wjert, 2025, Vol. 11 Issue 9, 61-75 *Review Article* **ISSN 2454-695X**

World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 7.029

THE ART OF EXTRACTING IMAGE FEATURES: A REVIEW PAPER

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Article Received on 14//07/2025 **Article Revised on 03/08/2025** **Article Accepted on 23/08/2025**

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ABSTRACT

The most crucial thing in computer vision or image processing could be the concept of feature extraction. It involves transforming the raw image data into compact and more meaningful representations of the image. These representations are known as features. The process involves encoding the image information like the content of the image, characteristics of an image or the structure of the image. These features are required for every task we do in computer vision like object detection, image classification, image retrieval, image alignment, image stitching and so on. So, it is a basic need that one can extract the feature in an accurate and efficient way but at the same time, one has to consider the exactness and relevancy of the feature as per the need of the application. The urge to get more precise and relevant features drives the development of new and modified algorithms and methods for feature extraction. Here is an attempt to collect and study the various methods for feature extraction of an image.

KEYWORDS: Computer Vision, Feature Extraction, Image Processing, Image Analysis.

1 INTRODUCTION

In the entire journey of Digital image processing to Computer Vision, one thing was very common in both, that is, feature extraction. Considering the image dataset, one expects to have derived features that represent an abstract, non-redundant set of features aimed to provide useful information for further processing of the data in a meaningful way. This extraction of features should not be for the sake of tradition but it should be a vehicle that helps in the process of learning and interpreting data by generalisation. Apart from its multiple outputs takeaway, feature extraction is also expected to deliver features with high information content, that are desirably unique and distinguishable, and that seems to be a challenge.[1] The extracted features must have invariance under varying geometric parameters.

The features to be extracted can be either of the following categories: colour features, texture features, geometric features, and statistical features, as briefed in Table 1.

Depending upon the features you are looking at, the extraction algorithms are designed. To mention a few: colour-based extraction methods- where information is extracted based on the distribution of the colour in an image. Shape-based feature extraction methods concentrate on the geometric shapes in the image. But whatever method one uses the result is a set of all the extracted features, generally stored in a feature vector which is capable of representing the entire image.

Table 1: Types of Features in an image.

Sr No	Feature Type	Description	Subtype	Description
Colour Features[2]				
a)	Colour Moments	These are scale-based values based on a probability distribution.	Mean	It is the mean colour value of the image
			Standard Deviation	It is the square root of the distribution variation
			Skewness	It is the degree of asymmetry in the distribution
b)	Colour Histogram	It is a representation of the distribution of colours in an image, that is, how many pixels in the image have these particular colour values.		
c)	Average RGB	It gives an overview of the overall colour tone of an image, that is which colour is dominant		
Texture Features: describes the spatial arrangement of the pixels[3]				
a)	Gray-Level Co-occurrence Matrix (GLCM)	It focuses statistical properties of pixel relationships,	Contrast	Considers the intensity between neighbouring pixels, and local variations are measured.
			Energy	Measure the uniformity or orderliness of the texture.
			Homogeneity	Take into account the closeness of the pixel intensities.
			Correlation	It is a description of linear dependencies between

				pixel intensities.
			Entropy	Counts the randomness in the texture pattern.
			Angular Features	Derived from the angles formed by pixel pairs gives directional texture information.
b)	Tamura features	Focus on perceptual aspects of texture	Coarseness	Describes the size of prominent texture elements.
			Contrast	Points out the difference in the brightness of the adjacent pixels.
			Directionality	Describe the orientation of the pattern.
			Regularity	Measures how orderly or uniform the texture is
			Line-Likeness	Assesses the presence of linear patterns in the texture
			Roughness	Measures irregularities or variations in the intensity

