

## List of Figures

1.1	Web Service deployment and discovery architecture.....	13
1.2	Two different Web service composition architectures.....	15
1.3	Community Web service architecture.....	16
2.1	Example of Fuzzy inference rule.....	46
3.1	Time series plot.....	68
3.2	Global Model.....	68
3.3	Local Model.....	69
3.4	Schematic view of GPR.....	71
3.5	Single Service Access Architecture.....	77
3.6	Table Entry format.....	77
3.7	Services in context ontology tree.....	81
3.8	Schematic view of Prediction procedure of Model 1.....	87
3.9	Common values between adjacent regime vectors.....	93
3.10	Schematic view of Prediction Procedure of Model 2.....	96
3.11	Reputation or Trust synthetically generated .....	105
3.12	Predictions from Markov Chain Local GPR (MLGPR) using square exponential GP kernel .....	106
3.13	Predictions from Markov chain Global GPR (MGGPR) using square exponential GP kernel.....	106
3.14	Prediction from Coarse Grained Hidden Markov GPR (CHMMGPR) using square exponential GP kernel.....	106
3.15	Cumulative distribution of prediction errors.....	107
3.16	3D plot of the trust values against the QoS attribute for the Cloud service ‘land1’.....	110
3.17	Prediction from Markov Chain based Global GPR.....	111
3.18	Scatter plot of prediction error using Markov chain Global GPR.....	111
3.19	Prediction from Markov Chain Local GPR.....	112
3.20	Scatter plot of prediction error using Markov chain Local GPR.....	112

3.21	Prediction from Coarse Grained HMM GPR.....	113
3.22	Prediction error from Coarse Grained HMMGPR.....	113
4.1.	Prediction of CO <sub>2</sub> emissions using a Radial basis function (RBF) kernel, sum of a RBF kernel and a Linear (Lin) kernel, sum of a Lin kernel to the product of a RBF kernel and a Periodic (Per) kernel.....	116
4.2	Compositions of basic kernels by addition and multiplication and the structures the composite kernels represent.....	119
4.3	Scenario of sequential interactions. (a) for first interaction, trust value is to be predicted from the previous values available in a given time horizon, (b) for second interaction, trust value is predicted by extending time horizon to the next time spot.....	120
4.4	Framework for ensemble Gaussian Processes.....	121
4.5	Illustration that a regime/cluster may have different regime vectors each sensitive to a particular dynamic. Each expert will be more specialize on a particular dynamic.....	122
4.6	Overview of Markov Chain Local Ensemble Predictor Model.....	122
4.7	Overview of Coarse grained Hidden Markov Ensemble Predictor.....	123
4.8	Simulation Environment where $\phi(s_j, u)$ is the experienced QoS of a service provider $s_j$ by a user in $u$ transaction. Dishonest users add a noise term $\varepsilon \sim N(0, k\sigma)$ to their experienced QoS to form recommendation. $k$ is a scaling factor in the range (1-3) and $\sigma = 0.01$ is the standard deviation.....	134
4.9	Trust model for consumer-2 based on RATEWeb[80].....	138
4.10	Exponential Time Decay Model.....	141
4.11	Performance of M4 and RATEWeb in prediction of behavior of an oscillatory Web service provider.....	144
4.12	Performance of M4 and RATEWeb in prediction of behavior of consistently good Web service provider.....	145
4.13	Performance of M4 and RATEWeb in prediction of behavior of consistently bad Web service provider.....	146

4.14	Performance of M4 and RATEWeb in prediction of behavior of Web service provider who swings from high to low performance.....	147
4.15	Performance of M4 and RATEWeb in prediction of behavior of Web service provider who swings from low to high performance.....	148
4.16	Selection of numbers of clusters by Elbow method.....	151
4.17	Predicted Vs actual trust values and prediction performance in the form of percentage error for all models.....	152
4.18	Response time values and country of origin of 10 randomly selected Web services.....	153
4.19	Plot of Mean Square Error (MSE) values for all models accorss 10 selected Web services.....	155
4.20	Plot of Symmetric Mean Abolute Percentage Error (SMAPE) values for all models accorss 10 selected Web services.....	156
4.21	Plot of Mean Absolute Error (MAE) values for all models accorss 10 selected Web services.....	156
5.1	Effect of time decay factor $k$ .....	162
5.2	False positive Rate and True Positive Rate.....	176
5.3	Time in second needed for prediction of one query point.....	177

## List of Tables

1.1	Major Research Questions for Single Web service architecture.....	18
1.2	Major Research Questions for Composite Web service architecture.....	18
1.3	Major Research Questions for Community Web service architecture.....	19
3.1	Observation for regression example.....	73
3.2	Example of generating a prediction using a Gaussian process with a radial basis function kernel. $w_i = (K(X, X) + \sigma_\varepsilon^2 I)^{-1} y_i, x_* = 3;$ .....	75
3.3	Categorization of Trust intermediaries.....	80
3.4	Details of data set selected from Cloud Armor dataset.....	109
4.1	Commonly used basic kernels for Gaussian process.....	118
4.2	Short names for the four proposed models.....	138
4.3	Models with their kernels.....	139
4.4	Parameters Setting for Simulation.....	139
4.5	Comparison of prediction performance of all models when the honest raters outnumbered the dishonest raters.....	142
4.6	Comparison of prediction performance of all models when the dishonest raters outnumbered the honest raters.....	143
4.7	Details of data set selected from Cloud Armor dataset.....	150
4.8	Performance indicators values for for models M1,M2,M33 and M4.....	155
5.1	Statistics of Epinions Dataset [119].....	173
5.2	Error measurements for 1000 prediction sessions: MSE, MAE and SMAPE.....	175

## List of Abbreviations

CRM	Customer relationship management
ERP	Enterprise resource planning
QoS	Quality of service
TTP	Trusted Third party
GP	Gaussian Process
GPR	Gaussian Process Regression
HMM	Hidden Markov Model
CHMM	Coarse Grained HMM
MLGPR	Markov Chain Local GPR
MGGPR	Markov Chain Global GPR
CHMMGPR	Coarse Grained Hidden Markov Model GPR
RBF	Radial basis function
SE	Square Exponential
RQ	Rational Quadratic Kernel
Lin	Linear Kernel
C	Constant Noise kernel
Per	Periodic kernel
ARMSE	Average Root mean square Error
HGP	Heteroscedastic Gaussian Process
MSE	Mean Square Error
SMAPE	Symmetric Mean Absolute Percentage Error
MAE	Mean Absolute Error