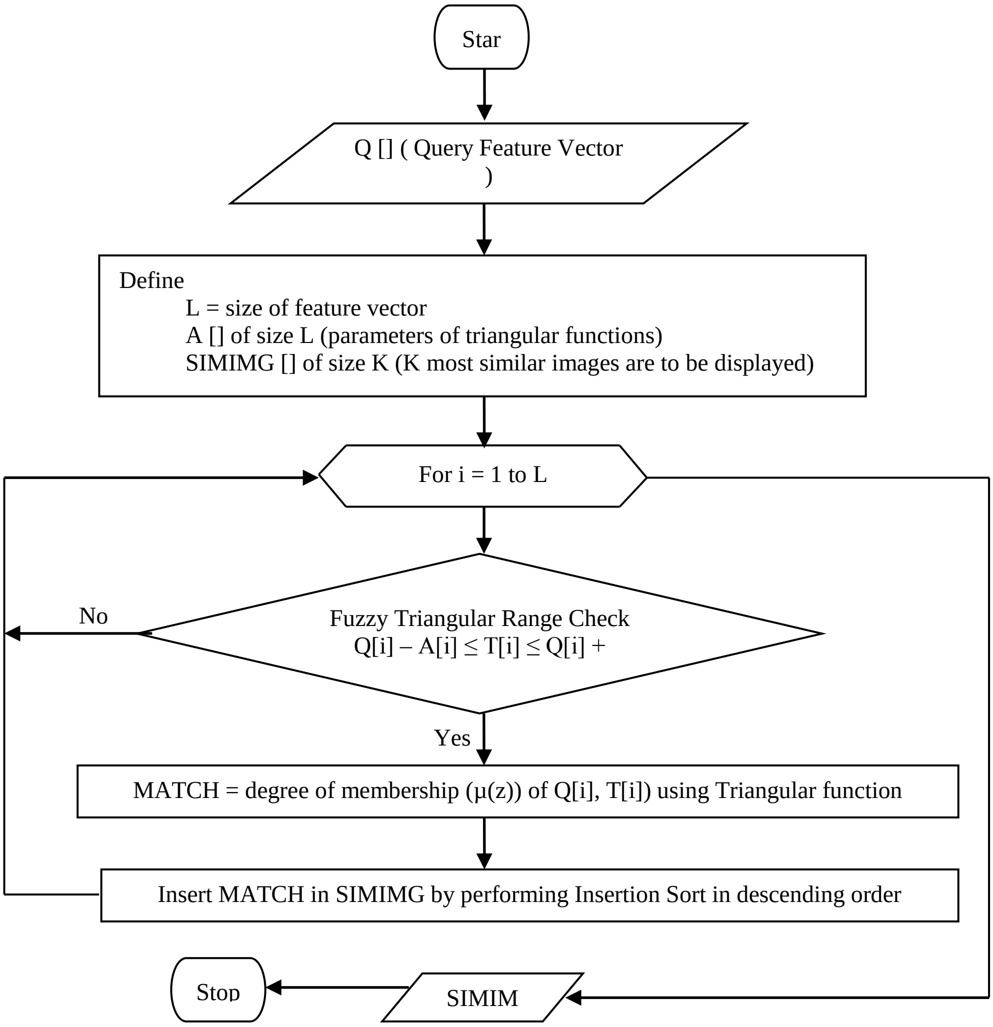
Type: Function

Responsibilities: Similarity between two images is measured by finding the difference between their feature vectors through fuzzy concept. Higher values indicate greater similarity. These similarity values for all test images when compared to the query image and sorted in descending order give the K most similar images. Thus, the role of this function is to arrive at the retrieval results that are to be displayed to the user.

Parameters:

Data Item	**Parameter Type**	**Data Type**
Query image feature vector	Input (as function argument)	double [] array
Test image feature vector	Input (as function argument)	double [] array
K most similar images (including the query image)	Output (as return data to GUI)	An object (or an array of objects) consisting of double [] array (or Vector) for similarity matches, string[] array (or Vector) for image paths (a prototype is class Data)

Processing:



Interface:

MySQL ODBC connectivity is required to retrieve the offline computed features (by the caller of the function). The features are to be retrieved from the table of the method specified by the user for feature extraction.

Constraints:

- This function is to be called for all test images whose features are computed offline and stored in the database
- Query and test features should be compatible i.e. obtained from the same feature extraction technique.
- Number of triangular membership functions is equal to the number of features. The expanse of the base of these functions (A []) are found out by certain statistical measure applied on a feature set of a large collection of images.
- Optimizing the values of K , checks on array indices and database errors

A.4) ***Manage Offline Features (Module 1.1.2)***

Type: Module

Responsibilities:

Its responsibility consists of the following functions:

1. Insertion of features in the database
2. Deletion of features corresponding to an image from the database
3. Viewing the existing database

<u>*Parameters:*</u>

Data Item	Parameter Type	Data Type
Image Path (Image to be inserted or deleted)	Input (as function argument)	String
Feature Extraction Technique (Indicates the table to/from which the image features are to be inserted/deleted)	Input (as function argument)	String
Function to be performed (Insertion/Deletion/View)	Input	-
Database records (View)	Output	ResultSet
Confirmation whether transaction has occurred (Insertion/Deletion/View)	Output (as return parameter)	Boolean

<u>*Composition:*</u>

The insertion function would use the following functions discussed in Module 1.1.3 to compute the features:

1. Get File
2. Compute Online Features to get the feature values to be inserted into the database

<u>*Interface:*</u>

MySQL ODBC connectivity. SQL queries are the fundamental requirement of this module.

<u>*Constraints:*</u>

- Check on database errors

B. Browsing Module

B.1) *Query Block (Module 2)*

<u>*Type:*</u> Module

<u>*Responsibilities:*</u> It accepts a small block of image containing identifiable object/region from the user . It then receives and displays the image in which similar or exact blocks have been found.

<u>*Constraint:*</u>

- Block image size (SXS) should be even and less than 64.

Parameters:

Data Item	Parameter Type	Data Type
Block Image path	Input	String
Highlighted blocks in a single or multiple images	Output	RenderedImage[] (in GUI)

B.2) ***Compute Block Features (Module 2.1.2)***

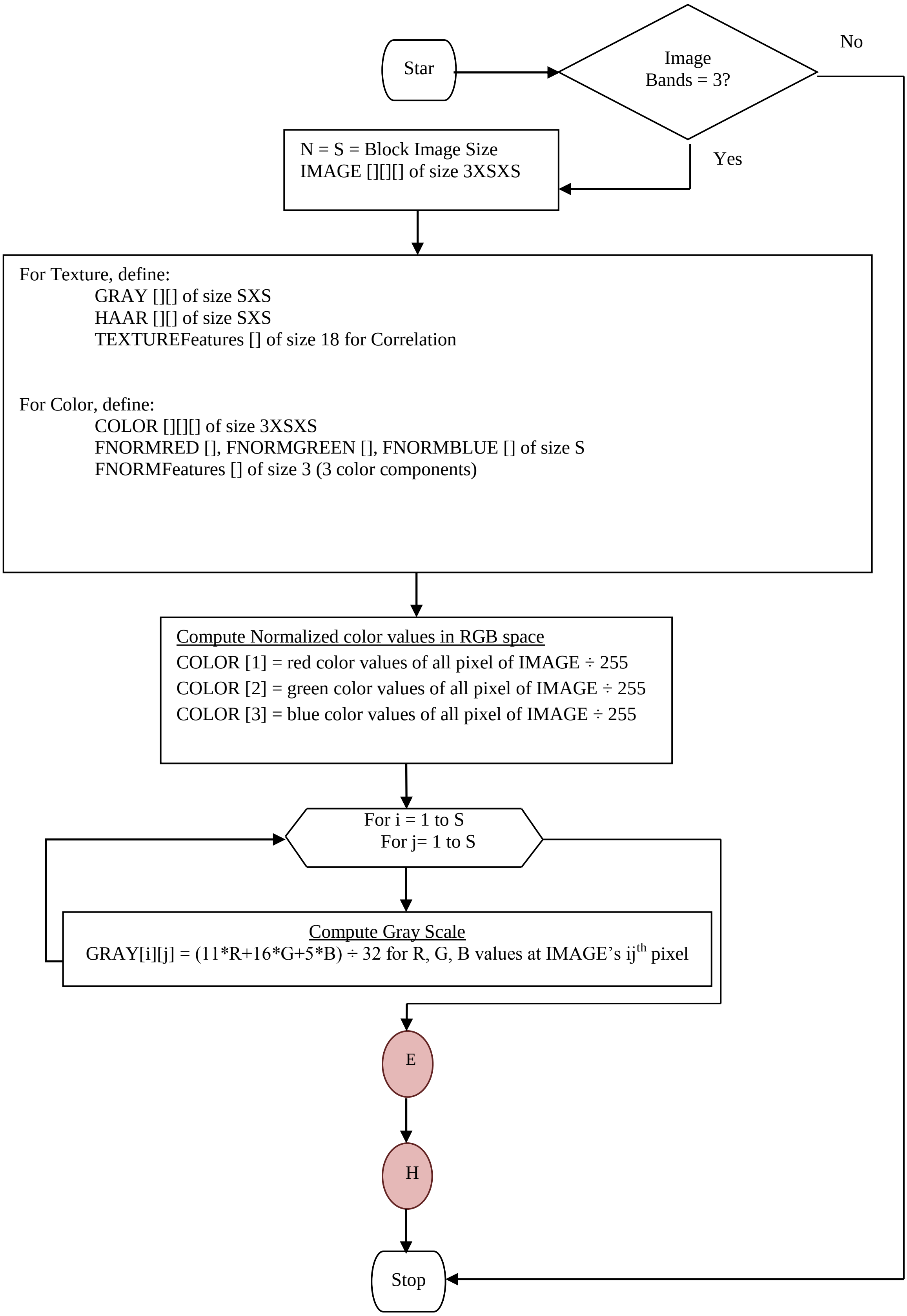
Type: Function

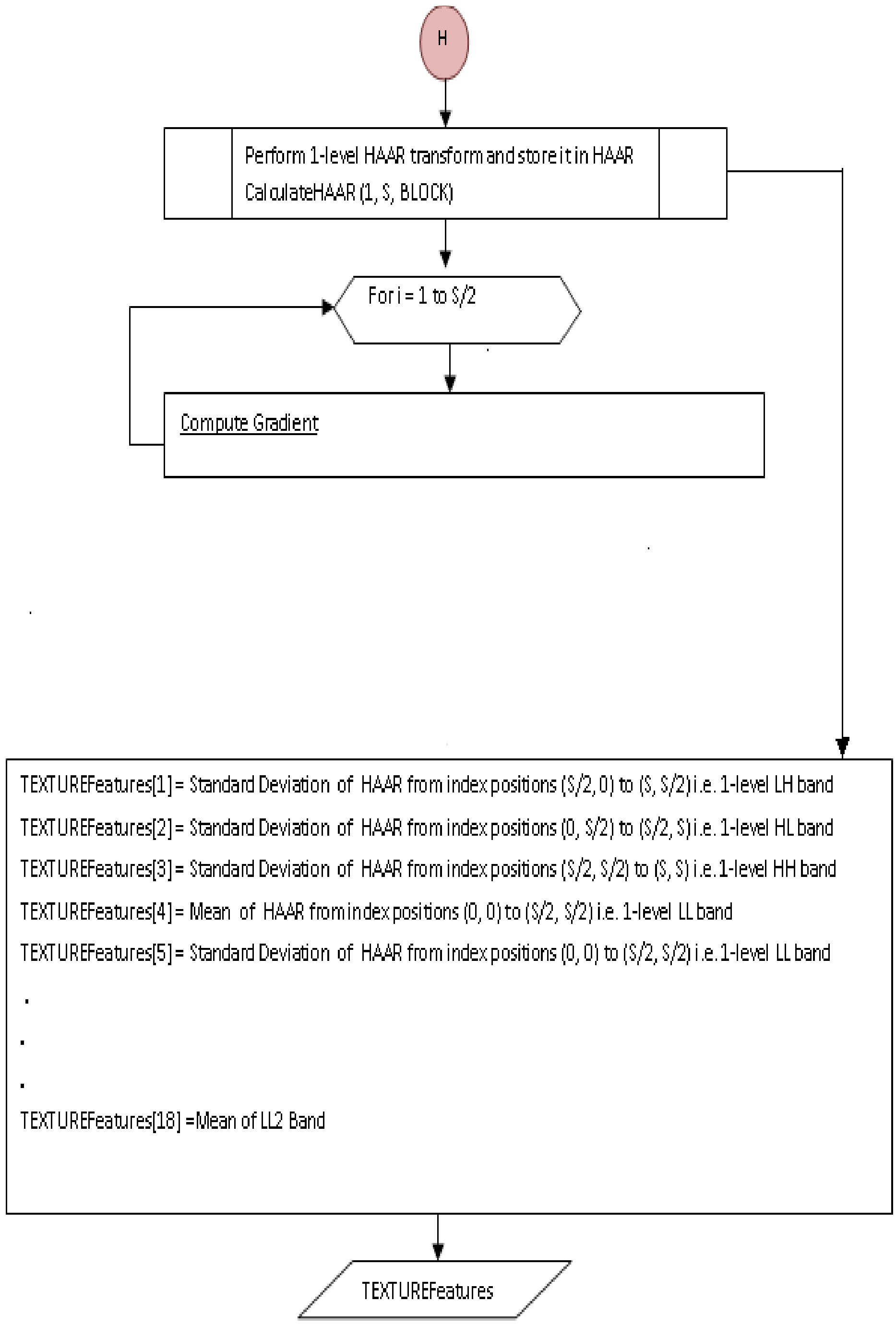
Responsibilities: It finds the color and texture features of a query block image.

Parameters:

Data Item	Parameter Type	Data Type
Image	Input (as function arguments)	RenderedImage or Image in the form of 3D array
Color Feature Vector	Output (as return data)	Float array
Texture Feature Vector	Output (as return data)	Float array

Processing:


Star
Image
Bands = 3?
No
Yes
N = S = Block Image Size
IMAGE [][][] of size 3XSXS
For Texture, define:
GRAY [][] of size SXS
HAAR [][] of size SXS
TEXTUREFeatures [] of size 18 for Correlation
For Color, define:
COLOR [][][] of size 3XSXS
FNORMRED [], FNORMGREEN [], FNORMBLUE [] of size S
FNORMFeatures [] of size 3 (3 color components)
Compute Normalized color values in RGB space
COLOR [1] = red color values of all pixel of IMAGE ÷ 255
COLOR [2] = green color values of all pixel of IMAGE ÷ 255
COLOR [3] = blue color values of all pixel of IMAGE ÷ 255
For i = 1 to S
For j= 1 to S
Compute Gray Scale
GRAY[i][j] = (11*R+16*G+5*B) ÷ 32 for R, G, B values at IMAGE's ijth pixel
E
H
Stop


H
Perform 1-level HAAR transform and store it in HAAR
CalculateHAAR (1, S, BLOCK)
For i = 1 to S/2
Compute Gradient
TEXTUREFeatures[1] = Standard Deviation of HAAR from index positions (S/2, 0) to (S, S/2) i.e. 1-level LH band
TEXTUREFeatures[2] = Standard Deviation of HAAR from index positions (0, S/2) to (S/2, S) i.e. 1-level HL band
TEXTUREFeatures[3] = Standard Deviation of HAAR from index positions (S/2, S/2) to (S, S) i.e. 1-level HH band
TEXTUREFeatures[4] = Mean of HAAR from index positions (0, 0) to (S/2, S/2) i.e. 1-level LL band
TEXTUREFeatures[5] = Standard Deviation of HAAR from index positions (0, 0) to (S/2, S/2) i.e. 1-level LL band
.
.
.
TEXTUREFeatures[18] =Mean of LL2 Band
TEXTUREFeatures

B.3)*Compute Window Features (Module 2)*

Type: Module

Responsibilities: It searches the query image for regions/objects with features similar to those received from the Compute Block Features module .

Parameters:

Data Item	Parameter Type	Data Type
Color & Texture feature vectors of the query block	Input	Serializable Object(of class QueryBlockSender)
K images with most similar highlighted regions	Output	Serializable Object (of class Image Sender)
Processing problems (if any errors occur)	Output	String

B.4)*Compute Similar Blocks: Module 2.1.3, 2.1.4, 2.1.5 & 2.1.6)*

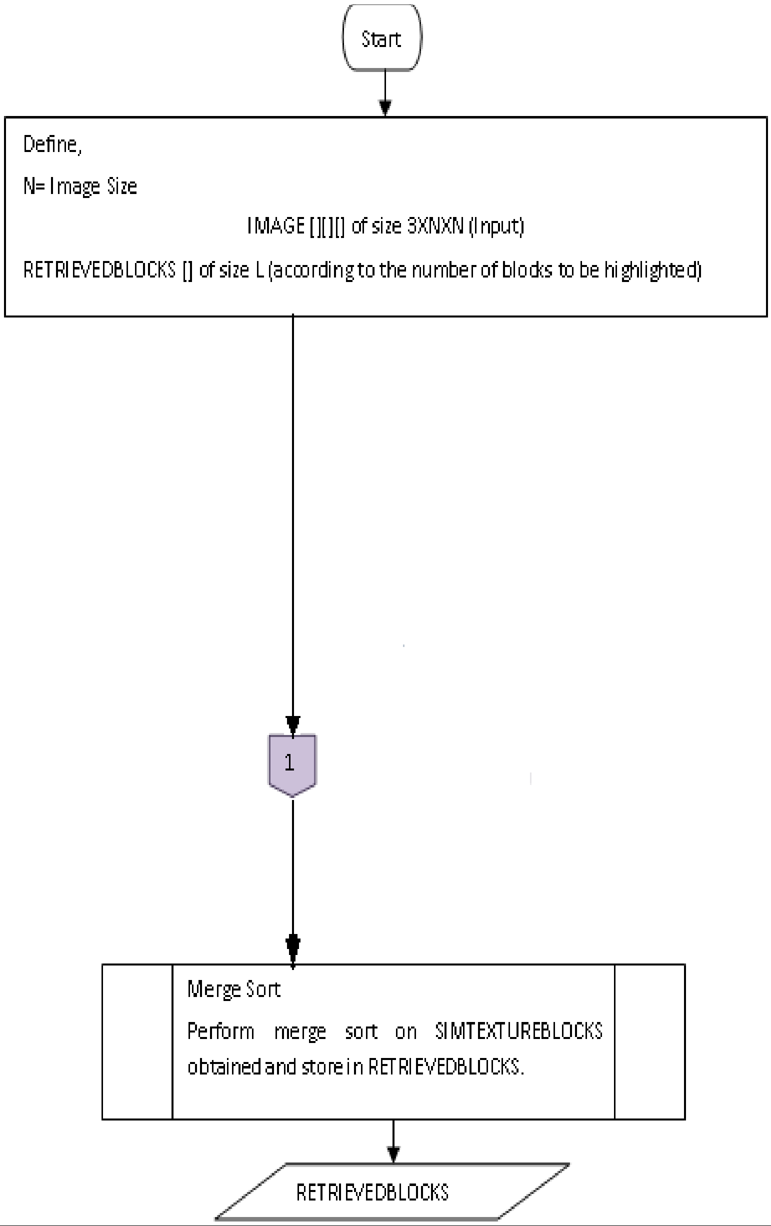
Type: Functions

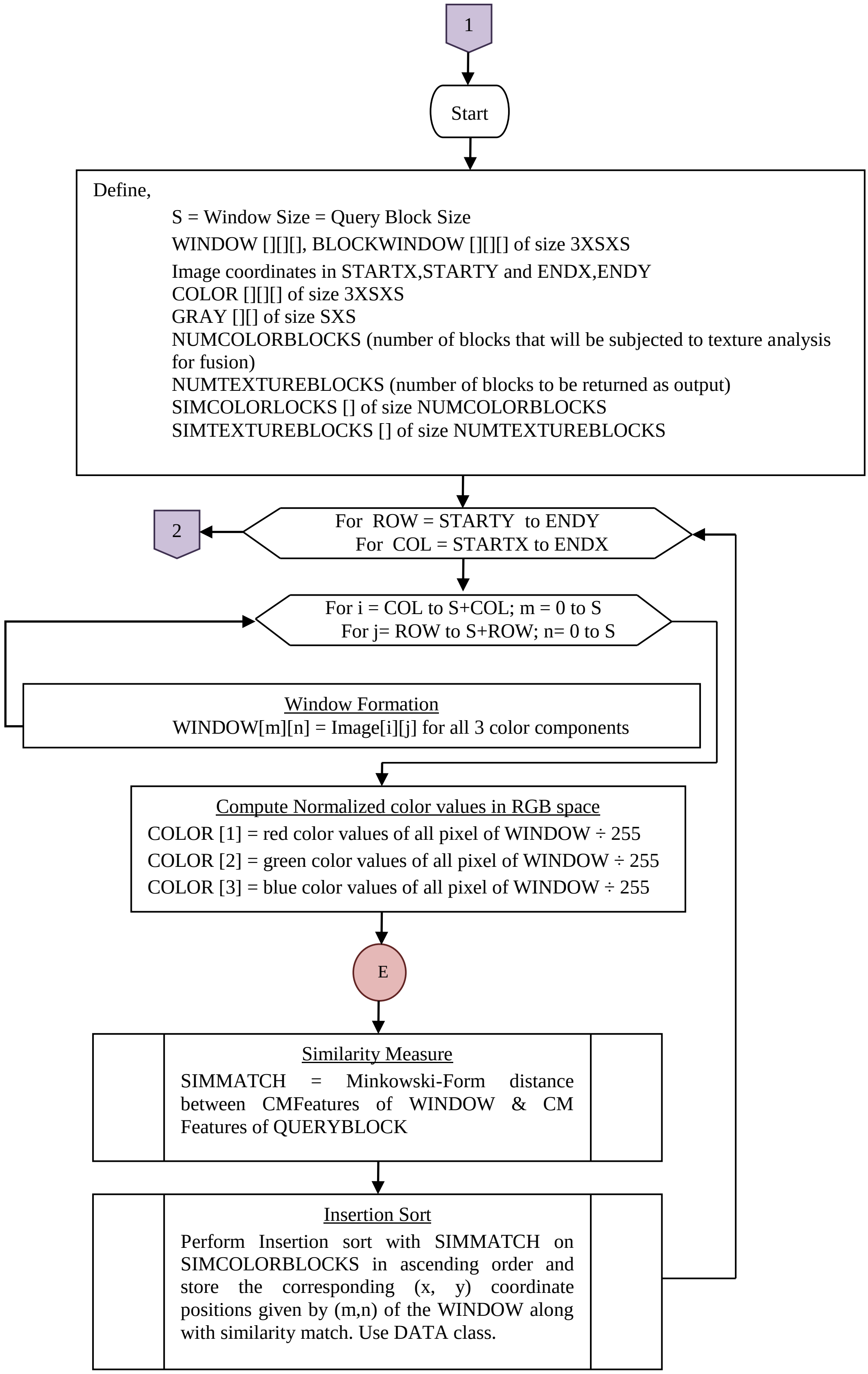
Responsibilities: It carries out the procedure that actually retrieves the similar blocks from image. Hence, the tasks of feature extraction and similarity matching for small blocks formed by moving in steps of 1 pixel are to be performed.

