CHAPTER 2

REVIEW OF LITERATURE

2.1 Overview

The term research means systematic investigation into a topic of interest to the seeker and the study of materials and sources in order to establish facts and reach new conclusions. According to Kothari et al. (2014), the term research is a logical and systematic search for new and useful information on a particular topic of interest. It is an investigation of finding solutions to scientific and social problems through objective and systematic analysis. It is a search for knowledge, that is, a discovery of hidden truths. Here the term knowledge means information about matters of interest. The information might be collected from different sources like experience, human beings, books, journals and nature etc.

A research can lead to new contributions to the existing knowledge to make progress in a field. Research determines the economic, social and political development of a nation. The results of scientific research very often force a change in the philosophical view of problems which extend far beyond the restricted domain of science itself. Research is not confined to science and technology only. There are vast areas of research in other disciplines such as languages, literature, history and sociology. Whatever might be the subject, research has to be an active, diligent and systematic process of inquiry in order to discover, interpret or revise facts, events, behaviors and theories. Applying the outcome of research for the refinement of knowledge in other subjects, or in enhancing the quality of human life has also become a kind of research and development. According to Rajasekar et al. (2013), research is done with the help of study, experiment, observation, analysis, comparison and reasoning. Research is in fact ubiquitous.

The man has been utilizing and enjoying the boons provided by the nature and therefore studying nature becomes utmost important. The nature provides man with food, shelter, clothes etc. Therefore, it has become quite important for man to know the flora and fauna, which has been at his service since ages. The role of plant life or flora in human life has a lot of importance and the whole sustenance of human existence depends upon the plants

which provide food for existence on this planet. Due to the increase in the human population, there is an increased demand for homes, therefore a dire need for building homes and for interconnectivity purpose roads need to be constructed at the cost of plants and trees which are being cut recklessly. There has been several movements to save the trees and plants from reckless deforestation. A time will come when there shall be hardly any plan or tree left for study purpose. Therefore, to preserve the plants for future, there is a need for proper study both at the botanical sciences level as well as the other budding science like computer vision, pattern recognition and machine learning must contribute with their efforts and tools.

The prime objective of the present research is to study the plants using the computer science based approach. As it is known that the plants have been studied for flowers, roots, seeds and leaves. For classification of the plants, these ornaments of the plants have been very often used either individually or in a group. The research work that is being carried out here deals with studying plants for classification purpose using their leaves as major components. The literature survey that has been carried out dates back from 1973 to the latest 2015.

2.2 Related Work

Haralick et al. (1973) utilized the concept for discriminating the digital images or the region of interest on this basis. The paper deals with photomicrographs of sandstone, aerial photographs of land use, and satellite imagery. The dataset was divided into training set and test set. The predictive accuracy was computed for the test images. The maximum achievable predictive accuracy was 89% for picomicrographs, 82% for aerial images and 83% for the satellite imagery. This work is purely based upon calculating the GLCM for the gray images with unit pixel distance and at different different orientation values. This work extracts 14 different second order texture features based on GLCM. The 14 features extracted are: angular second moment(ASM),Contrast, Correlation, Sum of Squares,

Inverse difference moments, Sum Average, Sum Variance, Sum Entropy, Difference Entropy, Information measure of Correlation, and Maximal Correlation Coefficient.

Troy et al. (1973) have worked on the gray level manipulation techniques, including changing the gray level distribution within the picture. The process of segmenting noise free objects from the noisy background involves segmenting objects which have gray values which do not overlap with the background gray values. But, for the images having objects and background of such images overlap over a range of gray values , the process of segmenting the such objects from the noisy environment becomes difficult and this work suggest use of combined techniques like gray level transformation and isolation procedures for effective results.

Haralick (1979) has described about the various prominent texture based techniques prevalent for studying the digital images. For microtextures, the statistical approach which include auto correlation functions, optical transforms, digital transforms, textural edgeness, structural element, gray tone co-occurrence and auto regressive models. It is further stated that histogram of the primitive properties is generally used. This work is one of the pioneering works in studying digital images through textures.

According to Kass et al. (1988), a snake is energy minimizing spline guided by external constraint forces. The snakes are active contour models and they lock onto nearby edges and localize them accurately. The Snakes are useful for interactive specification of image contours. They are used for matching the 3D models to the images. The scale space can greatly enlarge the capture region around the features of interest. This work has discussed some exemplary energy minimizing models like that of Sperling's Stereo model. The major utilization of such models is to explore energy landscape and develop energy functions that have few local minima and have least dependence on the starting points.

Gong et al. (1992) have used three types of features computed through three spatial feature extraction methods like (GLCM), Simple Statistical Transformation (SST) and Texture

Spectrum (TS). In this work, 27 features have been extracted in totality, ten image classes have been used for analysis purpose. All the features were obtained with a pixel window size of 5X5. The multispectral classification accuracy is 0.574%, but by using a combination of images the predictive accuracy value has gone up to 95%.

Tuceryan et al. (1993) have described about the general methods available for Image Texture analysis. This work is a literature review work for all the important techniques available for extracting features from the images. The geometric, random field, fractal, and signal processing models of texture have been presented. The major classes of texture processing problems such as segmentation, classification, and shape from texture have been discussed. The possible application areas of texture such as automated inspection, document processing, and remote sensing have been summarized.

Szelski et al. (1994) have designed a new algorithm based upon spline representation of the displacement field. There are large number of problems when working with image registration related tasks such as computation of optic flow stereo correspondences, structure from motion and feature tracking. This work combines the best features of local motion models and global motion models. The algorithm is computationally efficient than correlation based or spatial temporal filter based approaches.

Liu et al. (1995) have worked towards formulating the usage of Chi2 statistics parameter to evaluate the usefulness of the features and help in discretizing process. The empirical results show that Chi2 is comparatively effective in feature selection and discretizing the features which are numeric and ordinal in nature.