Geometry features: describe the spatial arrangement and relationships between objects or structures in an image.[4] These features are also known as shape-based features. Since it represents the physical structure of the object. In a paper called Detecting Tumours in Medical Images Using Segmentation and Feature Extraction Techniques, A. Sinduja has taken a review of all these concepts.[1]

a)	Area	The total number of pixels enclosed by the boundary of an object
b)	Perimeter	Specifies the length and boundary of the object.
c)	Centroid	It computes the geometric centre of an object
d)	Bounding Box	The smallest rectangle that accommodates an object
e)	Aspect Ratio	The ratio of the width to the height of an object's bounding box
f)	Eccentricity	Describes the elongation of an object like how stretched or compressed the object is
g)	Circularity	A measure of how closely an object resembles a perfect circle
h)	Orientation	The angle at which the major axis of an object's bounding box is oriented with respect to a reference axis.
i)	Solidity	The ratio of an object's area to the area of its convex hull.
j)	Convexity	It indicates the deviation of the object from its convex shape. It is represented by the ratio of the perimeter of that convex body to the total perimeter of the object.
k)	Elongation	It is the ratio of width to length of a bounded box of an object.
l)	Sphericity	It is the proportion of the radius of the inner circle to the outer circle of an object.
m)	Compactness	It is a measure of how dense or closely packed an object's shape is. It is used to quantify how well the shape fits in an enclosing area.
n)	Irregularity	Very similar to compactness but focuses on the unevenness of the boundaries. It measures the deviation of the shape being uniform, symmetrical or smooth.
o)	Extent	It indicates the amount of space a shape takes in the bounding box. If

		the value of extent is 1, it means the shape has taken all the space within the bounding box and lower values of extent indicate the sparsity.
Statistical Features: It is an analysis of pixel intensity within an image. It provides information like the distributions and relationships between the grey levels of an image.[5,1]		
a)	Mean	The average intensity value of all pixels in an image, talks about the central tendency of the image.
b)	Variance	A measure of the spread or dispersion of pixel intensities
c)	Standard Deviation	Measure of how much individual pixel intensities deviate from the mean
d)	Smoothness	It represents how smooth or rough the texture appears.
e)	Fifth and Sixth Central Moment	It provides information about the shape and skewness of the distribution of pixel intensities.
f)	Correlation	It provides information on how similar or dissimilar the textures are in different directions. The linear relationship between different pixel intensities at different positions is shown.
g)	Kurtosis	It provides insights into the distribution shape by measuring flatness in the pixel density area.
h)	Energy	It represents the texture's homogeneity and uniformity based on the sum of the squared pixel intensities.
i)	Root Mean Square	A measure of the Root Mean Square value of pixel intensities.
j)	Entropy	Represents the amount of randomness or disorder in the texture.
k)	Contrast	Measures the difference in intensity between neighbouring pixels

2 Literature Survey

A lot of research has already been done on feature extraction since it is the basis of any image-related operation. Every researcher attempts to utilise the existing algorithms and even suggests some changes or invents an entirely new algorithm for the extraction of features. Following is the study of a few of the research papers in an attempt to understand the basics of feature extraction in images.

Takumi Kobayashi and Nobuyuki Otsu[6], classify the feature into two different categories: a shift-invariant type and a local image descriptor type. The author proposes a method that extracts features that are shift-invariant and inherit the property of additivity. The said method is based on gradients, which use spatial and orientational auto-correlations between local image gradients. The local image gradients are represented in terms of magnitude and orientation. Once you get the G-O vector, the element-wise pair values are multiplied and summed over the image. The 1st order is simply a joint histogram that quantifies the distribution into D×D bins. The author also proposed another method where, instead of a gradient, a normal vector is utilised. The normal vector imagines the image in 3-D space, whereas the gradient was designed for a 2-D image plane. The dataset used in the experiment was the INRIA person dataset. Once the features are extracted for the sake of comparison, they are used for classification using SVM. The experiment shows that the Robert filter was more effective for this set of methods, and also, signed gradients show better performance. The weight factor w, tends to be best with min, which helps in removing the noise. For the gradient, the 1st order shows better promise and the 0th order seems redundant, whereas for Normal vector L2 with clipping component seems comparatively better, and instead of whole normalisation, block-wise normalisation shows better performance. The choices of bins were settled with 4 x 5 binning with spatial binning.

Somaieh Amraee,[7] focuses on two different methods, Histogram of Oriented Gradients (HOG) and Local Binary Pattern (LBP) for image feature extraction. For the paper, Analytical study of two feature extraction methods in comparison with deep learning methods for classification of small metal objects, the authors extracted the features and compared the performance of parametric and non-parametric models.

