## **List of Tables**

2.1	UML diagrams and their corresponding model elements	12
3.1	Three scenarios for the interaction in UML model of Figures 2.3 and A.1(b)	25
3.2	Dependency semantics in MDG and their corresponding notations	31
3.3	Experimental model description and its specification in terms of model elements	51
3.4	Artifacts for classes considered in each system model	52
3.5	Artifacts for interactions considered in each system model	52
3.6	Experimental model specification in terms of their corresponding MDG elements	54
3.7	Average runtime requirements of <i>ModelGraph</i> algorithm	55
3.8	Memory requirement of <i>ModelGraph</i> algorithm	57
4.1	Reverse mapping of MDG nodes into the corresponding model elements	77
4.2	Execution trace of loop in line 4 in pseudocode of Phase 2 of SSUAM algorithm for	
	the slicing criterion $[PC_{C2}, S_1]$	77
4.3	NodeTraverseList during execution of Phase 2 of SSUAM for example slicing	
	criterion	79
4.4	Average runtime of SSUAM algorithm	84
4.5	Memory requirement of SSUAM algorithm	86
4.6	Details of slice computation using SSUAM on experimental UML models	88
4.7	Backward and forward slice sizes and their computation times for SSUAM	88
5.1	Some <i>model data</i> for Example-2 UML model	106
5.2	Summary of loop execution in line 5 in Phase 2 of DSUAM algorithm for Examples	
	(1)-(4)	111
5.3	Average runtime of DSUAM algorithm	115
5.4	Memory requirement of DSUAM algorithm	118
5.5	Details of slice computation using DSUAM on experimental UML models	119
5.6	Backward and forward slice sizes and their computation times for DSUAM	119
5.7	Effect of slicing criteria on the DSUAM slice size with varying $D_M$	121
5.8	Summary of comparison with related work	124
6.1	StateInfo(:ClassB) for SM <sub>B</sub> given in Figure 6.1(a)	132
6.2	StateInfo(:ClassC) for SM <sub>C</sub> given in Figure 6.1(b)	132
6.3	StateInfo(:ClassD) for SM <sub>D</sub> given in Figure 6.1(c)	132
6.4	State information table $StateInfo(:ClassB)$ for $SM_B$	145
6.5	State information table $StateInfo(:ClassC)$ for $SM_C$	146

6.6	State information table <i>StateInfo</i> (:ClassD) for SM <sub>D</sub>	46
6.7	Summary of loop execution in line 6 in Phase 2 of SDSUM algorithm for examples	
	(1)-(4)	48
6.8	Average runtime of SDSUM algorithm	54
6.9	Memory requirement of SDSUM algorithm	56
6.10	Details of slice computation using SDSUM on experimental UML models 1	58
6.11	Backward and forward slice sizes and their computation times for SDSUM 1	58
6.12	Effect of slicing criteria on the SDSUM slice size with varying $D_M$ $\ldots$	60
A.1	Three scenarios for the interactions in Figures A.3 and A.4	72

## **List of Figures**

1.1	An example program	3
1.2	Dependencies among different model views for an example UML model	4
1.3	Conceptual schema of the planned work	6
1.4	Use case model of the work done	7
1.5	Activity diagram representation of work done	8
2.1	A taxonomy of UML models and model elements	12
2.2	A partial view of an example UML model, depicted using a class diagram	14
2.3	A partial view of an example UML model, depicted using a sequence diagram	15
2.4	A partial view of an example UML model, depicted using a state machine diagram	17
2.5	An example UML model. (a) Classes depicted using a class diagram (b) An interaction	
	depicted using a sequence diagram	20
3.1	Representation of a generic system model	24
3.2	An example class from a class diagram	26
3.3	Class diagram for the MDG metamodel	28
3.4	One-to-one mapping of UML metamodel elements to MDG representation	29
3.5	MDG representation of the UML Model given in Example-1 of Appendix A	33
3.6	Schematic of a MDG construction technique <i>ModelGraph</i> for a UML model	35
3.7	Pseudocode of <i>ModelGraph</i> algorithm	36
3.8	Pseudocode for the ConstructMDG() procedure used in <i>ModelGraph</i>	37
3.9	High level design of <i>MDGConstructor</i>	49
3.10	Schematic design of <i>MDGConstructor</i>	49
3.11	Increase in MDG size (see Table 3.6) with increase in model size (see Table 3.3)	53
3.12	Increase in average run time of <i>ModelGraph</i> with increase in model size	55
3.13	Increase in execution time of <i>ModelGraph</i> with increase in model size	56
3.14	Increase in memory requirement of <i>ModelGraph</i> with increase in model size	57
3.15	Memory requirement during execution of <i>ModelGraph</i>	58
41	Traversal path and Traversal point in MDG	64
4.2	Edge selection based on its annotation during MDG traversal	66
43	Manning and reverse-manning of model elements	68
4.5	Activity diagram representation of our static slicing technique	69
4 5	Pseudocode of SSUAM algorithm	69
т. <i>5</i> 46	MDG showing static model slice computed for the slicing criterion [PC S.] during the	07
4.0	execution of phase 2 of SSIIAM	78
		10