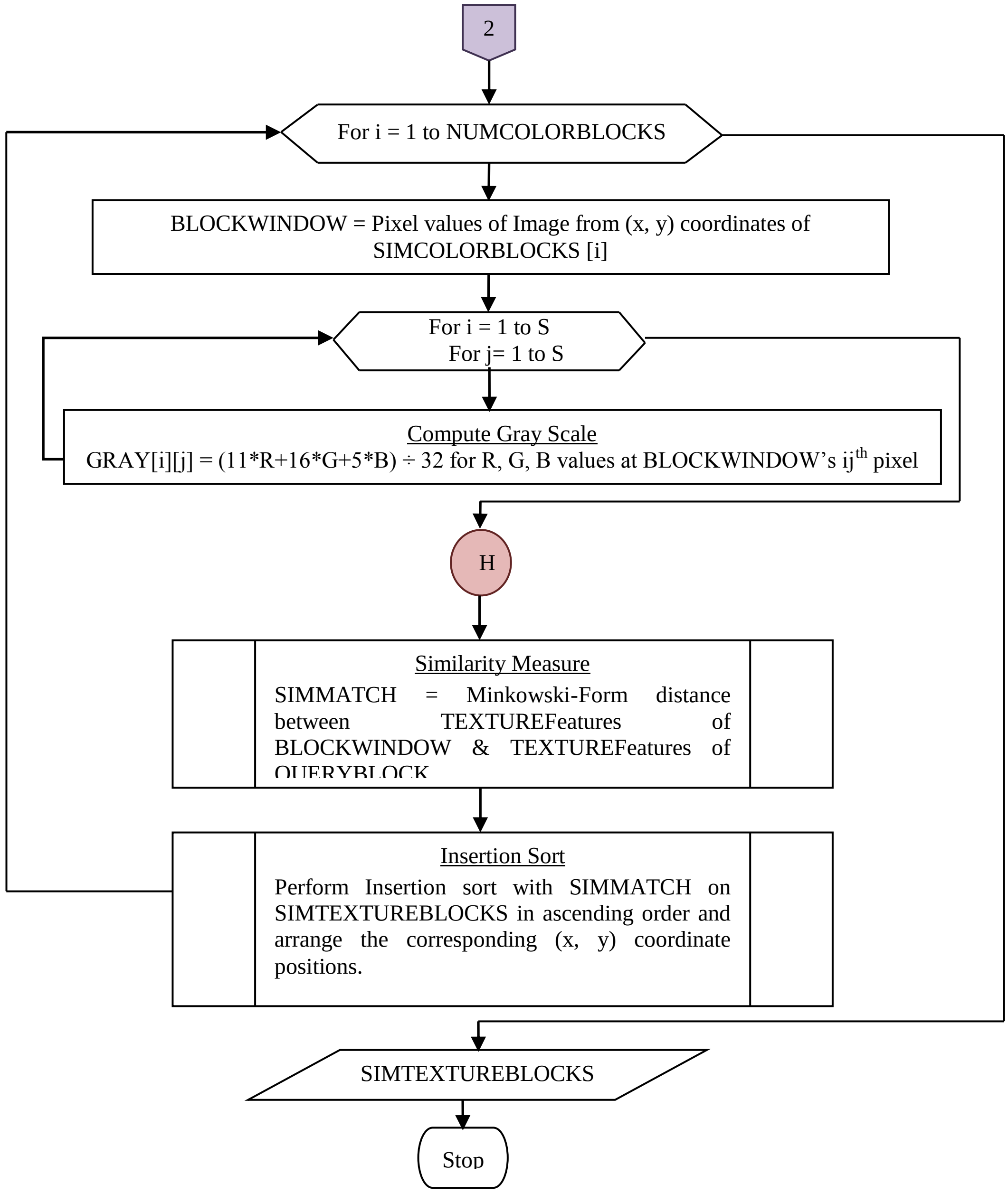
Parameters:

Data Item	Parameter Type	Data Type
Image (from library)	Input	RenderedImage or 3D array
Query Block Features (Color & Texture features)	Input	Object
L most similar regions in an image	Output	Object containing Image Path (String), Indices (Integer []) of the similar regions with their respective match values (Double[]) (a prototype is class Data)

__Processing:__


Start
Define,
N= Image Size
IMAGE [][][] of size 3XNXN (Input)
RETRIEVEDBLOCKS [] of size L (according to the number of blocks to be highlighted)
1
Merge Sort
Perform merge sort on SIMTEXTUREBLOCKS obtained and store in RETRIEVEDBLOCKS.
RETRIEVEDBLOCKS


1
Start
Define,
S = Window Size = Query Block Size
WINDOW [][][], BLOCKWINDOW [][][] of size 3XSXS
Image coordinates in STARTX,STARTY and ENDX,ENDY
COLOR [][][] of size 3XSXS
GRAY [][] of size SXS
NUMCOLORBLOCKS (number of blocks that will be subjected to texture analysis for fusion)
NUMTEXTUREBLOCKS (number of blocks to be returned as output)
SIMCOLORLOCKS [] of size NUMCOLORBLOCKS
SIMTEXTUREBLOCKS [] of size NUMTEXTUREBLOCKS
2
For ROW = STARTY to ENDY
For COL = STARTX to ENDX
For i = COL to S+COL; m = 0 to S
For j= ROW to S+ROW; n= 0 to S
Window Formation
WINDOW[m][n] = Image[i][j] for all 3 color components
Compute Normalized color values in RGB space
COLOR [1] = red color values of all pixel of WINDOW ÷ 255
COLOR [2] = green color values of all pixel of WINDOW ÷ 255
COLOR [3] = blue color values of all pixel of WINDOW ÷ 255
E
Similarity Measure
SIMMATCH = Minkowski-Form distance between CMFeatures of WINDOW & CM Features of QUERYBLOCK
Insertion Sort
Perform Insertion sort with SIMMATCH on SIMCOLORBLOCKS in ascending order and store the corresponding (x, y) coordinate positions given by (m,n) of the WINDOW along with similarity match. Use DATA class.



Constraints:

- Optimizing the values of parameters L
- Constraints imposed on Compute Online Features function for searching module are also applicable here

B.5) ***Compare Windows***

Type: Function

Responsibilities:

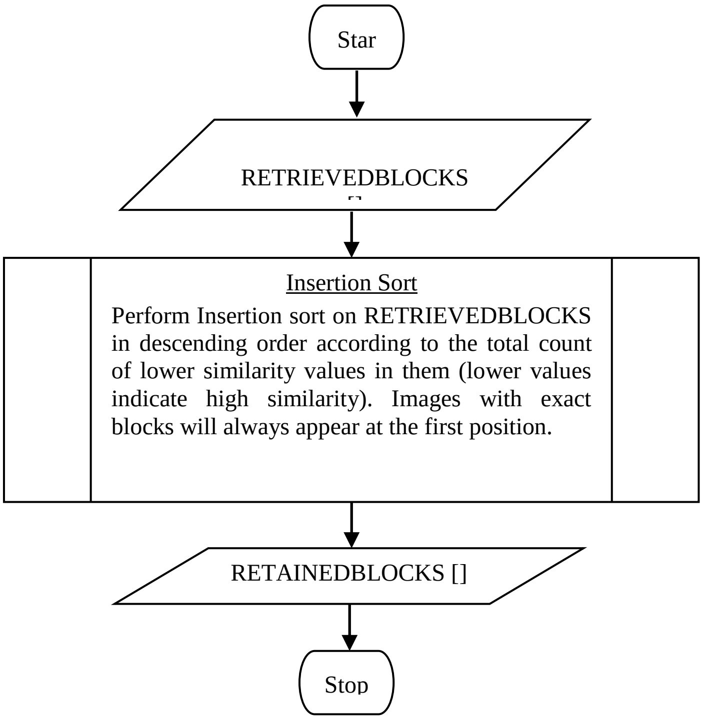
It compares the test block regions obtained for an image with the query block and highlights K most similar regions.

Parameters

:

Data Item	Parameter Type	Data Type
L most similar regions in an image	Input (as function argument)	Object containing Image Path (String), Indices (Integer []) of the similar regions with their respective match values (Double[]) (a prototype is class Data)
K images	Output	Serializable Object[] containing highlighted image 3D array (byte [][][]) (class ImageSender)

Processing:



Constraints:

- Optimizing the values of parameter K i.e. the number of image Blocks to be highlighted.

VI. LOGICAL DATABASE DESIGN

The structures of tables to be made in MySQL have been defined keeping in mind the entity specified in the ERD defined in SRS document. The number of tables is equal to the number of techniques that can be opted for.

TABLE VIII
DATABASE TABLES

Entity (Table)	Attributes	Attribute Type	Constraints	Comments
CORRELATIONTexture	ImagePath	varchar (255)	Primary key	Absolute path of an image file
	Feature1	Double	Not null	Weighted SD of level-1 LH band
	Feature2			Weighted SD of level-1 HL band
	Feature3			Weighted SD of level-1 HH band
	Feature4			Weighted SD of level-2 LH band
	Feature5			Weighted SD of level-2 HL band
	Feature6			Weighted SD of level-2 HH band
	Feature7			Correlation of LL1-HL1 band
	Feature8			Correlation of LL1-LH1 band
	Feature9			Correlation of LH1-HL1 band
	Feature10			Energy of LL1 band
	Feature11			Weighted SD of level-1 LL band
	Feature12			Mean of LL1 band
	Feature13			Correlation of LL2-HL2 band
	Feature14			Correlation of LL2-LH2 band
	Feature15			Correlation of

Entity (Table)	Attributes	Attribute Type	Constraints	Comments
				LH2-HL2 band
	Feature16			Energy of LL2 band
	Feature17			Weighted SD of level-2 LL band
	Feature18			Mean of LL2 band
FNormColor	ImagePath	varchar(255)	Primary key	Absolute path of an image file
	Feature1	Double	Not null	Weighted average of the F-Norm of Red color component
	Feature2			Weighted average of the F-Norm of Green color component
	Feature3			Weighted average of the F-Norm of Blue color component

Software Testing

I. INTRODUCTION

A. Purpose

This document portrays the unit and system testing undertaken to verify the functionality of the software according to the requirements collected. It gives an insight into the working of the system. It also specifies the rectifications to be made to the system by observing the test results.

B. Scope

The scope of this SRS document encompasses the following: -

1. The testing results are concluded in this document to enable rectification to be done by the programmers and serve as a reference for further testing procedures.
2. It helps in maintaining or extending functionalities of the system.

C. Audience

Testers, Programmers, Researchers

D. Definitions, Acronyms and Abbreviations

See Appendix

E. References of pertinent documents

SRS, Research and Exploration, SDS, Experimental Results

F. Interpretation of the tables

Test cases and the outcome of performing them are appropriately structured in tables. The headings of the table columns clearly describe the contents. However, a color coding scheme is used for the outputs. Red color is a symbol of erroneous result. The output have been colored green, if the desired results match the expected ones.

II. TESTS PERFORMED & RESULTS OBTAINED

A. Test Cases for Searching (DFD Process 1.1)

A.1) *Testing for Get File Function (DFD Processes 1.1.1 & 2.1.1)*

<u>*Purpose:*</u>

To check if BMP & TIFF file formats of different sizes are being converted to the Java's internal representation as an object of RenderedImage class and image in other file formats are not loaded into memory.

Input		Condition tested		Function called	Output
Image Path	Image Size	Condition	T/F		
D:\nnng\texture1\101.bmp	256X256	Filename contains ".bmp"	T	createBmpImage()	RenderedImage
D:\nnng\satimage\1.tif	512X512	Filename contains ".tif"	T	createTifImage()	RenderedImage
D:\pictures\bird.jpg	8X8	Filename contains ".bmp" or ".tif"	F	-	Format JPG not supported
D:\nnng\texture1\412.bmp	2048X2048	Filename contains ".bmp"	T	createBmpImage()	Memory heap space

Input		Condition tested		Function	Output
					error
D:\nnng\satimage\109 .tif	257X256	Filename contains ".tif"	T	createTifImage ()	RenderedIma ge
D:\texture1\101.bmp	Any	File not found	T	-	Appropriate message shown
D:\blocks\babyele.bm p	64x64	For browsing functionality, Filename contains .bmp	T	createBmpIma ge()	RenderedIma ge
D:\blocks\chilly.bmp	72x72	For Browsing, Size ≤64	F	-	Message " Size should be less than or equal to 64"
D:\blocks\tyre.bmp	11x11	For Browsing, Height, Width are even	F	-	Message " Size should be even"

A.2) ***Testing for Compute Online Features (DFD Processes 1.1.3)***

Purpose:

- The online features module consisting of various methods for feature extraction gives the desired result.
- All constraints mentioned in the SDS have been taken care of.
- The requirement of 3 bands is fulfilled.

Input				Function called	Output
Image	Image Bands	Image Size	Technique		
I=Rendered Image (Output of Get File)	3	256X256	CORRELATION	int G[][]=convertToGray(I) int H[][]=applyHaar(G,2) getCorrelationFeatures(H)	Successful. Double[8] with feature values returned
		120X120			Successful. Features returned but there was some loss of pixel values at the second level of Haar.
		121X150			Array index out of

Input				Function called	Output
					bounds exception in applyHaar()

Input				Function called	Output
Image	**Image Bands**	**Image Size**	**Technique**		
I=Rendered Image (Output of Get File)	3	256X256	Color F-Norm	Double C[][][]=findNormalizedRGB(I) Double R[]=calcWeightedFnorm(C[0]) Double G[]=calcWeightedFnorm(C[1]) Double B[]=calcWeightedFnorm(C[2]) getFnormFeatures(R, G, B)	Successful. Double[3] , Double[9] with feature values returned for this technique

Input				Condition Tested		Output
Image	**Image Bands**	**Image Size**	**Technique**	**Condition**	**T/F**	
Rendered Image (Output of Get File)	1, 4	Any	Any	ImageBands == 3	F	No further processing.

Conclusion:

Image size should be validated in the Get File function itself as it creates problem in applyHaar().

A.3) *Testing for Similarity Measure & Sorting (DFD Process 1.1.4, 1.1.5)*

Purpose:

To verify the accuracy of the feature extraction techniques implemented. The test also confirms the accuracy of similarity measurement and insertion sorting.

Input	Condition tested		Output
	Condition	**T/F**	
QFEAT= double[], TFEAT= double[], Double[] SIMIMAGES	T[i] lies within Q[i] – A[i] and Q[i] + A[i]	T	MATCH modified and insertion sort performed by comparing with previous K matches of array SIMIMAGES. Initially, SIMIMAGES are initialized

Input	Condition tested		Output
			with maximum value of double data type.
	T[i] lies within Q[i] – A[i] and Q[i] + A[i]	F	Checks for the next element in TFEAT without doing further calculations
	All elements of TFEAT checked	T	Output double[K] SIMIMAGES
	QFEAT==TFEAT	T	SIMIMAGES [0] = MATCH = 0.0. Successful

A.4) *Database Testing*

Purpose:

The functions that work with MySQL ODBC interface should be thoroughly tested for their transactions with the database. The following tests were performed for the functions mentioned below:

- Manage offline features
- Similarity measure, Sorting and Ranking

Tests	Error to be handled	Output
Connection to database not established (due to reasons like incorrect password or database driver)	java.sql.SQLException	Searching functionality not disabled. No message shown.
Error while retrieving, inserting or deleting records from the database (like tables do not exist, invalid attribute values, parsing error in the query)	Java.sql.SQLException (like table does not exist etc.)	Appropriate message shown. Exception handled.
ResultSet obtained is null i.e. no records exist in the database	ResultSet object is null	Condition handled. Appropriate message shown.
Duplicate entry for images	Java.sql.SQLException : duplicate entry	This insertion error was handled properly.
Select, Delete & Insert Queries	Java.sql.SQLException	Successful

Conclusion:

Searching functionality should not be allowed when database connection is not established. Appropriate message should be shown for the same. Queries executed properly when the connection was made.

Final Conclusion

The tests were conducted successfully, the results compiled and rectifications suggested. As per the requirements, test data set consisted of satellite images, Brodatz texture images, and a large set of color images.

Experimental Results

I. INTRODUCTION & MOTIVATION

Nowadays, and in the days to come, a large number of applications, including military, industrial and civilian generate, and will continue to generate, even more gigabytes of color images per day. As a result, there is a huge amount of information which cannot be accessed or made use of unless it is organized. Organization here means that appropriate indexing is available or in order to allow efficient browsing, searching and retrieving as in keyword searches of text databases. The easiest way to search is with the use of QbE, which means that the user has to present an image to the system and the latter searches for others alike by extracting features from the query image and comparing them to the ones stored in the database. The extraction of meaningful features is critical in CBIR and therefore, an open and active field of research. Of the features usually employed by researchers are color, texture and shape.

The aim of this study is to investigate the applicability of using efficient feature extraction techniques for the improvement of CBIR. Another goal is to explore their utility over satellite images to find out regions by extracting features from images in the archive at query time. For e.g.: areas of vegetation or objects like aero plane can be easily browsed in a satellite image archive by giving a region/object containing similar features as an example.

Our original motivation is development of efficient color and texture feature descriptors for CBIR.

II. OBSERVATIONS & CONCLUSIONS FOR SEARCHING

We have conducted an experimental analysis on the feature descriptors for CBIR by following the research done in this field. The experiments were performed with Java as front end and MySQL as back end.

A. Optimizing Parameters

A.1) *Variable K: Number of similar images to be retrieved for a query image*

The similar images retrieved for a query image depends on the diversity of the database. The user may be misleaded by the results if K is not chosen aptly, since the results may present a narrow and restrictive view of similar images. After experimenting, variable K for searching function was set to 10.

B. Results of Texture based approaches

B.1) *Brodatz Database*

B.1.1) Image library

18 different textures were taken from the Brodatz Texture Album. The image of each texture type was divided into 16 non-overlapping images of size 256x256, resulting in a database of 288 images. Therefore, there are 16 relevant images belonging to each texture type. Sample database for a texture type is shown below.