Hall (1999) has worked on the feature selection area and states that the features selection algorithms are basically of two types. In the first type, wrappers use the same learning algorithm to find the usefulness of the feature set. On the other hand the filters utilize the heuristics to identify the usefulness of the features in the dataset. In this work, Hall (1999)

has designed a correlation based algorithm and proposed that for a very large dataset the filter based techniques have been faring better as compared to the wrappers.

Baumann et al. (1999) have put forward the basic key structures for the identification of weeds in a region and utilizes plant structures as the key parameter for identification of the weeds. This work elaborately explains about three major varieties of weed namely: Broadleaves, Grasses and Sedges. This report explains about cotyledons present in the three different varieties of weeds. The key grass parts are leaf blade, the collar, the ligule and the sheath. The ligule may or may not be present on some grass seedlings. The sheath is an extension of the leaf blade that terminates at the node. The areas between the nodes are referred to as internodes. Some grass plants may have extensions of the sheath called auricles. A sedge, however, generally does not have a ligule or an auricle. The cross-sections of grasses may be either round or oval (flattened), compared to a sedge, which exhibits a triangular shape. According to this, work leaf margins (leaf blade edges) also are special features for identifying specific plants.

Pratt (2000) has worked towards master's thesis in plant leaf identification using Fourier Mellin transform to the digital images. The transform has been applied to the images regardless of scale, rotation and translation for the discrimination and classification of images. This work has carried out the testing of the transform over 7 different types of plant species. The results obtained from the use of Fourier-Mellin transforms to the digital leaf images does not provide with satisfactory results. This work further suggests improvements in the methodology to improve the discrimination results. According to this work, the leakage at the edges should be reduced, the work suggests to use magnified resolved images for Fourier Mellin transform and this work also suggest to use phase along the Fourier-Mellin magnitude to better recognize the objects.

According to Burks et al. (2000), the color co-occurrence matrix (CCM) can be utilized for calculating the texture features form the weed-leaf images and then applying discrimination process. The CCM technique is leaf scale and orientation independent. Initially the RGB

image is converted into HIS color model. The intensity value is calculated as the mean of the three RGB values and the hue and saturation values are calculated using geometric transformations of CIE chromaticity diagram. This work has utilized 6 classes (of which 5 plant and one soil) to discriminate between different classes. The average predictive classification accuracy value that has been achieved is 93%.

According to Perez et al. (2000) color and shape features can be suitably employed for leaf image classification purpose. This work states that the weed information is a must for implementing spatially variable herbicide application. This paper deals with the development of near-ground image capture and processing techniques in order to detect broad-leaved weeds in cereal crops under actual field conditions. The proposed methods use color information to discriminate between vegetation and background, whilst shape analysis techniques have been applied to distinguish between crop and weeds. The determination of crop row position helps to reduce the number of objects to which shape analysis techniques have been applied. To reduce lighting problems, a normalized difference index (NDI) using green and red channels was selected, similar to a vegetation index that uses near infrared and red light reflectance to separate plants from soil and residue. Moreover, this transformation makes it possible to work with a grey level image without significant loss in resolution.

$$\text{NDI}=\frac{green-red}{green+red} \tag{2.1}$$

In Eq. (2.1), green is the pixel value in the green channel and red is the pixel value in the red channel. This index was computed for all the pixels of the image, providing values ranging from -1 to +1. For each feature, the distance between the means of the two classes (weed and crop pieces), normalised by the variances (Fisher ratio) was used as a measure of how far the classes overlapped using Eq. (2.2).

$$V_{weed/crop} = \left| \frac{\overline{x}_{weed} - \overline{x}_{crop}}{\sigma^2_{weed} - \sigma^2_{crop}} \right| \tag{2.2}$$

This work obtained 1950 objects, from which 1433 correspond to crop pieces and 517 to weeds. Both Bayes Rule and *k*-NN methods have used all the possible combinations of the former features to evaluate the algorithms. The accuracy is round about 85%.

Wu et al. (2001) have worked with descriptors have given three texture descriptors for features and these texture descriptors have been included in the Committee Draft of the MPEG-7 Visual (ISO/IEC 15938-3).The three texture descriptors are the homogeneous texture descriptor (HTD), the edge histogram descriptor (EHD), and the perceptual browsing descriptor (PBD). In this work the three descriptors have a unique functionality and application domain. The HTD and EHD describe in details the statistical distribution of the texture in the digital images. It has been mentioned in the paper that the HTD is suitable for homogeneously textured regions and EHD can be employed for multi textured natural regions. HTD and EHD describe statistical distribution of the texture and are useful for image retrieval application, while HTD is for homogeneously textured region and EHD is for multi-textured natural image or sketch. PBD is a compact descriptor suitable for quick browsing application. HTD is composed of 62 numbers. The first two are the mean and the standard deviation of the image. The rest are the energy and the energy deviation of the Gabor filtered responses of the "channel", in the subdivision layout of the frequency domain. The EHD represents local edge distribution in the image. It describes edges in each 'sub-image', which is obtained by dividing the image using 4x4 grid. The PBD has elements for directionality, regularity and coarseness.

Soderkvist et al. (2001) is a master's thesis, a work carried in classifying the Swedish trees using the tree leaves. The trees have leaves with different shapes, color and sizes. The color of the leaves change with the season. In this work, after the preliminary processing of the collected images, colored images have been converted to gray scaled and then to binary

sets. The images after the preprocessing process have been subjected to the feature extraction process which computes curvature scale space, Incremental circular transform, circularity, Area, Modified Fourier Descriptors, Hu-Moments, Flusser and Suk's Descriptors and eccentricity. In this work fifteen different classes of the leaves from 15 trees have been studied. The features extracted were subjected to classification process with tree based algorithms, artificial neural networks.

