OBJECT RECOGNITION BASED ON GABOR WAVELET FEATURES

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Abstract-The proposed method is to recognize objects from different categories of images using Gabor features. In the domain of object recognition, it is often to classify objects from images that make only limited part of the image. Hence to identify local features and certain region of images, salient point detection and patch extraction are used. Gabor wavelet features such as Gabor mean and variance using 2 scales and 2 orientations and 2 scales and 4 orientations are computed for every patch that extracted over the salient points taken from the original image. These features provide adequate resolution in both spatial and spectral domains. Thus extracted features are trained in order to get a learning model, tested and classified using SVM. Finally, the results obtained using Gabor wavelet features using 2 scales and 2 orientations and 2 scales and 4 orientations are compared and thus observed that the latter performs better than the former with less error rate. The experimental evaluation of proposed method is done using the Caltech database.

I. INTRODUCTION

Object recognition is of greater task in computer vision. It is the concept of finding objects in an image or video sequence. The object recognition has extended their applications in many areas such as Image Panoramas, Image Watermarking, Global Robot Localization, Face Detection, Optical Character Recognition, Content-Based Image Indexing Automated Vehicle Parking Systems and Visual Positioning and Tracking [1]. Normally, Human visual systems recognize large number of objects from images with little effort even when they have different appearances in different circumstances. But computer systems face it with lot of difficulties to recognize objects that are occluded by other objects and that having different appearances [2]. The proposed method overcomes this strategy that it recognizes objects in these challenging circumstances and provides better results on Caltech database.

Salient point detection plays an important role in content based image retrieval in order to represent the local properties of the image. Since classic corner detectors cannot support natural images, detector based on wavelet transform to represent global as well as local features is used to detect the salient points [3, 4]. C.Schmid et al used local gray invariants for image retrieval where local gray invariants are computed automatically over the detected interest points [5]. Weber et al proposed the computation of K-means clustering algorithm at Forstner interest points for object recognition [6].

Patches have to be extracted at different scales to address the scale difference of the objects. Moreover occlusions of images can easily be handled by these patches [7]. Alexandra Teynor et al calculated gray values, Haar integral gray invariants and SIFT for image patches over the interest points for visual object class recognition [8].

Due to mathematical and biological properties, Gabor Wavelet Features are applied in Object Representation, Face Recognition, Tracking and Edge Detection [9]. The views of Gabor Features for various applications vary from author to author.

The work based on Gabor wavelet for face recognition is proposed by Shiguang Shan et al [10]. The work is done by implementing face recognition system based on discriminant analysis of Gabor representation. P.Kruizinga et al compared and evaluated the texture features using local spectrum obtained by a bank of Gabor filters [11]. Xiao gang Wang et al combined Bayesian Probabilistic model with Gabor features for face recognition [12]. Peifeng Hu et al proposed a method using Gabor filters for gray character classification where feature vectors are extracted based on dominant orientation matrix computed from the bank of Gabor filters [13]. The work done on object recognition using Gabor wavelet is proposed by SHEN Lin-Lin et al [14]. The work is based on extracting features using Gabor wavelet with 5 scales and 8 orientations and classifying features using SVM classifier for face recognition.

The main goal is to improve the literature survey by using effective features in order to handle occluded part of the image. The contribution of this work is, (i) Salient Point Detection and Patch Extraction to overcome the strategy of locating the objects present in the particular part of the image. (ii) Feature Extraction to handle various complex images which looks different in different circumstances. A fair amount of work has been done previously for face recognition using Gabor wavelet features with different scales and orientations. In this proposed method, the whole Caltech database is evaluated based on Gabor wavelet features with 2 scales and 2 orientations and 2 scales and 4 orientations. Gabor wavelet features highly discriminate the images irrespective of their localizations in different circumstances. Then these features are classified using SVM classifier. The single class object recognition task that is to recognize object or non object has been done here to increase the robustness of the proposed method. Thus the task evaluated using performance measures and error rate on different categories of Caltech database support proposed method with better results.

II. OUTLINE OF THE PROPOSED METHOD

The first step of the proposed system is Salient point detection.The points are detected from the original image taken from the Caltech database. The second step is Patch extraction. The patches are extracted over the salient points. The next step is Feature extraction. The features are extracted for each and every patch using Gabor wavelet. The final step is Classification. Here features are classified using SVM classifier. The overall proposed system is shown in Figure1.