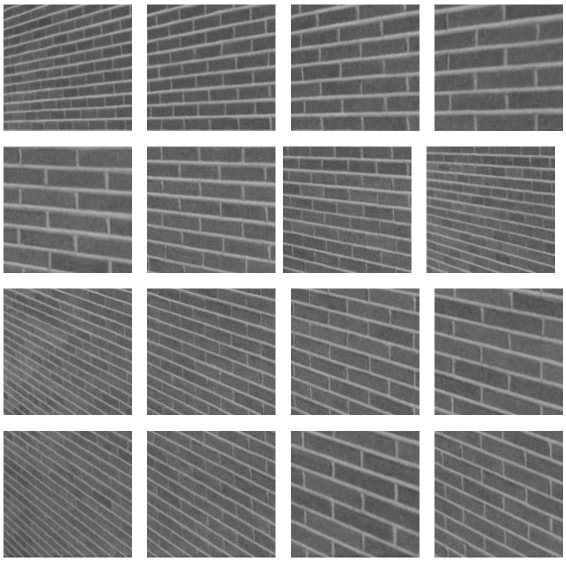


Fig. 16 A sample of 16 images of a texture type

B.1.2) Setup

For the texture based method to be studied (Correlation), the respective features of each database image were computed offline and stored. The feature computation for the query image was done online. Fuzzy Logic was used as the similarity measure. One image of each texture type was selected as query and K most similar images were considered for comparative study of retrieval performance of mentioned techniques.

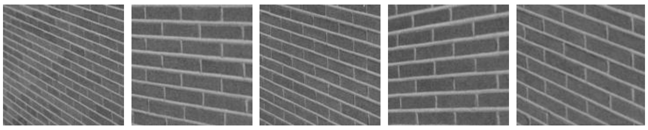
B.1.3) Correlation Retrieval Results

The similarity match (percentage) for Correlation was obtained by comparing the online computed feature vector with each stored feature vector and applying the 8 triangular fuzzy functions. The results are shown in descending order of similarity match.

The similarity match (percentage) for Correlation was obtained by comparing the online computed feature vector with each stored feature vector and applying the 18 triangular fuzzy functions. The results are shown in descending order of similarity match.

Query Image

100.00 73.96 69.78 65.84 61.34



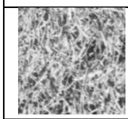
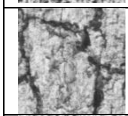
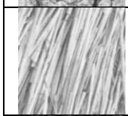
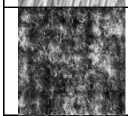
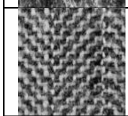
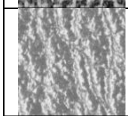
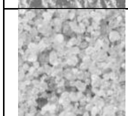
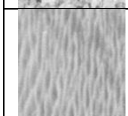
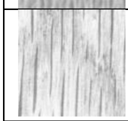
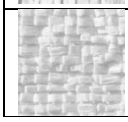
57.28 56.26 51.55 50.70 43.20

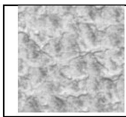
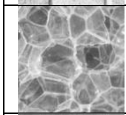
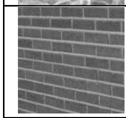
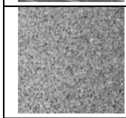
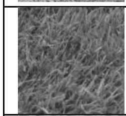
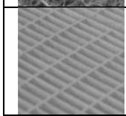
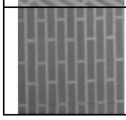
Fig.17 Query image and retrieved images along with the similarity percentage

B.1.4) Performance Analysis

The retrieval performance for 18 texture types is measured by precision and recall formulae (Research and Exploration VI.A.1) and the results have been summarized in the table shown below.

TABLE IX
RETRIEVAL ACCURACIES OF 18 TEXTURE TYPES

Texture Type	**CORRELATION**		**Gradient**		**GLCM**		**WSD**	
	Recall	**Precision**	**Recall**	**Precision**	**Recall**	**Precision**	**Recall**	**Precision**
	56.25	90.00	43.75	70.00	37.50	60.00	62.50	99.99
	62.50	99.99	31.25	50.00	62.50	99.99	62.50	99.99
	62.50	99.99	31.25	50.00	62.50	99.99	62.50	99.99
	62.50	99.99	62.50	99.99	62.50	99.99	62.50	99.99
	62.50	99.99	62.50	99.99	62.50	99.99	62.50	99.99
	56.25	90.00	56.25	90.00	50.00	80.00	62.50	99.99
	62.50	99.99	18.75	30.00	56.25	90.00	62.50	99.99
	62.50	99.99	18.75	30.00	50.00	80.00	62.50	99.99
	62.50	99.99	43.75	70.00	56.25	90.00	62.50	99.99
	62.50	99.99	62.50	99.99	62.50	99.99	62.50	99.99

	62.50	99.99	62.50	99.99	62.50	99.99	62.50	99.99
	62.50	99.99	50.00	80.00	18.75	30.00	50.00	80.00
	62.50	99.99	18.75	30.00	62.50	99.99	62.50	99.99
	62.50	99.99	43.75	70.00	25.00	40.00	56.25	90.00
	62.50	99.99	56.25	90.00	43.75	70.00	62.50	99.99
	62.50	99.99	62.50	99.99	62.50	99.99	62.50	99.99
	62.50	99.99	50.00	80.00	50.00	80.00	62.50	99.99
	62.50	99.99	62.50	99.99	62.50	99.99	62.50	99.99

Finally, overall average precision and recall was computed as the average of precision and recall values obtained for each of the 18 texture types. Table XI presents the corresponding results along with the maximum and minimum values of the two measures.

TABLE X
MAXIMUM, MINIMUM & OVERALL AVERAGE RETRIEVAL ACCURACY

	Retrieval Accuracy (in percentage)							
	CORRELATION		**Gradient**		**GLCM**		**WSD**	
	Recall	**Precision**	**Recall**	**Precision**	**Recall**	**Precision**	**Recall**	**Precision**
Average	61.8000	98.888	46.527	74.444	52.777	84.444	61.458	98.333
Minimum	56.25	90.00	18.75	30.00	18.75	30.00	50.00	80.00
Maximum	62.50	99.99	62.50	99.99	62.50	99.99	62.50	99.99

B.2) *VisTex Database*

B.2.1) Image library

The database was created with the intention of providing a large set of high quality textures for computer vision applications. Unlike other texture collections, the images in VisTex do not conform to rigid frontal plane perspectives and studio lighting conditions. The goal of VisTex is to provide texture images that are representative of real world conditions.
A database of 681 Images from the VisTex Album was used with each image having size 256 x 256.

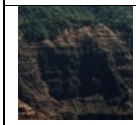
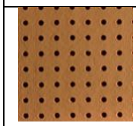
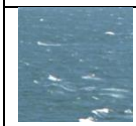
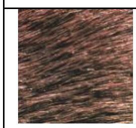
Fig. 18 A sample of 12 images from VisTex Album

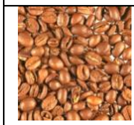
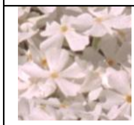
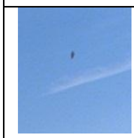
B.2.2) Setup

For the texture based method to be studied (Correlation), the respective features of each database image were computed offline and stored. The feature computation for the query image was done online. Fuzzy Logic was used as the similarity measure. One image of each texture type was selected as query and K most similar images were considered for comparative study of retrieval performance of mentioned techniques.

B.2.3) Performance Analysis

TABLE XI
RETRIEVAL ACCURACIES OF 16 IMAGES

Texture Type	CORRELATION		Gradient		GLCM		WSD	
	Recall	**Precision**	**Recall**	**Precision**	**Recall**	**Precision**	**Recall**	**Precision**
	75.00	90.00	66.66	80.00	66.66	80.00	75.00	90.00
	31.25	99.99	18.75	60.00	18.75	60.00	31.25	99.99
	60.00	90.00	20.00	30.00	53.33	80.00	53.33	80.00
	58.33	70.00	16.66	20.00	58.33	70.00	50.00	60.00
	66.66	80.00	83.33	99.99	75.00	90.00	83.33	99.99
	83.33	99.99	75.00	90.00	25.00	30.00	75.00	90.00
	75.00	90.00	25.00	30.00	25.00	30.00	50.00	60.00
	100.00	60.00	100.00	60.00	83.33	50.00	50.00	30.00
	44.44	40.00	66.66	60.00	77.77	70.00	33.33	30.00
	60.00	60.00	10.00	10.00	70.00	70.00	50.00	50.00

Texture Type	CORRELATION		Gradient		GLCM		WSD	
	Recall	Precision	Recall	Precision	Recall	Precision	Recall	Precision
	83.33	99.99	8.33	10.00	66.66	80.00	83.33	99.99
	66.66	60.00	11.11	10.00	33.33	30.00	66.66	60.00
	100.00	40.00	100.00	40.00	50.00	20.00	75.00	30.00
	50.00	30.00	50.00	30.00	16.66	10.00	33.33	20.00
	60.00	60.00	40.00	40.00	40.00	40.00	40.00	40.00
	66.66	40.00	16.66	10.00	50.00	30.00	83.33	50.00

Finally, overall average precision and recall was computed as the average of precision and recall values obtained for 16 Sample Images. Table XII presents the corresponding results along with the maximum and minimum values of the two measures.

TABLE XII
MAXIMUM, MINIMUM & OVERALL AVERAGE RETRIEVAL ACCURACY

	Retrieval Accuracy (in percentage)							
	CORRELATION		Gradient		GLCM		WSD	
	Recall	Precision	Recall	Precision	Recall	Precision	Recall	Precision
Average	67.547	69.375	44.260	42.500	50.613	52.50	58.305	61.875
Minimum	31.25	30.00	8.33	10.00	16.66	10.00	31.25	20.00
Maximum	100.00	99.99	100.00	99.99	83.33	90.00	83.33	99.99

B.3) Conclusions

The table clearly shows the improved precision of the Correlation approach over the other three methods. A significant increase in retrieval accuracy (recall and precision) is observed particularly for the cases where the performance of the other three methods was found to be degraded. This can be attributed to the fact that Correlation based method uses the detailed information of all the sub bands, obtained after applying Haar DWT. The decomposition of an image using Haar DWT is advantageous over gradient operation and the Correlation technique further enhances the performance of image retrieval system. A noticeable improvement in performance of Correlation is also observed when comparing with the results of GLCM approaches where relationship between neighbouring pixels is directly used to calculate the features.

C. Results of Color based F-Norm approach

C.1) *Image library*

For the testing of this approach, database of 837 colored images each of size 256X256 was taken. Sample database for two colored images is shown below.

(a)

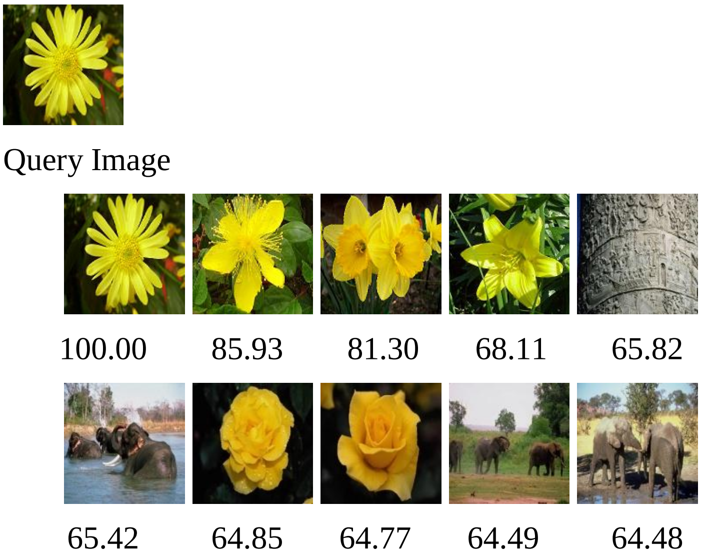
(b)

Fig.19 (a) Sample of yellow flowers (b) Sample of horses

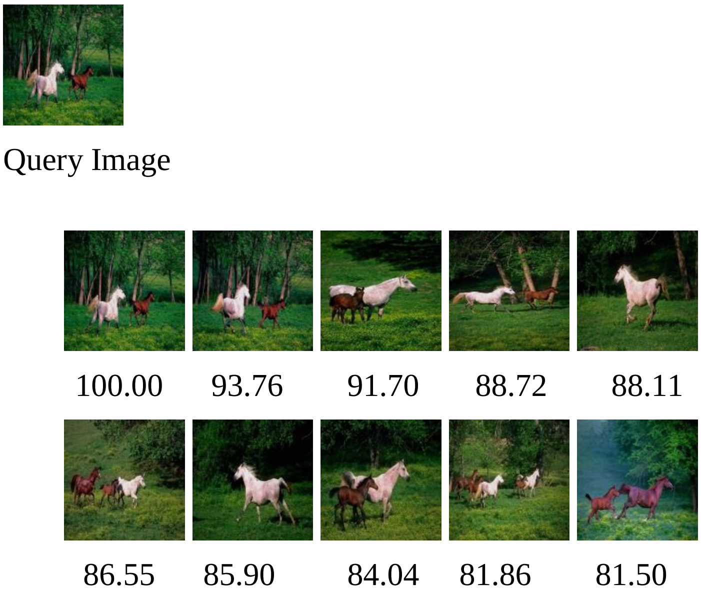
C.2) *Setup*

The 3 F-norm features were computed offline for database images and online for query image. Then, the similarity match percent was calculated using 3 triangular fuzzy functions and the results shown in descending order.

C.3) *F-Norm Retrieval Results*



(a)



(b

Fig.20 Retrieval based on color with similarity matches

III. Observations & Conclusions for Browsing

A. Fusion approach

Multi-feature fusion is used by adopting the following techniques to combine the features.

Color Descriptor: Color F-Norm

Texture Descriptor: Correlation

It is a common observation that processing images takes a considerable amount of time, especially, when computation has to be done with every pixel of the image. This approach searches the larger image for a smaller queried portion by traversing from left to right and top to bottom in steps of one pixel.

The steps followed in the main task (as shown in Fig.13 of Research & Exploration document) are listed below:

- A small block of size SXS, say BLOCK, is input.
- Three color features of BLOCK, say TCOLORFEATURES, are calculated.
- Eighteen texture features of BLOCK, say TTEXTUREFEATURES, are calculated.
- A larger image of size NXN, say IMG, is input.
- The steps for each are as follows:

1. Repeat steps 2 to 4 moving BLOCK one pixel at a time over IMG from left to right and top to bottom, starting from the first pixel positions to the ending positions of the corresponding IMG.
2. Color features for SXS block of IMG partition overlapped by BLOCK (as mentioned in step 1), say QCOLORFEATURES, is calculated.
3. The similarity match between QCOLORFEATURES and TCOLORFEATURES is computed.
4. Insertion sort is used to keep track of the NUMCOLORBLOCKS lowest matches (most similar areas) for the partition.
5. After the blocks of the entire image have been analysed on the basis of color property, the blocks corresponding to the NUMCOLORBLOCKS lowest matches are subjected to texture analysis by computing similarity match between the NUMCOLORBLOCKS blocks’ eighteen texture features, say QTEXTUREFEATURES and TTEXTUREFEATURES. The NUMCOLORBLOCKS values are rearranged in ascending order according to texture feature similarity.

B. Optimizing Parameters for browsing

B.1) ***Variable NUMCOLORBLOCKS: Number of similar regions whose color properties qualify them for further refinement through texture introspection.***

The parameter’s value was chosen to be 100 after carefully examining the relevance of the results obtained. A lower value biased the results towards color, thus ignoring significant areas; while a higher value; either took the results in the wrong direction or did not show major improvement in capturing the texture property.

B.2)***Variable K: Number of large images containing similar regions/objects to be retrieved for a block image***

Depending on the number of images in the image library, this parameter ranges its value from 1 to 25. Experimentation yielded that a maximum of 20 images were sufficient to capture relevant information.

B.3)***Variable L: Number of similar regions/objects images in a large image to be highlighted for a block image***

- For IRS LISS III

This parameter was set to 20. Twenty regions would give a proper idea of the portions in an image that are nearest to the query.

- For IKONOS

This parameter was set to 5. Five regions would give a proper idea of the portions in an image that are nearest to the query.

B.4)***Block Size SxS: Size of the query block***

1. *Satellite Images:* In an image taken from IRS (LISS – III) satellite, a pixel covers an area of approx. 23.5x23.5 sq.m. A block size of 16x16 pixels would thus contain a significant amount of territorial information covering 141376 sq.m. and hence, the value S was chosen to be 16. For IKONOS images, even block sizes are taken.
2. *Non satellite images:* Different values were selected for SxS in such a manner that it covered a significant amount of color and texture information from the given area in color image.

C. Setup for satellite images

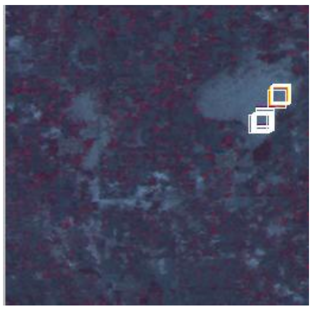
Few MSS satellite images of different sizes, NxN, were collected from the web for the experimental purpose. Blocks of size 16x16 for IRS images and SxS for IKONOS images, containing certain identifiable objects/regions like marshy land, buildings, water bodies, cultivated land, forests, aeroplanes, ships, oil tanks etc. were queried. These blocks were searched on the same NxN image to which they belonged and also on any other image.

D. Results of Browsing satellite images

D.1) ***IRS LISS III Images***

The following figures illustrates the exact match found in an IRS image when blocks of IRS images were cut and queried on other IRS images.

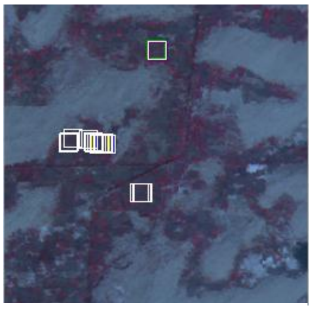
1. Desert



Query Image

Query Block

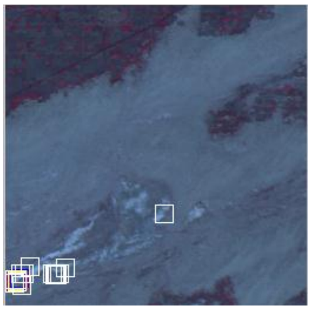
2. Vegetation



Query Image

Query Block

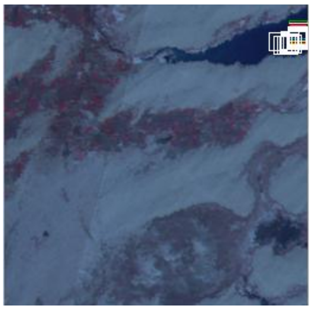
3. Salt Deposit



Query Image

Query Block

4. Water

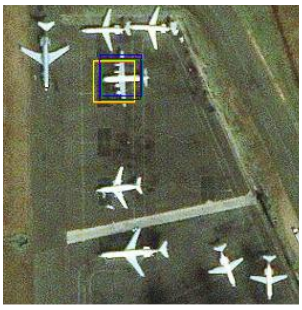


Query Image

Query Block

D.2) ***IKONOS Images***

Some 256x256 sized images were cut from IKONOS pictures of different airports present in the satellite imagery collection. The following figures illustrate the nearest matches found when an aeroplane block sliced out from one of the images comprising the same collection was browsed over the cut images.



Query Image

Query Block

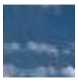
Query Image

Query Block

E. Results of Browsing non-satellite images

In the following figures images largely containing sky and water were taken. Blocks of sky and water were cut from images and browsing was done on images other than the ones from which they were cut. The objective was to determine whether the program could correctly differentiate between sky and water.

Query Image



Query Block

Query Image

Query Block

Query Image

Query Block

F. Conclusions

Fusion approach

Experiments on the basis of collaborated similarity of color and texture features have proved to be accurate and impressive on all kinds of images. A remarkable improvement in the search results was seen when a fusion of both color and texture features was done. It was also observed that a single search criterion may be equally preferable for satellite images.

