Final Report On UGC Major Research Project Entitled

SKELETON BASED SHAPE REPRESENTATION TECHNIQUES FOR OBJECT RECOGNITION

UGC File No: 43-269/2014(SR)
Dated 15.Oct.2015

Submitted to
UNIVERSITY GRANTS COMMISSION
NEW DELHI – 110 002

Submitted By
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Final Report in **PDF** format
(**Annexure VIII & IX** of UGC MRP guidelines)

Annexure -VIII

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002.

Annual/Final Report of the work done on the Major Research Project.

(Report to be submitted within 6 weeks after completion of each year)

1. Project report No. 1st /2nd /3rd/Final---- **Final Report**
2. UGC Reference No. ---------- **F.N0. 43-269/2014(SR), Dt.15.Oct.2015**
3. Period of report ---------- **From 01.07.2015 to 30.06.2018**
4. Title of research project ----

   Skeleton based Shape Representation Techniques for Object Recognition

5. (a) Name of the Principal Investigator --- **Dr.Atluri Srikrishna**

   (b) Department --- **Department of Information technology**

   (c) University/College where work has progressed-------

   Department of Information Technology,
   R.V.R. & J.C. College of Engineering (Autonomous)
   (Affiliated to Acharya Nagarjuna University)

6. Effective date of starting of the project ------- **01.07.2015**
7. Grant approved and expenditure incurred during the period of the report:
   a. Total amount approved Rs.---------- Rs.10,25,000.00
   b. Total amount released Rs.---------- Rs.6,65,000.00
   c. Total Interest amount earned ---------- Rs.30,911.00
   d. Total expenditure Rs. ---------- Rs. 6,53,824.13
   e. Total amount Refunded ---------- Rs.42,086.87

   (Through Andhra Bank D.D No.159448, Dt.18.08.2018)

c. Report of the work done: (Please attach a separate sheet)

i. Brief objective of the project----

- The study focuses on building efficient structural shape representation of the input shapes. Each shape component is a shape element and it is selected to represent a significant part(relative to its size) of the given shape.

- To explore the relationship between various proposals, and aim to develop efficient, unified algorithms for computing connected filters based on a variety of generalized connectivities.
- To develop algorithms for obtaining shape-scale and orientation-scale spaces using connected filters.
- To apply the number of algorithms developed to the problem of enhancing details in 2-D and 3-D medical images, in particular the detection of filamentous details such as blood vessels, anomalies in them, hair cracks in the bones using X-ray details simultaneously at multiple scales.

ii. Work done so far and results achieved and publications, if any, resulting from the work (Give details of the papers and names of the journals in which it has been published or accepted for publication-----

The proposed method focuses on to propose algorithms for obtaining shape-scale and orientation-scale spaces using connected filters and to develop unified algorithms for computing connected filters based on a variety of generalized connectivities.

- Initially we worked to propose method based on morphological thinning operation. Thinning is an interesting and challenging problem, and plays a central role in reducing the amount of information to be processed during pattern recognition, image analysis and visualization, computer-aided diagnosis.

Based on this work we have presented a paper on **" Topology Preserving Skeletonization techniques for Gray Scale Images"** in Sixth International Conference on Advances in Computing, Control, and Telecommunication Technologies - ACT 2015, organized by the IDES and the Association of Computer Electrical Electronics and Communication Engineers (ACEECOM). The paper is presented in the conference held during Oct 30-31, 2015; Trivandrum, India.

- Through references we have identified the if skeletons are obtained on a image if contains noise , then it generates unexpected results, so we planned to propose a efficient denoising scheme in the pre-processing step.

Based on this we have worked on denoising scheme based on pixonal model and published a paper **" Pixon Based Image Denoising Scheme by Preserving Exact Edge Locations",** Springer Journal of Institution Engineers(INDIA):Series B, September 2016, Volume 97(3), Print ISSN :2250-2106, Pp:395–403.

- Later we proposed work on identification of cataract from a eye image based on connected components from edge candidates. A cataract is a clouding of the lens inside the eye which causes to a decrease in vision or sight. Visual loss occurs because opacification of the lens obstructs light from passing and being focused on to the retina at the back of the eye. It is most commonly due to biological aging, but there are a wide variety of other causes also. As time passes, the yellow-

brown pigment is deposited within the lens and this, together with disruption of the normal architecture of the lens fibres, leads to reduced transmission of light, which in turn leads to visual problems. Detecting cataract from human eye images is a challenging task owing to their variable appearance and the wide range of poses that they can adopt. The first need is a robust feature set that allows the human form to be discriminated cleanly, even in cluttered backgrounds under difficult illumination and noise conditions. A number of approaches have been proposed in the literature to match the cataract images by extracting texture information using Local Binary Pattern (LBP) , Histogram of Oriented Gradient(HOG) , and Scale Invariant Feature Transform (SIFT) .

To identify the cataract from a eye image we proposed a method based on nonlinear principle and published a paper on **"Computer Assisted Cataract Identification system from Noisy Images",** International Journal of Scientific and Engineering Research (IJSER) **,** Volume 7, Issue 9, September 2016, Print ISSN 2229-5518,Pp:981-990.

- The offline signature verification is an automatic verification system that works on the scanned image of a signature. Signature verification uses the gray level measure with varying foreground features. The signature verification is performed by identifying feature vector using local patterns. The Local Binary Pattern (LBP) in signature verification has used to extract the local structure information by establishing the relationship between central pixel and adjacent pixels and Support Local Binary Pattern (SLBP) extracts features for signature verification.

To address this we proposed a paper using LBP and SLBP for signature verification and published " **Offline Signature Verification using Support Local Binary Pattern",** International Journal of Artificial Intelligence & Applications, Volume 7, Issue 6, November 2016**,** Print ISSN **0**976-2191,Pp:85-94. The signatures are tested on MCYT dataset. The accuracy of the proposed method is tested against k-Nearest Neighbour Classifier (KNNC) and Linear Discriminant Classifier (LDC).

- Object recognition is a procedure for recognizing a particular object in an advanced video or image. Appearance-based or feature-based techniques are used for object recognition. An object skeleton is the useful cue for object recognition, which provides a structural representation to specify the relationship among object parts. The shape's geometry and topology can be efficiently encoded. To recognize the object we extracted skeleton first from the given input image and then we obtained skeleton features which are used for object recognition. Skeleton features are extracted from the obtained skeleton. Skeleton features are end points, junction points, boundary junctions, boundary length and skeleton length. A skeleton point is referred as the center pointof a maximally inscribed disk.A skeleton endpoint is defined as a skeleton point having only one neighboring point.A junction point is referred as askeleton point having three or moreadjacent points. A connection point is defined as if a skeleton point is notan endpoint or a

junction point.A branch pointis referred as a skeleton segment between two skeletons or a junction point.The branch of skeleton is the series of connection points between two directly associated skeleton points.

To recognize the real objects from the given input image based on skeleton features we proposed a paper "**Object Recognition based on Topology Preserving Skeleton Features"** and communicated with Scopus indexed journal International Journal of Advanced Intelligence Paradigms, Print ISSN : 1755-0386 , Online ISSN : 1755-0394 and under revision for publication.

iii. Has the progress been according to original plan of work and towards achieving the objective if not, state reasons--- **Yes**

iv. Please indicate the difficulties, if any, experienced in implementing the project --- **No**

v. If project has not been completed, please indicate the approximate time by which it is likely to be completed. A summary of the work done for the period (Annual basis) may please be sent to the Commission on a separate sheet. ----

Project has been completed in the month of June 2018.

vi. If the project has been completed, please enclose a summary of the findings of the study. One bound copy of the final report of work done may also be sent to University Grants Commission.

Project has been completed in the month of June 2018.

Summary of work done :

The proposed method focuses on to propose algorithms for obtaining shape-scale and orientation-scale spaces using connected filters and to develop unified algorithms for computing connected filters based on a variety of generalized connectivities.

- Initially we worked to propose method based on morphological thinning operation. Thinning is an interesting and challenging problem, and plays a central role in reducing the amount of information to be processed during pattern recognition, image analysis and visualization, computer-aided diagnosis. Based on this work we have presented a paper on **" Topology Preserving Skeletonization techniques for Gray Scale Images"** in Sixth International Conference on Advances in Computing, Control, and Telecommunication Technologies - ACT 2015, organized by theIDES and the Association of Computer Electrical Electronics and Communication Engineers

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vii. Any other information which would help in evaluation of work done on the project. At the completion of the project, the first report should indicate the output, such as (a) Manpower trained (b) Ph.D. awarded (c) Publication of results (d) other impact, if any

Any other information which would help in evaluation of work done on the project

(a) Manpower Trained

- Research fellow is trained with the concepts related to the project,assigned to collect the literature survey, and involved in implementation.
- Number of M.Tech students are trained on Skletonization concepts for object recognition.