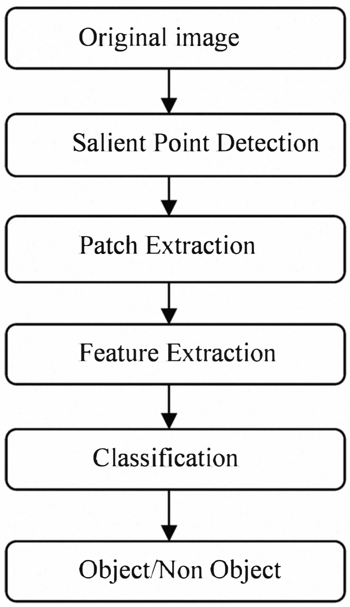

Figure1. Block diagram of overall proposed system

A. *Salient point Detection*

The salient points are not confined to corners, but show variations that happen at different resolutions in the images [3]. The salient points are detected from different categories of Caltech database. These points are detected using wavelet transform which is used to extract both global as well as local features [4]. The main aim is to find relevant points to represent global variation by tracking wavelet coefficient at finer resolutions.

The algorithm for detecting relevant salient points using Haar wavelet transform is given as,

1. For each wavelet cefficient, maximum child coefficient is found.
2. Track the maximum wavelet coefficients recursively in finer resolutions.
3. Set the saliency value of the tracked pixel: the sum of the wavelet coefficients tracked.
4. The most prominent points are chosen finally based on the saliency value.

The wavelet with full level decomposition is used here. Thus the horizontal, vertical and diagonal coefficients are tracked recursively at finer resolutions where variations occur in the images. The prominent salient points detected from each and every categories of Caltech database is 250 in order to view the input images more clearly. Fig. 2 shows the prominent salient points for sample images from all categories like airplane, car, bike, face, leaf along with two background images in Caltech database.

B. *Patch Extraction*

The collection of smaller sub square images that is modeled from the variability of images is called patches [1]. Here these sub square images are extracted from the original images over the salient points. Patch size is of great importance in extracting patches. Patches are extracted at different sizes such as 5x5, 7x7, 9x9, 11x11, and 15x15. In this proposed method patch of size 11 x 11 is extracted over the salient points, since Caltech database performs well for patch of size 11x11 [2].

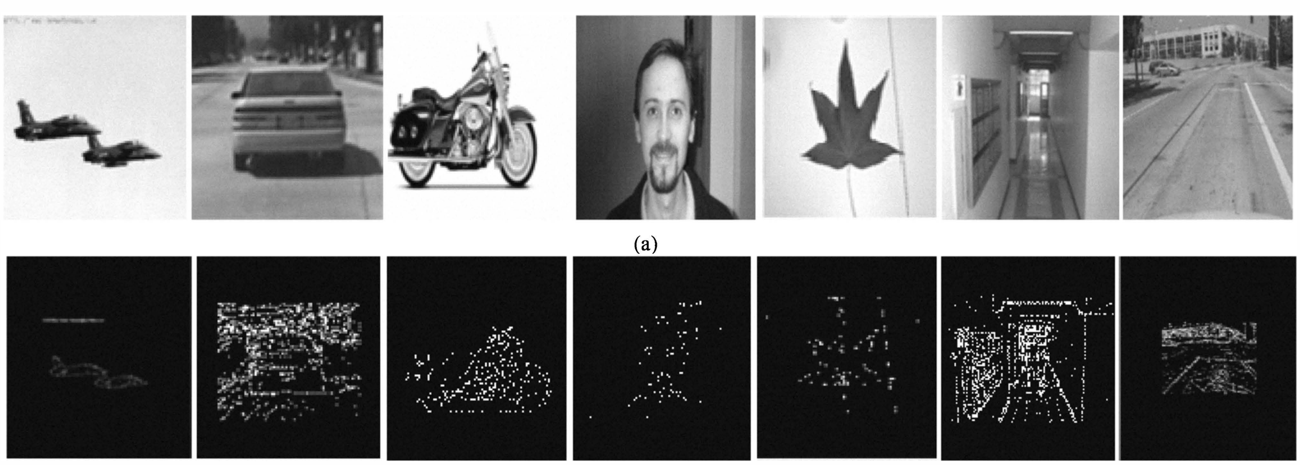

Figure2.(a). Categories in Caltech Database (b). Prominent Salient Points Detected for corresponding Categories

C. Feature Extraction

The feature extraction is a special form of reduction in pattern recognition and in image processing. Normally, the input data is transformed into a set of features which is called as feature extraction. The reduced information instead of full size input is used to recognize various complex images with better accuracy. The features used here is Gabor wavelet features.

