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PERFORMANCE EVALUATION OF SPARSE BANDED FILTER MATRICES USING CONTENT BASED IMAGE RETRIEVAL

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ABSTRACT

Content Based Image Retrieval (CBIR) is an extensively used application in the field of Image Processing. It is used to search through a massive database and retrieve the images that have similarity with the query image. In this paper, performance is evaluated for Sparse Banded Filter matrices (ABfilter) against the standard edge detection filters through Content Based Image Retrieval. Performance factor of ABfilter directly relates to its edge detection capabilities. Here, edge detection followed by the Singular Value Decomposition (SVD) is done for feature extraction for both the query and images in database. Query image feature and database image features are matched and those having similar values are retrieved. Similarity measurement is done by computing the distance between corresponding features. Experimental results indicate that retrieval results using ABfilter is much better than using standard edge detection filters for the same, which in turn establishes its superiority in edge detection.

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KEY WORDS

Content Based Image Retrieval; Singular Value Decomposition; Histograms; Edge Detection; Sparse banded filter matrices; Euclidean distance

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INTRODUCTION

Vision is the most important of our senses and plays a vital role in human perception [1]. Electronic snapshots of real world scenarios such as photographs, scanned documents, printed texts, manuscripts, artwork can be termed as digital images. Digital images are stored as numerical values having fixed number of rows and columns [2]. Image processing is used for analyzing and manipulating digital images. It is a kind of signal processing where an image is given as an input and an enhanced version or the features/characteristics associated with the image is produced as an output. Image processing has been proved as a promising technology for analysis in various fields and applications. It is used in most instances including medical imaging, remote sensing, artificial intelligence, military, film industry, forensic studies, agriculture etc. [1]. Image retrieval system is used in agriculture for determining insect attack and growth [3]. It is also used for detecting weeds and for differentiating weeds from soil regions [4]. Identification of targets from satellite photographs, recognition of enemy aircraft from radar screens and provision of guidance systems for cruise missiles are some instances in military applications [5]. Identity of fingerprints, shoe prints and tire threads are done using image retrieval in digital forensics [5] [6]. Face recognition is also an advanced technology used in forensics [6]. MR brain imaging is one of the main application in medical imaging [7]. Also, image retrieval is used to display images relating to a named patient, and can be used to find similar past cases [5].

Traditionally, images were managed by annotating their contents and were retrieved using text based retrieval methods. But, the exponential increase in digital data made it almost impossible to prepare the databank for images. Two main challenges faced were massive labor required for manual annotation and different perception of same image by different people [8]. Limitation of text based method paved the way for Content Based Image Retrieval (CBIR). It is also known as Query by Image Content (QBIC). It aims at extracting and indexing images using its visual content such as shape, color, textures and other information that can be used for retrieval. Each image is described using its own features rather than metadata such as tags, descriptions or keywords [9]. Unlike in Text Based Image Retrieval (TBIR), characteristics are extracted automatically. Being the most recognizable feature, color is widely used in image retrieval. Color in a digital image is represented as RGB, HSV, YCbCr, CIELab etc. Color histograms are used to denote the pixel count of various colors stored in the image. Textural

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features are also an effective method to represent an image. It produces a mathematical symbolization for representing the repeating patterns on the surface of the image. Remarkable texture analysis methods include directionality, coarseness, line-likeliness, regularity, as well as roughness. Furthermore, Gabor features are also used in texture analysis task. Shape is another visual feature used in CBIR. Compared to others, image retrieval using shape features is one of the toughest task. An image is a 2D object when digitally represented, but is 3D in real world. Mapping from a 3D representation to 2D results in loss of one dimension. Thus, shape extracted represents only a partially projected object. Further researches are ongoing in this field [10].

Edges are also one of the major feature used in the fields of image retrieval. It denotes sudden change of intensities in an image. Edge detection is a process for detecting the boundaries of objects present in an image. There are several methods to implement edge detection. However, the most can be considered as two: gradient and Laplacian [11]. Gradient method is done by finding the minimum and maximum values belonging to the first derivative of the image. Zero crossings in the second derivative are used for Laplacian edge detection. Canny, Prewitt, Roberts, Sobel are types of filters used for edge detection. Performance of the application is conditional to the selected edge detection algorithm. Efficient edge detection techniques are required by applications such as data compression, object recognition and tracking, image segmentation and pattern recognition.