(b) Ph.D Awarded

- One of my scholar (M.Pompapathi, with admission No:11PH012, with JNTUA) has been awarded Ph.D from JNTUA, Ananthapuramu in the month of November 2016, and proposed methodologies in his thesis are helpful in completion of his research work.

- One of another scholar (N.Neelima) is pursuing Ph.D from JNTUH, Hyderabad and the results obtained in this project are highly useful for her research work and workdone

under this project given a research paper on "**Object Recognition based on Topology Preserving Skeleton Features"** and communicated with Scopus indexed journal International Journal of Advanced Intelligence Paradigms, Print ISSN : 1755-0386 , Online ISSN : 1755-0394 and under revision for publication.

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(c) Publications

The following are the publications published in Journals/Conferences from the starting of the Major Research Project from 01.07.2015.

1. **Dr. A. Sri Krishna**, Dr. K. Gangadhar, N. Neelima, K. Ratna Sahithi, **"Topology Preserving Skeletonization techniques for Gray Scale Images"** presented in Sixth International Conference on Advances in Computing, Control, and Telecommunication Technologies - ACT 2015.
2. **Dr.A.Srikrishna,** Dr.B.Eswara Reddy, **M.Pompapathi, "Pixon Based Image Denoising Scheme by Preserving Exact Edge Locations",** Springer Journalof Institution Engineers(INDIA):Series B, September 2016, Volume 97(3), Print ISSN :2250-2106, Pp:395–403.
3. VickramPentyala, **M.Pompapathi,** and **Dr.AtluriSrikrishna**, **"Computer Assisted Cataract Identification system from Noisy Images",** International Journal of Scientific and Engineering Research **(IJSER) ,** Volume 7, Issue 9, September 2016**, Print** ISSN 2229-5518,Pp:981-990.
4. VickramPentyala**, Dr.AtluriSrikrishna** and D.Swapna " **Offline Signature Verification using Support Local Binary Pattern",** International Journal of Artificial Intelligence & Applications,Volume 7, Issue 6, November 2016**,** Print ISSN 0976-2191,Pp:85-94.
5. N.Neelima, **Dr.AtluriSrikrishna,** Dr.K.Gangadhara Rao, and **Dr.M.Pompapathi,** "**Object Recognition based on Topology Preserving Skeleton Features"** and communicated with Scopus indexed journal International Journal of Advanced Intelligence Paradigms, Print ISSN : 1755-0386 , Online ISSN : 1755-0394 and under revision for publication.

(d) Results –

The following are the results obtained and concluded efficient from our proposed methodologies in various publications.

1. **"Topology Preserving Skeletonization techniques for Gray Scale Images"**

The proposed Topology preserving skeletonization technique iteratively removes pixels of a gray scale image. A gray scale image is taken as input. The output is a set of points that belongs to its

skeleton. For every pixel in the gray scale image, check the acyclicity, i.e., if a candidate pixel is 1 and its 8-neighbourhood pixels are also 1, then it is cyclic else it is acyclic. If it is acyclic, then the value of that pixel is set to 1 otherwise 0. Check for connectivity to retrieve thinned component of the original image.

The proposed method is applied on English alphabet set both on lower case and upper cases are chosen for experiment analysis because they contain different shapes. The thinned alphabet set contains no restoration and they are not affected by any border noises which are usually present in most of the skeleton approaches. One of the main problems with thinning method was loss of information due to binarisation because it could not always be possible to correctly binarise the whole character image using one threshold value.

The proposed Topology preserving skeletonization algorithm is used for representing different modes of operation in thinning . The performance of the thinning algorithm can be compared and evaluated on the basis of following parameters:

a) Connectivity of Pattern.

b) Data Reduction Rate (DRR)

a) Connectivity of Pattern

By comparing the original image with its skeleton obtained by topology preserving skeletonization algorithm, we can see that the connectivity is maintained in the skeleton of the image.

b) Data Reduction Rate

The algorithm will guarantee the highest data reduction value producing perfect skeleton. It reveals information about how good is the algorithm in data reduction when comparing the skeleton S and the original pattern P. Formally: this can be measured as $Mdr = |S|/|P|$. Data reduction rate for different images is shown in Table I.

Table I : Data Reduction Rate for different images.

SNO.	IMAGE	% of Data Reduction Rate
1	A	19.35
2	C	19.02
3	G	16.08
4	H	16.95
5	U	18.27
6	X	18.14
7	Y	17.86

The proposed algorithm has been tested over all uppercase and lowercase alphabets. But for convenience, only some of the alphabets are shown in Fig.1 and Fig.2.

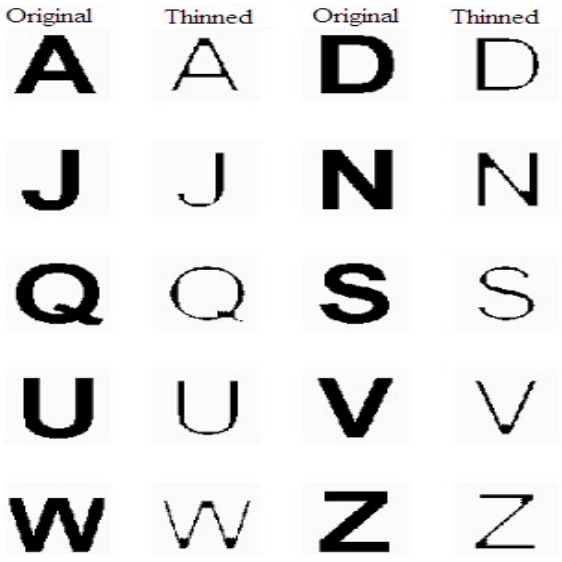
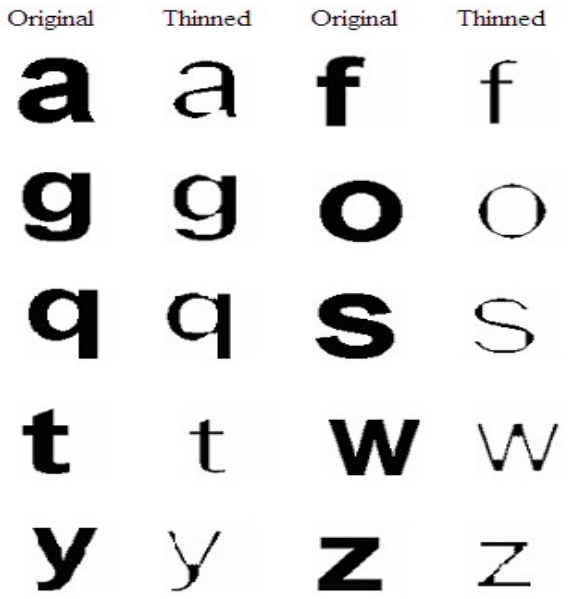


Fig.1. Original and Thinned Image of English Upper-case alphabets.



.Fig.2. Original and Thinned Image of English Lower-case alphabets.

The topology preserving thinning algorithm is used to retain the morphological properties of the images. It checks for the acyclicity condition and removes the pixels from a gray scale image. The shape preserving algorithm tends to retain the original shape of the image. This algorithm is very simple and easy to obtain skeletons. The performance of the skeleton is evaluated and is observed that for all the images connectivity is obtained and reduction rate is less than 20%.

2. "Pixon Based Image Denoising Scheme by Preserving Exact Edge Locations"

The proposed methodology is helpful as a pre-processing step in order to remove occurred noise from a noisy image before identifying skeleton of an image for object recognition. Denoising of an image is an essential step in many image processing applications. In any image de-noising algorithm, it is a major concern to keep interesting structures of the image. In this paper we proposed an efficient algorithm called pixon based image denoising method for image de-noising obtains integrated and consecutive original image from noisy image using diffusion equations in pixon domain. The process mainly consists of two steps. In first step we obtain the pixons for noisy image by using K-means clustering process and next step includes applying diffusion equations on the pixonal model of the image to obtain new intensity values for the restored image. The process has been applied on a variety of standard images and the objective fidelity has been compared with existing algorithms. The experimental results shows that the proposed algorithm has a better performance by preserving all the structural properties of an image visually and improved Peak-to-signal-noise-Ratio (PSNR) Value.

Subjective Assessment on Gray Scale Images

Fig.3 and Fig.4 shows the original koala image corrupted Gaussian noise and by salt & pepper noise respectively and restored output image is compared with few standard existing methods called Standard median filter method, Mean filter method and Alpha-trimmed Mean filter.