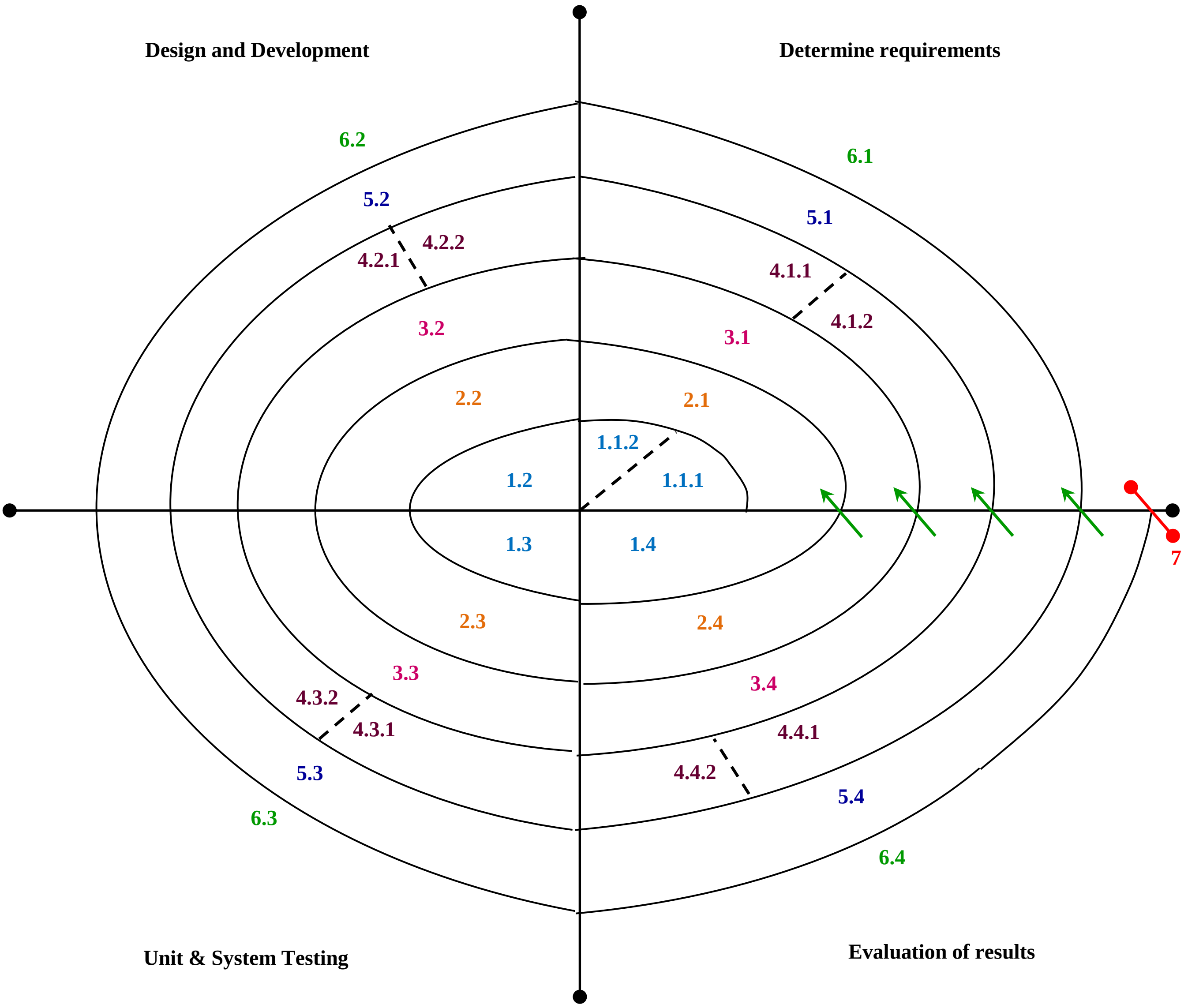
Software Planning & Execution

IV. Introduction

The development of the task was carried out in spiral fashion. Each iteration of the spiral laid out a new cycle of requirement, design, development, testing and evaluation. Since research and introduction of novelty were the major fields to be worked upon, inherent risks accompanied them. These risks included:

- Unrealistic schedule
- Developing the wrong software functions
- Uncertainty of success of an experiment
- Many unresolved requirement issues
- Requirements in the SRS that are not testable
- Overestimation of tasks

V. Planning & Execution Model



Item	Description	Work Done	Work Product
1.1.1	Exploring CBIR		
1.1.2	Analysis of implemented texture based techniques	Research paper studied	
1.2	Implementing the already done work for self understanding	Concept of research paper implemented	Code
1.3	Tested the tasks in 1.2	Experimental results accumulated	Observations
1.4	Evaluation of the tasks to improve the techniques	Evaluation and discussion of the test results	Conclusions
2.1	Requirement of developing an efficient texture descriptor for CBIR.	Alternative methods for texture descriptors explored, discussed and finalised.	Research & Exploration document
2.2	Development of the finalised method	SDS prepared and method coded	Design document & code
2.3	Testing the developed method	Test cases prepared	Test results accumulated
2.4	Evaluation of the developed method	Test results observed and concluded	Experimental results finalised for Correlation technique
3.1	Requirement of developing an efficient color descriptor for CBIR.	Alternative methods for color descriptors explored, discussed and finalised.	Research & Exploration document
3.2	Development of the finalised method	SDS prepared and method coded	Design document & code
3.3	Testing the developed method	Test cases prepared	Test results accumulated
3.4	Evaluation of the developed method	Test results observed and concluded	Experimental results finalised for Color F-Norm technique
4.1	1) Re-evaluating the Correlation results 2) Enhancing the results of F-Norm	1) Other texture descriptors studied 2) Other color descriptors studied and alternative approaches discussed	1, 2) Research and Exploration document
4.2	Development of finalised method	SDS for 3 texture descriptors prepared and coded the same.	Design document and code
4.3	Testing the developed methods	Test cases prepared	Test results accumulated
4.4	Evaluation of the developed methods	1) Methods compared with Correlation Technique 2	Research Paper submitted
5.1	Requirement for Defence purposes to search out parts of an image in large satellite images	1) Discuss the alternatives, constraints, limitations of processing large images 2) Studied the fundamental of Satellite Imagery	Research & Exploration document
5.2	Development of the discussed strategy	SDS prepared and strategy coded	Design document and code
5.3	Testing the strategy	Test cases prepared and rigorous testing done	Test results accumulated
5.4	Evaluation of the test results	Test results observed and summarized	Results recorded
6.1	Requirement to further refine the browsing results and minimize the processing time for large sized databases	Alternatives discussed	Research & Exploration document
6.2	Development of the finalised strategy	SDS prepared and strategy coded	Design document and code
6.3	Testing the strategy	Test cases prepared and rigorous testing done	Test results accumulated
6.4	Evaluation of the test results	Test results observed and summarized	Results recorded

Item	Description	Work Done	Work Product
7	All the units were incorporated as a system, GUI developed	System tested	Software system with GUI

VI. Aggregated Work Product

This report is an aggregation of all the work products obtained during the life cycle of the project.

1. All the requirements have been gathered together in the SRS document.
2. Research and Exploration document puts forward a comprehensive idea of the topics explored for the various phases of the spiral corresponding to the requirements.
3. SDS is a union of the common and distinct functionalities designed and programmed as the development proceeded in a constructive manner.
4. Unit and regression testing performed for all the requirements have been cumulated in the document titled “Software Testing”.
5. Experimental results are the proof of the work actually done.
6. Finally, GUI presents the complete project.

User Interface Design & Testing

I. GUI FOR DATABASE MANAGEMENT

A. *Manage Offline Features*

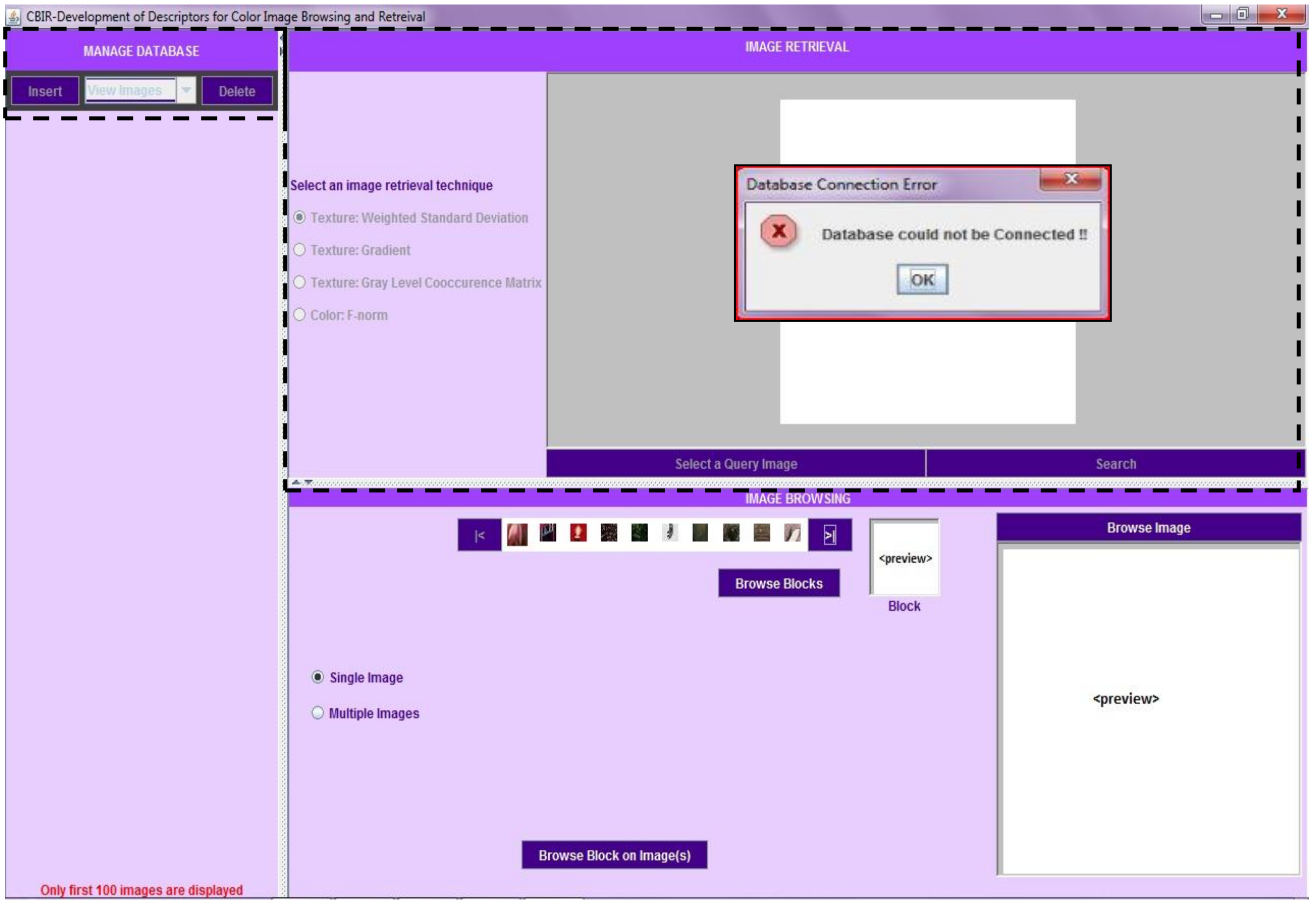


Fig. 32 Database connectivity problems result in disabling of the interfaces of "Manage offline features" and "Searching" functionalities (emphasized by dotted lines)

A.1) View Database Function

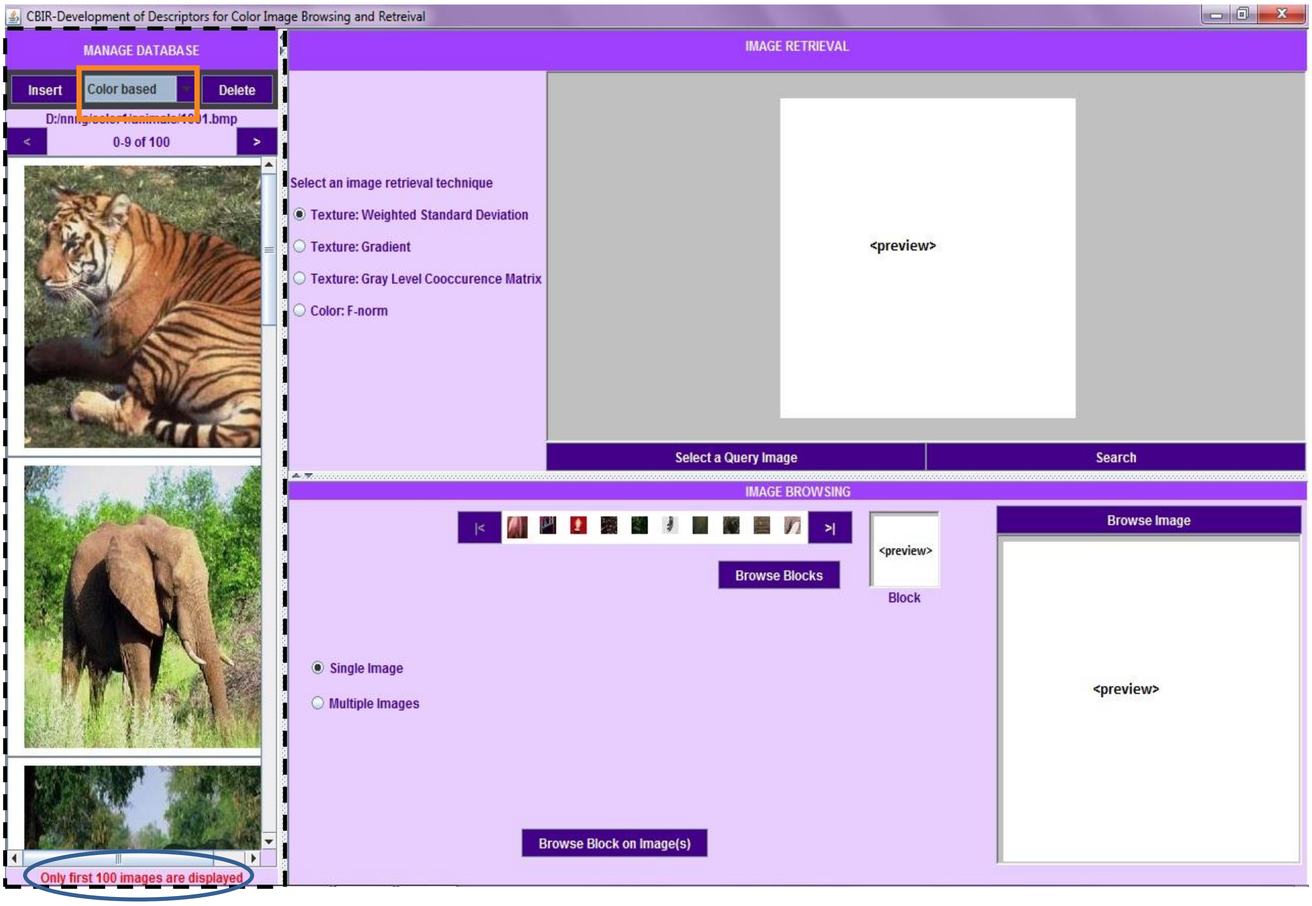


Fig. 33 View Database Function of Manage Offline Features Module which shows the images whose offline features are stored in tables of Color based descriptors. The highlighted oval indicates the memory constraint

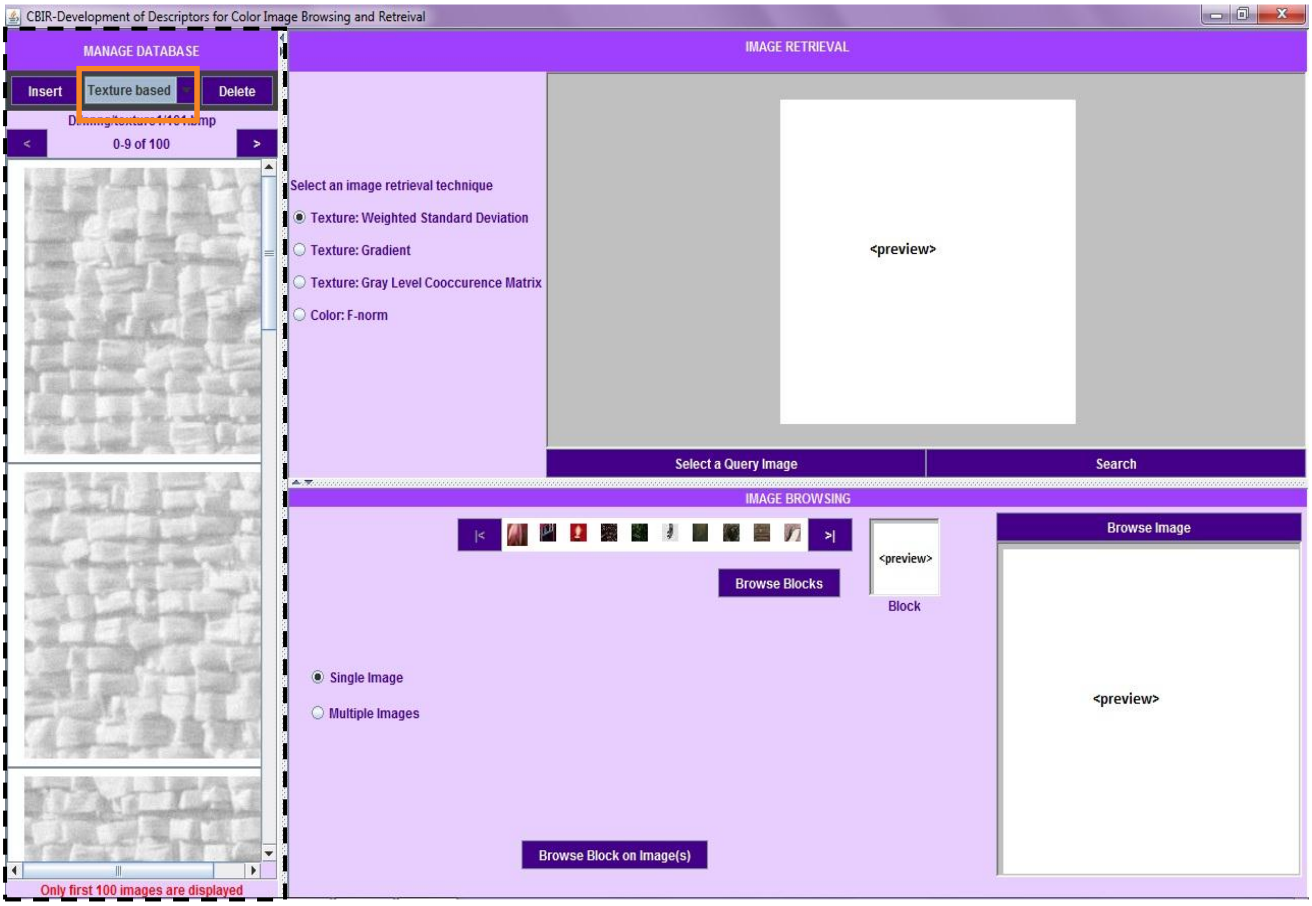


Fig. 34 View Database Function of Manage Offline Features Module which shows the images whose offline features are stored in tables of all Texture based descriptors