2D Gabor wavelet is a Gaussian kernel modulated by a sinusoidal plane wave in the spatial domain [15]. As, the set of Gabor filters are obtained using different scales and orientations, here Gabor filter bank is obtained using 2 scales and 2 orientations and 2 scales and 4 orientations for each and every patch extracted from the original image. 2D Gabor wavelet is defined in (1).

$$g(x, y) = 1/2\pi\sigma_x\sigma_y\,[e^{-1/2(x^2/\sigma_x{}^2+y^2/\sigma_y{}^2)+2\pi j\omega_x}] \quad (1)$$

g (x, y) is a mother Gabor wavelet, self similar filter dictionary can be obtained by appropriate scales and orientations of g(x, y) through generating function and is given in (2).

$$g_{mn}(x, y) = a^{-m}G(x', y') \quad (2)$$

where $X' = a^{-m}(x\cos\theta + y\sin\theta)$

$y' = a^{-m}(-x\sin\theta + y\cos\theta)$

a^{-m} is scale factor

$a = \left(\frac{U_h}{U_l}\right)^{M-1}$

M- Number of scales,

U_h and U_l is upper and lower center frequency respectively

θ=orientation of Gabor wavelet= $^{n\pi}/_{k}$

K= Number of orientations

σ_x, σ_y are standard deviations along x and y axis and are given in (3) and (4) respectively.

$$\sigma_x = \left[\left(\sqrt{2\ln 2}(a+1)/(a-1)U_h\right)\right] \quad (3)$$

$$\sigma_y = 1/2\pi\tan(\pi/2k)\left[\sqrt{U_h{}^2/2\ln 2}\sqrt{1/2\pi\sigma_x{}^2}\right] \quad (4)$$

Thus the filter bank of Gabor wavelet constructed for single patch using 2 scales and 2 orientations and 2 scales and 4 orientations are 4 filtered images and 8 filtered images respectively.

Mean and standard deviation, on these corresponding filtered images gives the feature vectors for each and every patch.

D. Classification

The classification is done using Support Vector machines. This is a special form of learning machine, based on statistical learning theory. SVM uses Polynomial Classifiers, Neural Networks, and Radial Basis Function Kernel (RBF) networks as a special case [16].

As Caltech database used here is a complex database, non linear SVM classifier is used to avoid increased complexity. The suitable kernel used here to map input space into high dimensional space and so converts nonlinear domain into linear domain is Radial Basis Function Kernel (RBF).

III. Performance Measure

The performance of an object recognition system can be measured based on the two quantities of interest. One quantity is to maximize the number of correct decisions and the other is to minimize the number of false detections.

The quantity Recall indicates the proportion of the objects that are correctly detected. The other quantity Precision gives the number of false detections relative to the total number of detections made by the system. The two quantities are given in (4) and (5) respectively

$$Recall = \frac{TP}{TP+FN} \quad (4)$$

$$Precision = \frac{TP}{TP+FP} \quad (5)$$

IV. RESULTS AND DISCUSSIONS

There are 1074 airplane images, 1155 car images, 826 bike images, 450 face images and 186 leaf images in the Caltech database. Along with this there are 900 mixed background images commonly used as negative images for all four categories except car and separate 1370 background images containing only roads and street scenes which are used as negative images for car category. The images in Caltech database are of various sizes and for the experimental purpose; they are converted into gray scale images [17].

Initially 250 most prominent points are taken using wavelet based salient point detector for every image. The patch of size 11×11 is extracted over each salient point. Then Gabor wavelet features such as Gabor mean and variance are extracted for each and every patch that extracted from the original images over the salient points. Finally, the features thus obtained are given to SVM classifier in order to recognize objects based on these Gabor wavelet Features.

A. Experimental Results for Single Class Object Recognition

The task in case of single class object recognition is to classify objects from backgrounds. Thus to recognize the objects from backgrounds and so to have a suitable learning process, both positive and negative images of Caltech database are trained and tested.