The HOG technique takes the image as an input, divides the image into smaller cells and then computes the gradient of each of the cells based on the magnitude and direction. The author tries out different filters for performing the convolution to get better results. After calculating the gradient, the matrix of magnitude and angle is divided into multiple bins to get the histogram. The authors recommend that the size of the bins be nine. For the sake of the experiment, the author has created each of the cells with a size of 64 x 64. The length of the HOG feature vector was 360. The angle was also limited to be from 0 to 180 degrees only.

The second method used by the researcher was LBP. The greyscale image is considered as an input and divided into a hierarchy of blocks and cells. Each of the pixels is compared with its neighbouring eight pixels in a clockwise manner. If the compared neighbour has more value than the central pixel, then it is replaced with 1; otherwise, it is replaced with 0. Then this eight-digit binary number is converted to a decimal number in the range of 0 to 255. So, as we have 256 values, many bins are created for the histogram. Thus, one can have a signature of the image. Here the researcher kept the cell size of 64, and the uniform feature vector generated was of size 160, which is rotationally invariant.

The results were object and method-specific. But still, in conclusion, the authors underline the use of HOG is better than LBP, particularly for the detection of small objects. And the combined feature vector HOG-LBP does a decent job in comparison. However, the author records his observation that these feature extraction methods cannot detect the position of foreground objects.

An Online Extraction Algorithm for Image Feature Information Based on Convolutional Neural Network, in this paper Dahuan Wei,[8] talks about the use of a Convolution Neural Network for the extraction of features. The author summarizes different filters that could be used for the extraction of features.

Table 2: Filters used for extraction of features.

Sr. No	Name of Filter	Description
1	Sobel filter	Sobel filters are known for their ability to detect edges and search for intensity patterns. The Sobel filter finds the approximate derivative of the image in the x, y directions.
2	Laplace Filter	These filters are priorities when the position of the edges in the image is needed. It is in the form of a second-order differential isotropic operator. But these filters have little restrictions that is they work fine with images without noise. If the noise is induced, one must select a low-pass filter.
3	Canny Filter	Used for edge detection and image segmentation. This technique is famous for minimising the detection of false edges caused by noise. So robust to noise.
4	Filtering with two thresholds	Two thresholds are used, the one with a gradient magnitude more than the high threshold is considered a strong edge otherwise it is termed a weak edge.

The researcher has two different datasets for his experimentation, CK+ and FER201. Both methods show a high rate of accuracy based on the features that are extracted by deep Convolution Neural Networks.

Ze Li in his paper named 'A novel image-orientation feature extraction method for partial discharges'[9] mentions the use of the U-SURF method for image extraction. U-SURF is a variation of the SURF method which is a local feature extraction method and is supposed to be robust to changes in scale, rotation as well as illumination. The U-SURF method does not consider rotation since the experimental images are taken at the same viewing angle.

Here the authors first converted the image into grayscale and made sure that the size of every image should be the same. For the construction of scale space instead of Gaussian filters, box filters were used and convolution operation was performed. Fast-Hessian detectors were used for the extraction of feature points. Non-maximum suppression principle was considered for the exact determination of the location of feature points. The scale-space location for which the Hessian matrix gives the maximum value is considered as the feature point. The researchers claim that the accuracy for classification of the image using this feature extraction method shows highest accuracy. The researchers also prove that the proposed method can work even with noisy data.

Jing Zhang[10] proposed a Channel-Attention-Based Spatial–Spectral Feature Extraction Network (CSSFENet) for feature extraction. In the first stage of this method, shallow features of the image are extracted using the 3d features convolution technique. The output raw features are then fed to Channel-Attention-Based Spatial–Spectral Feature Extraction Modules. The module learns the non-linear mapping between spectral dimensions and spatial dimensions and extracts the feature better way. In the third step of the method, the up-sampling of low-resolution hyperspectral images is worked out using a module named as an image reconstruction module. Here the author suggests the use of 3D sub-pixel convolution to restore the hyperspectral SR image with an upscale factor of r. In the last stage to compute the MAE, the author combines, the feature diversity loss function and spatial spectral gradient function. Three different data sets, the CAVE, Pavia, and Pavia University (PaviaU) hyperspectral image dataset, were used for the experiment. The loss function used played their role well, the feature diversity loss function could enhance the independence of each element. The increase in the smoothness of hyperspectral images could be seen due to spatial–spectral gradient loss function. The proposed Channel-Attention-Based Spatial–Spectral Feature Extraction Module can extract the image depth features.