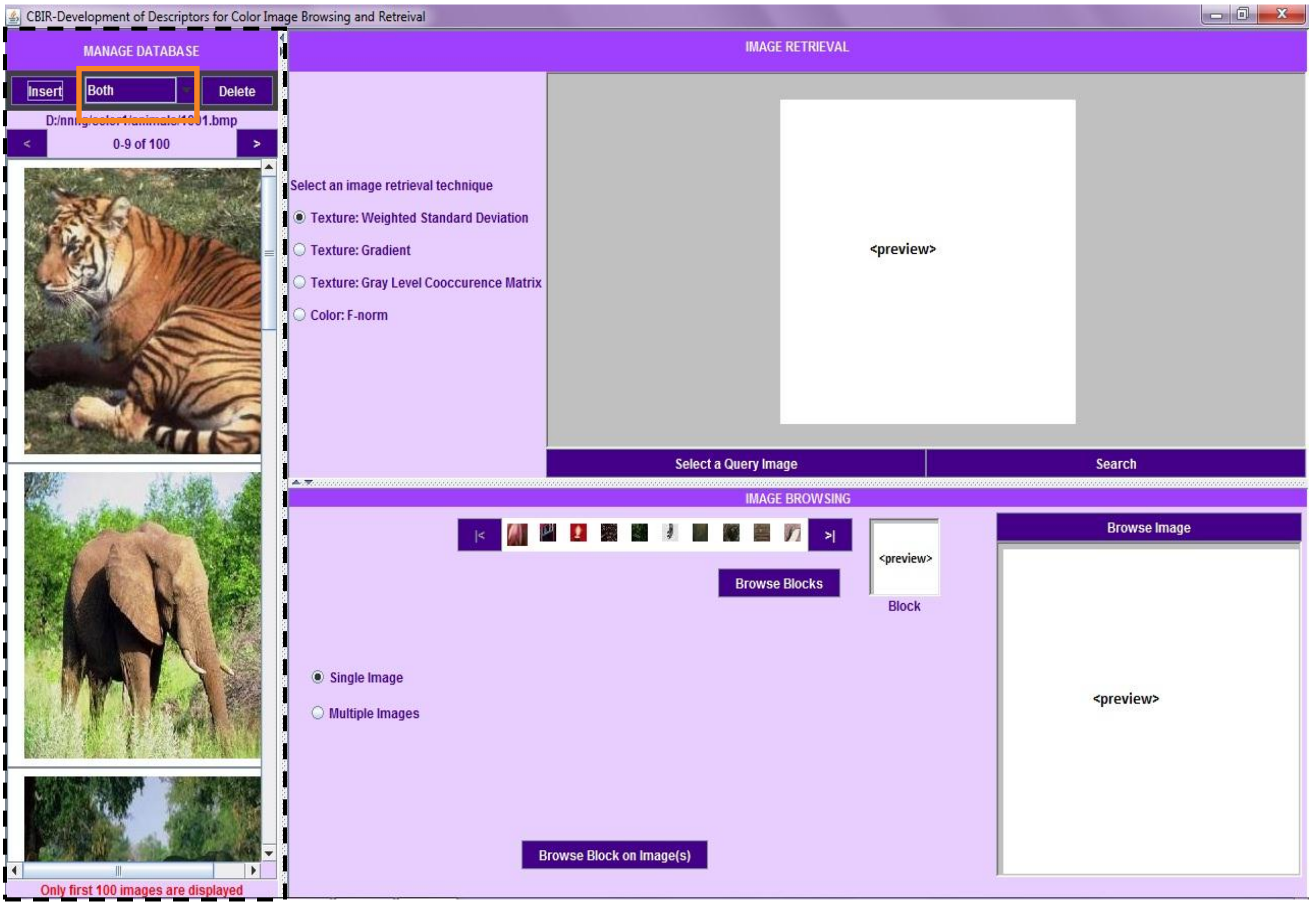
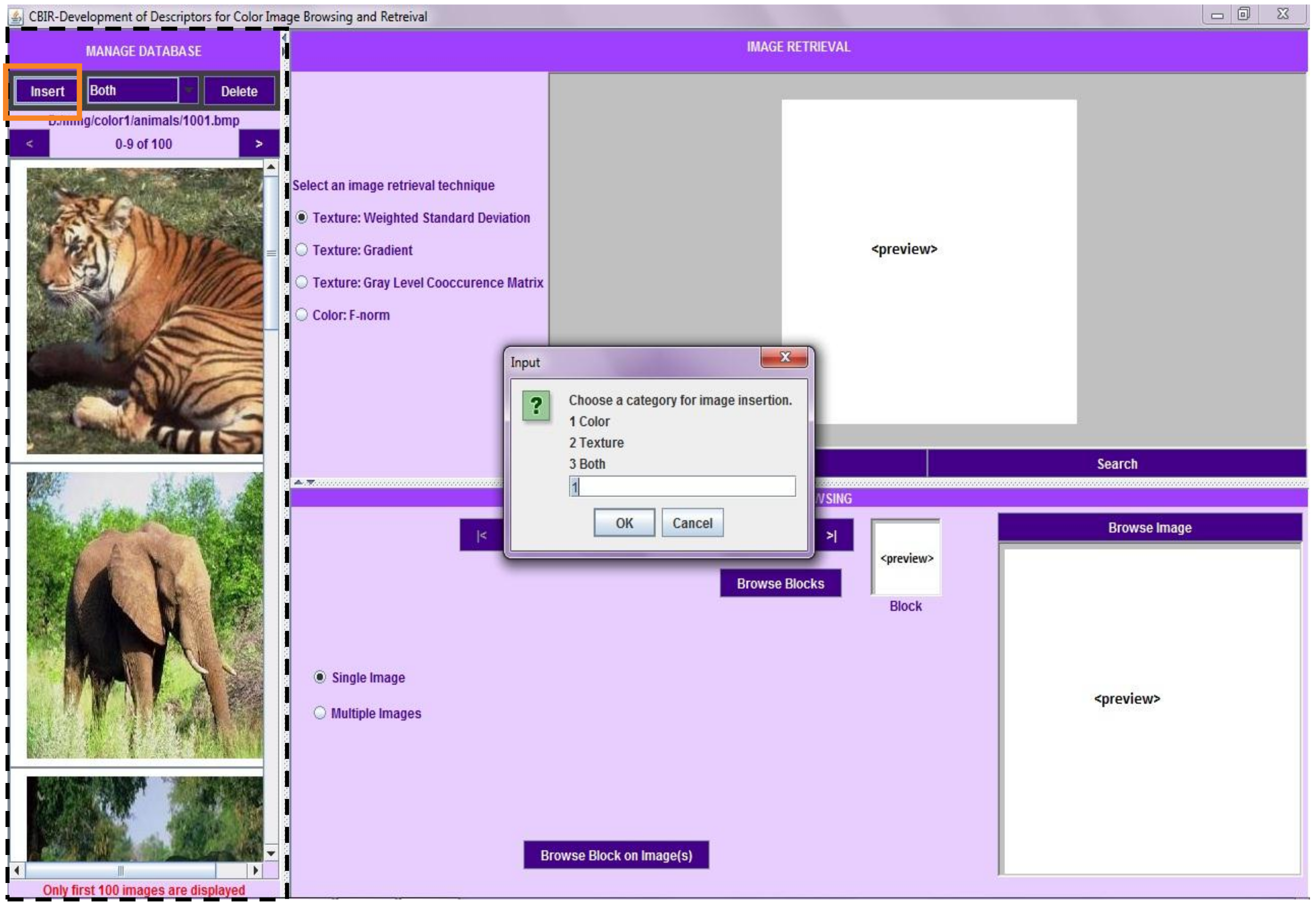


Fig. 35 View Database Function of Manage Offline Features Module which shows the images whose offline features are stored in tables of both Color and Texture based descriptors

A.2) Insert Function



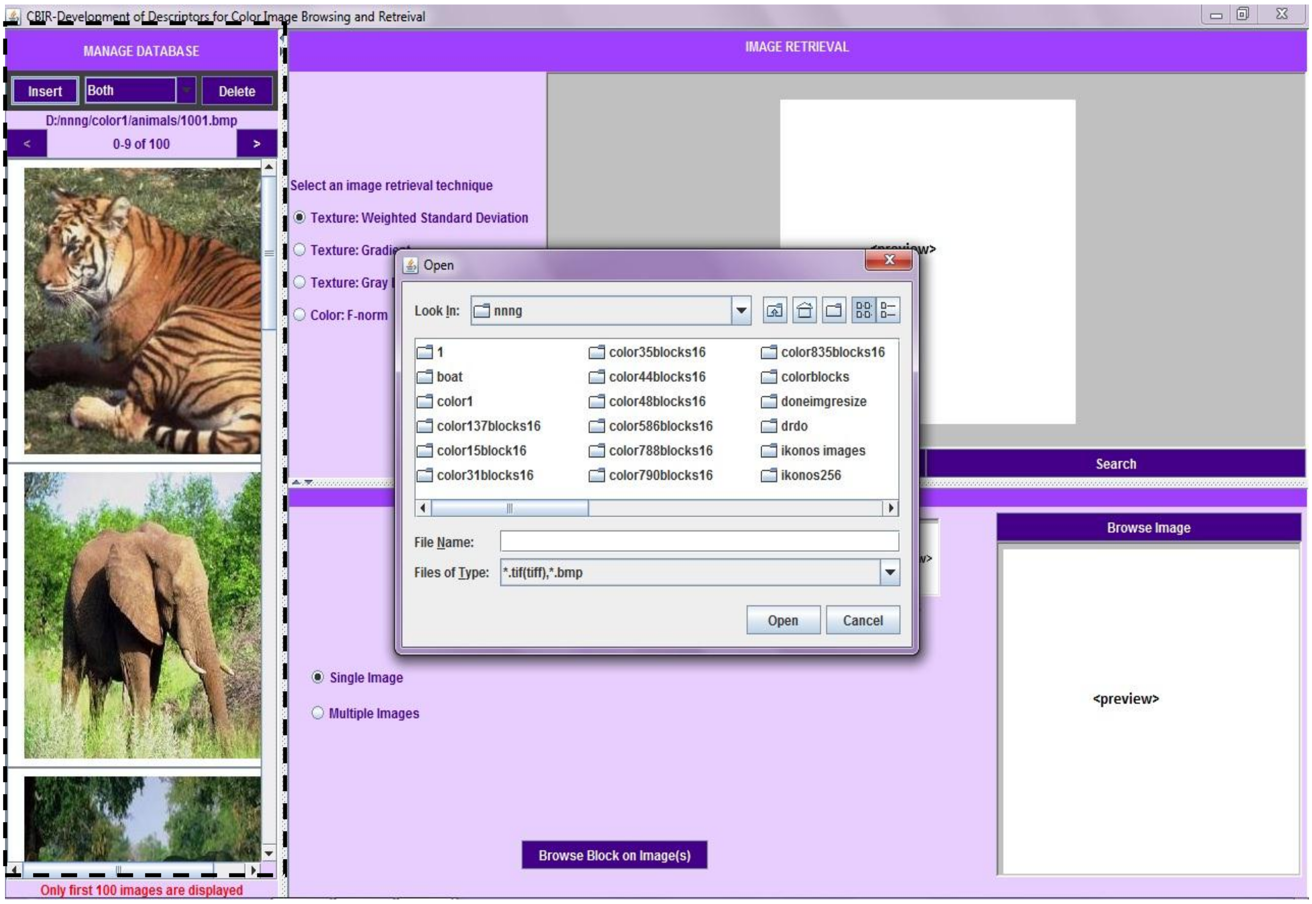
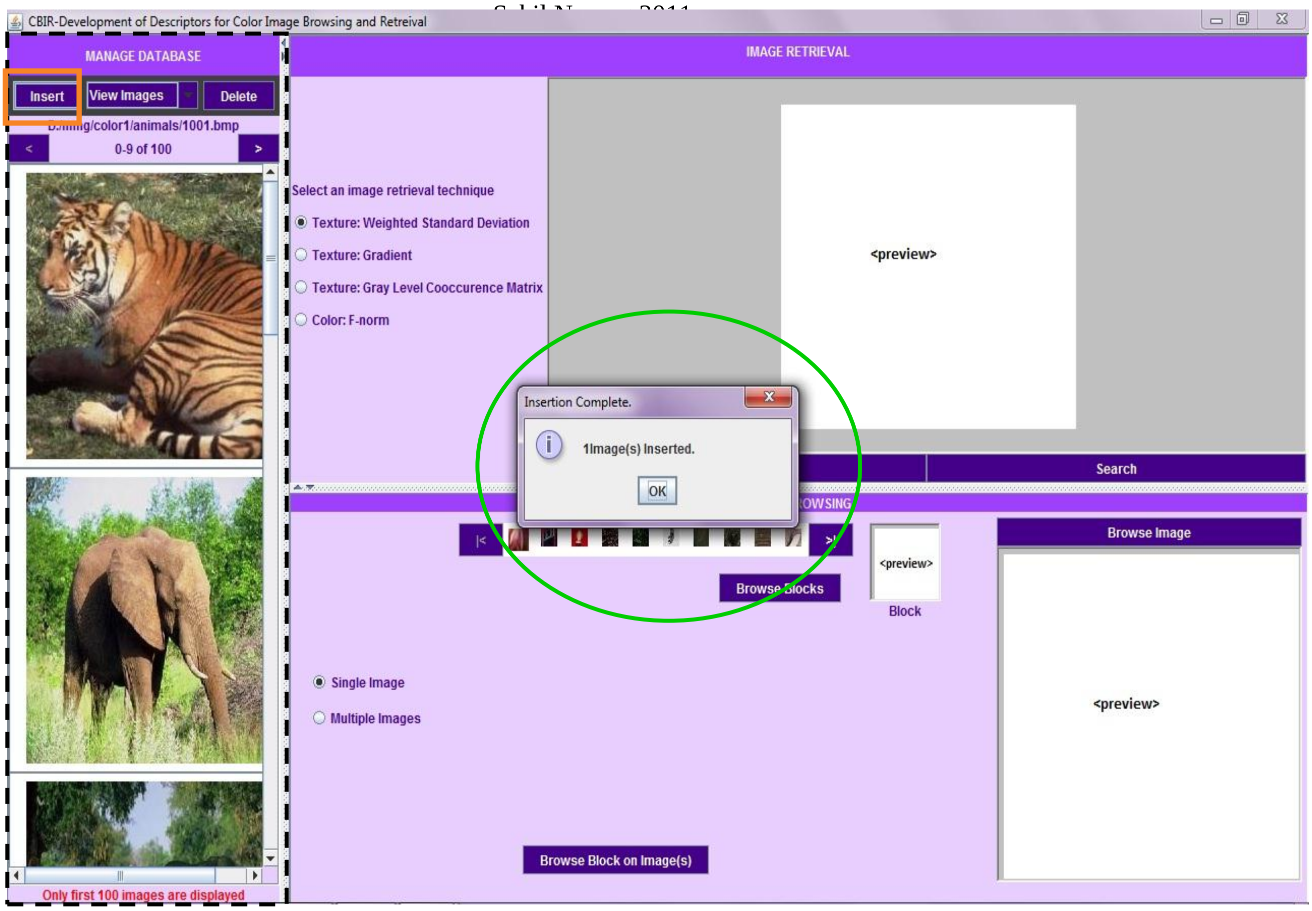


Fig. 36 When the button Insert highlighted in orange is clicked, two inputs a) the type of descriptor b) the path of the image(s) to be inserted are taken in sequence as shown in upper and lower snapshots respectively



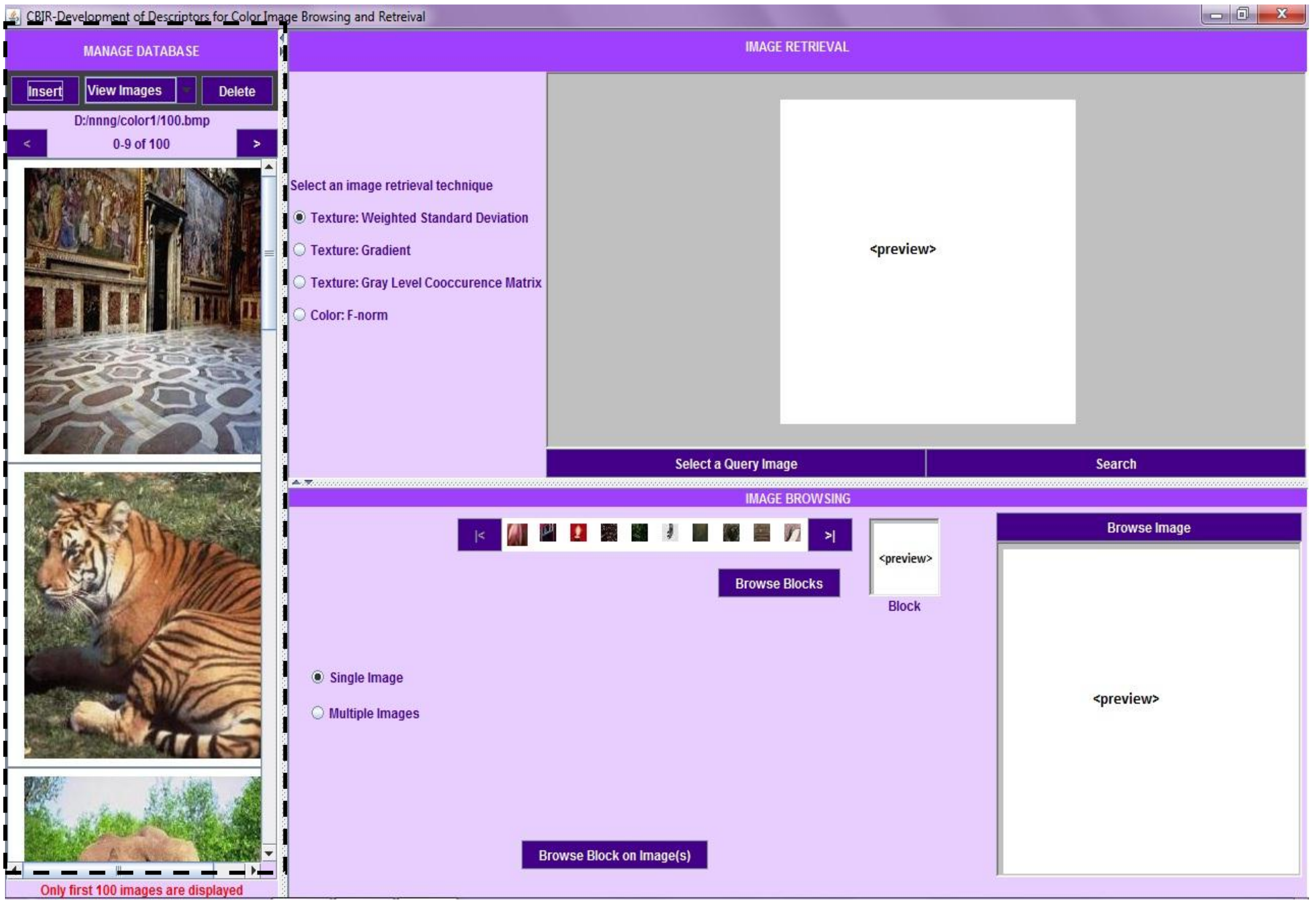
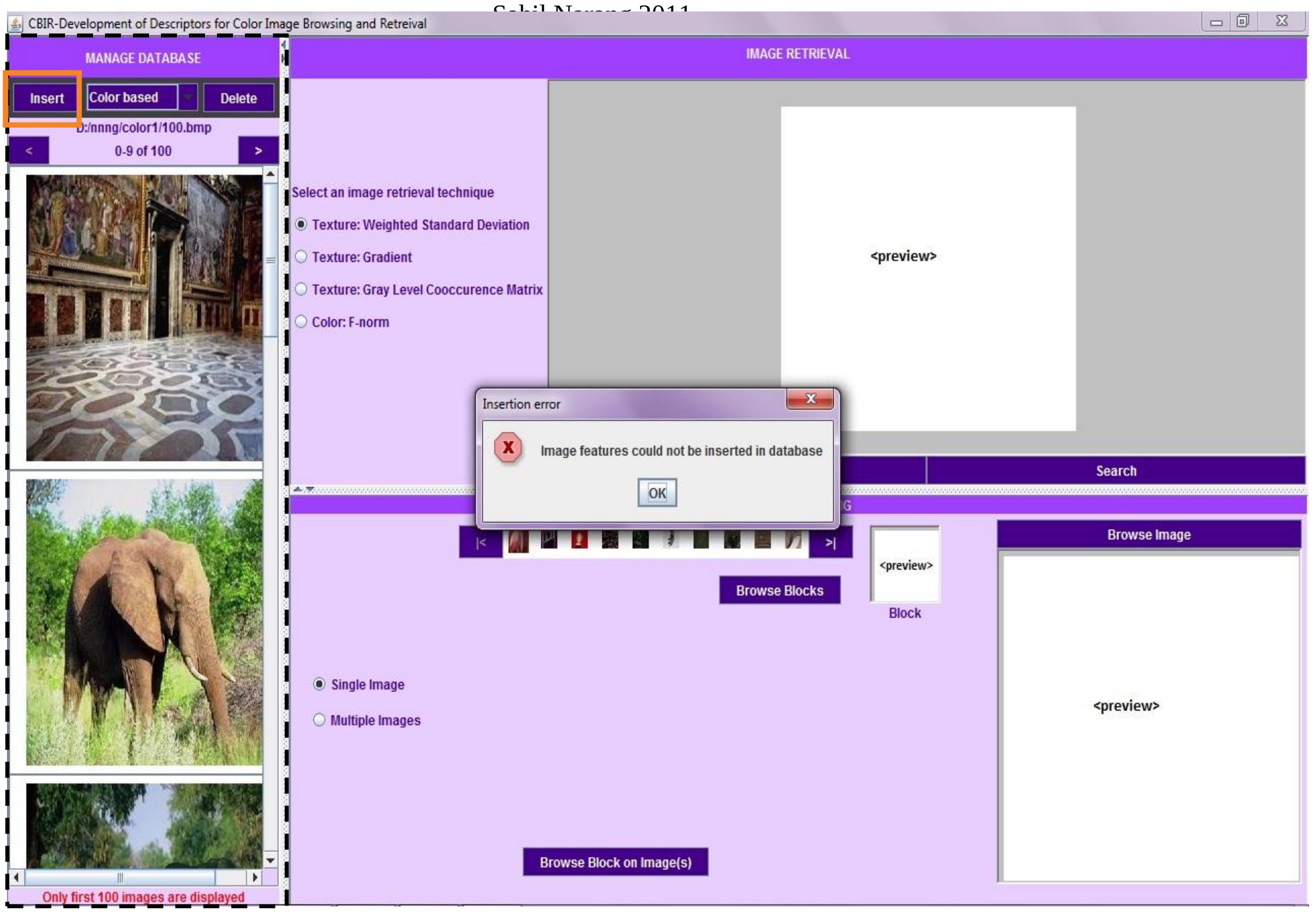


Fig. 37 The output of successful insertion of the image(s) in the database is shown here. The upper snapshot shows the message box and the next is obtained when the displayed images are refreshed after insertion