Based on the below visual figures we may compare that in Mean filter method,edges are not preserved and smoothens local variations in an image. In Median filter, those Pixels which are not noisy are also replaced, less effective in removing Gaussian noise, if filter size increased the restored image gets blurred and it is effective only for corrupted images with low noise densities. In Alpha-trimmed mean approach, If the value of d=0, then alpha trimmed filter acts as a mean filter where the noise is reduced but blurring effect is included so it is leastly prefarable.

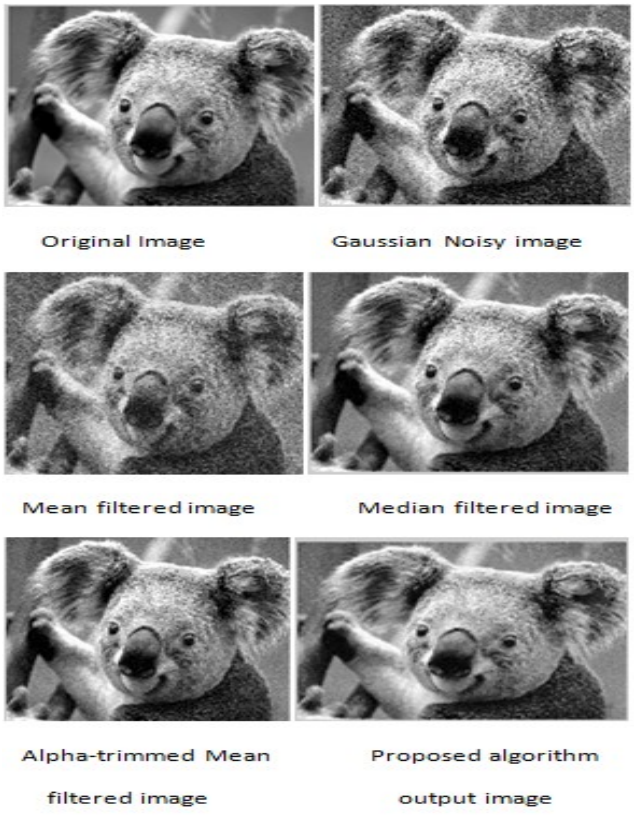


Fig.3 The proposed algorithm output for Gaussian noise comparison with other methods.

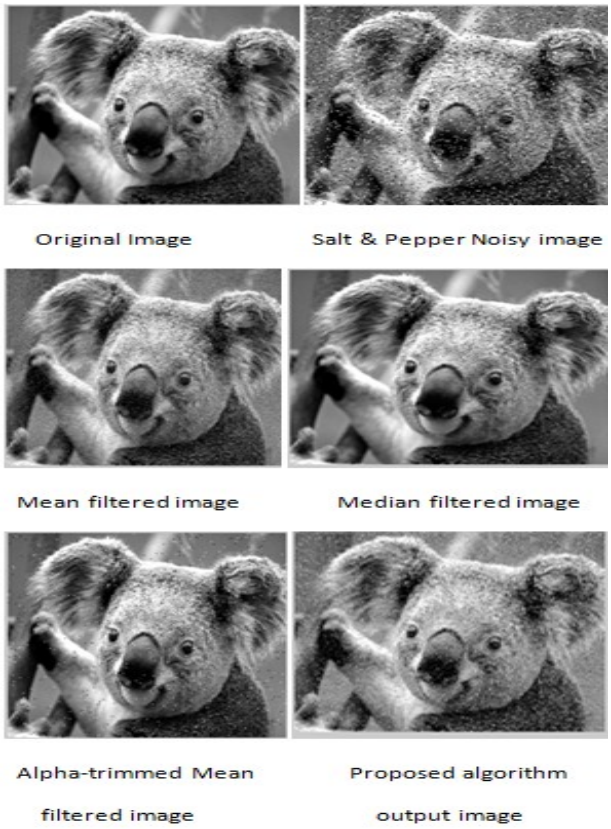


Fig. 4 The proposed algorithm output for salt & pepper noise comparison with other methods.

Subjective Assessment on Color Images

The proposed algorithm is tested on variety of color images also and identified the restored image looks visually pleasant appearance. The following Fig.5 shows the results obtained by applying proposed algorithm on a koala color image corrupted with Gaussian noise.

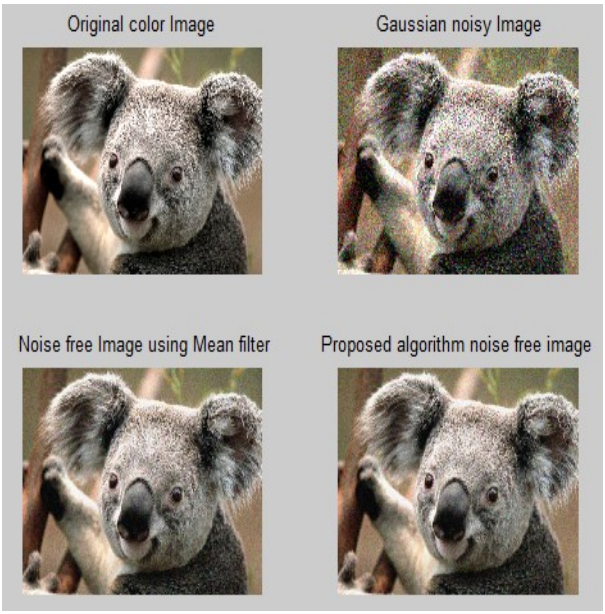


Fig. 5 Restored images using mean filter and proposed method on a koala image

The following Fig.6 shows the results obtained by applying proposed algorithm on a baboon color image corrupted with salt & pepper noise.

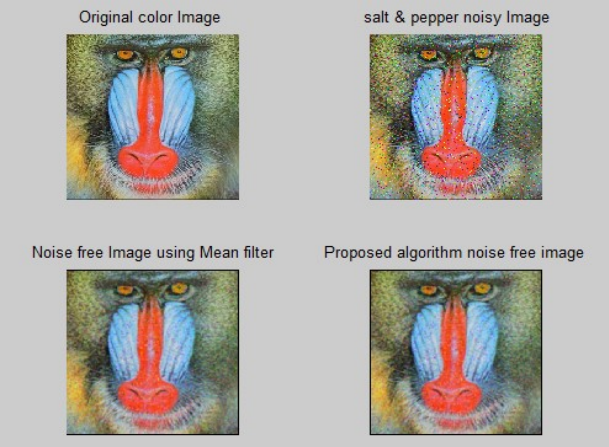


Fig.6 Restored images using mean filter and proposed method on a baboon image

The proposed denoising algorithm, removes the gaussian noise and salt & pepper noise efficiently while retaining the edge details. The experimental results demonstrates that, proposed approach performs much better than other existing filtering techniques (Mean, Median, Max-Min , Mid-point ,Alpha-trimmed mean filter) in terms of both objective fidelity and subjective fidelity(visual quality). The experimental results show that, in comparision with other existing methods, the proposed algorithm has a better performance in terms of PSNR and FOM values.

3. "Computer Assisted Cataract Identification system from Noisy Images"

Identification of cataract nature of objects from a noisy eye image is still a challenging problem for researchers. To address, this issue we proposed a system for recognition of cataract(Object recognition) from a noisy image by applying the non linear robust edge detector to obtain the edge image from a noisy cataract image without using image regularization. Then edge connected components are extracted, for each edge connected component recognition properties are obtained for the test image and compared these properties with the training dataset for recognition process. The recognition rate for the cataract images is obtained from the set of images to measure the performance of a proposed recognition process. The applicability of the proposed method is tested on normal eye images and dataset from MESSIDOR database. It is observed that recognition rate for the proposed method is highly acceptable.

Subjective Assessment - Recognition of Cataract from Noisy Images:

The Fig.7 shows the set of sample images from the training data set, which contains set of sample images with cataract nature and normal eye nature(without cataract) for which we calculated the recognition properties after obtaining largest five edge connected components and maintained in a file. Later these are used for recognition process with the given test image to recognize whether it is to be assigned with cataract nature or normal nature.

Fig.7 (a) Normal eye data set (b) Cataract eye data set

The Fig.8 and Fig.9 shows the recognition of cataract nature from the given test eye image.

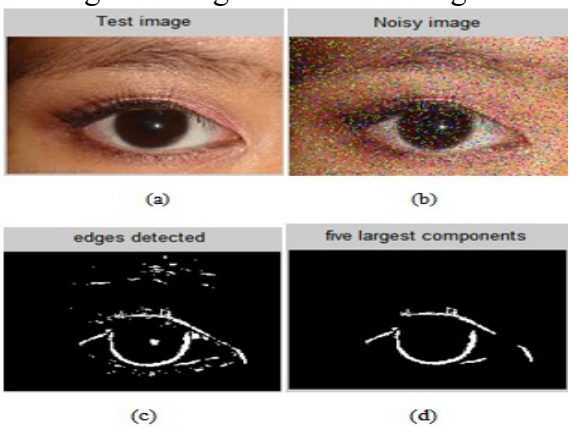


Fig.8 (a) Test image. (b) Test image with noise. (c) edges obtained by applying improved Robust Edge detector. (d) Extracted largest five connected componets by applying iterative algorithm.