Latest trends in edge detection include quick edge detection with the help of structured forests. The edge mask so formulated helps in detecting the edges in the image by the method of mask processing. The main advantage is that; it can be used for real time applications since its edge detection capability is much faster than presently used modern approaches [12]. Another method includes the Roberts Edge Detection using CUDA and OpenGL, which makes use of the Pixel Buffer Object (PBO) for image creation using CUDA on pixel by pixel basis and displaying the so obtained by using OpenGL. This image so formed is edge detected using Roberts filter [13]. A method for image retrieval using shape features for similarity measurement is proposed [14]. A weighted bipartite graph matching algorithm and homogenous attribute is used to find the correspondence between features.

In this paper, performance evaluation of ABfilter is done using Content Based Image Retrieval. As per theory [15], ABfilter uses a new approach using sparse banded matrices to reduce the chance of appearance of unrelated images, which in turn suggests that its edge detection is advanced. We confirm this by experimental approaches. The rest of the paper is arranged as follows; IInd section describes the scheme used for evaluating the performance of the ABfilter along with the theory related to the ABfilter as well as Singular Value Decomposition. In Section III, experimental results are narrated. Section IV explains the experimental setup and conclusion of the paper is done in Section V.

MATERIALS AND METHODS

ABfilter

The main concept behind ABfilter [16] is the use of the sparse banded filter matrices proposed by Selesnick et.al. [15] for one dimensional signal processing. The concept is then applied to the two dimensional and used for edge detection of images [16]. The sparse banded high pass filter is applied for rows and columns to extract the vertical and horizontal edges of the images respectively. Due to the sparsity property associated with the filter, it presents much efficient computation when compared with the existing standard filters. The main advantage which makes this filter outperform other filters is that it is possible of capturing continuous edges without any kind of parameter tuning.

Singular Value Decomposition (SVD)

Canonical form or decomposition of matrix is one among the most valuable idea in the field of linear algebra. Singular value decomposition takes a special role in decomposition of matrices. Matrix A is factorized into product $U\Sigma V^T$; U and V^T are unitary matrices, Σ is diagonal matrix [17] [18].

$$A = U\Sigma V^T$$

where A is a real matrix of size m x n,

$$\Sigma = diagonal(\sigma_1, \sigma_2, ..., \sigma_n)$$

consists of diagonal elements which are non-negative in nature arranged in decreasing order,

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$$V = (v_1, v_2, \ldots, v_n) \quad \text{and} \quad U = (u_1, u_2, \ldots, u_n)$$

are orthogonal. Frobenius norm is denoted by || . || and is defined by,

$$\| A \|^2 = \sum_{p,q} a_{pq}^{\ 2} = \sum_{q} \sigma_p^{\ 2}$$

PROPOSED WORK

The proposed work discusses the implementation of the ABfilter in the Content Based Image Retrieval application to evaluate its edge detection capabilities. The algorithm for the retrieval process used here is Line Edge Singular Value Pattern [19] which incorporates the notion of edge detection and Singular Value Decomposition [19]. The experiment compares the retrieval outputs obtained from ABfilter and standard edge detection filters (Sobel, Roberts, Prewitt and Canny) and accuracy is observed. The retrieval process is represented in **[Figure–2]**.

ALGORITHM

1) The query image as well as the image database is loaded and then converted to grayscale as shown in **[Figure–1 A]**. Both query and database is first subjected to edge detection [20] using the ABfilter as well as standard set of edge detection filters like Canny, Prewitt, Sobel and Roberts. From this output, we select a 3x3 block as shown in **[Figure–1 B]**.

2) The absolute values of the edge detected output is determined as in **[Figure–1 C]**.

3) Singular Value Decomposition (SVD) is determined for the selected 3x3 block and the maximum value of Singular Value Matrix is computed. The center pixel is replaced by this maximum value as in **[Figure–1 D]**. In this way, the procedure is applied to all the pixels in the image and are replaced by their corresponding maximum values.