Meade et al. (2003) has utilized 34 Asian species of the Uvaria group, a large palaeotropical group of climbing Annonaceae having imbricate petals and stellate hairs. The raw data was normalized into 15 ratio characters using $\log_{10}$ transformations. The ratio transformed data gave 52% predictive accuracy value. When the dataset was divided into subsets then the average predictive accuracy values vary from 67% to 100%.

Castellano et al. (2004) have worked on the application of texture based methods on medical images. This work discusses about Histogram, Absolute gradient, run length matrix, GLCM, auto regression model, wavelets etc. According to this work, application of texture based techniques have dominated in the cases of MRI images, which involve extraction of useful features from region of interest and performing statistical analysis.

Yu et al. (2004) have worked on the reduction of the features in a large dataset and proposed a correlation based method for identifying the relevancy and redundancy amongst features and developed a framework for decoupling redundancy and relevancy amongst features in a large dataset. This process of selecting a few features out of a large set of features should provide with the same level of results be it percentage predictive accuracy values as provided by the complete set. With the help of few features the dataset size is considerably reduced and the computation time is reduced as well.

Lee et al. (2004) has worked with 2dimensional computer vision problems for Tomato plant leaves. In the computer vision based systems the occluded images create predictive accuracy problem as some portion of the image remains hidden and the results become

improper. This work performs five modifications to the Watershed algorithms for separating occluded plant leaves. This comparative work was performed over tomato cotyledons and true tomato leaves. By bringing about modifications to the original Watershed algorithm, the computation time has reduced by 11% from the original time. The predictive accuracy results improve when the Watershed algorithm is applied, but finally it has been concluded that the Watershed algorithm is not suitable for working with occluded images.

Mokhtarian et al. (2004) have worked on the two-dimensional (2-D) shape representation and matching in the presence of self-intersection for large image databases and this may occur when part of an object is hidden behind another part and results in a darker section in the gray level image of the object. The boundary contour of the object must include the boundary of this part which is entirely inside the outline of the object. The CSS-based shape representation method has been selected for MPEG-7 standardization. This work studies the effects of contour self-intersection on the Curvature Scale Space image. When there is no self-intersection, the CSS image contains several arch shape contours, each related to a concavity or a convexity of the shape. The process of self-intersections create contours with minima as well as maxima in the CSS image. An efficient shape representation method has been introduced in this paper which describes a shape using the maxima as well as the minima of its CSS contours. The conventional matching algorithm has also been modified to accommodate the new information about the minima. The method has been successfully used in a real world application to find, for an unknown leaf, similar classes from a database of classified leaf images representing different varieties of chrysanthemum. This work was tested for 120 leaf images of 12 different varieties of chrysanthemum.

Omaran (2004), has worked on Particle Swarm Optimization (PSO) based techniques for pattern recognition and image processing. The author has proposed a clustering based method on PSO and has investigated the use of clustering based PSO to unsupervised classification and segmentation of images using dynamic clustering algorithm which

determines the optimum number of clusters. This work further investigates the PSO based approach to tackle the color image quantization and spectral minimizing problem.

McNeill et al. (2005) have performed 2D Shape classification process using correspondence based shape technique for efficient shape classification and retrieval problems. Here in this work, the shape boundaries have been described by a set of (ad hoc) equally spaced points and does not require the landmark points. The equal spacing of points can be defined in terms of either perimeter distance or radial angle or both. By using both the perimeter distance and the radial angle, more number of objects can be described with different shapes. The algorithm was tested on the MPEG-7 shape database and was shown to outperform the popular contour Fourier method.

According to Viera et.al. (2005), Items such as physical exam findings, radiographic interpretations, or other diagnostic tests often rely on some degree of subjective interpretation by observers. Studies that measure the agreement between two or more observers should include a statistic that takes into account the fact that observers will sometimes agree or disagree simply by chance. The kappa statistic (or kappa coefficient) is the most commonly used statistic for this purpose. A kappa of 1 indicates perfect agreement, whereas a kappa of 0 indicates agreement equivalent to chance. A limitation of kappa is that it is affected by the prevalence of the finding under observation. The Kappa is the most commonly reported measure in the medical literature. Kappa makes no distinction among various types and sources of disagreement. Because it is affected by prevalence, it may not be appropriate to compare kappa between different studies or populations. According to this work, the Figure 2.1 shows the interpretation of the Kappa.

According to Sim et.al. (2005), the reliability of clinicians' ratings is an important consideration in the areas such as diagnosis and the interpretation of examination findings. Often, these ratings lie on a nominal or an ordinal scale. For such a data, the kappa coefficient is an appropriate measure of reliability. Kappa is defined, in both weighted and unweighted forms, and its use is illustrated with examples from musculoskeletal research.

Factors that can influence the magnitude of kappa (prevalence, bias, and non-independent ratings) have been discussed, and ways of evaluating the magnitude of an obtained kappa are considered. The kappa value is calculated using Eqs. (2.3) and (2.4).

$$k = \frac{Observed\_Agreement - Chance\_Agreement}{1 - Chance\_Agreement} \tag{2.3}$$

$$k = \frac{P_o - P_c}{1 - P_c} \tag{2.4}$$

where *Po* is the proportion of observed agreements and *Pc* is the proportion of agreements expected by chance.

