

LIST OF FIGURES

FIGURE	TITLE	PAGE NUMBER
1.1	Representation of feature vector	4
1.2	Feature space boundaries	4
1.3	Types of features (a) Good (b) Bad	5
1.4	Internal structure of an eye	6
1.5	Wavelength perceived by an eye for three colors	7
1.6	Cross-sections of the human retina at the level of the inner segments showing (a) cones in the fovea and (b) cones in periphery	8
1.7	Cone density plotted as a function of distance from the center of fovea for seven human retinas	8
1.8	Effects of (a) Mach band (b) Simultaneous contrast	10
1.9	Face identification through IRIS recognition: Picture taken in (a), (b) 1984 and appeared in National Geographic (c) 2002	11
1.10	Smart Cars	12
1.11	Google Cars (a) In a traffic (b) With a driver	12
1.12	Foundation of computer vision	12
1.13	Machine learning tasks (a) Supervised learning (b) Unsupervised learning (c) Semi-supervised learning	13
1.14	Machine learning tools (a) AM350 Portable Leaf Area Meter (b) Leafsnap	16
1.15	(a) Screenshot of Lamina (b) Example of cropped image with dimension measurement and serration detection (c) Cropped image with holes (marked in green) and serration (marked in blue) (d) Regression analysis to compare data generated (e) Principle component analysis with loadings	16
1.16	Pattern recognition process	19
1.17	Various pattern recognition tasks	19

1.18	Pattern recognition techniques	21
1.19	Schematic drawing of a typical neuron or nerve cell.	25
1.20	Different pattern recognition approaches in botanical sciences	27
1.21	Parts of leaves	29
1.22	Types of simple leaves	30
1.23	Types of compound leaves	31
1.24	Different shapes of plant leaves	32
1.25	Leaf Phylotaxy	33
1.26	Different types of leaf arrangement	34
1.27	Different varieties of leaf tips	36
1.28	Different types of leaf bases	36
1.29	Different types of leaf margins	37
1.30	Different types of leaf venation patterns	38
1.31	Different types of leaf attachments	39
1.32	Types of features and their extraction methodologies	39
1.33	Various shape description techniques	44
1.34	Different types of machine learning algorithms	47
2.1	Interpretation of Kappa	63
3.1	A sample of Leaf image dataset	86
3.2	Leaf image for Slice-1 and its enhanced leaf image Slice-1E with their respective histograms	86
3.3	Time domain diagram for Gabor filter for Slice-1 at different orientation values	95
3.4	Slice-1 convolved with Gabor filter, generates 32 images at different scales and orientation values	96
3.5	Concept of meta learners in Random Forest	97
3.6	Resampling over subset size	99

3.7	Visualization of variable importance	99
3.8	Predictive accuracy chart for the complete feature set	100
3.9	Predictive accuracy chart for five feature set	101
3.10	Number of records plotted against predicted margin values for each leaf image class	103
3.11	The number of trees constructed corresponding to the error rate generated per class	103
4.1	A sample of visual texture images	108
4.2	Sample leaf image of Slice-1 with (a) Dorsal side (b) Ventral side	108
4.3	A complete montage for a set of 500 leaf images with dorsal as well as ventral sides	111
4.4	Complete montage of the 8-bit gray leaf image dataset	112
4.5	Image of Slice-1 and its enhanced image as Slice-1E for the dorsal side of the leaf image	113
4.6	Histograms for the dorsal side of Slice-1 and its enhanced image Slice-1E	113
4.7	Image of Slice-265 and its enhanced image as Slice-265E for the ventral side of the leaf image	114
4.8	Histograms for the ventral side of Slice-265 and its enhanced image Slice-265E	114
4.9	Slice-1 convolved with Gabor Filter, generates 32 images at different scales and orientation values.	115
4.10	Image details for Slice-1 convolved with Gabor Filter, generates 32 images at different scales and orientation values.	116
4.11	Adjusted Box Plot for TFDD	119
4.12	Adjusted Box Plot for TFDV	120
4.13	Adjusted Box Plot for TFDDV	120
4.14	Predictive classification accuracy results	123
4.15	Comparison of present work with other contemporary works	123