In a paper titled ‘Image feature extraction algorithm based on visual information’, Zhaosheng Xu[11] proposed a hybrid method by combining a combination of Scale-invariant feature transform (SIFT) and sparse coding algorithm. SIFT algorithm is a feature descriptor algorithm which uses the gradient direction histogram of the object and then samples it with high density. So, the information of the object in the gradient’s direction is obtained and retained. In the proposed algorithm, as a primary step, SIFT extracts the feature by centralised sampling. Then the feature matrix is inputted to the K-Single Value Decomposition algorithm. K-SVD is a dictionary learning algorithm which tries to preserve details of the image by using a sparse representation of the SIFT features using the K-Nearest neighbour algorithm. In the third stage of the proposed algorithm, SIFT features are combined with other information like colours, depth etc. and then the author proposed to use the Pyramid pooling method to extract different features like; image block features, SIFT-based sparse coding features and block feature-based sparse coding. When all these features are combined the characteristics of the object could be obtained. With different sets of experiments, the researchers proved that the proposed algorithm can recognize and match the features of the image.

To deal with the feature extraction of different kinds of medical images, Farag Hamed Kuwil,[12] proposed a new set of methods which he named as Feature Extraction Based on Region of Mines. In the first method FE-AM, the image is read into a matrix with dimension (n, n,3) and supportive information of the channel is captured in three other matrices of size (n, n). These matrices are further divided into two regions on the median and termed as upper and lower median, and accordingly mean, standard deviation and coefficient of variance is computed for each separately. So, in all 9+27=36 different features are extracted in this method.

The second method FE-CM (Feature extraction for coloured image), uses formulas based on the median and follows a series of steps like image processing, signal processing, skewness and statistical measure. The method uses grayscale and binary scale and then applies discrete wave transform. The feature extraction goes through image processing and signal processing and could generate 51 features.

FE-UM (Feature extraction for uncoloured images) was the last method suggested by the author, uses less amount of data so applying transformation at many places in the metrics there will be zero. 33 features could be extracted from this method. So, the combined approach of the proposed methodology is image representation, data distribution and finally feature extraction. Three different datasets were considered for the experimentation part. All three variations suggest for this approach skewness in the data distribution. The experiment shows that this method works well for both coloured and uncoloured images in comparison to the other methods available.

Feature Extraction Processing Method of Medical Image Fusion Based on Neural Network Algorithm,[13] in this paper, the author proposed a novel approach to the fusion of more than one type of image feature for an increase in accuracy. Here, the three different types of features were under consideration for fusion; geometric feature, LBP texture feature and Gray scale features. The researcher divides the entire algorithm into four sections; image feature segmentation, then comes the feature region extraction, the segments are then goes under feature region analysis and extraction, and finally medical image feature classification using neural network and recognition.

For the Grayscale features, the author considers Gray mean, Gray variance and Gray histogram entropy etc. The lesion part of the medical image contributes more in finding the texture feature. These texture features are generally represented as a Gray-level convenience matrix. The fusion method proposed by the method considers multi-features, but when combining multiple features, the restriction is that the feature dimensions have to be the same. Then the fused feature undergoes the normalisation process for a betterment of accuracy. The researchers also compared different methods with the fused feature set and found that the accuracy is found to be better of this proposed method when compared to other methods like SURF, Gabor texture, Grayscale Texture etc. This comparison experiment is considered for different types of medical images like lung images, chest images, liver images and brain images. In all the four subsets the fusion method shows the highest accuracy.