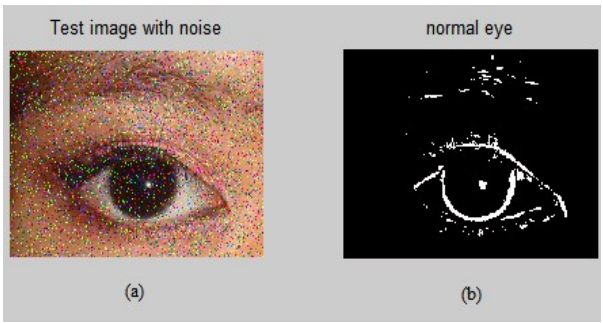


Fig.9 (a) Test image. (b) Recognized and assigned nature for test image.

The results are calculated not only considering the set of eye images by downloading from the google, evaluated on standard data set also. We have tested on retina of eye images with normal eye nature and with cataract nature, which are downloaded freely from MESSIDOR database. MESSIDOR (Methods to evaluate segmentation and indexing techniques in the field of retinal ophthalmology) is a project funded by the French Ministry of Research and Defense with an objective of an issuing and to create large databases of retina images and to use them in order to evaluate the various existing algorithms. And found that the proposed method works well for retina images of eye also exactly. Moreover, we cropped and normalized all images of size 512 X 512 pixels, based on the ground truth position of the retina of an eye. The Fig.10 and Fig.11 shows results obtained by applying on retina of an eye images from MESSIDOR database.

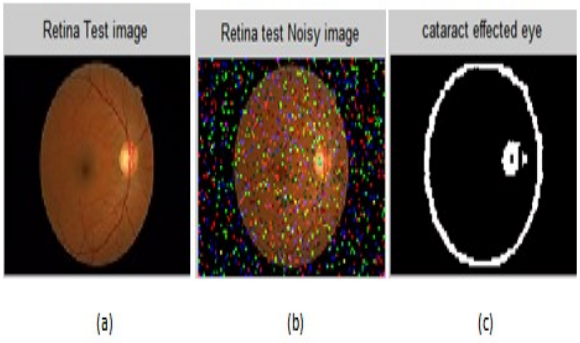


Fig.10. (a) Retina test image. (b) Retina test image with added noise. (c) Recognized and assigned nature for test image.

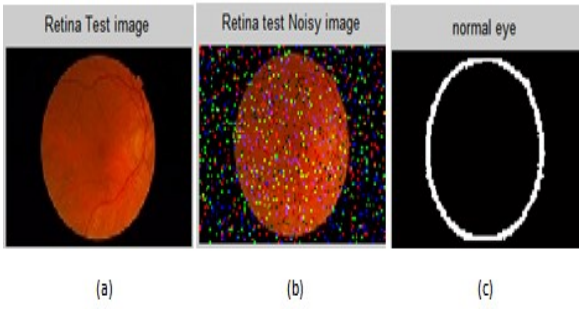


Fig.11. (a) Retina test image. (b) Retina test image with added noise. (c) Recognized and assigned nature for test image.

In this paper we proposed a method for recognition of the cataract for the given test image even it is contaminated in presence of noise. It applies first NLRED method on a given test image to obtain edge image, then obtained largest edge connected components, for which we computed the recognition properties. These properties were used for matching process during cataract recognition with properties of the training dataset. The proposed algorithm acts as a diagnostic tool for the physician for the early detection of cataract. The results produced by the proposed method are highly acceptable. This method works well even images containing high density noise also.

4. ” Offline Signature Verification using Support Local Binary Pattern” :

The offline signature verification is an automatic verification system that works on the scanned image of a signature. Signature verification (Object recognition) uses the gray level measure with varying foreground features. The signature verification is performed by identifying feature vector using local patterns. The Local Binary Pattern (LBP) in signature verification has used to extract the local structure information by establishing the relationship between central pixel and adjacent pixels. The proposed method for recognition of signature from scanned documents uses the Support Local Binary Pattern (SLBP) features. The signatures are tested on MCYT dataset. The accuracy of the proposed method is tested against k-Nearest Neighbour Classifier (KNNC) and Linear Discriminant Classifier (LDC).

The Flow chart of signature verification is shown in fig.12.

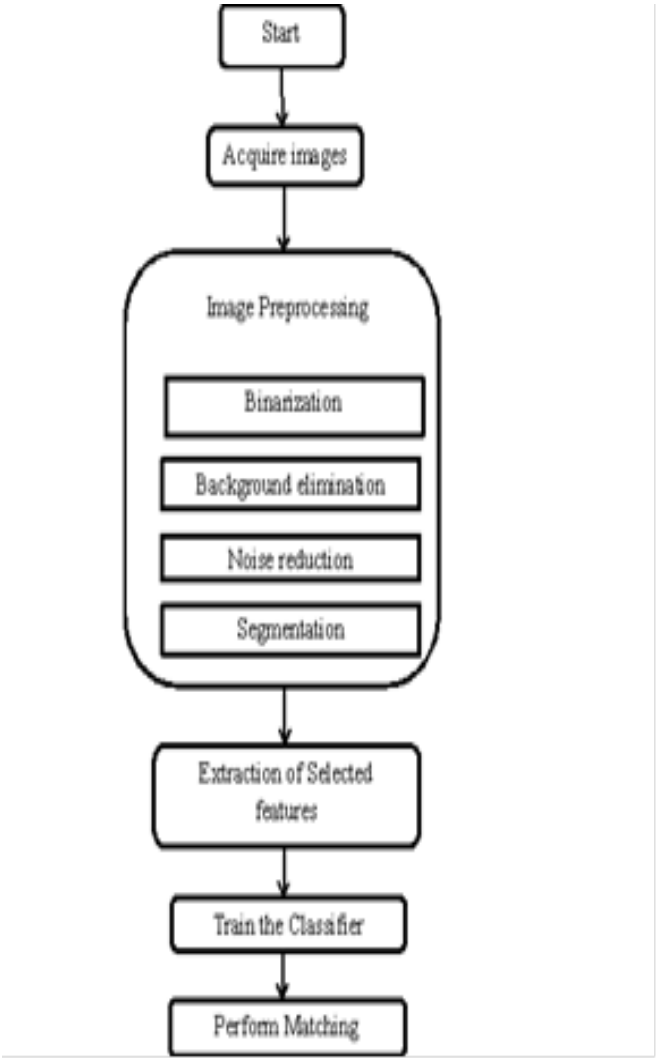


Fig 12: Flow chart of signature verification.

EXPERIMENT AND SIMULATION EVALUATION

The MCYT database is used for the signature verification. From four different Spanish sites it includes totally 75 signers. For each signer the database includes 15 genuine signatures and 15 simulated forgeries. In two sessions, genuine signatures were acquired. To imitate the shape forgers are given the signature images of clients after training with them several times. All the signatures in the signature database were acquired with the same inking pen. 12 bank checks and 8 invoices with different background complexity, totally 20 images are included in check database. Training data set taken during experiment evaluation are from the checks with signatures shown in fig. 13 and fig.14 respectively.

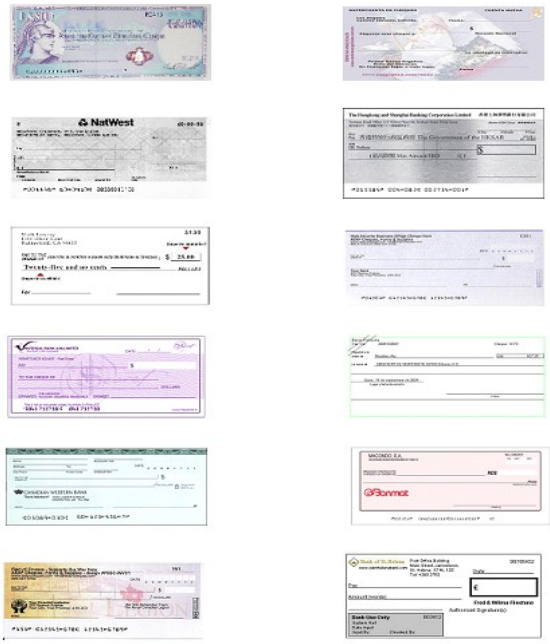


Fig 13: Different checks in check database

Fig 14: Different signatures in MCYT dataset

Signature verification of scanned image with complex background includes several steps, which usually begin with preprocessing, feature extraction using various local patterns and classification. A MCYT database has been used in all the experiments.