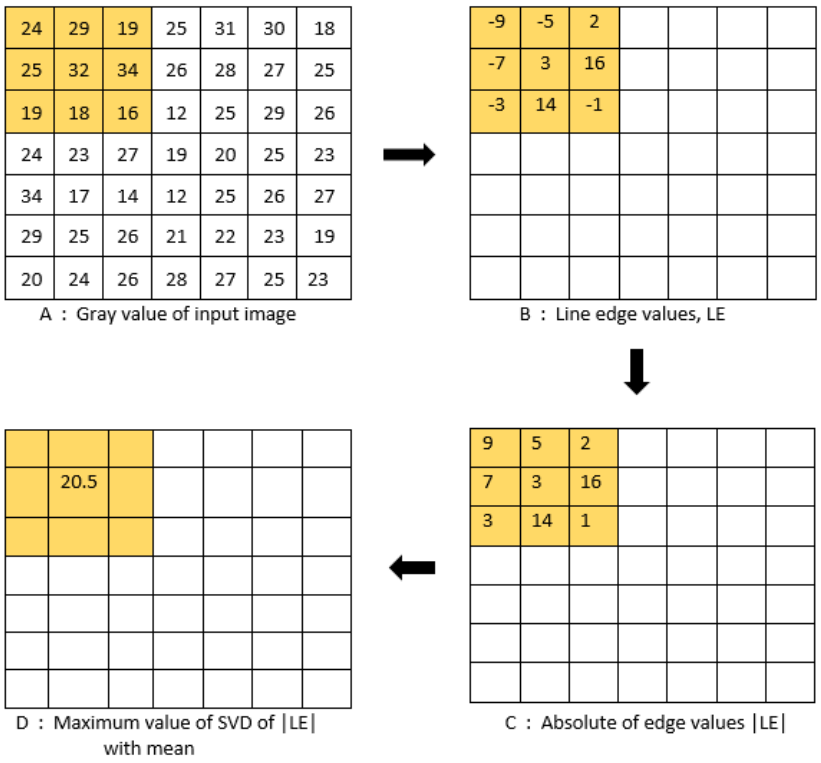

Fig: 1. Depiction of determining maximum singular value in 3x3 block

4) Histogram is computed for the previously obtained matrix.

5) The histogram so obtained is normalized. This step marks the end of the feature extraction process with features being the normalized histogram.

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6) The above steps from 2 to 6 is repeated for all the images in the database as well as for query image for feature extraction process.

7) The next step followed by feature extraction is retrieval. Pairwise Euclidean distance for the query image feature is calculated followed by calculating the pairwise Euclidean distances for all the features in the database.

8) Difference between the query features and each of the database feature is calculated.

9) Then absolute value of the difference is computed followed by taking its summation.

10) The computed value is matched with a threshold value.

11) The threshold value is calculated by taking the mean of the all the above mentioned computed values.

12) Images that falls under threshold value are retrieved.