The experimental evaluation is done by training 150 positive and negative images of all four categories of Caltech database except leaf, whereas in case of leaf, 100 positive and negative images are trained. The remaining images in the whole database are used for testing.

The images used for training and testing the whole database both in numbers and their respective percentage is shown in Table I.

TABLE I
NUMBER OF IMAGES USED FOR TRAINING AND TESTING

Category	Number of Images used for Training		Number of Images used for Testing	
	Positive Images	Negative Images	Positive Images	Negative Images
Airplane	150(13.9%)	150(16.6%)	924(86%)	750(83.3%)
Car	150(12.9%)	150(10.9%)	1005(87%)	1220(89.1%)
Bike	150(18.1%)	150(16.6%)	676(81.8%)	750(83.3%)
Face	150(33.3%)	150(16.6%)	300(66.6%)	750(83.3%)
Leaf	100(53.7%)	100(11.1%)	86(46.2%)	800(88.8%)

The performance measures namely Recall, Precision, F-measure along with the error rate that calculated in percentage for all five categories of Caltech Database is given in Table II. In Table II, GWF1 indicates Gabor Wavelet Features obtained with 2 scales and 2 orientations. In case of this 4 filtered images are constructed. Mean and standard deviation are computed for each filtered images and so gives the feature dimension of 8 for a single patch. Since 250 patches are constructed for a single image, the total number of features thus obtained is 2000.

GWF2 indicates Gabor Wavelet Features obtained with 2 scales and 4 orientations. In case of this 8 filtered images are constructed. Mean and standard deviation are computed for each filtered image. This gives the feature vector of dimension 16 for a single patch. Thus the total number of features obtained is 4000 per image.

The values are highlighted in bold in order to represent the features with less error rate and high performance measure. While evaluating the performance measures namely Recall and Precision on individual categories of Caltech database, Recall which retrieve the relevant positive results is obtained better for all the four categories except leaf while using GWF2. Therefore, it is observed that maximum number of objects have been detected for all these four categories namely airplane, car, bike and face using GWF2 and thus confirmed that this feature is well suited for categories with both simple and cluttered backgrounds.

In case of leaf, Recall is higher while using GWF1. So, it is inferred that GWF1 supports category with complex backgrounds.

On considering precision which gives equal importance in evaluating both positive and negative images, better precision is obtained for airplane and face while using GWF1. In case of car, bike and leaf, precision is higher by using GWF2. It is inferred that precision of leaf while using both GWF1 and GWF2 is very less when compared to other categories. This is due to large deviations in testing the images of both positive and negative category.

Moreover, it is also observed that GWF2 handles evaluation of both positive and negative images with equal importance by giving better recall for four categories, better precision for three categories among five categories of Caltech database respectively. Therefore from the overall performance measures, it is inferred that GWF2 performs better than GWF1.

In addition with the performance measures, the error rate is calculated here to highlight the effective feature that supports proposed method with better accuracy. Lesser the error rate better will be the performance.

The error rate is calculated by dividing the total number of false detections by total number of images used for testing both positive and negative categories of Caltech Database. In the Table II, it is inferred that the error rate is obtained less for all five categories by using GWF2.

Moreover, while comparing the error rate of all five categories, face category have maximum error rate than all other categories. Obviously, the performance of these Gabor wavelet features on recognizing face is also very less. This is mainly because the face images of Caltech databases contain collection of faces surrounded by many complex backgrounds that lead to much false detections which are the significant factor to provide maximum error rate and so less performance.

However, by depicting the overall performance of the proposed method, GWF2 performs better by providing less error rate than GWF1.

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TABLE II
PERFORMANCE MEASURES AND ERROR RATE FOR ALL FIVE CATEGORIES OF CALTECH DATABASE

Category	True positive		False Negative		True Negative		False Positive		Recall (%)		Precision (%)		Error Rate (%)	
	GW F1	GW F2	GW F1	GW F2	GW F1	GW F2	GW F1	GW F2	GW F1	GW F2	GW F1	GWF 2	GW F1	GWF2
Airplane	580	811	344	113	739	719	11	31	62.7	**87.8**	**98.1**	96.3	21.2	**8.6**
Car	988	1003	17	2	777	918	443	302	98.3	**99.8**	69	**76.8**	20.7	**13.6**
Bike	574	590	102	86	695	696	55	54	84.9	**87.3**	91.2	**91.6**	11	**9.8**
Face	168	180	132	120	669	661	81	89	56	**60**	**67.5**	66.9	20.3	**19.9**
Leaf	74	62	12	24	576	739	224	61	**86**	72	24.8	**50.4**	26.6	9.5

