

List of Figures

1.1	Example of Time Series	4
1.2	First One: Non-Stationary, Second One: Stationary	8
1.3	Clone-Bug-Failure Relationship	12
3.1	Debian Bug Growth Pattern	77
3.2	Eclipse Bug Growth Pattern	77
3.3	Mozilla Bug Growth Pattern	78
3.4	Linear Transfer Function	80
3.5	Log Sigmoid Transfer Function	80
3.6	Tansig Transfer Function	80
3.7	Radial Basis Function	80
3.8	Debian Bug Database (UDD)	81
3.9	Sorted Bug Number Data (Debian)	81
3.10	Debian Bug Number Data	82
3.11	Proposed System	84
3.12	Neural Network Model for Debian Bug Number Series	86
3.13	Comparison of Actual and Predicted output:Logsig	87
3.14	Comparison of Actual and Predicted output:Tansig	87
3.15	Comparison of Actual and Predicted output:Untrained NN:RADBSN	88
3.16	Proposed Hybrid Model	94
3.17	ACF Plot: Debian Series	96
3.18	Comparison of RMSE and MAE value between the three Models (Training Set)	99
3.19	Comparison of RMSE and MAE value between the three Models (Test Set)	100
3.20	Ensemble Model	101
3.21	Comparison of RMSE and MAE value between the three Models (Training Set)	104
3.22	Comparison of RMSE and MAE value between the three Models (Test Set)	105
3.23	Debian Bug Growth Pattern:2000-2008	108
3.24	Debian Bug Growth Pattern:2009-2013	108
3.25	Debian Bug Growth Pattern:2000-2013	109
3.26	Markov State Representation	112
3.28	Plot for Change in Bug Number per Month (Sorted)	112

3.27	Plot for Change in Bug Number per Month	113
3.29	Distribution of Markov States-1[2000-2008]	114
3.30	Distribution of Markov States-1[2009-2013]	115
3.31	Prediction Result for Prediction window of different size [Markov Model(1st Order vs 2nd Order)]	123
3.32	Debian Bug Growth Pattern	126
3.33	Mozilla Bug Growth Pattern	126
3.34	Mozilla Commit Growth Pattern	126
3.35	Mozilla Contributors Growth Pattern	126
3.36	HMM Model for Temporal Bug Patterns	128
3.37	HMM Mode-1 for Temporal Bug Patterns	129
3.38	HMM Model-2 for Temporal Bug Patterns	130
3.39	HMM Model-3 for Temporal Bug Patterns	131
3.40	Time Series Representation for Exact Match Clone Sets for ArgoUML	143
3.41	Time Series Representation for Near Miss Clone Sets for ArgoUML	144
3.42	Proposed Hybrid Model	146
3.43	Hybrid and ARIMA Predicted Series vs. Original Series	149
3.44	RMSE Comparison between two Models (Train Data)	150
3.45	RMSE Comparison between two Models (Test Data)	150
3.46	Multi-Layer Perceptron Model	155
3.47	Diagrammatic Representation: Model 1	156
3.48	Diagrammatic Representation: Model 2	157
3.49	Diagrammatic Representation: Model 2	158
3.50	MAPE for Models using the Individual Metric Values (EMCS)	159
3.51	MAPE for Model using the Individual Metric Values (NMCS)	160
3.52	Comparison among Univariate and Multivariate Modelling (Linear Regression)	162
3.53	Comparison among Linear and Nonlinear Modelling (Multivariate Modelling)	162
3.54	Flow Diagram Representation for MOGA-NN	168
3.55	Pareto Plot Between X-AXIS:(1-PICP) and Y-AXIS: NMPIW(EMCS)	170
3.56	Pareto Plot Between X-AXIS:(1-PICP) and Y-AXIS: NMPIW(NMCS)	170
3.57	ARIMA Model Representation	172
3.58	Back-Propagation based Neural Network	172
3.59	MOGA based Neural Network Modelling for EMCS and NMCS	173
3.60	Actual vs. ARIMA Predicted Series (EMCS)[ArgoUML]	176
3.61	Actual vs. Back Propagation based NN Predicted Series (EMCS)[ArgoUML]	177
3.62	Actual vs. MOGA based NN Predicted Series (EMCS)[ArgoUML]	177
3.63	Actual vs. ARIMA Predicted Series (NMCS)[ArgoUML]	178
3.64	Actual vs. Back Propagation based NN Predicted Series (NMCS)[ArgoUML]	178
3.65	Actual vs. MOGA based NN Predicted Series (NMCS)[ArgoUML]	179

3.66	EMCS NRMSE Test Data[ArgoUML]	179
3.67	EMCS NRMSE Test Data[ArgoUML]	180
3.68	Proposed Hybrid Model	190
3.69	RMSE Comparison for Test Set	193
3.70	MAE Comparison for Test Set	193
3.71	Flow Diagram Representation for MOGA-NN	199
3.72	Flow Diagram Representation for ELM	203
3.73	Pareto Plot Between X-AXIS:(1-PICP) and Y-AXIS: NMPIW (System 5)	205
3.74	Pareto Plot Between X-AXIS:(1-PICP) and Y-AXIS: NMPIW (System 40)	205
3.75	Pareto Plot Between X-AXIS:(1-PICP) and Y-AXIS: NMPIW (System SS3)	205
3.76	MOGA-NN Modelling Diagram	206
3.77	ELM Modelling Diagram	206
3.78	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System 5)[MOGA-NN (Train Data)]	211
3.79	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System 40)[MOGA-NN (Train Data)]	212
3.80	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System SS3)[MOGA-NN (Train Data)]	212
3.81	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System 5)[MOGA-NN (Test Data)]	213
3.82	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System 40)[MOGA-NN (Test Data)]	213
3.83	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System SS3)[MOGA-NN (Test Data)]	214
3.84	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System 5)[ELM (Train Data)]	214
3.85	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System 40)[ELM (Train Data)]	215
3.86	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System SS3)[ELM (Train Data)]	215
3.87	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System 5)[ELM (Test Data)]	216
3.88	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System 40)[ELM (Test Data)]	216
3.89	Plot of Target series, Lower bound $L(X)$ and Upper bound $U(X)$. (System SS3)[ELM (Test Data)]	217
3.90	Comparison of PICP Values Between MOGA-NN and ELM +KNN[System 5]	218
3.91	Comparison of PICP Values Between MOGA-NN and ELM +KNN[System SS3]	219
3.92	Comparison of PICP Values Between MOGA-NN and ELM +KNN[System 40]	219