FLOWCHART

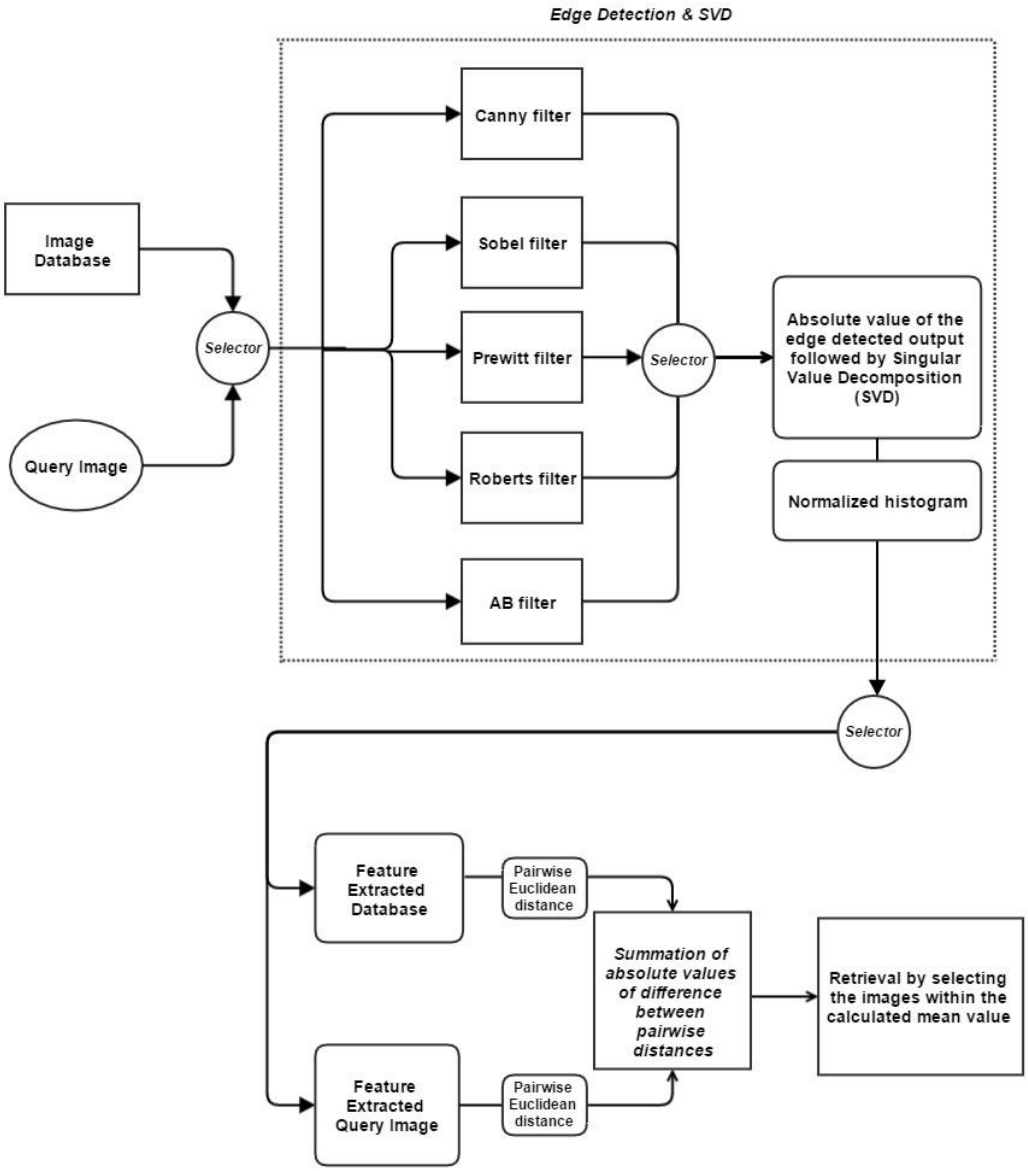

Fig: 2. CBIR retrieval process

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RESULTS

The experimental results for the retrieval for class 'Rose' is shown in **[Table–1]**. It consists of 10 images with image numbered from 41 to 50. Each of this image is taken as query image and the algorithm is followed for feature extraction. Query image feature and database image features are matched for retrieval process. Retrieval for Canny, Sobel, Prewitt, Roberts and ABfilter is noted. In **[Table–1]**, precision explains how much images are correctly retrieved. It is given by the formula [21],

$$\text{Precision \%} = \frac{\text{No. of images relevant to the content retrieved}}{\text{Total no. of images retrieved}} \times 100$$

When the query image numbered 41 is passed for retrieval, ABfilter retrieves all the 10 images in the class correctly among the 70 in the entire database taken for performance testing. This gives a precision of 24% as per the above formula. Both Sobel and Roberts retrieves 8 out of the 10 images while Canny and Prewitt retrieves only 6 images. So likewise, all the images in the class Rose are tested for retrieval and the average precision is calculated. In the end, ABfilter gives the best retrieval with 27.9 %. The experiment is repeated for all the 7 classes and it was determined that ABfilter correctly retrieves all the images in same class as that of query image.

The overall retrieval results so obtained is compared as shown in **[Table-2]**. Overall retrieval is computed by calculating the mean of precision of the filters applied to the entire database consisting of 70 images, 7 class with 10 images each. ABfilter has the best precision out of all of them with 23.69%. Corresponding graphical results are shown in **[Figure–3]**.

Table: 1. Retrieval output for the image class "Rose" by different filters

Image No.	Canny Retrieval			Sobel Retrieval			Prewitt Retrieval			Roberts Retrieval			ABfilter Retrieval		
Rose	Relevant	Total	Precision %	Relevant	Total	Precision %	Relevant	Total	Precision %	Relevant	Total	Precision %	Relevant	Total	Precision %
41	6	40	15	8	36	22	6	35	17	8	36	22	10	42	24
42	8	43	19	6	33	18	6	35	17	10	34	29	10	36	28
43	8	43	19	10	38	26	10	39	26	8	33	24	10	39	26
44	10	42	24	8	36	22	8	37	22	6	37	16	10	35	29
45	10	43	23	10	33	30	10	35	29	10	33	30	10	35	29
46	6	40	15	6	34	18	6	34	18	6	36	17	10	36	28
47	10	40	25	10	34	29	10	35	29	10	33	30	10	35	29
48	8	43	19	6	35	17	6	35	17	6	37	16	10	36	28
49	10	42	24	10	34	29	10	35	29	10	33	30	10	35	29
50	10	40	25	10	33	30	10	35	29	10	33	30	10	35	29
	Average precision %		**20.8**	**Average precision %**		**24.1**	**Average precision %**		**23.3**	**Average precision %**		**24.4**	**Average precision %**		**27.9**