RESULTS AND DISCUSSIONS

The SLBP is analyzed on the sample signature images. The histogram feature vectors are calculated using SLBP histogram as shown in figure 15. These histogram feature vectors are evaluated with different classifiers, k-nearest neighbour (KNNC) and Linear Discriminant Classifier (LDC). In experiment, 100 sample signatures are taken from MCYT database and 15 individual signatures are from each sample total 1500 signatures are taken as training set (some of the examples of signature samples in training set are shown above). The testing of SLBP (feature extraction) is carried out using training set. Results are of classifiers are shown in table II and table III.

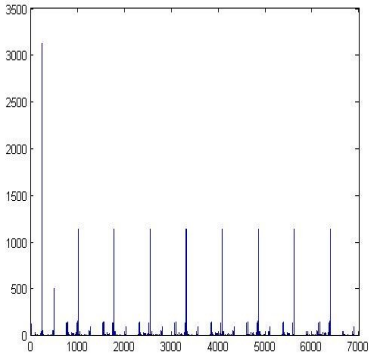


Fig.15 SLBP histogram

Table II Confusion matrix with Linear Discriminant Classifier (LDC)

True labels	1	2	3	4	5	6	Totals
1	12	3	0	0	0	0	15
2	1	10	0	0	0	4	15
3	0	0	15	0	0	0	15
4	0	0	0	13	0	2	15
5	0	0	0	2	13	0	15
6	1	1	0	0	0	13	15
Totals	14	14	15	15	13	19	90

Table III Confusion Matrix with k-nearest neighbour classifier (KNNC)

True labels	1	2	3	4	5	6	Totals
1	14	1	0	0	0	0	15
2	2	12	0	0	0	1	15
3	0	0	15	0	0	0	15
4	0	0	0	15	0	0	15
5	0	0	0	0	2	13	15
6	3	1	0	1	0	10	15
Totals	19	14	15	18	13	11	90

The algorithm is tested on MCYT database. The offline automatic signature verification is performed using SLBP features. In the experiment same features have been used for both CLBP and SLBP for signature verification. These feature vectors were evaluated using k- nearest neighbor and Linear Discriminant Classifiers. It has been observed that the CLBP and SLBP gives the same results for KNN classifier but SLBP gives less error rate as compared to the CLBP if we are using Linear Discriminant Classifier.

5. "Object Recognition based on Topology Preserving Skeleton Features"

Topology preserving skeletonization technique has been developed. The skeleton features have been identified for object recognition. The classifier used here is Support Vector Machine. The skeleton features used are shown to be effective and accurate in identifying objects. The dataset is tested on three variations SVM, Kernal SVM, MultiKernal SVM and observed that it is efficient with the classification of noisy artificial and real skeletons into different classes and in providing skeletons that are similar for a similar object. In order to achieve high accuracy, the algorithm preserves all the features needed for object recognition. The skeleton has an advantage that it requires less storage space and requires minimum bandwidth.

Figure 16 shows the general classification model used to recognize the objects based on skeleton features. In this model, the given image is pre-processed to extract the skeleton from training images by applying topology preserving skeletonization method. Once the skeleton is extracted, then the skeleton features are obtained and loaded. Then Support Vector Machine classifier was applied to different set of training to recognize the objects later test image sets are uploaded to recognize the objects exactly.

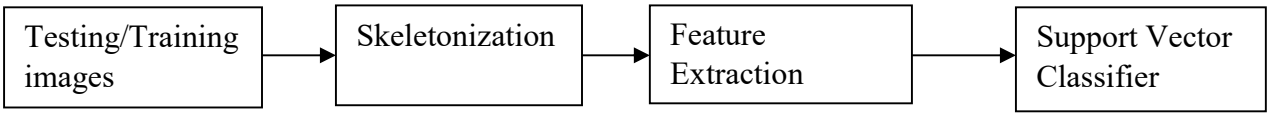


Fig.16. General Classification Model

Experiment Results

For object recognition, MPEG-7 dataset is used. This database comprises of images of 15classes of objects, each having 20 members. This dataset has many class shapes. Figure 17 shows some of the images chosen for training and testing during object recognition process.

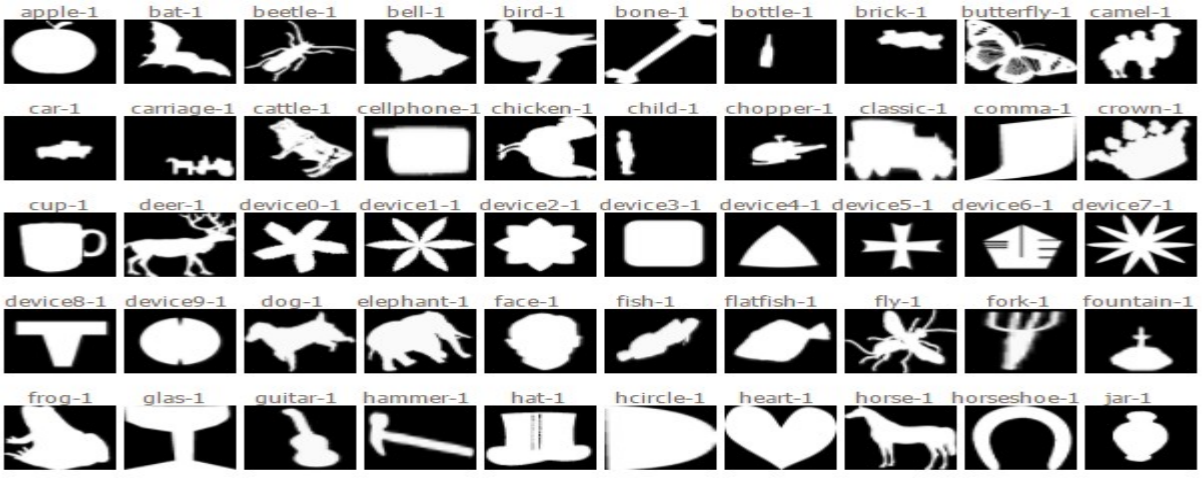


Fig.17. Training dataset used to obtain skeleton image

Figure 18 shows the skeletons obtained from the few images of training dataset for which recognition features are calculated during experimental results for object recognition.