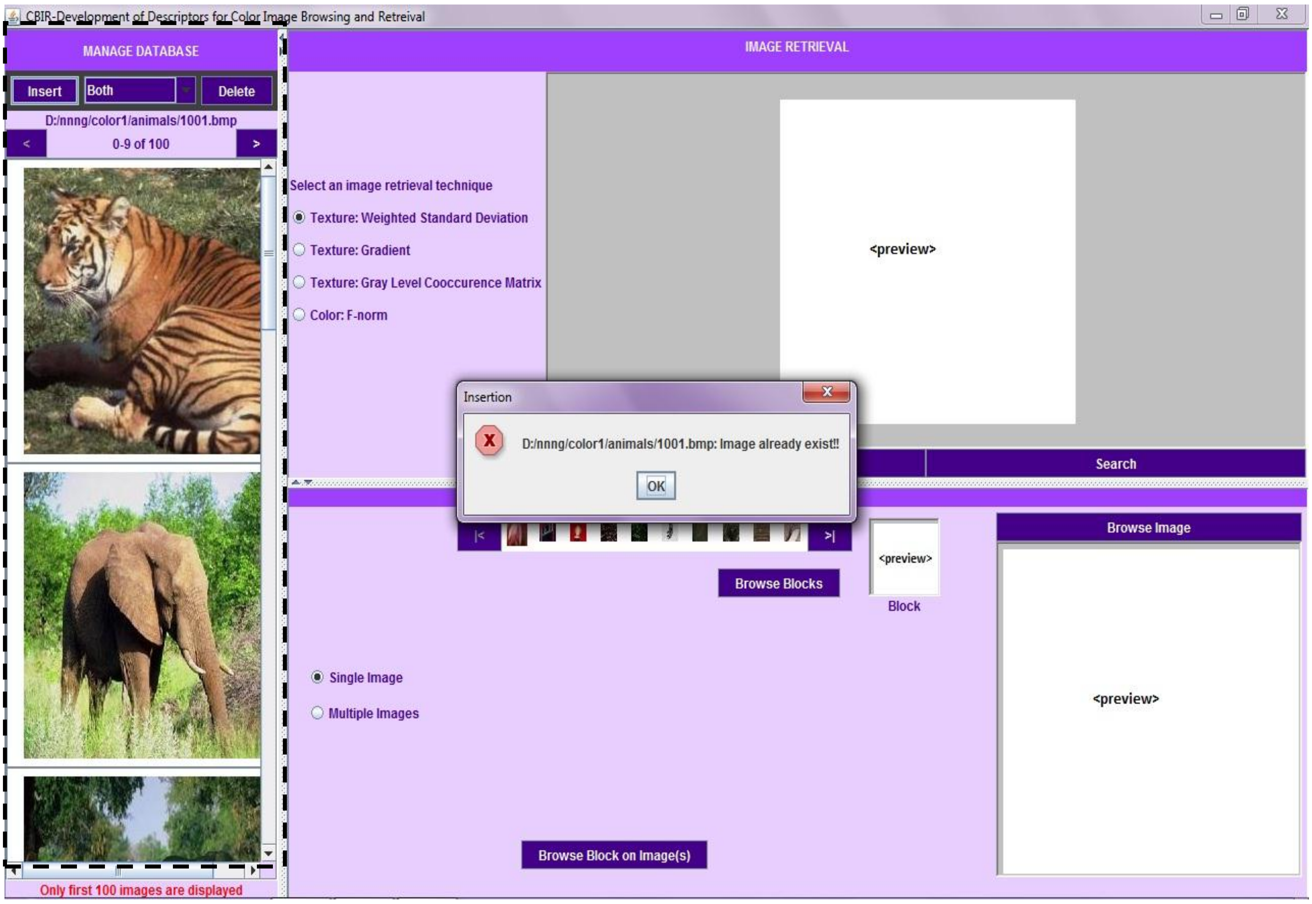
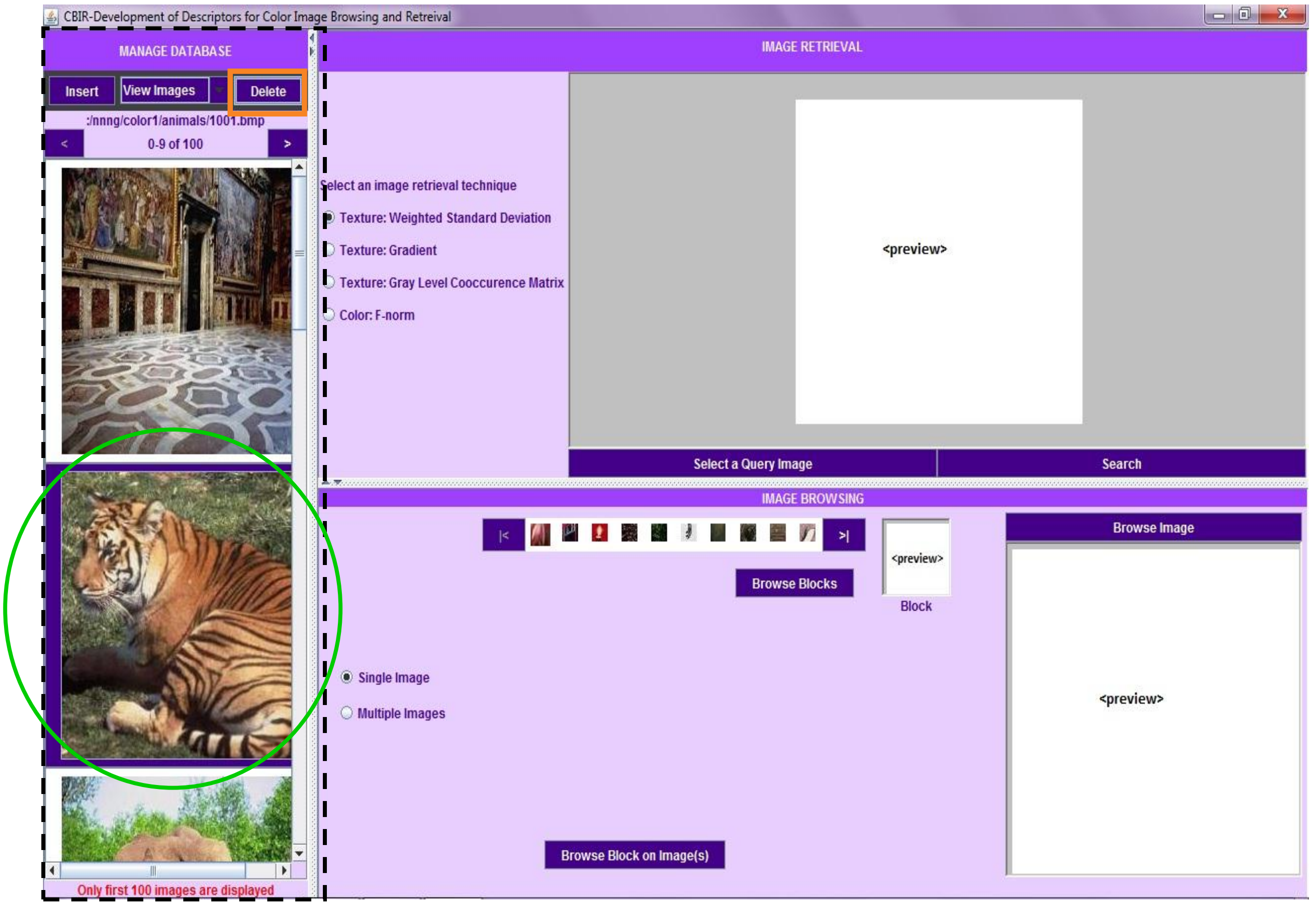


Fig. 38 Illustration of erroneous output of insert operation on databases is presented here. The upper error occurs when general problem in insertion occurs whereas the specific primary key problem is shown in the lower snapshot

A.3) Delete Function



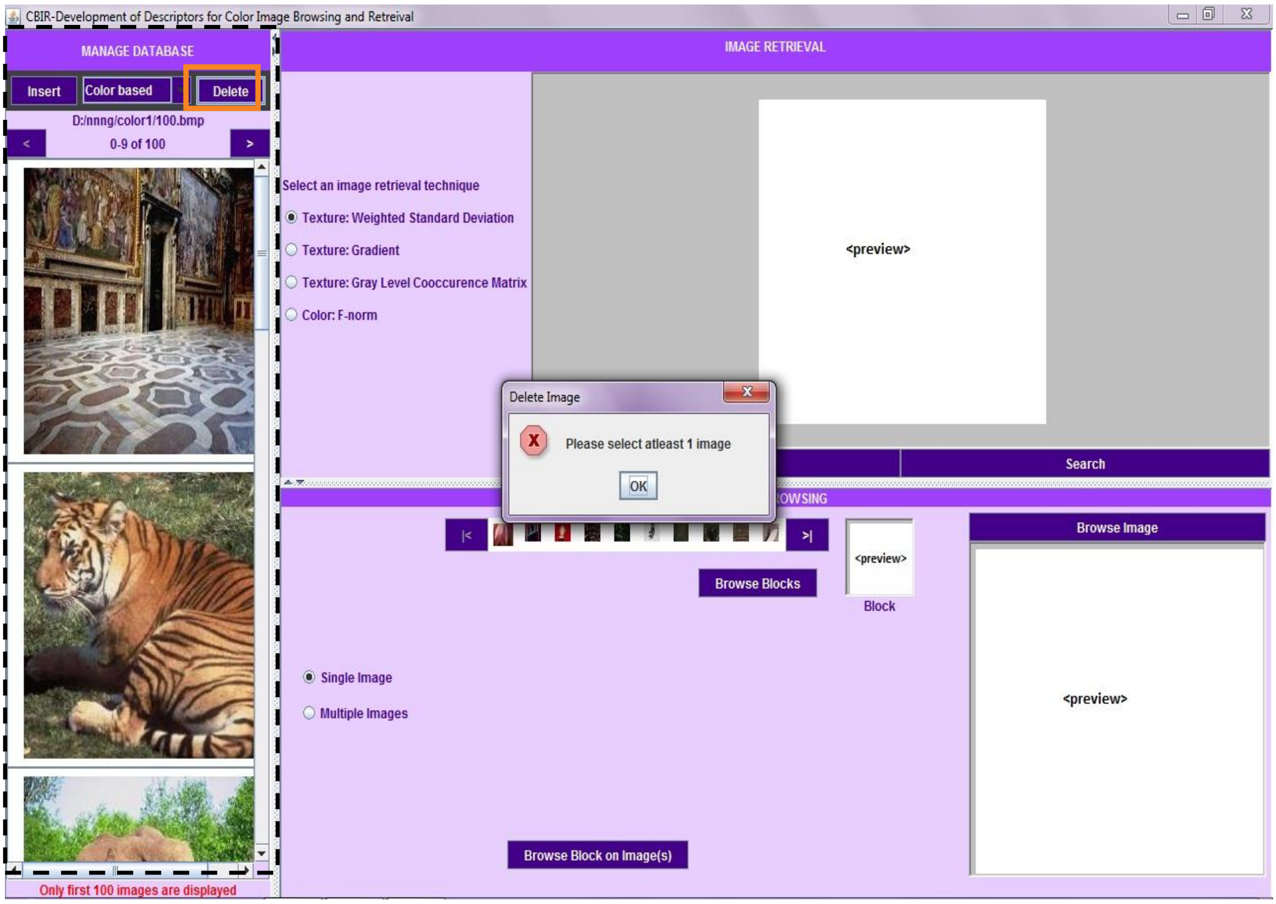


Fig. 39 To delete an image from the database, an image from the list is selected and Delete button clicked. On clicking the button without selection, a validity check is performed failing which an error message is displayed.

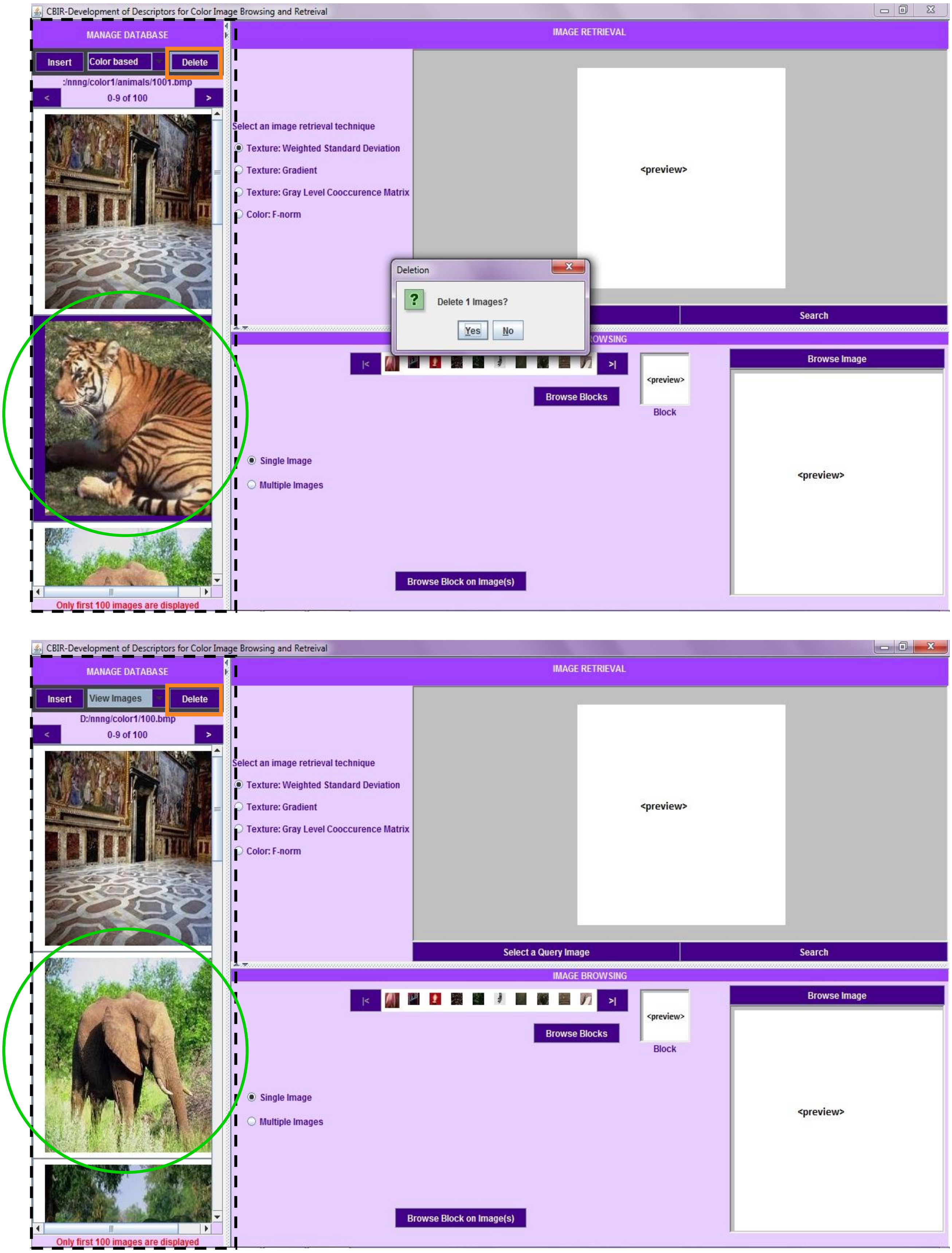


Fig. 40 The image is removed after successful deletion from the database on user's confirmation.

II. SEARCHING MODULE

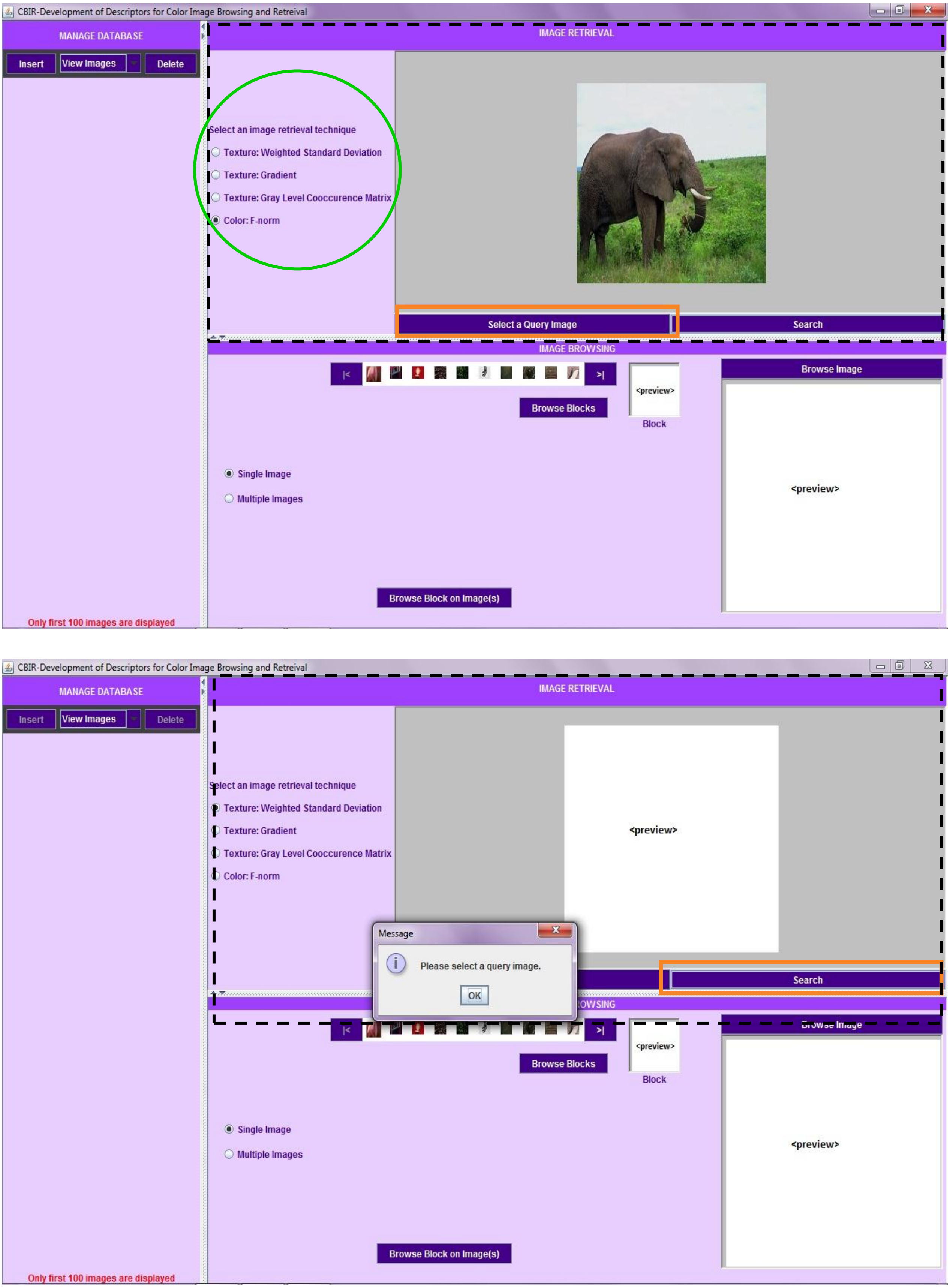


Fig. 41 The input to the search function is the type of technique specified by choosing a radio button encircled in green and a query image given by clicking on the left button. When the search button is directly clicked without the query image input, a validation is performed.