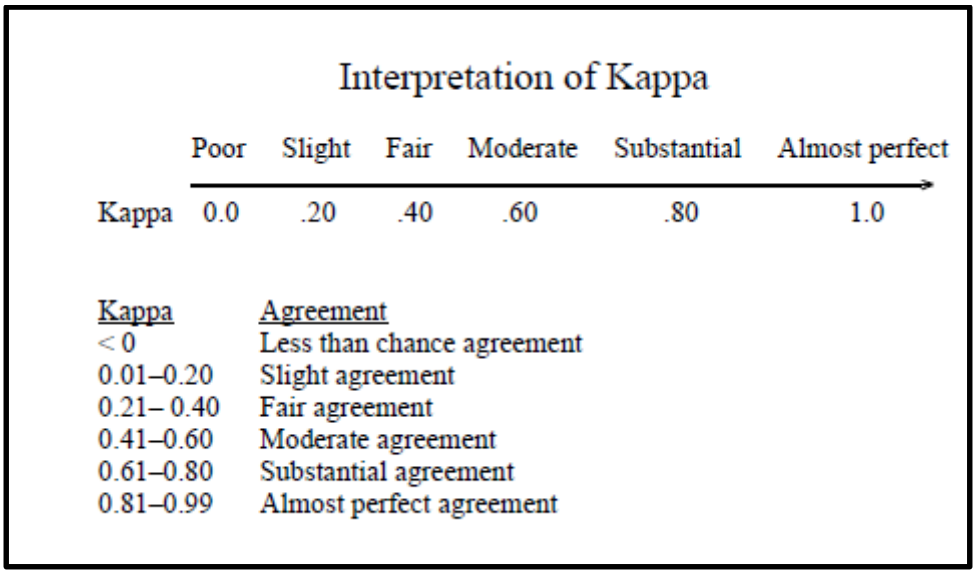

Figure 2.1 Interpretation of Kappa

There are varieties of plants and vegetation on the earth and every plant species has different types of venation pattern marked on the leaves both on the dorsal and ventral sides. According to Fujita et al. (2006), as there is diversity in the venation pattern. There is positive feedback regulation between plant hormone auxin and its efflux carrier. Fujita et al. (2006) developed a mathematical model to understand the logic behind the venation

design pattern and can generate auxin flow pathways based on polar auxin transport. It is further stated that this model can produce diverse leaf venation patterns with spatial regularity under similar conditions to those of leaf development, that is, in the presence of leaf expansion and auxin sink. These results of this paper indicate that the positive feedback regulation between auxin and its efflux carrier is a central dynamic in leaf venation pattern formation. The diversity of leaf venation patterns in plant species is probably due to the differences of leaf shape and leaf expansion pattern. It is further stated that the extension of veins in a random or directional manner depends largely on the leaf shape.

Neto et al. (2006) utilized Elliptical Fourier descriptors for extracting useful features from the young plant leaf images. This work uses soybean, sunflower, redroot and velvet leaf plant species for classification purpose using leaf shapes. In this work chain coded elliptic Fourier harmonic functions were generated based on leaf boundary. The Principle component Analysis was used to find the best set of Fourier descriptors. The concept of Canonical Discriminant analysis was used for discriminating the images into various classes. The maximum average predictive accuracy achieved was 89.4%.

Lee et al. (2006) used region based features as compared to contour based features. The features adopted for this study include aspect ratio, compactness, centroid, and horizontal/vertical projections. The predictive accuracy value achieved is 82.33%. In this work 600 images of 60 different classes have been used. The gray scaled images have been used for texture based image analysis. GLCM has been used for extracting the features from the gray images. This work uses the colored images for extracting the GLCM based second order statistical features from the digital images. To compute the 2^{nd} order statistical features from the colored images, the channels of the colored images are separated and then the GLCM based mathematical formulae has been applied. Similarly the Gabor Features have also been extracted from the images whose three color channels have been separated. The features extracted from the three individual channels were combined together forming a single vector. For a 128X128 image, the Color GLCM algorithm has provided 95% predictive accuracy value.

Ji-Xiang et al. (2007) has worked on the classification of the plants using leaf images and proposed a new technique for discrimination purpose and named it as move median center (MMC) hyperspace classifier for leaf database based on the leaf morphological features. The features that have been studied in this work are Aspect ratio, Rectangularity, Area ratio of convex Hull, Perimeter ratio of the convex hull, Sphericity, Circularity, Eccentricity, Form factor and Invariant moments. This algorithm (MMC) identifies the median for each of the points of a class. Initially the center of the hypersphere is assumed and then the maximum radius is found covering the maximum number of points of the class and the similar steps have been followed for other classes. In this work, 20 different classes have been considered for the classification purpose. The results of the MMC classifier have been compared with 1-NN and then with K-NN algorithms. The correct rate of classification with MMC is 91% ; with 1-NN, the accuracy achieved is 93% and with 4-NN is 92%.

Mingqiang et al. (2008) provides with an in-depth study of the existing shape based feature extraction techniques. According to Mingqiang et al. (2008) the shape features must present some very essential properties like Identifiability which deals with the shapes which have been found to be visually similar by the humans have the same set of features; the extracted features are independent of the translation, rotation and scaling; the extracted features must be affine invariant; the extracted features must be invariant to any kind of noise; the extracted features must be occultation invariant which means that when some part of the object view is occulted by the other objects, the features extracted from the remaining visible portion should remain invariant to the original shape; and finally the extracted shape features must remain the same as long as one deals with the same pattern. This work has further described about the shape parameters like center of gravity, axis of least inertia, digital bending energy, eccentricity, circularity ratio, elliptic variance, rectangularity, convexity, solidity, euler number, profiles, and hole area ratio which are very essential in describing the shapes of the objects of interest. The work has further described about the one dimensional shape descriptors, spatial interrelation feature moments to describe the features, scale space approaches and finally shape transform

domains, and it is finally concluded from this work that there is no single generalized shape based method which shall extract all the shape features and discriminate the images into various classes.

Kirchoff et al. (2008) have given altogether a new scheme for identification and discrimination of plants on the basis of the keys. Keys are character based tools for plant identification. They are based on the decomposition of the plant into very small, atomistic parts. These parts have been described with the technical and often arcane terminology of plant taxonomy. The plant is looked at as if it consisted of a series of isolated parts that are classified by name. The images are displayed on the screen and the user is asked to make the selection. The computer will track these selections and compute Bayesian probability for the likelihood of the unknown identity. It has been concluded by the authors that this system of keys is workable for small set of images and as and when the dataset increases in size, the effectiveness of the system decreases.