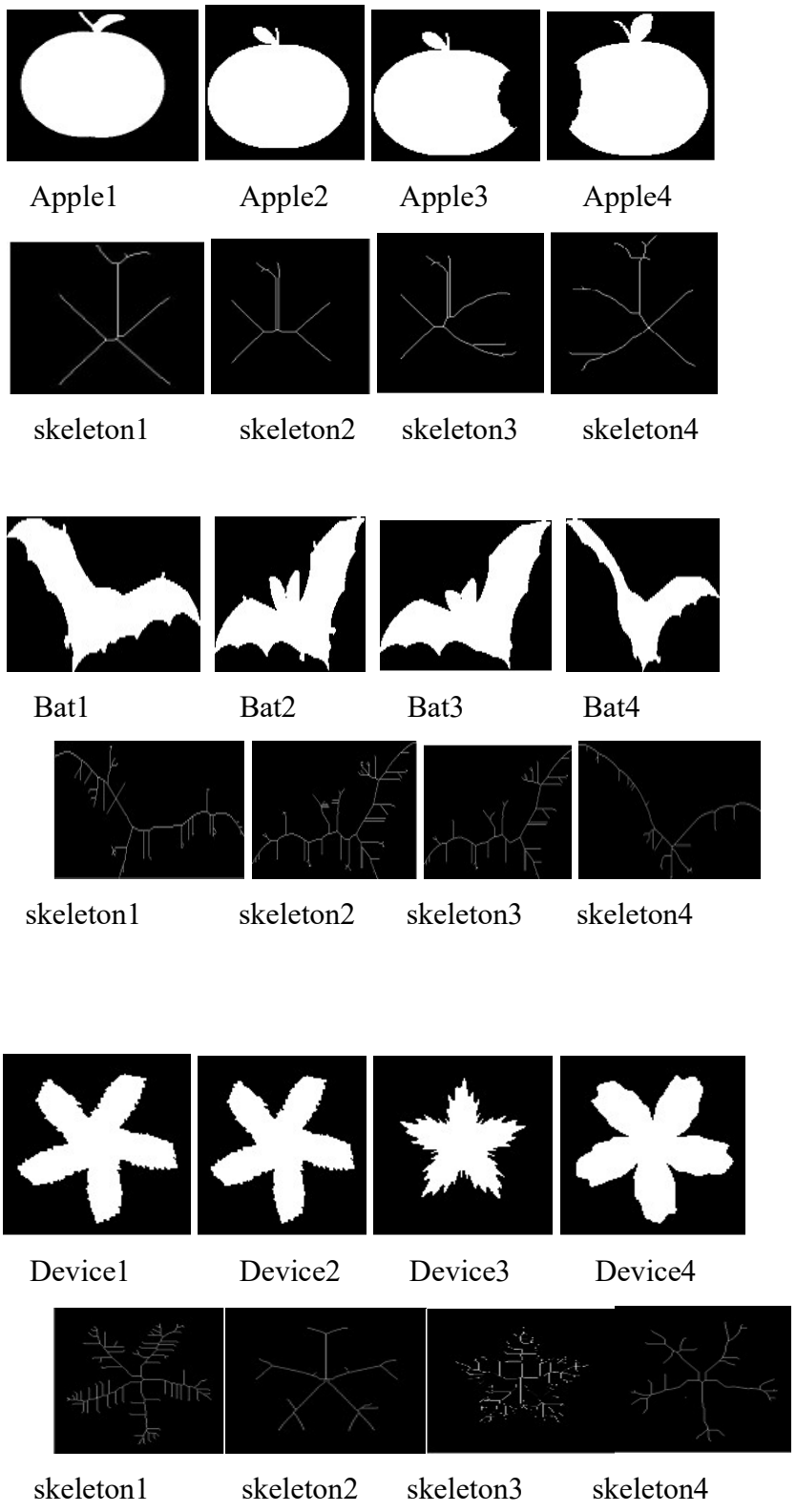


Fig.18. Skeletons extracted from few images taken from training dataset

SVM (linear): -

Table IV shows the results obtained by applying proposed skeletonization and SVM classification with a kernel linear on few classes from training dataset.

Table IV: Measuring accuracy by SVM (linear) based on TP, TN, FP, and FN.

SVM	TP	TN	FP	FN	ACC	SEN	SPEC
'Apple'	20	379	80	0	0.832985	1	0.825708
'Bat'	16	397	62	4	0.862213	0.8	0.864924
'Beetle'	18	447	12	2	0.970772	0.9	0.973856
'Bell'	19	318	141	1	0.703549	0.95	0.69281
'Butterfly'	17	422	37	3	0.916493	0.85	0.91939
'Camel'	20	157	302	0	0.36952	1	0.342048
'Car'	20	377	82	0	0.82881	1	0.821351
'Cup'	20	318	141	0	0.705637	1	0.69281
'Deer'	19	431	28	1	0.939457	0.95	0.938998
'Device'	161	241	38	39	0.839248	0.805	0.863799
'Elephant'	12	358	101	8	0.772443	0.6	0.779956
'Jar'	20	247	212	0	0.557411	1	0.538126
'Octopus'	20	225	234	0	0.511482	1	0.490196
'Rat'	19	343	117	0	0.755741	1	0.745652
'Tree'	19	320	139	1	0.707724	0.95	0.697168

In few cases, the suggested skeleton features utilized exhibits correctness about more than80%. In few cases, accuracy is between 35%-70% due to complexity in image shapes.

From Table IV, it is observed that, for the given input images, Beetle, Butterfly, Deer, their accuracy values are 97%, 91%, and 94% respectively. This shows that the proposed skeletonization method will preserve all the feature points needed for an object recognition process in order to achieve high accuracy.

KernalSVM(quadratic): -

Table V shows the results obtained by applying proposed skeletonization and SVM classification with a kernel quadratic on few classes from training dataset.

Table V: Measuring accuracy by SVM (quadratic)based on TP,TN,FP, and FN.

Kernal SVM	TP	TN	FP	FN	ACC	SEN	SPEC
'Apple'	20	385	74	0	0.845511	1	0.83878
'Bat'	20	391	68	0	0.858038	1	0.851852
'Beetle'	19	454	5	1	0.987474	0.95	0.989107
'Bell'	19	342	117	1	0.753653	0.95	0.745098
'Butterfly'	18	439	20	2	0.954071	0.9	0.956427
'Camel'	20	376	83	0	0.826722	1	0.819172
'Car'	20	410	49	0	0.897704	1	0.893246
'Cup'	20	350	109	0	0.772443	1	0.762527
'Deer'	20	447	12	0	0.974948	1	0.973856
'Device'	185	233	46	15	0.872651	0.925	0.835125
'Elephant'	18	364	95	2	0.797495	0.9	0.793028
'Jar'	20	254	205	0	0.572025	1	0.553377
'Octopus'	20	387	72	0	0.849687	1	0.843137
'Rat'	19	415	45	0	0.906054	1	0.902174
'Tree'	18	337	122	2	0.741127	0.9	0.734205

In most of the cases, the suggested skeleton features utilized exhibits correctness about more than85%. In few cases, accuracy is between 50%-84% due to complexity in image shapes.

From Table V, it is observed that, for the given input images, Beetle, Butterfly, Deer, Rat, their accuracy values are 98%, 95%, 97%, and 91% respectively.

MultiKernal SVM(linear_quadratic):

Table VI shows the results obtained by applying proposed skeletonization and SVM classification with a kernel linear and quadratic on few classes from training dataset.

Table VI: Measuring accuracy by SVM (linear_quadratic)based on TP,TN,FP, and FN.

Multi Kernal SVM	TP	TN	FP	FN	ACC	SEN	SPEC
'Apple'	20	430	29	0	0.939457	1	0.936819
'Bat'	20	410	49	0	0.897704	1	0.893246
'Beetle'	20	456	3	0	0.993737	1	0.993464
'Bell'	19	418	41	1	0.912317	0.95	0.910675
'Butterfly'	17	454	5	3	0.983299	0.85	0.989107
'Camel'	20	403	56	0	0.88309	1	0.877996
'Car'	20	418	41	0	0.914405	1	0.910675
'Cup'	0	459	0	20	0.958246	0	1
'Deer'	20	450	9	0	0.981211	1	0.980392
'Device'	198	234	45	2	0.901879	0.99	0.83871
'Elephant'	20	398	61	0	0.872651	1	0.867102
'Jar'	20	385	74	0	0.845511	1	0.83878
'Octopus'	0	457	2	20	0.954071	0	0.995643
'Rat'	0	455	5	19	0.949896	0	0.98913
'Tree'	19	399	60	1	0.872651	0.95	0.869281

In most of the cases, the suggested skeleton features utilized exhibits correctness about more than 90%. In few cases, accuracy is between 85%-90% due to complexity in image shapes.

From Table VI, it is observed that, for the given input images, Apple, Bat, Beetle, Bell, Butterfly, Car, Cup, Deer, Device, Octopus, Rat, their accuracy values are 93%, 90%, 99%, 91%, 98%, 91%, 96%, 98%, 91%, 95%, and 95% respectively. This shows that, in order to achieve high accuracy, the proposed skeletonization method will preserve all the feature points needed for an object recognition process.

Performance of SVM for images in Training set: -

Accuracy:

Figure 19 shows the accuracy of various images in graphical form.

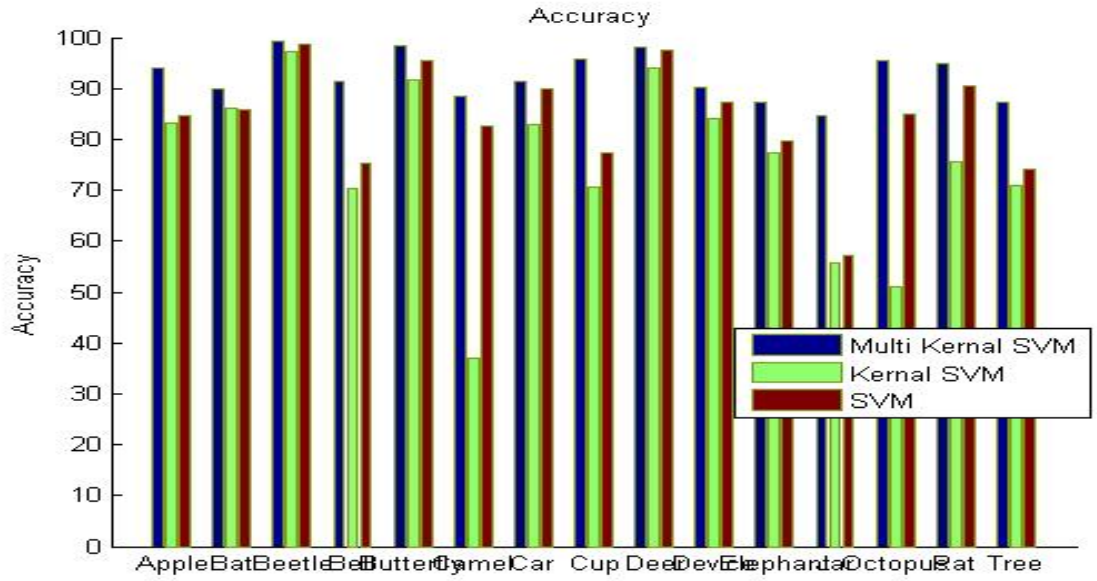


Fig. 19.Graphical representation of accuracy on various images using MultiKernalSVM, Kernal SVM, SVM

It is observed that from Figure 4, more than 90% accuracy is achieved for all the objects used in experimental results for object recognition with MultiKernal SVM classifier. This indicates that the extracted feature points from the skeleton obtained by applying a proposed method will suit for classifying any kind of objects appearing in the images.