III. Browsing Module

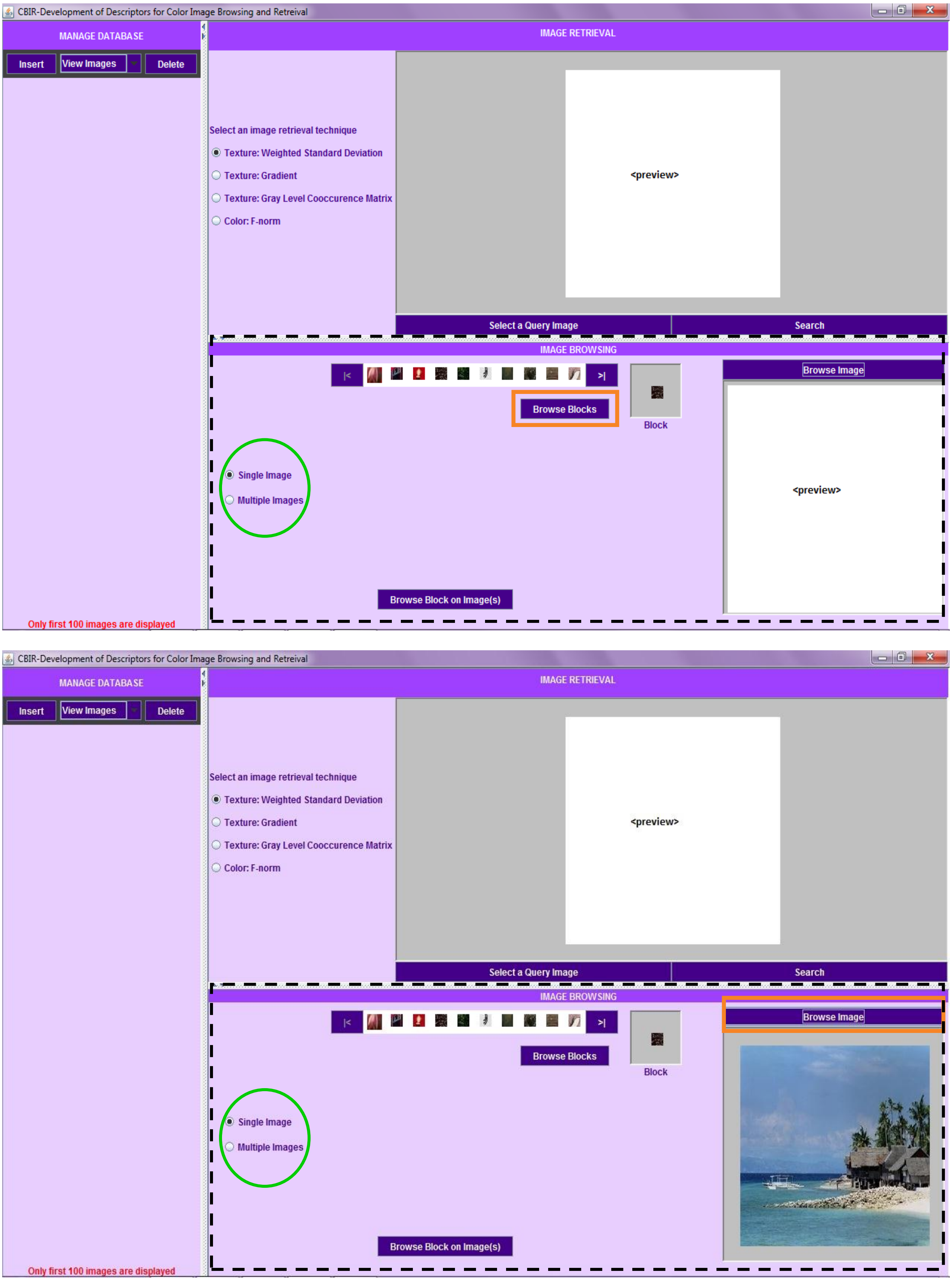
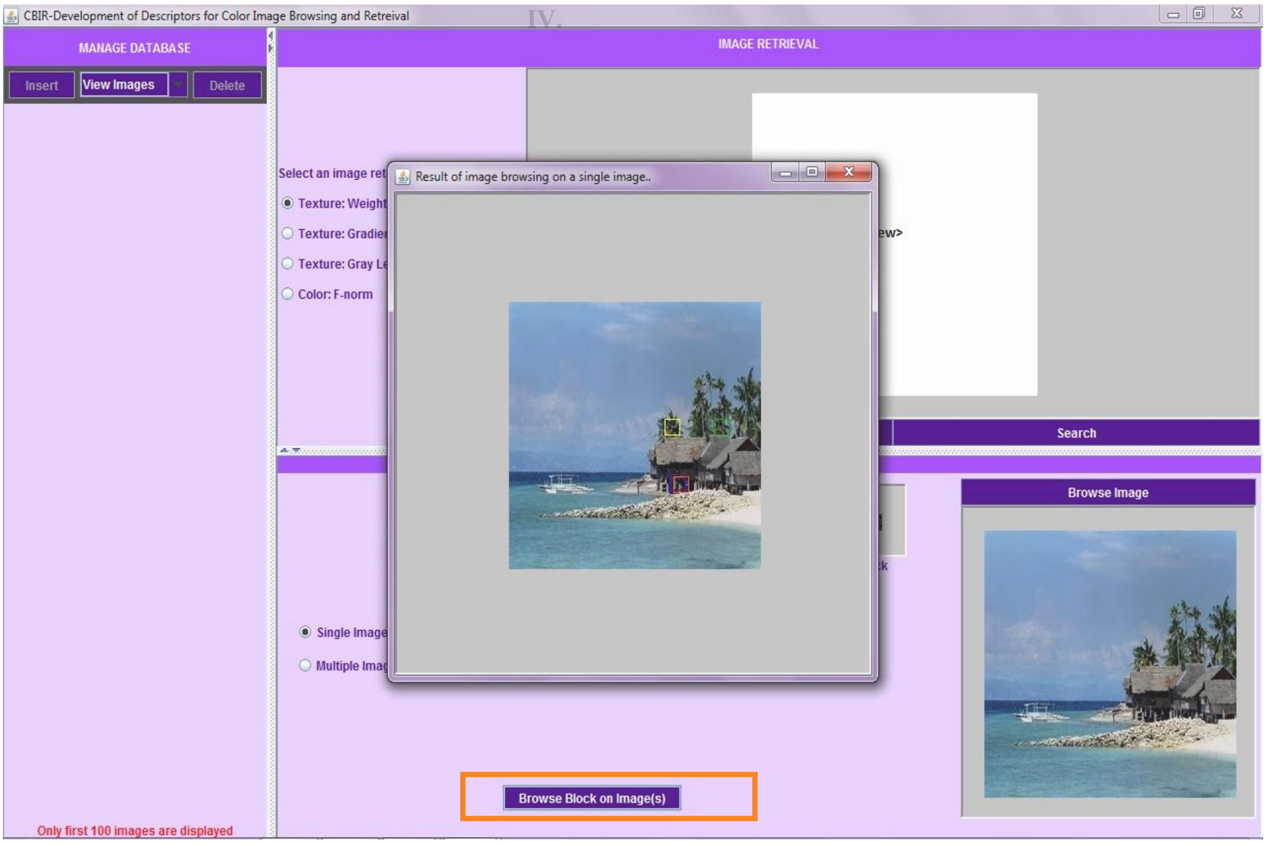


Fig. 44 Two inputs for the block and the image to be browsed are taken



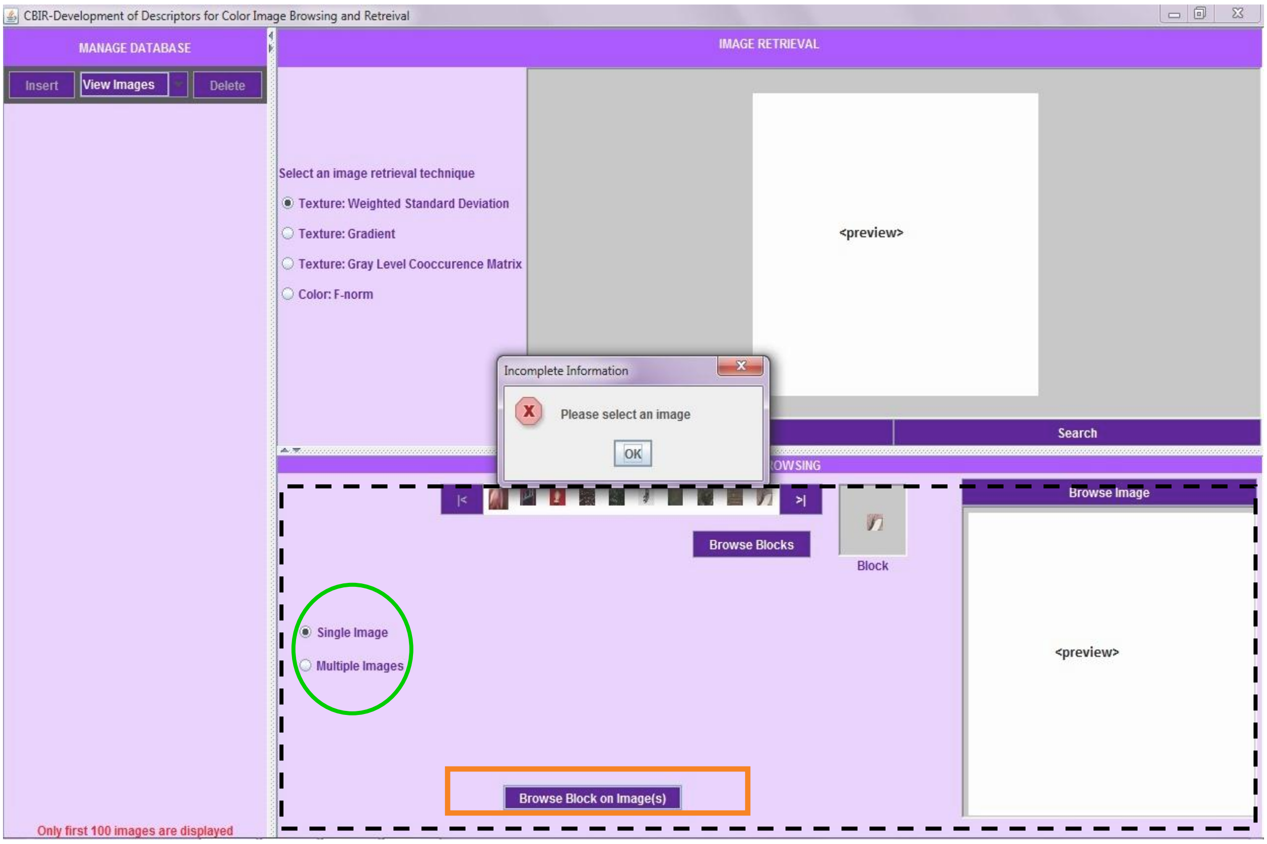


Fig. 45After supplying the inputs, the button outlined with orange color is clicked to trigger the processing and receive the output as portrayed in the upper snapshot. If the user directly clicks on the button without giving all the required inputs, an error message appears.

IV. GUI FOR GET FILE FUNCTION

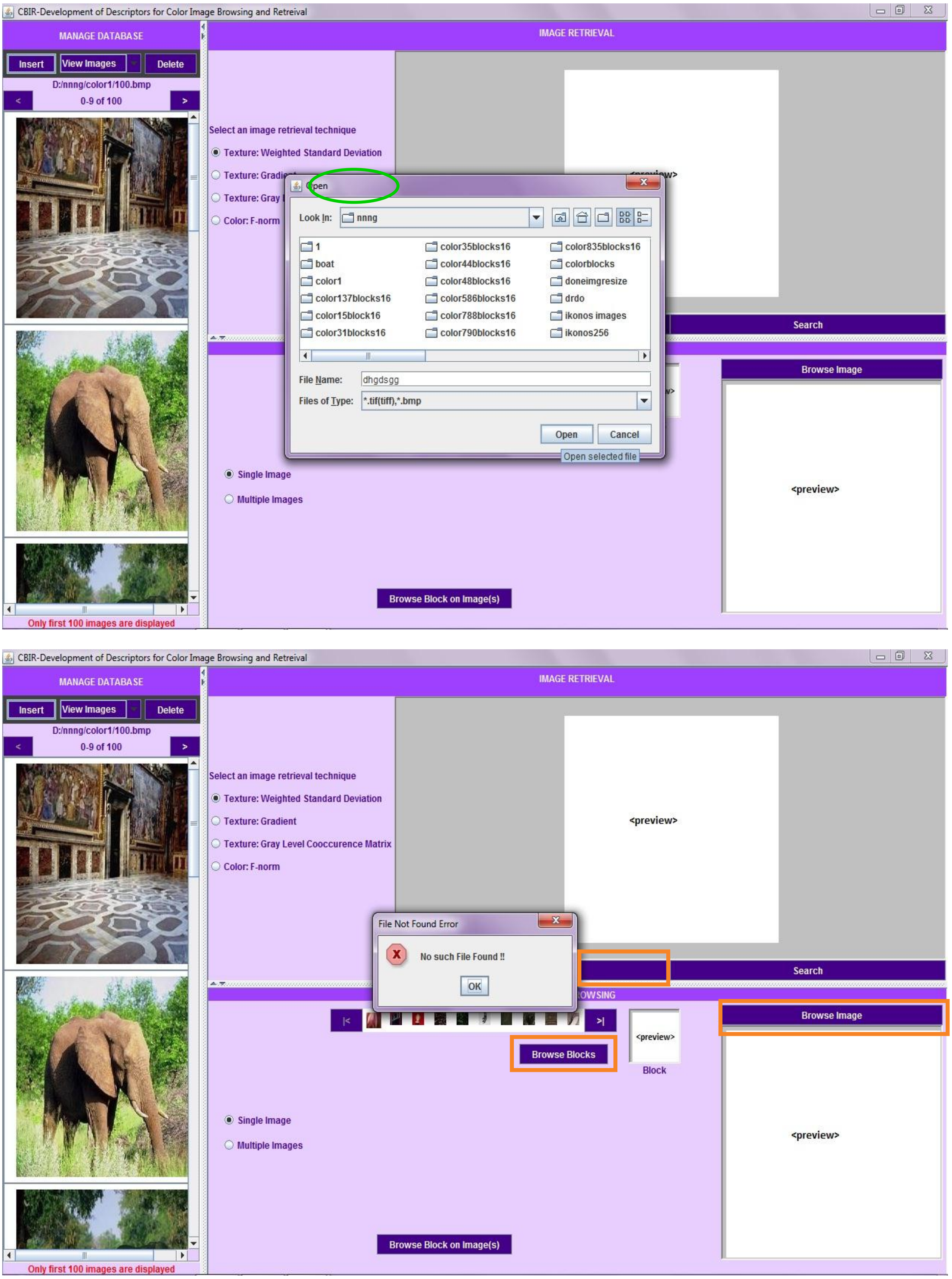


Fig. 53 Image paths for query image, block image and image to be browsed are entered by the user through the "Open" window provided to him. If an invalid path is entered an error message is displayed

RESEARCH PAPER SUBMITTED

S. NO.	PAPER TITLE	CONFERENCE	STATUS
1	Texture based Image Retrieval using Correlation on Haar Wavelet Transform	CNC 2012, Chennai	Accepted. To be Published by Springer.

The papers were submitted under the guidance of D. N. Verma, Scientist 'E', DTRL, DRDO, Ministry of Defence.

Appendix

Chapter I

I. REPRESENTATION OF IMAGES

A. Respresenting Digital Images

Let f(s, t) represent a continuous image function of two continuous variables. This function is converted into a digital image by sampling and quantization. The continuous image is sampled into a 2D array, f(x, y) containing M rows and N columns, where (x,y) are discrete coordinates. For notational clarity and convenience, integer values are used for these discrete coordinates:

$$x = 0, 1, 2 \dots M\text{-}1 \text{ and } y = 0, 1, 2 \dots N\text{-}1$$

The section of the real plane spanned by the coordinates of an image is called the spatial domain. An image can be represented as an array of numerical values of f(x, y). For example, f of size 256X256 would represent an image containing 65536 elements. In equation form, representation of an MXN numerical array can be written as:

$$f(x,y) = \begin{pmatrix} f(0,0) & f(0,1) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & \dots & f(1,N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \dots & f(M-1,N-1) \end{pmatrix}$$

Each element of this matrix is called an *<u>image element</u>*, *<u>picture element</u>*, *<u>pixel</u>*, *<u>or pel.</u>*

B. Respresenting Color Images

A color image stores set of component values such as a triplet of (R, G, B) or that of hue, saturation, intensity (H, S, I) representing the quantized values of the color spectrum. The matrix representation shown above is capable of storing only the achromatic attribute or gray levels of an image expanding from black to white. Several such matrices are required to store the values of each component comprising the color at a pixel, together giving a representation of color image.

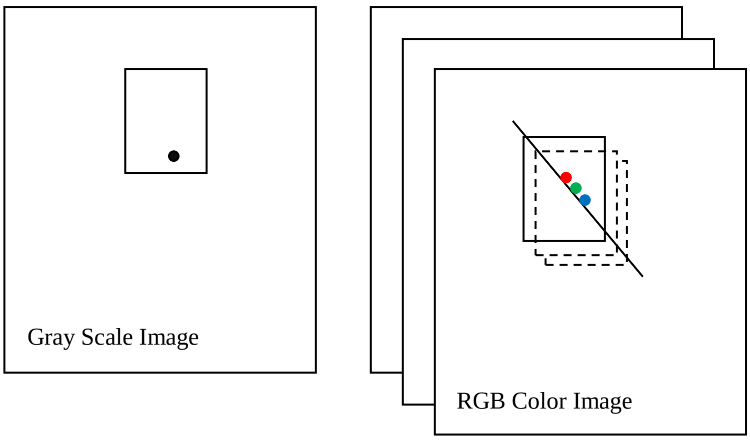


Fig. showing representation of color and gray scale images

II. IMAGE FORMATS

Image file formats are standardized means of organizing and storing images. This description is about digital image formats used to store photographic and other images.

Image files are composed of either pixel or vector (geometric) data that are rasterized to pixels when displayed in a vector graphic display.

A. Bitmap Images (BMP)

A.1) *Introduction*

The BMP file format (Windows bitmap) handles graphics files within the Microsoft Windows OS. Typically, BMP files are uncompressed, hence they are large; the advantage is their simplicity, wide acceptance, and use in Windows programs. BMP format can accommodate images that are black and white (1 bit per pixel) up to true color (24 bits per pixel). A BMP file consists of either 3 or 4 parts. The first part is the header, followed by an information section, and then the palette follows for indexed color images, and last of all is the pixel data. The header contains position of the image data with respect to the start of the file, image width and height, the type of compression and other useful information.

A typical BMP file usually consists the following blocks of data:

TABLE I
BLOCKS OF DATA FOR BMP FILE

Block	Description
BMP Header	Stores general information about the BMP file
Bitmap Information	Stores detailed information about the bitmap image
Color Palette	Stores the definition of the color being used for indexed color bitmaps
Bitmap Data	Stores the actual image, pixel by pixel

A.2) *Bitmap File Header*

TABLE II
BMP FILE HEADER

Start	Size	Name	Standard Value	Purpose
1	2	bfType	19778	Must always be set to ‘BM’ to declare that it is a BMP file
3	4	bfSize	??	Specifies the size of file in bytes
7	2	bfReserved1	0	Must always be set to 0
9	2	bfReserved2	0	Must always be set to 0
11	4	bfOffBits	1078	Specifies the offset from the beginning of the file to the bitmap data
15	4	biSize	40	Specifies the size of the *Bitmap Info Header* structure in bytes
19	4	biWidth	100	Specifies width of image in pixels
23	4	biHeight	100	Specifies height of image in pixels
27	2	Biplanes	1	Specifies the number of planes of the target device, must be set to 0
29	2	biBitCount	8	Specifies the number of bits per pixel
31	4	biCompression	0	Specifies the type of compression,

Start	Size	Name	Standard Value	Purpose
				usually set to 0 (no compression)
35	4	biSizeImage	0	Specifies size of image data in bytes. If there is no compression, it is valid to set this member as 0
39	4	biXPelsPerMeter	0	Specifies horizontal pixels per meter on the designated target device, usually set to 0
43	4	biYPelsPerMeter	0	Specifies vertical pixels per meter on the designated target device, usually set to 0
47	4	biClrUsed	0	Specifies number of colors used in the bitmap, if set to 0, the number of colors is calculated using biBitCount member
51	4	biClrImportant	0	Specifies number of colors that are 'important' for bitmap, if set to 0, all colors are important

A.3) *RGB Quad Array*

The following table shows a single RGBQUAD structure, which helps in retrieving red, green and blue color value of a pixel:

TABLE III
BMP RGB QUAD ARRAY INFORMATION

Start	Size	Name	Standard Value	Purpose
1	1	rgbBlue	-	Specifies the blue part of color
2	1	rgbGreen	-	Specifies the green part of color
3	1	rgbRed	-	Specifies the red part of color
4	1	rgbReserved	-	Must always be set to 0

B. Tagged Image File Format (TIFF or TIF)

B.1) *Introduction*

TIFF (Tagged Image File Format) is a flexible image file format. A file is defined to be a sequence of 8-bit bytes, where the bytes are numbered from 0 to N. the largest possible TIFF file is 2^{32} bytes in length. The TIFF file format's flexibility is both blessing and curse, because no single reader reads every type of TIFF file. The TIFF image format is not widely supported by web browsers.

A TIFF file begins with an 8-byte image file header that points to an image file directory (IFD). An image file directory contains information about the image, as well as pointers to the actual image data.

B.2) *Image File Header*

A TIFF file begins with an 8-byte image file header, containing the following information:

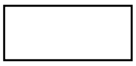
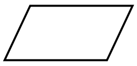
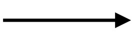
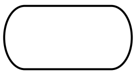
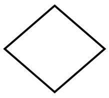
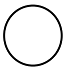
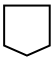
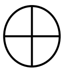
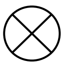
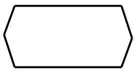
TABLE IV
TIFF FILE HEADER INFORMATION

Bytes	Values	Purpose
0 – 1	II (4949.H)	Specifies that the byte order used in the file is from the least significant to the most significant byte, for both 16-bit and 32-bit integers. This is called *Little Endian byte order*.
	MM (4D4D.H)	Specifies that the byte order used in the file is from the most significant to the least significant byte, for both 16-bit and 32-bit integers. This is called *Big Endian byte order*.
2 – 3	42	An arbitrary but carefully chosen number (42) that identifies the file as a TIFF file. The byte order depends on the bytes 0 – 1
4 – 7	-	The offset (in bytes) of the first IFD. The directory may be at any location in the file after the header but *must begin on a word boundary*. In particular, an Image File Directory may follow the image data it describes. Readers must follow the pointers wherever they may lead. The term *byte offset* is always used in this document to refer to a location with respect to the beginning of the TIFF file. The first byte of the file has an offset of 0.