According to Direkoğlu et al. (2008), in shape recognition, a multiscale description provides more information about the object, it increases discrimination power and immunity to noise. In this work, a new multiscale Fourier-based object description in 2-D space using a low-pass Gaussian filter (LPGF) and a high-pass Gaussian filter (HPGF), separately has been developed. The LPGF, at different scales, represents the inner and central part of an object more than the boundary. On the other hand using the HPGF, at different scales, represents the boundary and exterior parts of an object more than the central part. The evaluation indicates that representing the boundary and exterior parts more than the central part using the HPGF performs better than the LPGF based multiscale representation, and in comparison to Zernike moments and elliptic Fourier descriptors with respect to increasing noise.

Oliveira et al. (2009) have studied the application of texture based techniques to computed tomography images(CT) to assess ischemic brain stroke. This work utilizes the concept of Gray level co-occurrence matrix and applied on CT images for extracting the texture features. This work has taken five patients and 5 control subjects and has studied the texture

parameters between patients ad controls, texture parameters for lesion and non-lesion tissue patients. This type of work is useful for neurologists who can use it for assessment of ischemic stroke and quantification of affected and non-affected areas. This work further states that the recognition of stroke affected areas in X-Ray computed tomography images during the early hours of the symptoms onset can be difficult and depends on the ability of the examiner, therefore such automatic methods based on texture analysis can be helpful to the examiners in proper assessment work.

Nikam et al. (2009) have worked on fingerprint detection and utilized co-occurrence probabilities and wavelet-based spoof. According to this work, perspiration phenomenon is very significant to detect the liveness of a finger, however, it requires two consecutive fingerprints to notice perspiration, and therefore may not be suitable for real time authentications. In this paper, to detect liveness a new texture-based method using only the first fingerprint has been proposed. It is based on the observation that real and spoof fingerprints exhibit different texture characteristics. Textural measures based on GLCM have been used to characterize fingerprint texture. This is based on structural, orientation, roughness, smoothness and regularity differences of diverse regions in a fingerprint image. Wavelet energy signature has also been used to obtain texture details. Dimensionalities of feature sets have been reduced by Sequential Forward Floating Selection (SFFS) method. GLCM texture features and wavelet energy signature have been independently tested on three classifiers: neural network, support vector machine and KNN. Finally, two best classifiers are fused using the "Sum Rule". In this work fingerprint database consisting of 185 real, 90 Fun-Doh and 150 Gummy fingerprints has been created and multiple combinations of materials have been used to create casts and moulds of spoof fingerprints. The experimental results indicate that, the new liveness detection method is very promising, as it needs only one fingerprint and no extra hardware to detect vitality.

Li et al. (2009) have used color co-occurrence matrix method to compute the texture features from the weed images. This work has used six weed species for testing purpose and has extracted Angular second moment, Inertia quadrature, local homogeneity and

entropy from the images. By using back propagation algorithm under Neuroshell 2 software, the maximum predictive accuracy achieved is 78%. This work has used best testing error as the stopping criteria and the learning rate has been set to 0.1. There has been 8 input, 40 hidden layers and 1 output layer used in this work.

Amaro et al. (2009) have discussed in details about the methods for understanding and clustering the digital images based on statistical shape properties. This work has described about variations in shapes obtained from the statistical data. The statistical shape models have been applied on brain images. The brain is a complex structure and varies widely with the subjects. Therefore, it has been proposed that instead of global shape models, the local shape models are required for the efficient understanding of the internal structures present in the brain. This work has proposed to utilize point distribution model combined with fractal analysis and Markov chain Monte Carlo method. This work has also used curvature scale space representation for the problem of contour localization and performs hierarchical shape analysis using Gaussian and Laplacian pyramids. Finally the work has proposed that the local shape models are effective in detailing the complex structures like brain and are generalized to be utilized for any kind of shapes in the images, in the biological objects of interest.

Petty (2009) has worked with one of the most important topics in pattern analysis and recognition. This work has focussed on two areas and they are: the first area of research focuses on the analyses of proteins displayed as spots on 2-dimensional planes. The second area of research focuses on a specific protein and how interactions with this protein can naturally prevent or, in the presence of a pesticide, cause toxicity. This work has developed a method to create a union of replicate images, which can then be used alone in further analyses to reduce computational expense. This work has improvised how the data can be modelled to enable the inference on the quality of a dataset. In this work, the first area of research builds on previously developed EM methodology to infer the matching and transformation necessary to superimpose two partially labelled point configurations, focusing on the application to 2D protein images. This work has developed a method to

create a union of replicate images, which can then be used alone in further analyses to reduce computational expense.

Ehsanirad et al. (2010) have classified plants using digital leaf image characteristic features such as second order statistical features and principle components extracted directly from the digital leaf images. In totality 22 texture features based on Gray Level Co-occurrence matrices computed for pixels placed at unit distance apart and at different orientation values. At 0^0 the predictive accuracy value is 78.46%, at 45^0 ,it is 49.23%, at 90^0 the value is 78.46%, at 135^0 the value is 70.76%and the predictive accuracy value obtained with PCA is 98.46%. The dataset consisted of 390 images with 13 classes.

According to Megchelenbrink (2010), for a better understanding of many biological processes, it is necessary to find functionality specific residues in proteins. The automated computing of these residues from multiple sequence alignments (MSA) can aid biologists in this task. It is generally assumed that conservation of residues within a subfamily of a MSA and divergence of this residue between subfamilies is a strong lead for functional specificity. Relief-based algorithms compute a feature weight Wi for every residue i. Consider the simple case where a MSA is divided into two subfamilies. Relief computes the weight by finding the nearest neighbor of a sample X from the same subfamily (the nearest hit, NH) and one from the opposite subfamily (the nearest miss, NM).

$$W_i = W_i + \alpha_0 | X_i - NM_i | - \alpha_1 | X_i - NH_i | \quad (2.5)$$

In Eq. (2.5), $|.|$ is the distance between residues. Weights have been computed by iterating over all samples. This method called Relief, uses $\alpha_0 = \alpha_1 = 1$, which means that within-class conservation and inter-class divergence are 'weighted' equally. According to this work by emphasizing conservation too much the inter-class divergence gets oppressed. This means that for high α1 values the divergence is almost neglected, which is lost

information that results in lower predictive accuracy. This makes it difficult to incorporate this method into new algorithms, because the optimum settings are not known a priori.