Sensitivity:

Figure 20 shows the graphical representation of sensitivity of various images.

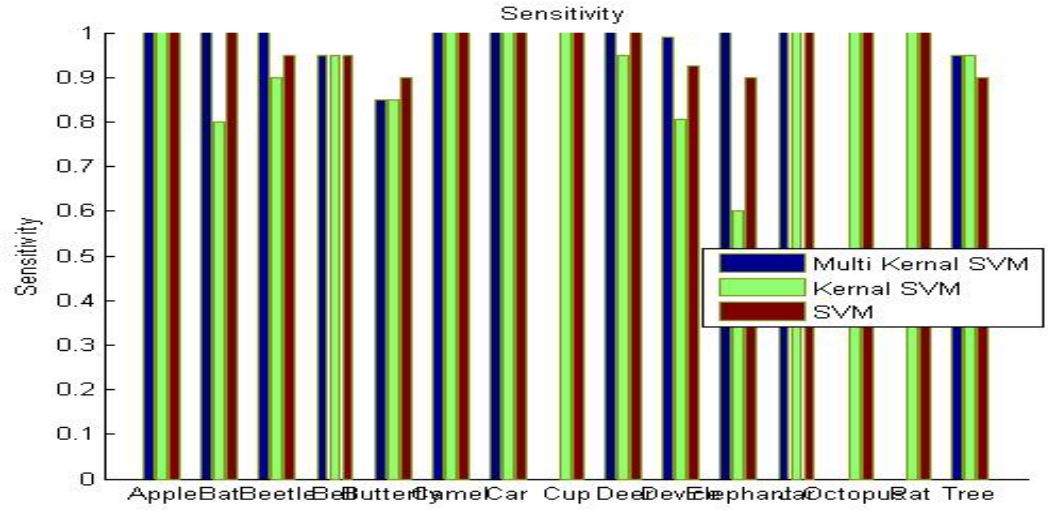


Fig. 20.Graphical representation of sensitivity on various images using MultiKernal SVM, Kernal SVM, SVM

It is observed that from Figure 5, all the objects used in experimental results for object recognition with Multi Kernal SVM classifier are correctly predicted. This indicates that the extracted feature points from the skeleton obtained by applying a proposed method will suit for classifying any kind of objects appearing in the images.

Specificity:

Figure 21 shows the graphical representation of Specificity of various images

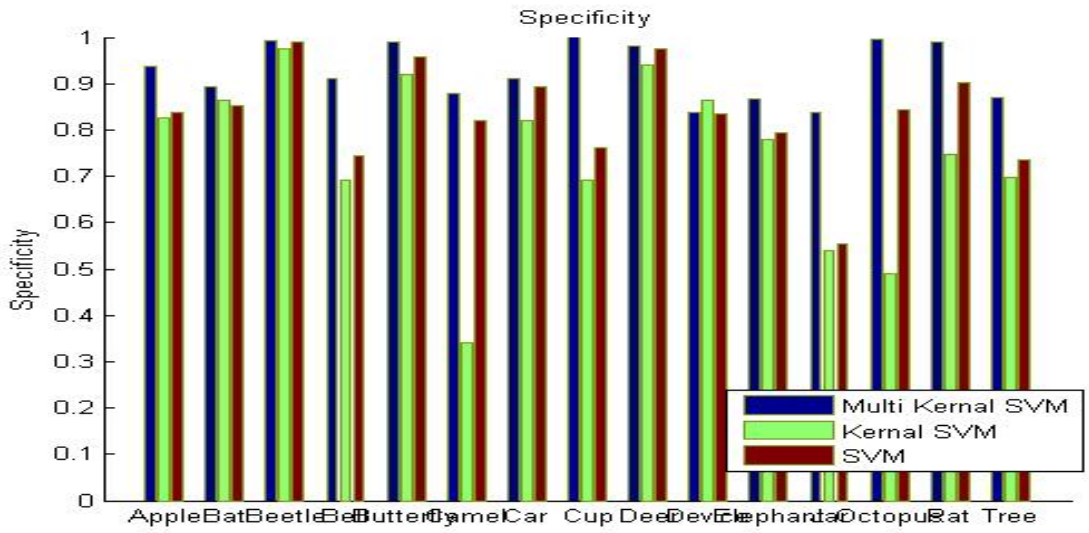


Fig. 21. Graphical representation of specificity on various images using MultiKernal SVM, Kernal SVM, SVM

It is observed that from Figure 6, some of the objects used in experimental results for object recognition with Multi Kernal SVM classifier are correctly predicted. This indicates that the extracted feature points from the skeleton obtained by applying a proposed method will suit for classifying any kind of objects appearing in the images.

Annexure – IX

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

1. Title of the Project –

   Skeleton based Shape Representation Techniques for Object Recognition

2. NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR –
   Dr.Atluri Srikrishna,
   Professor & HOD IT,
   Department of Information Technology,
   R.V.R. & J.C. College of Engineering,
   Chowdavaram, Guntur – 522 019

3. NAME AND ADDRESS OF THE INSTITUTION –
   R.V.R. & J.C. College of Engineering,
   Chowdavaram, Guntur – 522 019

4. UGC APPROVAL LETTER NO. AND DATE - - **F.N0. 43-269/2014(SR), Dt.15.Oct.2015**

5. DATE OF IMPLEMENTATION--- **01.07.2015**

6. TENURE OF THE PROJECT … **3 Years**

7. TOTAL GRANT ALLOCATED …….. Rs.10,25,000.00

8. TOTAL GRANT RECEIVED …….. Rs. 6,65,000.00
   TOTAL INTEREST AMOUNT EARNED ---------- Rs.30,911.00

9. FINAL EXPENDITURE …….. Rs. 6,53,824.13
   TOTAL AMOUNT REFUNDED …….. Rs.42,086.87

   (Through Andhra Bank D.D No.159448, Dt.18.08.2018)

10. TITLE OF THE PROJECT ---

Skeleton based Shape Representation Techniques for Object Recognition

11. OBJECTIVES OF THE PROJECT ……

- The study focuses on building efficient structural shape representation of the input shapes. Each shape component is a shape element and it is selected to represent a significant part(relative to its size) of the given shape.
- To explore the relationship between various proposals, and aim to develop efficient, unified algorithms for computing connected filters based on a variety of generalized connectivities.
- To develop algorithms for obtaining shape-scale and orientation-scale spaces using connected filters.
- To apply the number of algorithms developed to the problem of enhancing details in 2-D and 3-D medical images, in particular the detection of filamentous details such as blood vessels, anomalies in them, hair cracks in the bones using X-ray details simultaneously at multiple scales.

12. **WHETHER OBJECTIVES WERE ACHIEVED …… Yes**

13. ACHIEVEMENTS FROM THE PROJECT ……

The major research project focuses on to propose algorithms for obtaining shape-scale and orientation-scale spaces using connected filters and to develop unified algorithms for computing connected filters based on a variety of generalized connectivities. The following are the achievements attained in terms of research publications during the implementation of the major research project.

1. Initially we worked to propose method based on morphological thinning operation. Thinning is an interesting and challenging problem, and plays a central role in reducing the amount of information to be processed during pattern recognition, image analysis and visualization, computer-aided diagnosis.

Based on this work we have presented a paper on **" Topology Preserving Skeletonization techniques for Gray Scale Images"** in Sixth International Conference on Advances in Computing, Control, and Telecommunication Technologies - ACT 2015, organized by theIDES and the Association of Computer Electrical Electronics and Communication Engineers (ACEECOM). The paper is presented in the conference held during Oct 30-31, 2015; Trivandrum, India.

2. Through references we have identified the if skeletons are obtained on a image if contains noise , then it generates unexpected results, so we planned to propose a efficient denoising scheme in the pre-processing step.

Based on this we have worked on denoising scheme based on pixonal model and published a paper **" Pixon Based Image Denoising Scheme by Preserving Exact Edge Locations",** Springer Journal of Institution Engineers(INDIA):Series B, September 2016, Volume 97(3), Print ISSN :2250-2106, Pp:395–403.