5.1	Colored sample of dorsal and ventral leaf images	129
5.2	Geometry for measurement of gray level co-occurrence matrix for 4 distances d and 4 angles	130
5.3	Image of size 4×5 with $N_g = 8$ gray levels and its corresponding gray-level co-occurrence matrix $C(i,j)$, $i = j = 0, \dots, N_g - 1$, for offset parameters $\Delta x = 0$ and $\Delta y = 1$	131
5.4	Illustration of offset parameters Δx and Δy	131
5.5	Histogram of the Gray leaf image for Slice-1	141
5.6	Surface plot of the subsection of leaf image Slice-1	141
5.7	Profile plot of leaf image Slice-1	142
5.8	Average kappa values versus feature selection algorithms for ITDD	155
5.9	Average kappa values versus feature selection algorithms for ITVD	155
5.10	Average kappa values versus feature selection algorithms for CITDVD	156
5.11	Average kappa values versus feature selection algorithms for ISDD	156
5.12	Average kappa values versus feature selection algorithms for ISVD	157
5.13	Average kappa values versus feature selection algorithms for CISDVD	157
5.14	Comparison of average accuracy of different data models with Chaki et al.(2015)	158
5.15	Comparison of average predictive accuracy of different data models	161
5.16	Average misclassification rate versus no. of features selected using (a) ITDD (b) ITVD (c) CITDVD respectively.	162
5.17	Average misclassification rate versus no. of features selected using (a) ISDD (b) ISVD (c) CISDVD respectively.	164

5.18	Comparison of accuracy values versus no. of features used in ISDD with the different researchers[Shardlow (2015); Rampun et al. (2013)]	165
6.1	Colored sample of dorsal side of the leaf images	172
6.2	Colored sample of ventral side of the leaf images	172
6.3	Dorsal side of the leaf image Slice-1 and ventral side of the leaf image Slice-265 after preprocessing	173
6.4	Boxplot values for different plant classes for different statistical features for dorsal leaf image dataset	173
6.5	Boxplot values for different plant classes for different statistical features for ventral leaf image dataset	174
6.6	Boxplot values for different plant classes for different statistical features for dorsal-ventral leaf image dataset	174
6.7	(a) Original Slice-2 and its orientation map for (b) dorsal side (c) ventral side	176
6.8	Directionality histogram for Slice-2 with its analysis values	177
6.9	Directionality Histogram for (a) Dorsal (b) Ventral sides of the leaf images	178
6.10	Box plot of Predictive accuracy and Kappa results for Statistical feature set for dorsal side of the leaf image dataset	181
6.11	Box plot of Predictive accuracy and Kappa results for Statistical feature set for ventral side of the leaf image dataset	181
6.12	Box plot of Predictive accuracy and Kappa results for Statistical feature set for dorsal-ventral combined leaf image dataset	182
6.13	Predictive accuracy and Kappa results for Statistical-directionality feature set for dorsal side of the leaf image dataset	182
6.14	Predictive accuracy and Kappa results for Statistical-directionality feature set for ventral side of the leaf image dataset	183

6.15	Predictive accuracy and Kappa results for Statistical-directionality feature set for dorsal-ventral combined leaf image dataset	183
6.16	Classification accuracy for Statistical feature sets	185
6.17	Classification accuracy for Statistical-Directionality feature sets	185
6.18	Comparison chart for classification accuracy of different sides of leaf images using RF	186
7.1	3D surface plot of the leaf texture for Slice-24E of dorsal side	194
7.2	3D surface plot of the leaf texture for Slice-24E of ventral side	195
7.3	Thirty two convolved images obtained for Slice-24E at different scales and orientation values	195
7.4	Correlation plot for Gabor dorsal dataset	197
7.5	Correlation plot for Gabor ventral dataset	197
7.6	Box Plot for features in the Gabor dorsal dataset	198
7.7	Box Plot for features in the Gabor ventral dataset	198
7.8	Particle Swarm Optimization Model	200
7.9	Predictive classification accuracy results for PSO based subset of features	203
7.10	Resampling results for PDFS	204
7.11	Resampling results for PVFS	204
7.12	Difference results for PDFS	205
7.13	Difference results for PVFS	205
7.14	Comparison of the present work with Hossain et al. (2010)	206
7.15	Comparison of the present work with Kadir (2015)	207
A I.1	ImageJ interface with different menu options	231
A I.2	Colored image slice-008 in ImageJ	231
A I.3	Stack of image slices with slider in ImageJ	232
A I.4	Trademark of R	233