Biva (2010) has worked towards master's thesis for the classification of the plants using leaves with different features. In this work the salient features of the plant leaves have been used and they are: convex hull ratio, isoperimetric quotient, extraction of eccentricity and aspect ratio. The isoperimetric quotient has been calculated using area and the perimeter of the leaves. The aspect ratio is applicable for rectangular objects, but for the leaves it has been calculated as the ratio of the minor axis to the major axis. The preprocessing process includes converting colored images into gray scale and then to binary format. The size was reduced using Ostu method using automatic thresholding. The overall predictive accuracy value achievable is 97.14%.

Gao et al. (2010), have worked on designing an algorithm for classification of images based on support vector machines and optimized the classification results by using PSO. Further, the genetic algorithm and PSO have been hybrid for selecting the control parameters and the results have shown improved classification rates.

Zhang et al. (2011) has worked on the classification of tobacco leaves based on the image processing techniques. This work has devised an automatic leaf image classification based on Digital Image Processing techniques and Fuzzy Logic for comprehensive results. This work is able to design a grading system for tobacco leaves which have been flue cured. This work is based on the concept of extracting color, size, shape and surface texture features from the digital leaf images and then subjecting them to the discrimination process. The neural network concept was used to estimate and forecast the membership function for the comprehensive fuzzy logic based system. A predictive accuracy value of 94% for the trained and 72% for the non-trained system has been obtained for the flue cured tobacco leaves.

Woolley et.al. (2011) have worked with brain-microdevice interface using Device capture histology. histological methods require device extraction prior to tissue processing, often disrupting and removing the tissue of interest which had been surrounding the device. The Device-Capture Histology method, presented here, overcomes many limitations of the conventional Device-Explant Histology method, by collecting the device and surrounding tissue intact for subsequent labeling. With the implant remaining in situ, accurate and precise imaging of the morphologically preserved tissue at the brain/microdevice interface can then be collected and quantified. First, this article presents the Device-Capture Histology method for obtaining and processing the intact, undisturbed microdevice-tissue interface, and images using fluorescent labeling and confocal microscopy. Second, this article gives examples of how to quantify features found in the captured peridevice tissue.

Cope et al. (2012) have discussed the main computational, morphometric and image processing methods that have been used in the recent years to analyze the different plant species using digital leaf images with the measurement of characteristic leaf outlines, shape, vein structures and leaf textures. The work also discusses the important techniques like leaf shape, elliptical Fourier descriptors, contour signatures, landmarks and linear measurements. Finally, this work concludes that there is no single method that provides the panacea for plant species identification through digital leaf images. The leaf image identification process mainly rely on both domain knowledge and wide range of morphometric methods.

Yang et al. (2012) have worked towards the application of texture analysis on sonographic features of parotid gland which gets affected due to irradiation of head and neck region due to cancer treatment. The problem that comes up is called dry mouth or Xerostomia. This work has employed eight sonographic features: angular second moment (ASM), inverse differential moment (IDM), contrast, variance, correlation, entropy, cluster shade, and cluster prominence. The sonographic features were tested in a pilot study of 12 post radiotherapy patients and 7 healthy volunteers. The mean follow-up time for the post radiotherapy patients was 17.2 months (range: 12.1–23.9 months) and the mean radiation

dose to the parotid glands was 32.3 Gy (range: 11.0–63.4 Gy). Each participant underwent one ultrasound study in which longitudinal (vertical) ultrasound scans were performed on the bilateral parotids – a total of 24 post irradiation and 14 normal parotid glands were examined. The 14 normal parotid glands served as the control group. The authors observed significant differences ($p < 0.05$) in all sonographic features between the normal and post radiotherapy parotid glands.

Fongaro et al. (2012) have worked on the food item and performed surface texture analysis over the food items. This work has included 3 commercial samples of cereal products and 5 samples of plum cakes. This work has extracted second order statistical features using GLCM and evaluated statistical significant differences $p<0.05$ level. This work has also applied principle component analysis on the AMT spectra obtained from the food stuff used for experimental purpose and then applied partial Least square discriminant analysis and observed sensitivity value >0.83 and specificity value >0.69.

Lu et al. (2012) have used leaf characteristics to classify the Camillia (Theaceae) species of the plants. This work utilized 93 species from five sections of genus Camillia to assess and utilized the supervised pattern recognition algorithms like Linear Vector Quantification algorithm (LVQ), Dynamic Architecture for ANN (DAN2) and C-Support Vector Machines. The features that have been studied under this work are whole lamina shape; base; Apex ; Abaxial Surface; Adaxial surface; Reticulate Veins; secondary vein shape; secondary veins balance; Areoles development; Margin Shape ;Margin Spacing; ASVPV of Middle, upper, lower parts; VADSV and Veinlets. It has been observed that DAN2 and SVM algorithms fare better and the average predictive accuracy value is 97.92% and 91.11% for DAN2 and SVM respectively.

The method of classifying digital images especially food objects, depending upon the concept of topmost layer called the texture has been a quite popular technique. In 1994, Andrle introduced a new technique to analyze geomorphology of coastlines. In 1996, this concept was utilized in chemometrics for the characterization of signal and texture

complexities of images. This concept further finds its utilization in measuring the texture properties of Italian Peculiar pasta (Pizzoccherri) before and after cooking. In this work Fongaro et al. (2013) transformed the image into one dimensional spectrum without the loss of important structural information. This method involves the unfolding, finding the mean angle (MA) and then explaining the mean angle spectra data. Fongaro et al. (2013) worked on the Heterogeneity, Gray Level co-occurrence matrix and angular measurement techniques applied over digital images of the Pasta and found that AMT is a powerful Image analysis technique in obtaining the fingerprint of the surface aspect of foods. In this work Partial Least Square discriminant analysis method was applied over GLCM and AMT methods. Though, GLCM fared better in discriminating the images but, it the AMT can be a close competitor in obtaining the AMT spectra of the food samples and understanding the items in a better way.