Dong Jin and co-authors suggested the Shuffle-PG feature extraction model for the extraction of deep features.[1] The model was proposed with three components: Shufflenet V2 backbone, global pooling and pointwise group convolution. Feature extraction is carried out by Shufflenet v2 backbone and pointwise group convolution and global pooing convert the feature map into a feature vector

Farid Al-Areqi[14] in his paper mentions that grey-level-based texture provides a better set of information whenever tissue heterogeneity is found in the image. The author also talks about other methods like texture-based features, which are known for finding the spatial relationship between neighbouring pixels, and shape-based features, which talk about the geometry of the tissue. Intensity-based first-order features can differentiate between various tissues.

The PyRadiomics library of Python was used to extract the radiologic features. This library contains shape and texture-based feature extraction methods. The texture-based methods extract the texture features in matrices. Then these matrices are used to derive statistical features. The following table summarises the methods used by researchers:

Table 3: Texture-based matrix.

Sr. No	Name of the method	Working
1	Gray Level Co-occurrence Matrix (GLCM)	This method looks for a pair of pixels with specific values in a specific direction and calculates how many such pixel pairs can be found in the entire matrix. GLCM tries to identify 24 different statistical features like autocorrelation, Cluster Tendency, Cluster Shade etc.
2	Gray Level Run	GLRLM focuses on the length or consecutive pixels for which

	Length Matrix (GLRLM)	the gray level values are the same. This method can extract 16 different statistical features like Gray Level Non-Uniformity, Gray Level Non-Uniformity Normalized, Low Gray Level Run Emphasis etc.
3	Gray Level Size Zone matrix (GLSZM)	This method first locates the homogenous valued pixels. If a more homogenous nature is found in texture, the matrix will be more wider and flatter. After quantifying the pixels with the same Gray level, the statistical features are extracted by this method and in this case found to be 16 like Gray Level Non-Uniformity, Gray Level Non-Uniformity Normalized, Zone Percentage etc.
4	Neighbouring Gray Tone Difference Matrix (NGTDM)	Here a Gray level value and its neighbours Gray values average are considered and the difference between these two in a specific distance is computed. This method could extract five different statistical features like Busyness, Coarseness, Complexity, Contrast and Strength.
5	Gray Level Dependence Matrix (GLDM)	In this method, GLDM measures several connected pixels from the central pixel within a given threshold distance. Here features like Small Dependence Emphasis, Large Dependence Emphasis, Small Dependence Low Gray Level Emphasis etc. are extracted.

Then the researchers combine the features extracted by texture-based methods, statistical features captured by first-order statistics and descriptive properties extracted by shape-based methods and generate a new feature vector. The researcher claims that the best accuracy is achieved after combining the features from GLDM, GLRLM and GLSZM. The author also mentions that in comparison with the Grayscale feature, the features extracted by first-order statistics and shape features are more important.

Chuanbao Niu,[15] worked on image feature extraction techniques using partial differential equations. In the paper entitled, “Using Image Feature Extraction to Identification of Ancient Ceramics Based on Partial Differential Equation”, the authors proposed this technique for feature extraction of ancient ceramic identification. The dataset considered had 5834 images with a total of 272 classes of ceramics. To count the texture feature of ancient ceramic images, the author worked on two different types of statistical features i.e., Gray level occurrence matrix that represents machine vision and Tamura texture feature that represents human vision. For the Grayscale Occurrence Matrix, four different features (annoyance, autocorrelation, contrast and homogeneity) are selected out of fourteen features. These features are fused with other colour features like colour histogram, HSV colour space average similarity rate etc. The result shown by the experiment met the expectations of the authors.

Lucero Verónica Lozano-Vázquez[16] in his paper mentions the importance of feature enhancement before feature extraction, since the extracted features won't be very useful if the image quality is compromised. Image quality can be degradable if the image capturing is affected by a poorly illuminated environment like fog, pollution or poor light. So, to enhance the image, one has to modify a few characteristics of the image, like the sharpness of the image or removing the noise. There are various methods mentioned in the literature that talk about the enhancement of the images. The researcher compared a few of the methods as:

Table 4: image enhancement methods.