V. CONCLUSION

The work proposed here focuses on recognizing various objects by computing features for each and every patch that are extracted over the salient points in complex images. Thus the extracted features using Gabor wavelet proves to be a challenging task, as several factors complicate this successful method such as clutter, occlusion and object transformations like translation and scaling. This proposed method increases stability, uniqueness, and accuracy and thereby decreases the computational complexity, since few points are enough to recognize the objects. The results on this task of Caltech database have proved that proposed method can be able to recognize objects with good recognition rate along with backgrounds based on Gabor wavelet Features.

REFERENCES

[1] Daniel Martin Keysers, "Modeling of Image Variability for Recognition", RWTH, Aachen University, Germany, 2006.

[2] Andre Hegerath, "Patch-based Object Recognition", Diploma Thesis, Human Language Technology and Pattern Recognition Group, RWTH Aachen University, Germany, 2006.

[3] Nicu Sebe, Michael S. Lew, " Comparing salient point detectors", Pattern Recognition Letters, Leiden Institute of Advanced Computer Science, Leiden University, pp.89-96, 2003.

[4] E. Loupias, N. Sebe, S. Bres, and J-M. Jolion, "Wavelet-Based Salient Points for Image Retrieval", In International Conference on Image Processing, vol.2, pp.518-524, 2000.

[5] C. Schmid, R.Mohr, "Local Gray Value Invariants for Image Retrieval", In Proceedings of IEEE Transactions on Pattern Analysis and Machine Intelligence, pp.530-534, 1997.

[6] M. Weber, M. Welling, and P.Perona, "Unsupervised Learning of Models for Recognition", In Proceedings of the Sixth European Conference of Computer Vision, 2000

[7] Thomas Deselaers, Daniel Keysers, and Hermann Ney, " Improving a Discriminative Approach to Object Recognition using Image Patches", In Proceedings of DAGM, 2007.

[8] Alexandra Teynor, Esa Rahtu, Lokesh Setia, and Hans Burkhardt, "Properties of Patch Based Approaches for the Recognition of Visual Object Classes", In Proceedings of DAGM, pp.284-293, 2006.

[9] L.Shen and L. Bai, "A review of Gabor wavelets for face recognition" , Pattern. Analysis and Applications, pp.273-292, 2006.

[10] Shiguang Shan, Wen Gao1, Yizheng Chang, Bo Cao1, Pang Yang, "Review the Strength of Gabor features for Face Recognition from the Angle of its Robustness to Mis-alignment", In ICPR, vol.1, pp.338-341, 2004.

[11] P. Kruizinga, N. Petkov and S.E. Grigorescu, " Comparison of texture features based on Gabor filters", In Proceedings of the 10th International Conference on Image Analysis and Processing, Venice, Italy, September 1999.

[12] Xiaog Xang Wang, Xiaoou Tang, " Bayesian Face Recognition Using Gabor Features", In Proceedings of WBMA, 2003.

[13] Peifeng Hu, Yannan Zhao, Zehong Yang, Jiaqin Wang, "Recognition of Gray Character using Gabor Filters", In the proceedings of 5th International Conference on Information Analysis, pp.419-424, 2002.

[14] Shen Lin-Lin, JI Zhen, "Gabor Wavelet Selection and SVM Classification for Object Recognition", ACTA, Automatica Simica, 2008.

[15] Wei Jiang, Kin-Man Lam, and Ting-Zhi Shen, "Efficient Edge Detection Using Simplified Gabor Wavelets", IEEE Transactions on Systems, Man, and Cybernetics, pp.1036-1049, 2009.

[16] B.Scolpkopf, K.Sung, G.Burges, F.Girosi, P.Niyogi, "Comparing Support Vector Machines with Gaussian Kernel to Radial Basis Function Classifiers",IEEE Transactions on Signal Processing, vol.45, issue.11, pp.2758-2765, 1996.

[17] Thomas Deselaers, Andre Hegerath, Daniel Keysers, and Hermann Ney, "Sparse Patch-Histograms for Object Classification in Cluttered Images", In Proceedings of DAGM,2007.