Sari et al. (2013) have studied the leaf recognition performances of different features and dataset of plants using digital image processing techniques. This work has studied general shape features, Fourier Descriptors, Average Multidimensional distance matrix (MDM-A) over FLAVIA and SLID datasets. This work has gone further into the fusion of the features and their effects on the overall predictive accuracy values. The average predictive accuracy value for fusion based data is 98.51% and 96.07% for training and testing sets respectively. For MDM-A the values 96.22% and 92.505 have been obtained for training and testing sets respectively.

Hati et al. (2013) have utilized the shape features for discriminating the different plant species. The eight shape features that have been computed are aspect ratio, width ratio, apex ratio, apex angle, base angle, centroid deviation ratio, moment ratio and circularity. These features have been input to the neural network for final discrimination purpose. This work has used 534 plant leaf images for 30 different classes. The average predictive accuracy that has been achieved using this work is 92%. Hati et al. (2013) have designed Java based software LEAFilia for feature extraction and classification.

Pantic et al. (2013) have worked to quantify cell and tissue textural properties using the concept of Gray Level Co-Occurrence matrix. This method is capable of evaluating the fine structural changes in nuclear structure which is very difficult to be detected under the normal microscopy. This work indicates that entropy, angular second moment, variance and texture correlation of lymphocyte nuclear structure determined by GLCM method are different from thymus cortex and medulla regions. This work has studied 150 nuclei from cortex and 150 nuclei from medullar regions. It has been observed that Cortical lymphocytes had significantly higher chromatin angular second moment ($p < 0.001$) and texture correlation ($p < 0.05$) compared to medullar lymphocytes. Nuclear GLCM entropy and variance of cortical lymphocytes were on the other hand significantly lower than in medullar lymphocytes ($p < 0.001$).

Sumathi et al.(2013) have used the shape of the plant leaves as the parameter for discriminating the plants into various classes. A comparative discrimination results have been depicted amongst Normalized Cubic Spline-Feed Forward Neural Network (NCS-FFNN) ,RBF,CART and MLP algorithms. It has been proposed that the NCS-FFNN fares better amongst all the above discriminating algorithms and able to achieve 94.08% of predictive classification accuracy value.

According to Rampun et. al.(2013), the image texture features can be extracted by using segmentation based algorithm which is purely based on texture features. The texture features have been extracted using Gray Level co-Occurrence Matrices. The features that have been extracted are noise removed features which forma an effective texture descriptors. The PCA concept has been used to reduce the dimensionality. This work has used Brodatz texture images. In order to make sure that the segmentation results are less influenced by intensity aspects the images are normalized by using Eq. (2.6).

$$J(p,q) = \frac{I(p,q) - \mu}{\sigma} \tag{2.6}$$

Where *I(p,q)* represents a pixel greylevel value at position *(p,q)*, μ and σ are the average image intensity and standard deviation, respectively. After the extraction of the features, each of them was normalized between 0 and 1. This normalization of each of the features resulted in consistency in the dynamic range for the data as mentioned in Eq. (2.7).

$$Normalised(e(p,q)) = \frac{e(p,q) - E_{\min}}{E_{\max} - E_{\min}} \tag{2.7}$$

where $e(p, q)$ is a feature value and $E_{\min}$ and $E_{\max}$ are the minimum and maximum values of $e(p,q)$ respectively. A 5X5 window was used for segmentation over the normalized images for two orientation values. For noise reduction this work uses used two-stage noise reduction based on the discrete cosine transform (DCT) followed by replacement of each pixel by the average of the neighbouring pixel values. The smallest percentage error for classification is 3.57%.

Kulkarni et al.(2014) have worked on the iris recognition aspect of biometrics. This work has proposed to use multi class iris recognition with region of interest (ROI) iris image on supervised learning. In this paper, the term ROI has been referred as Un-normalized iris. The iris features have been extracted using GLCM and a multiclass training vector is created. Further, iris image is classified based on fuzzy K-nearest neighbor (FKNN) and KNN classification. The test samples features have been matched with the stored repository by various matching techniques such as max fuzzy vote, euclidean distance, cosine and city block. The experiment has been carried on standard database CASIA-IrisV3-Interval and result shows that multiclass approach with ROI segmented iris has better recognition accuracy using FKNN and KNN.

Fliegener et. al.(2014), have presented a novel procedure for the generation of a representative volume element for long fiber reinforced thermoplastics and materials with a similar microstructure. It has been characterized by a maximum fiber aspect ratio of approx. 5000 and a maximum fiber volume fraction up to 25%. The modeling procedure

has been based on characteristic values describing the microstructure in a statistical sense, which are the fiber orientation distribution, the fiber length distribution and the fiber volume content. The resulting mesh for finite element analysis represents the microstructure with a relatively low element count, modeling each fiber only by a single element per cross section. Hence, the model is computationally very efficient and allows the analysis of comparably large structures which include the complete fiber length spectrum of the investigated material. The procedure is validated against the elastic properties of three material variants with different fiber volume fractions, incorporating their experimental measured fiber orientation and length distributions.