Table: 2. Overall retrieval results (precision rate) for all the image classes using different filters

Categories	Canny	Sobel	Prewitt	Roberts	ABfilter
Bus	16	21.3	21.8	23.2	23.1
Dinosaur	23.7	22.4	21.7	17.2	26.1
Food	19.5	23.8	23.4	23.3	20.6
Horse	18.7	19.6	20	19.8	22
Monuments	20.6	25.3	25	23.8	24
Rose	20.8	24.1	23.3	24.4	27.9
Tribal	21.1	18.5	18.4	20.8	22.1
Average precision %	**20.06**	**22.14**	**21.94**	**21.79**	**23.69**

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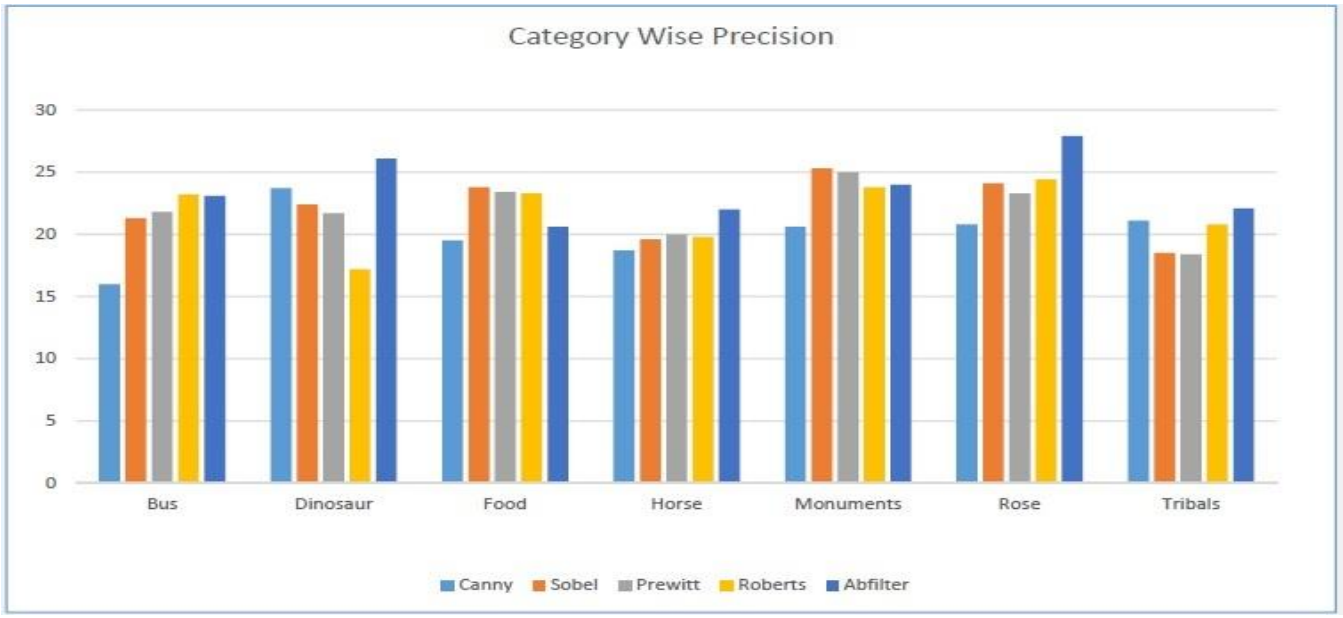

Fig 3: Category wise retrieval plot

The result confirms that the ABfilter has best content retrieval when compared to the filters like Roberts, Prewitt, Sobel and Canny.

[Figure–4] shows the sample edge detection of an image by all the filters. It is evident that the ABfilter captures all the horizontal and vertical variations perfectly. Moreover, it only detects the object of interest. While in Canny, it is seen that along with the object, it also detects the background. Rest Prewitt, Roberts and Sobel exhibits edge detection with discontinuities. This solidifies the fact that the ABfilter has better edge detection capabilities with respect to other filters.