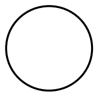
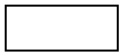
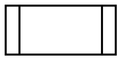
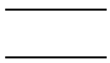
Chapter II

I. STRUCTURAL MODEL

A. Flowchart

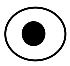
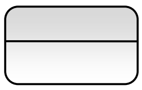
Symbols	Symbol Name	Description
	Process	Show a Process or action step.
	Data	Indicates inputs to and outputs from a process. As such, the shape is more often referred to as an I/O shape than a Data shape
	Predefined Process (Subroutine)	Marker for another process step or series of process flow steps that are formally defined elsewhere. This shape commonly depicts sub-processes.
	Flow Line (Connectors)	Show the direction that the process flows.
	Terminator	Show the start and stop points in a process. When used as a Start symbol, terminators depict a *trigger action* that sets the process flow into motion.
	Condition	Indicates a question or branch in the process flow. Typically, a Decision flowchart shape is used when there are 2 options (Yes/No, No/No-Go, etc.)
	Connector	Show a jump from one point in the process flow to another. Connectors are usually labeled with capital letters (A, B, AA) to show matching jump points. They are handy for avoiding flow lines that cross other shapes and flow lines. They are also handy for jumping to and from a sub-processes defined in a separate area than the main flowchart.
	Off- Page Connector	Shows continuation of a process flowchart onto another page. When using them in conjunction with Connectors, it's best to differentiate the labels, e.g. use numbers for Off-Page Connectors and capital letters for Connectors.
	Merge	Shows the merging of multiple processes or information into one.
	Extract	Shows when a process splits into parallel path.
	Or	Shows when a process diverges - usually for more than 2 branches. When using this symbol, it is important to label the out-going flow lines to indicate the criteria to follow each branch.
	Summing Junction	Shows when multiple branches converge into a single process.
	Loop	Shows the steps of the process that are performed iteraticely

B. Data Flow Diagram

Symbols	Symbol Name	Description
	Data Process	Show a Process or action step.
	Source/ Destination	Indicates the external users/ entities of the system.
	Data Flow	Show the direction that the data flows.
	File Store	Show the data stored in files.
	External Data Storage	Show the data stored in the database

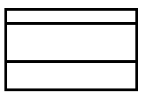
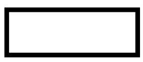
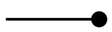
II.BEHAVIORAL MODEL

A. State Diagram

Symbols	Symbol Name	Description
	Filled Circle	Show initial state
	Filled circle in hollow circle	Show final state
	Rounded Rectangle known as State	Top of the rectangle contains a name of the state. Can contain a horizontal line in the middle, below which the activities that are done in that state are indicated
	Arrow denoting transition	The name of the event causing this transition labels the arrow body. A guard expression may be added before a "/" and enclosed in square-brackets ([***event Name*** **[guard Expression]**), denoting that this expression must be true for the transition to take place. If an action is performed during this transition, it is added to the label following a "/" (event ***Name*** **[guard Expression]/action**).

III. OBJECT ORIENTED MODEL

A. Class Diagram

Symbols	Symbol Name	Description
	Class	Indicates the name of the class in the first partition, attributes in the second partition and operations in the third partition.
	Active class	Initiate and control the flow of activity, while Passive class store data and serve other class.
+, −, #	Visibility (Public, Private, Protected)	These are markers to signify who can access information within a class.
	Link	It is used when a class inherits the Serializable class

Chapter III

I. INSERTION SORT

Insertion sort is a simple sorting algorithm, a comparison sort in which the sorted array (or list) is built one entry at a time. It is much less efficient on large lists than more advanced algorithms such as quick sort, or heap sort.

A. Algorithm

Every iteration of insertion sort removes an element from the input data, inserting it into the correct position in the already-sorted list, until no input elements remain.

```
InsertionSort( Array A)
Begin
        For I = 2 to length[A] – 1 step 1
        Begin
                Value = A[i]
                J = I – 1
                Done = false
                Repeat
                        If A[J] > value then
                        Begin
                                A[J+1] = A[J]
                                J = J – 1
                                If J < 0 then
                                        Done = true
                                Else
                                        Done = false
                Until done
                A[J+1] = Value
        End For
    End
```

B. Analysis

The **best** case input is an array that is already sorted. In this case insertion sort has a linear running time (i.e., Θ (n)). During each iteration, the first remaining element of the input is only compared with the right-most element of the sorted subsection of the array.

The **worst** case input is an array sorted in reverse order. In this case every iteration of the inner loop will scan and shift the entire sorted subsection of the array before inserting the next element. For this case insertion sort has a quadratic running time (i.e., O (n^2)).

The **average** case is also quadratic, which makes insertion sort impractical for sorting large arrays.

However, insertion sort is one of the fastest algorithms for sorting arrays containing fewer than sixteen elements.

II. MERGE SORT

Merge sort is an *O* (*n* log *n*) comparison-based sorting algorithm. In most implementations it is stable, meaning that it preserves the input order of equal elements in the sorted output. It is an example of the Divide and Conquer algorithmic paradigm.

A. Algorithm

```
MergeSort (Array M)
Begin
        If (Length (M) ≤ 1)
                Return M
        Middle = Length (M) ÷ 2
        For each X in M up to Middle
                Add X to left
        For each X in M up to Middle
                Add X to right
        Left = MergeSort(Left)
        Right = MergeSort(Right)
        Result = MergeSort(Left, Right)
        Return Result
End
```

After writing MergeSort, it is required to merge both the left and right lists created above.

```
Merge (Left, Right)
        While Length (Left) > 0 and Length (Right) > 0
                If first (Left) ≤ first (Right)
                        Append first (Left) to Result
                        Left = rest (Left)
                Else
                        Append first (Right) to Result
                        Right = rest (Right)
        End While
        If Length (Left) > 0
                Append Left to Result
        Else
```

Append Right to Result

Return Result

End

B. Analysis

In sorting N objects, merge sort has an **average** and **worst** case performance of O (N log N).

Chapter IV

4.1 WSD TECHNIQUE

The decomposed gray level image obtained after applying the Haar transform is subjected to feature extraction procedure by using statistical tools as discussed below. The output of this procedure is a vector containing quantitative values that describe the texture content of the image.

1. An image after L-level DWT contains 3*L+1 sub bands. The standard deviation of 3*L bands (3 of each level) along with the mean and standard deviation of the approximation image obtained at the L^{th} level are calculated.
2. Since these high frequency sub bands lose information at higher levels of decomposition, the standard deviation (SD) of each high frequency sub band image at i^{th} level is weighted by the factor $½^{(i-1)}$, thus assigning higher weights to lower level bands.
3. The 3*L+2 sized feature vector is defined as follows:-

$$TF = \{\sigma_1^{LH}, \sigma_1^{HL}, \sigma_1^{HH}, ½\, \sigma_2^{LH}, ½\, \sigma_2^{HL}, ½\, \sigma_2^{HH} \ldots ½^{(L-1)}\, \sigma_2^{LH}, ½^{(L-1)}\sigma_2^{HL}, ½^{(L-1)}\, \sigma_2^{HH}\, \mu_L^{LL}, \sigma_L^{LL}\}$$

where, *TF stands for Texture Features, σ_iMM is the SD of the MM (stands for LL, LH, HL, or HH sub bands) at decomposition level i and μ is the mean of the approximation image (LL sub band at level 2).*

This texture feature extraction technique is called Weighted Standard Deviation (WSD).

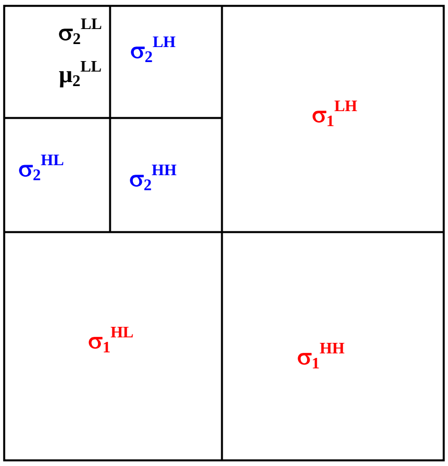


Fig.7 WSD method on 2-level haar

4.2 Gradient Operation on Haar Discrete Wavelet Transform (DWT)

This approach calculates texture features by following steps given below:

1. 1-Level Haar discrete wavelet transform is applied on gray scale images
2. The HL and LH sub bands are used to obtain gradient direction using the formula

$$\theta = \tan^{-1}\left(\frac{gy}{gx}\right)$$

where, gx, gy are horizontal (HL) and vertical (LH) gradient magnitudes, respectively.

3. After calculating gradient theta, 9 bins, each of 40 degree are calculated.
4. For each calculated bin, one or a combination of mean, standard deviation and entropy are computed resulting in the texture feature content descriptor.

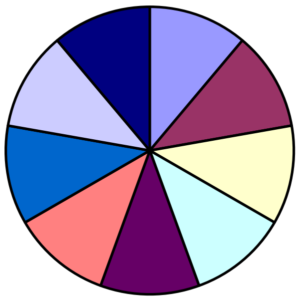


Fig.7 Division of θ values in 9 bins of 40º each. Statistics is applied on the values of each bin

4.3 Gradient Operation

The Sobel gradient mask is applied directly on gray scale image to obtain the gradient direction, theta of each pixel. Then, steps 3, 4 mentioned above are followed.

1	0	-1
2	0	-2
1	0	-1

1	2	1
0	0	0
-1	-2	-1

Fig.8 Vertical & Horizontal Sobel masks

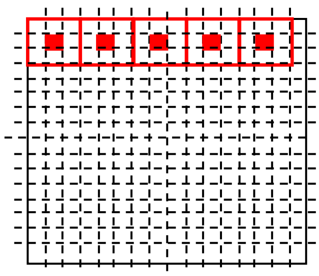


Fig.9 A brief illustration of masking

4.4 WSD with Gradient Operation

This approach calculates texture features by following steps given below:

1. 1-Level Haar discrete wavelet transform is applied on gray scale images.

2. 5 WSD features are computed.

3. Gradient theta is calculated and divided into 9 bins.

4. For each bin, a pair of statistical methods is computed resulting in a total of (9*2 + 5 =23) features.

4.5 Implementation of Co-occurrence Matrix on Image

GLCM is a spatial domain technique. It is a tabulation of how often different combinations of pixel brightness values (Gray Levels) occur in an image. The texture features are calculated by following the underlined steps in order:

1. Four co occurrence matrices are computed from the gray scale image by considering distance between pixels to be 1 and the four directions as 0^0, 45^0, 90^0 and 135^0.
2. For each co occurrence matrix so obtained, four features namely; contrast, correlation, energy and homogeneity are calculated, thus resulting in a feature vector of size 16.

1	2	3
1	3	1
4	3	1

	1	**2**	**3**	**4**
1	**2**	0	0	**1**
2	0	0	**1**	0
3	**1**	0	**1**	0
4	0	0	0	0

Fig.10 Formation of co-occurrence matrix for 90° direction and a single gap between the pixels

Definitions, Acronyms & Abbreviations

I. DEFINITIONS

Bands

In Java AWT API, a sample is the most basic unit of image data. Each pixel is composed of a set of samples. For an RGB pixel, there are 3 samples; one for Red, Green, Blue. All samples of the same kind across all pixels in an image constitute a band. For e.g.: in an RGB image, all red samples together make up a band. Therefore, an RGB image has three bands. A three-color subtractive image contains three bands; one each for cyan, magenta, and yellow (CMY). A four-color subtractive image contains four bands; one each for cyan, magenta, yellow, and black (CMYK).

Color Band

The set of all samples of one type in an image, such as all red samples or all green samples

Color Space

A color model is a specification of a coordinate system and a subspace within that system where each color is represented by a single point. The purpose is to facilitate the specification of colors in some standard way.

Discrete Wavelet Transform

See Multiresolution Theory

Frequency Domain

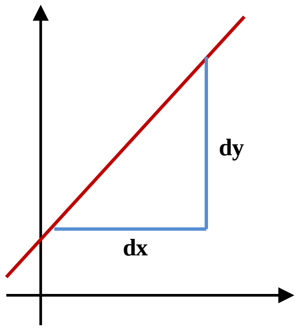
In general, this domain causes changes in image position correspond to changes in the spatial frequency. This is the rate at which image intensity values are changing in the spatial domain image.

In context with Image Processing, it transforms the image to its frequency representation, perform image processing and compute inverse transform back to the spatial domain.

Example of Frequency Domain is Fourier Transform.

Gradient

The gradient or slope of a line describes its steepness, incline, or grade. A higher value indicates a steeper incline. The slope is defined as the ratio of the “rise” divided by the “run” between two points on a line. In other words, it is the ratio of the altitude change to the horizontal distance between two points. Given two points (x_1, y_1) and (x_2, y_2) on a line, the slope *m* of a line is:



$$m = (y_2 - y_1) \div (x_2 - x_1)$$

A horizontal line has slope 0º, a 45º rising line has a slope of +1, a 45º falling line has a slope of -1. a vertical line's slope is undefined. The angle θ a line makes with the positive X-axis is closely related to the slope *m* via the *tangent function*:

$$m = \tan \theta$$

$$\theta = \tan^{-1}(m)$$

Two lines are parallel if and only if their slopes are equal and they are not coincident or if they both are vertical and therefore have undefined slopes. Two lines are perpendicular if the product of their slopes is -1or one has a slope of 0 (a horizontal line) and the other has an undefined slope (a vertical line).

Gray Level

It refers to a scalar measure of intensity that ranges from black, to grays, and finally to white.

Multi-resolution Theory

Multi-resolution analysis incorporates and unifies techniques from a variety of disciplines including subband coding and pyramidal image processing. It is concerned with the representation and analysis of signals at more than one resolution. Features that might go undetected at one resolution may be easy to detect at another. The three image-related operations which are tied to MRA are briefed here:

1. *Image Pyramid:* An image pyramid is a collection of decreasing resolution images arranged in the shape of a pyramid. The base of the pyramid contains a high resolution representation and the apex contains a low resolution approximation as shown in the figure. Prediction residual pyramid is obtained by finding prediction residual, which is defined as the difference between the approximations of two subsequent levels.

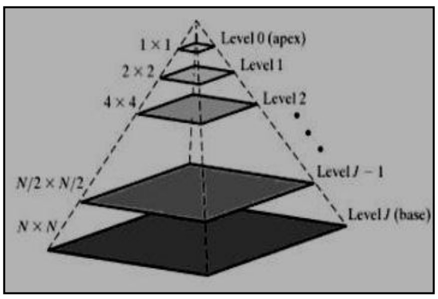


Fig. showing image pyramid

2. *Subband Coding:* In subband coding an image is decomposed into a set of band limited components called sub bands. The decomposition is done by using digital filters. The output of a low pass filter is called an approximation (LL), while those of high pass filter are called high frequency or detailed part (HH, LH, HL).
3. *Haar Transform:* This is the third and final imaging-related operation which ties to MRA.

The combination of pyramid coding, subband coding and Haar transform is called the *Discrete Wavelet Transform.*

Pixel

It is the smallest unit of information in an image. *See chapters.*

Raster

It is a Java 2-D image Data class. It represents a rectangular array of pixels and provides methods of representing data. A Raster has methods that directly return pixel data for the image data it contains.

RenderedImage

Java 2-D API introduces a notion of resolution independent image rendering by introduction of Renderable and Rendered Interfaces, allowing images to be pulled through a chain of filter operations, with image resolution selected through a rendering context.

Satellite

A satellite is an object that moves in a definite path around a planet. Satellites have enabled man to gather and study information of the earth's surface through the sensors mounted on them.

Sensor

A remote sensing sensor system records the electromagnetic radiation from the earth's surface through a specified window. This window allows only a particular wavelength of energy to pass through it. For example, radar is a sensing system from which the waves, propagating near the sensor, bounced on the earth's surface are recorded by it on their return.

Sets

A set is a collection of distinct objects. It can be defined as any collection *M* of definite, distinct objects *m* (which are called the "elements" of *M*). The elements or members of a set can be anything: numbers, people, letters of alphabet etc.

Set Theory is the branch of mathematics that studies sets. It begins with a binary relation between an object O and a set A. If O is a member of A, it is denoted as O € A. Since sets are objects, the membership relation can relate sets as well.

Spatial Domain

Spatial Domain is known as the “Normal” image space. In this domain, changes in pixel positions correspond to changes in the scene and distances correspond to real distances.

In context with Image Processing, it directly process the input image pixel array.

II. ACRONYMS & ABBREVIATIONS

	Full Form
BMP	Bitmap
CBIR	Content Based Image Retrieval
DWT	Discrete Wavelet Transform
GLCM	Gray Level Co-occurrence Matrix
GUI	Graphical User Interface
IRS	Indian Remote Sensing
JAI	Java Advanced Imaging
JRE	Java Runtime Environment
LISS	Linear Image Self Scanning
MRA	Multi-resolution Analysis
MSS	Multi –spectral Scanner
ODBC	Open Database Connectivity
Opt.	Operation
QbE	Query by Example
QbT	Query by Text
RAM	Random Access Memory
RDBMS	Relational Database Management System
SD	Standard Deviation
SDS	Software Design Specification
SRS	Software Requirement Specification
SQL	Structured Query Language
TIFF	Tagged Image File Format
WSD	Weighted Standard Deviation

Formulae

Feature Extraction Technique	Descriptor	Explanation	Formula
Correlation	Correlation	It gives a measure of the correlation between two images. This measure is not defined if either SD is 0.	$\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}(P1_{ij}-\overline{P1})(P2_{ij}-\overline{P2})}{\sqrt[2]{\sum_{i=i}^{N}\sum_{j=1}^{N}(P1_{ij}-\overline{P1})\sum_{i=1}^{N}\sum_{j=1}^{N}(P2_{ij}-\overline{P2})}}$
	Standard Deviation	It gives the variation of the pixel values from the mean of all pixel values.	$\sqrt[2]{(1/(N^2-1))\sum_{i=1}^{N}\sum_{j=1}^{N}(P_{ij}-Mean)^2}$
	Energy	It gives a measure of the information content of a image.	$\sum_{i=1}^{N}\sum_{j=1}^{N}(P_{ij})^2$
	Mean	It is the average of all pixel values in the image.	$(1/N^2)\sum_{i=1}^{N}\sum_{j=1}^{N}P_{ij}$
Here NxN is the size of image, N^2 is the no. of pixels. P_{ij}, $P1_{ij}$, $P2_{ij}$ represents the value of the pixel at position (i,j) of the corresponding images. $\overline{P1}$ and $\overline{P2}$ represent the mean of pixel values of the corresponding images.			
Gradient	Mean	It is the average of direction of pixels taken over the number of pixels in a region	$(1/N)\sum_{i=1}^{N}\theta_i$
	Standard Deviation	It gives the variation of the direction of pixels in a region.	$\sqrt{(1/(N-1))\sum_{i=1}^{N}(\theta_i-Mean)^2}$

	Entropy	It is the measure of the amount of gradient information present	$\sum_{i=1}^{N} P_i \log(1/P_i)$
Here, N is the number of pixels in a region, θ_i is the direction of pixel, P_i is the probability of occurrence of each direction angle of a bin			
GLCM	Contrast	A measure of intensity contrast between a pixel and its neighbor over the entire image	$\sum_{i=1}^{K}\sum_{j=1}^{K}(i-j)^2 P_{ij}$
	Correlation	A measure of how correlated a pixel is to its neighbor over the entire image. This measure is not defined if either SD is 0.	$\sum_{i=1}^{K}\sum_{j=1}^{K}\frac{(i-m_r)(j-m_c)P_{ij}}{\sigma_r\sigma_c}$
	Energy	A measure of uniformity in the range [0, 1].	$\sum_{i=1}^{K}\sum_{j=1}^{K}(P_{ij})^2$
	Homogeneity	Measures the spatial closeness of the distribution of elements in co-occurrence matrix to the diagonal	$\sum_{i=1}^{K}\sum_{j=1}^{K}\frac{P_{ij}}{1+\lvert i-j\rvert}$
Here, K is the number of rows/columns of image matrix Q, P_{ij} is the probability that a pair of points in Q will have values (z_i, z_j), m_r and m_c are the mean of rows and columns respectively, σ_r and σ_c are the standard deviation of rows and columns respectively			

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