Kalyoncu et. al. (2015) have used the geometric leaf properties for classification purpose. This work has been able to distinguish leaf margins and has used Linear Discriminant Classifier classification, therefore using features that are noisy for some leaf types does not reduce the performance of the system. This work has used two different databases namely Flavia and Leafsnap. For the first database, a simple adaptive threshold segmentation has been employed over blue channel.

$$(x, y) \in \text{Leaf} \Leftrightarrow_{blue} I_{x,y} < E[_{blue}I] \tag{2.8}$$

In Eq. (2.8) x and y are the coordinates of the corresponding pixel and I is the input image. The first database used in this work contained a total of 1907 scanned images of 32 different plants. These images have white background with small amount of noise. This work has selected 4375 samples from the second database containing 132 classes. This work has not used Pinales leaves as they are completely removed by the stalk removal algorithm. The second database contained shadows, variable background intensity and fair amount of noise. To define the leaf shape in general, this work has employed Multi-scale Distance Matrix (MDM) feature metric. This work has used LDC for leaf classification. There has been an accuracy improvement as proposed by this work by using segmentation, noise removal and MDM smoothing.

Chaki et. al. (2015) have used a combination of texture and shape features. The texture features of the leaf have been extracted using Gabor and Gray Level Co-occurrence matrix techniques, whereas the shape features have been captured using Curvelet transform and Image Moments. This work has employed two classifiers and they are: Neuro-fuzzy controller (NFC) and a feed-forward back-propagation multi-layered perceptron (MLP) to discriminate between 31 classes of leaves. The features have been applied individually as well as in combination to investigate how recognition accuracies can be improved. The experimental results demonstrate that the proposed approach has been effective in recognizing leaves with varying texture, shape, size and orientations to an acceptable degree. The maximum accuracy that has been achieved is 67.7%.

2.3 Research Gap Identified

During the phase 1973-2000, the major thrust has been in utilizing the 2^{nd} order statistics in digital image feature extraction process. The texture features have been extracted using GLCM based technique. The texture property can be one of the important characteristic feature of the digital image, but it alone cannot be the only feature on the basis of which images can be classified, it forms just the part and reliability of classification results depends upon the multiple other factors which have not been considered during this phase.

During the phase 2001-2005, the classification algorithms have improved and ANN has become the part of pattern recognition approach. During this period, color feature has been adopted as a feature for classification purpose. As the image dataset is small, the computational complexity and computational time is low, the robustness, and reliability of the classification engine depends upon use of large dataset, with millions of species which was a major lacuna in this phase.

During the phase 2006-2007, the concepts like leaf venation pattern, which forms an important part of the leaf for the identification of plant images, the concept of Elliptical Fourier Descriptors and Moving Median Centers have been used, which are though advancement toward the classification of digital images, but the new feature representation techniques for leaves increased the overall time complexity for classification of the leaf tested against a large plant leaf data set of the order of several gigabytes and with ambiguity of synonyms.

During the phase 2008-2010,the concepts like Bayesian techniques for classification of plant images with various features extracted from leaf arrangement, use of shape analysis techniques for proteins, brain matter and animal images and use of the GLCM and PCA techniques for the different shapes including that of sword-shaped, oblanceolate, lobed and cordate have been used. For plant classification color, venation patterns were not taken into consideration. During this phase, very small number of shapes were considered for study purpose and in the case of plant leaves, only four types of leaf shapes were considered and rest types of shapes were not taken into consideration. So a proper justification of the application of newer techniques cannot be drawn.

During the phase 2011-2013, the work using leaf architecture variation techniques has been carried out on the Tobacco and Camillia plant species. The classification techniques based on single and hierarchical tools have been used for small image dataset. The Fourier descriptors and ANN based techniques have been employed. There is as such no single algorithm available to extract all the different types of features available which describe the digital images of the plants completely from all types of leaf images and to classify them suitably

During the phase 2014-2015, the multiclass images have been studied including Iris images, using the concept of Fuzzy Logic embossed with KNN algorithm. The 3D microstructure has been studied for thermoplastics. The new technique like geometric leaf property for classification has been used. The concept of Multiscale distance matrix feature

metric has increased the overall predictive accuracy values but the problem of large dataset with a bundle of image variety is still a hurdle for the successful deployment of any classification algorithm.

It has been observed that a consolidated database of the leaves of the entire flora is not available in digital format to till date. Though the universities like Oxford, Caltech etc. are providing the free digital leaf image dataset, but a lot of field work is still required for image collection from the inaccessible terrain. The process of plant image classification is a tedious task as two leaf images may have the same texture properties, but their species may be different and this shall lead to erroneous results. Even the subspecies may exhibit different characteristic properties. If color features are extracted from the digital leaf images, the major problem is that the leaves exhibit different color shades at the time of birth and at maturity. There is a seasonal variation in the color of the leaf images from spring to autumn. If shape is considered as a feature for classification, then approximation of shape, average shape boundaries, shall not provide hundred percent results as expected.

Handling of large image database and then querying it is another hurdle in the successful implementation of automatic plant classification systems. The present day automatic classification systems are slow. The plants can be classified according to the shapes, colors, textures and structures of their leaf, bark, flower, seedling and morph. But flowers, seedlings and morph are three dimensional structures whereas the leaves are two dimensional structures, so there is another school of thought to classify on the basis of leaves and their features.

2.4 Objectives of Research Work

The whole essence of this research survey carried out and jotted down chronologically is to find out the methods prevalent in the past for the classification of digital images. It has

been observed that there is a long list of techniques popular amongst the researchers to capture the unique feature sets for the digital images under study. In the past several theory and principles have been proposed for the classification of the feature sets. At the same time, the optimization techniques played their role in reducing the dataset and helped in obtaining same values of statistical parameters like predictive accuracy from a small feature subset. The objectives of this research work have been carefully drafted by taking into consideration the formulas and principles which have performed effectively in capturing the feature subset, reducing the size of the feature set and finally classifying such features into suitable classes. The proposed objectives of this research work are as follows:

- To Design a feature extraction algorithm for the Leaf Images.
- To Design an algorithm for the comparison of the new image whose features have been extracted to that of the existing database.
- To find whether the ventral side of the leaf images can be considered for leaf image classification or not.