Sr. No	Method name	Information
1.	Retinex	It is a method inspired by the human visual cortex. It improves the colour balance and brightness, which is very useful if the image is captured in a low-luminous environment.
2.	Multi-scale Retinex (MSR)	It decomposes the image into multiple scales and then re-adjusts the intensity values for each scale separately so that a better visual representation can be obtained.
3.	Multi-scale Retinex with colour restoration (MSRCR)	Apart from enhancing image quality by adjusting dynamic range, this method addresses the issue of colour distribution. Wherever the colour accuracy is a critical issue, this method is preferred.
4.	Retinex algorithms to high dynamic range (HDR)	Useful for the enhancement of the images that are captured in a more luminous environment. After colour restoration, tone mapping is applied to compress the dynamic range to the displayable range.
5.	Gamma Correction	It talks about the relationship between pixel value and the luminosity associated with it. This method is useful for adjusting different characteristics like brightness, colour etc.
6.	Histogram equalisation	Here pixels in the same bins are made more similar with respect to their values to get linear commutative property.
7.	Sharpening with Unsharp Masking	Used for contrast enhancement by subtracting the blurred image (unsharp mask) from the original one.
8.	Gan-Based Low Light Enhancement Method	Less dependency on the training data set and can work with other images from different domains.

Once the images are enhanced by any one of the above methods, the next step taken by the researcher is feature extraction. The author proposed various methods:

Table 5: Feature extraction methods.

Sr. No	Method name	Information
1	SIFT	Scale-Invariant Feature Transform detects key points by searching for local extrema. This is done with the help of the difference in Gaussian function. These features are robust to transformational changes like rotation, illumination and viewpoint.

2	SURF	Speeded Up Robust Features detect the key points with the help of approximation of the determinant of the Hessian matrix. Requires less computation.
3	ORB	Oriented FAST and Rotated BRIEF is a combination of the Oriented FAST detector and the BRIEF descriptor. Key points are detected by Features from the Accelerated Segment Test algorithm. Binary Robust Independent Elementary Features descriptor computes binary string by comparing intensity pairs.
4	AKAZE	This method is a two-dimensional method for feature detection and description which works in the nonlinear scale space method. The detection is entirely based on a Hessian matrix. Since it uses Scharr filters, it is invariant to translation.

The experimental results show that image enhancement followed by feature extraction is a good policy. The results also show that MSR when combined with SIFT or AKAZE the performance is found to be increased. The researchers also made a comment on poor performance of MSR, if the images are captured in the dark.

To extract the detailed extraction and analysis of the information in the image, Pegah Dehbozorg[1] and co-authors used Radiomics Techniques in their paper entitled, "A comparative study of statistical, radiomics, and deep learning feature extraction techniques for medical image classification in optical and radiological modalities" where the medical images are transformed to quantifiable data. Since the author preferred Radiomics techniques, they could retrieve detailed information about tissue characteristics like intensity, shape, spatial relationships etc. The researchers also claimed that radiomics methods take less time for feature extraction than statistics-based images. Apart from this the authors also preferred using a deep learning approach for feature extraction. The intention was to use the pre-trained model and extract the feature from the medical dataset. So, the author tries out 5 different network models as.[1]

Table 6: pre-trained models.

Sr. No	Name of the model	Information
1	VGG16	This model contains 13 CNN and 3 Fully connected layers and is known for its simplicity but slow due to a large number of parameters to learn
2	ResNet50	With the help of residual connections offers a good balance between performance and computational cost. Consists of 49 convolutional layers and 1 fully connected layer
3	DenseNet121	Though uses 121 layers, because of the reusing of features the number of parameters used is less comparatively
4	InceptionV3	It can employ parallel convolution layers and varying Kernels. So,

		features can be captured at different scales at the same time.
5	MobileNetV2	Specially designed for resource-constrained environments and mobiles. Uses the concept of inverted residual block.

3 CONCLUSION

The strive for goodness and accuracy is unlimited and to achieve the same, different algorithms focus on extracting the correct features. Here few of the methods were discussed to understand how different techniques are used in the literature for feature extraction. The method to be used is based on what type of data you have and what is the application for which you are extracting the features. This need to extract the accurate features will ask more and more researchers to come forward and contribute to the new, accurate and efficient methods for feature extraction.

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