3. Later we proposed work on identification of cataract from a eye image based on connected components from edge candidates. A cataract is a clouding of the lens inside the eye which causes to a decrease in vision or sight. Visual loss occurs because opacification of the lens obstructs light from passing and being focused on to the retina at the back of the eye. It is most commonly due to biological aging, but there are a wide variety of other causes also. As time passes, the yellow-brown pigment is deposited within the lens and this, together with disruption of the normal architecture of the lens fibres, leads to reduced transmission of light, which in turn leads to visual problems. Detecting cataract from human eye images is a challenging task owing to their variable appearance and the wide range of poses that they can adopt. The first need is a robust feature set that allows the human form to be discriminated cleanly, even in cluttered backgrounds under difficult illumination and noise conditions. A number of approaches have been proposed in the literature to match the cataract images by extracting texture information using Local Binary Pattern (LBP) , Histogram of Oriented Gradient(HOG) , and Scale Invariant Feature Transform (SIFT) .

To identify the cataract from a eye image we proposed a method based on nonlinear principle and published a paper on **"Computer Assisted Cataract Identification system from Noisy Images",** International Journal of Scientific and Engineering Research **(IJSER) ,** Volume 7, Issue 9, September 2016**, Print** ISSN 2229-5518,Pp:981-990.

4. The offline signature verification is an automatic verification system that works on the scanned image of a signature. Signature verification uses the gray level measure with varying foreground features. The signature verification is performed by identifying feature vector using local patterns. The Local Binary Pattern (LBP) in signature verification has used to extract the local structure information by establishing the relationship between central pixel and adjacent pixels and Support Local Binary Pattern (SLBP) extracts features for signature verification.

To address this we proposed a paper using LBP and SLBP for signature verification and published " **Offline Signature Verification using Support Local Binary Pattern",** International Journal of Artificial Intelligence & Applications,Volume 7, Issue 6, November 2016**,** Print ISSN **0**976-2191,Pp:85-94. The signatures are tested on MCYT dataset. The accuracy of the proposed method is tested against k-Nearest Neighbour Classifier (KNNC) and Linear Discriminant Classifier (LDC).

5. Object recognition is a procedure for recognizing a particular object in an advanced video or image. Appearance-based or feature-based techniques are used for object recognition. An object skeleton is the useful cue for object recognition, which provides a structural representation to specify the relationship among object parts. The shape's geometry and topology can be efficiently encoded. To recognize the object we extracted skeleton first from the given input image and then we obtained skeleton features which are used for object recognition. Skeleton features are extracted from the obtained skeleton. Skeleton features are end points, junction points, boundary junctions, boundary length and skeleton length. A skeleton point is referred as the center pointof a maximally inscribed disk.A skeleton endpoint is defined as a skeleton point having only one neighboring point.A junction point is referred as askeleton point having three or moreadjacent points. A connection point is defined as if a skeleton point is notan endpoint or a junction point.A branch pointis referred as a skeleton segment between two skeletons or a junction point.The branch of skeleton is the series of connection points between two directly associated skeleton points.

To recognize the real objects from the given input image based on skeleton features we proposed a paper "**Object Recognition based on Topology Preserving Skeleton Features"** and communicated with Scopus indexed journal International Journal of Advanced Intelligence Paradigms, Print ISSN : 1755-0386 , Online ISSN : 1755-0394 and under revision for publication.

14. SUMMARY OF THE FINDINGS ……

Summary of The work done for the period of 01.07.2015 to 30.06.2018

- Literature survey has been conducted.
- The information necessary for reducing the amount of information to be processed during pattern recognition, image analysis and visualization, computer-aided diagnosis is identified and checked the applicability of morphological transformations.
- A topology preserving thinning algorithm is used which removes the pixels from a gray scale images. First it checks for the condition whether a pixel is acyclic or not. If a pixel is acyclic, then it is removed from the image else retains in the image. A topology preserving skeleton is a synthetic representation of an object that retains its shape, topology, geometry, connectivity and many of its significant morphological properties.

- It has been observed in our experiments that thinning algorithm is stable and robust and yield promising performance for wide range of images.
- Through references we have identified the if skeletons are obtained on a image if contains noise , then it generates unexpected results, so we planned to propose a efficient denoising scheme in the pre-processing step.
- Late by applying the above concept we have proposed a method for classification.
- The offline signature verification is an automatic verification system that works on the scanned image of a signature. Signature verification uses the gray level measure with varying foreground features. The signature verification is performed by identifying feature vector using local patterns.
- Recently we worked to recognize the objects based on skeleton features and proposed a paper Object Recognition based on Topology Preserving Skeleton Features. To recognize the object from the given image we first obtained the skeleton of an image the we extracted the following Skeleton features end points, junction points, boundary junctions, boundary length and skeleton length.
- Topology preserving skeletonization technique has been developed for object recognition. The skeleton features have been identified for object recognition. The classifier used here is Support Vector Machine. The skeleton features used are shown to be effective and accurate in identifying objects. The dataset is tested on three variations SVM, Kernal SVM, MultiKernal SVM and observed that it is efficient with the classification of noisy artificial and real skeletons into different classes and in providing skeletons that are similar for a similar object. In order to achieve high accuracy, the algorithm preserves all the features needed for object recognition. The skeleton has an advantage that it requires less storage space and requires minimum bandwidth.

15. CONTRIBUTION TO THE SOCIETY ……

Shape extraction technology can be applied to a wide spectrum of problems including:

- Character recognition: Mail sorting, label reading, text reading, vehicle number recognition.
- Medical image analysis: Tumor detection, Fracture analysis, measurement of size and shape of internal organs growth.
- Industrial automation: Parts identification on assembly lines, Flaw detection and fault inspection.
- Robotics: Recognition and interpretation of object in a scene, motion control and execution through visual feedback.
- Cartography: Map making from photographs, synthesis of thematic maps such as weather maps, water resource maps, Road net work maps, urban utility maps.
- Radar imaging: Target detection and identification, guidance of aircraft in landing, guidance of remotely piloted vehicles.

- Remote sensing: Multi spectral image analysis, weather prediction, classification and monitoring of urban, agricultural, and marine environments from satellite images.
- Biometrics: Identification of criminals at entry & exit points at places such as air ports and railway stations.
- Certification: Quality of seeds, grains, food grains etc. certification.

16. WHETHER ANY Ph.D. ENROLLED/PRODUCED OUT OF THE PROJECT…… 2

- One of my scholar (M.Pompapathi, with admission No:11PH012, with JNTUA) has been awarded Ph.D. from JNTUA, Ananthapuramu in the month of November 2016, and proposed methodologies in his thesis are helpful in completion of his research work.

- One of another scholar (N.Neelima, with admission No:1203PH06B7, with JNTUH) is pursuing Ph.D. from JNTUH, Hyderabad and the results obtained in this project are highly useful for her research work and workdone under this project given a research paper on "**Object Recognition based on Topology Preserving Skeleton Features"** and communicated with Scopus indexed journal International Journal of Advanced Intelligence Paradigms, Print ISSN : 1755-0386 , Online ISSN : 1755-0394 and under revision for publication.

17. NO. OF PUBLICATIONS OUT OF THE PROJECT ……. 05

The following are the publications published in Journals/Conferences from the starting of the Major Research Project from 01.07.2015.

1. **Dr. A. Sri Krishna**, Dr. K. Gangadhar, N. Neelima, K. Ratna Sahithi, **"Topology Preserving Skeletonization techniques for Gray Scale Images"** presented in Sixth International Conference on Advances in Computing, Control, and Telecommunication Technologies - ACT 2015.
2. **Dr.A.Srikrishna,** Dr.B.Eswara Reddy, **M.Pompapathi, "Pixon Based Image Denoising Scheme by Preserving Exact Edge Locations",** Springer Journalof Institution Engineers(INDIA):Series B, September 2016, Volume 97(3), Print ISSN :2250-2106, Pp:395–403.
3. VickramPentyala, **M.Pompapathi,** and **Dr.AtluriSrikrishna**, **"Computer Assisted Cataract Identification system from Noisy Images",** International Journal of Scientific and Engineering Research **(IJSER) ,** Volume 7, Issue 9, September 2016**, Print** ISSN 2229-5518,Pp:981-990.

4. VickramPentyala**, Dr.AtluriSrikrishna** and D.Swapna " **Offline Signature Verification using Support Local Binary Pattern",** International Journal of Artificial Intelligence & Applications,Volume 7, Issue 6, November 2016**,** Print ISSN 0976-2191,Pp:85-94.

5. N.Neelima, **Dr.A.Srikrishna**,Dr.K.Gangadhara Rao, and **Dr.M.Pompapathi,** "**Object Recognition based on Topology Preserving Skeleton Features"** communicated with Scopus indexed journal International Journal of Advanced Intelligence Paradigms, Print ISSN : 1755-0386 , Online ISSN : 1755-0394 and under revision for publication.