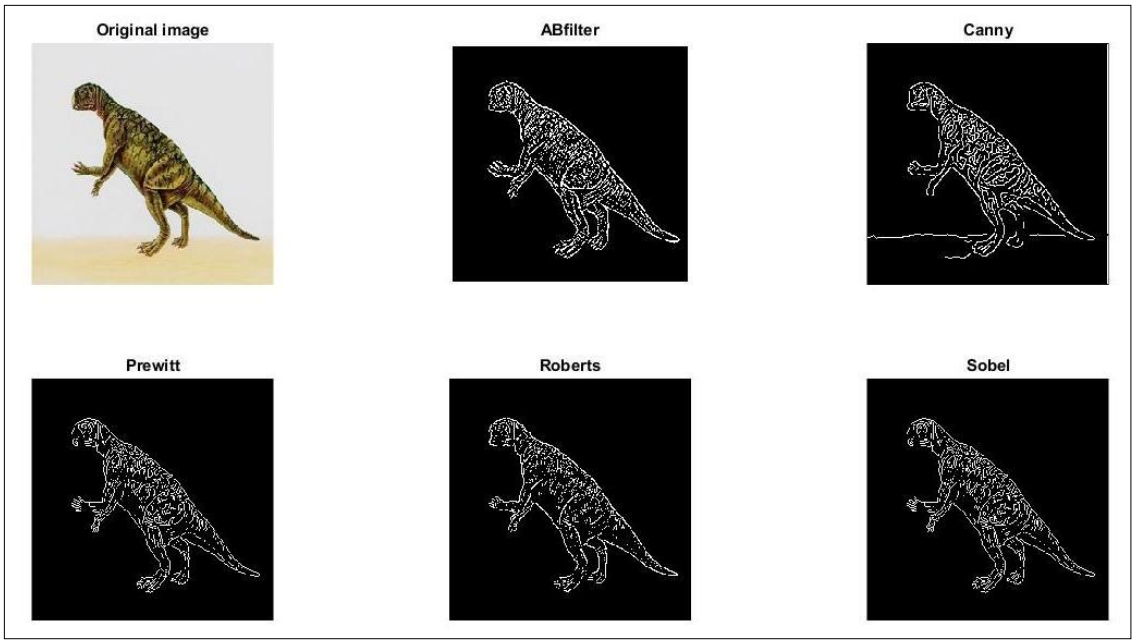

Fig: 4. Edge Detected Outputs of filters

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DISCUSSION

In order to perform this experiment, we have used Matlab and WANG database [19] for implementing the program. It is a subcategory of Corel stock database consisting of 10 classes of 100 images each, which are selected manually and thereby totaling up to 1,000 images. The image dimensions are 256 x 384 or 384 x 256 pixels. Assume that user is having an image pertaining to a particular class and searching for similar images in the database. Here, all the 99 images pertaining to same class as that of query image is considered relevant while the rest are deemed irrelevant. For our experiment, we took 7 classes (Bus, Dinosaur, Food, Horse, Monument, Tribals and Rose) out of the 10 classes and from each class having 100, we randomly selected 10 images for performance testing. So our database amounts to a total of 7 classes each are having 10 images. Then, images belonging to each class are individually passed as query image to the program for retrieval purposes. The ABfilter gives the good retrieval which is evident from the experimental results indicated by **Table-1** and **-2**.

CONCLUSION

This paper highlights the edge detection capability of ABfilter which is practically evaluated by its application in Content Based Image Retrieval. Retrieval of the ABfilter is compared with the standard edge detection filters. During the observation, it has been determined that the ABfilter filter performs much better when compared with the others. By conducting the experiments throughout the different image classes, it has been established that the ABfilter retrieves only the content related to query image from the image database and thereby giving best retrieval rates among all. Hence, it is experimentally established that the edge detection property of the ABfilter is much superior to the standard edge detection filters. ABfilter can serve as a replacement to the standard edge detection filters in the image processing applications like medical imaging, autonomous car etc.

Advantages of ABFilter

- Has less discontinuity, when compared with the existing edge detection methods.
- Sparsity property of the banded filter leads to efficient computation of edge extraction without any parameter.

CONFLICT OF INTEREST
Authors declare no conflict of interest.

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