4.7	MDG showing static model slice computed for the slicing criterion $[CA_{CC}, I_1(2) \dots I_1(8)]$ during the execution of phase 2 of SSUAM	78
4.8	MDG showing forward static model slice computed for the slicing criterion $CA_{CC}$ , $S_1(7)$ during the execution of phase 2 of SSUAM	80
4.9	MDG showing the backward static model slice computed for the slicing criterion $\begin{bmatrix} 2 & -2 & -2 \end{bmatrix}$	00
4.10	$[CA_{C2}, S_1(6)]$ during the execution of phase 2 of SSUAM	80
	the execution of phase 2 of SSUAM	81
4.11	Schematic design model of the prototype tool <i>ArchliceS</i>	82
4.12	Increase in execution time of SSUAM with increase in model size	83
4.13	Increase in average run time of SSUAM with increase in model size	84
4.14	Increase in memory requirement of SSUAM with increase in model size	86
4.15	Memory requirement during execution of SSUAM	87
4.16	Comparison of SSUAM backward and forward static model slice sizes listed in Table 4.7	89
5.1	Activity diagram representation of our dynamic slicing technique	99
5.2	Pseudocode of DSUAM algorithm	99
5.3	MDG representation of the UML model given in Example-2 in Appendix A	107
5.4	MDG showing dynamic architectural model slice computed for the slicing criterion	
	$[\texttt{PC}_\texttt{C},\texttt{S}_{\texttt{12}},\texttt{D}_\texttt{M} = \{\texttt{attrib\_a1} = -1,\texttt{attrib\_a2} = \textit{xxy},\texttt{attrib\_c1} = 0,\texttt{attrib\_c2} =$	
	5}] during the execution of phase 2 of DSUAM	108
5.5	MDG showing dynamic architectural model slice computed for the slicing criterion	
	$[PC_{C}, S_{13}, D_{M} = \{attrib_{a}1 = 1, attrib_{c}1 = 0\}] \text{ during the execution of phase } 2$ of DSUAM	110
5.6	MDG showing dynamic architectural model slice computed for the slicing criterion	
	$[\_NULL\_, S_{12}, D_M = \{\texttt{attrib\_a1} = -1, \texttt{attrib\_a2} = xxy, \texttt{attrib\_c1} = 0, \texttt{attrib\_c2} = 0\}$	
	5}] during the execution of phase 2 of DSUAM	112
5.7	MDG showing dynamic architectural model slice computed for the slicing criterion	
	$[\mathtt{CA}_{\mathtt{F}}, \mathtt{S}_{\mathtt{21}}, \mathtt{D}_{\mathtt{M}} = \{ \mathtt{attrib\_d1} = \mathit{aaa}, \mathtt{attrib\_d2} = \mathtt{1}, \mathtt{attrib\_f1} = \mathtt{1}, \mathtt{attrib\_f2} =$	
	2, attrib_f3 = xyx, attrib_e1 = $aba$ ] during the execution of phase 2 of DSUAM	112
5.8	Schematic design model of the prototype tool <i>ArchliceD</i>	113
5.9	Increase in execution time of DSUAM with increase in model size	115
5.10	Increase in average run time of DSUAM with increase in model size	116
5.11	Increase in memory requirement of DSUAM with increase in model size	117
5.12	Memory requirement during execution of DSUAM	117
5.13	Comparison of DSUAM backward and forward dynamic slice sizes listed in Table 5.6	120
5.14	Impact on average DSUAM slice size with changing $D_M$ in the slicing criteria. (a) Change	
	in average slice size with increase in number of slicing criteria used with parameter	
	$D_M = \_NULL_(b)$ Change in average slice size with increase in number of slicing criteria	
	used with parameter $D_M = \_FEW(c)$ Change in average slice size with increase in number	
	of slicing criteria used with parameter $D_M = \_ALL\_(d)$ Comparison of average slice sizes	
	obtained in (a), (b), and (c)	122

5.15	Summary of experimental results for SSUAM and DSUAM algorithms. (a) Comparison of increase in average run time with increase in model size, (b) Comparison of increase in execution time of phase 1 with increase in model size, (c) Comparison of increase in execution time of phase 2 with increase in model size, (d) Comparison of increase in average memory requirement with increase in model size, (e) Comparison of increase in memory requirement in execution of phase 1 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size.	125
6.1	State-machine diagrams for the ClassB, ClassC, and ClassD objects used in the interactions of UML model given in Example-2 of Appendix A	131
6.2	Schematic of the modified MDG construction technique for a UML model	133
6.3	MDG representation of UML model given in Example-2 of Appendix A	134
6.4	Pseudocode for the modified ConstructMDG() procedure used in <i>ModelGraph</i>	137
6.5	Pseudocode of modified <i>ModelGraph</i> algorithm	138
6.6	Pseudocode of SDSUM algorithm	140
6.7	MDG showing state-based model slice computed for the slicing criterion $[PC_C, S_{12}, D_M = {attrib_a1 = -1, attrib_a2 = xxy, attrib_c1 = 0, attrib_c2 = 5}]$ during the execution of phase 2 of SDSUM	147
6.8	MDG showing state-based model slice computed for the slicing criterion $[PC_C, S_{13}, D_M = {attrib_a1 = 1, attrib_c1 = 0}]$ during the execution of phase 2 of SDSUM	149
6.9	MDG showing state-based model slice computed for the slicing criterion [_NULL_, $S_{12}$ , $D_M = $ {attrib_a1 = -1, attrib_a2 = xxy, attrib_c1 = 0, attrib_c2 = 5}] during the execution of phase 2 of SDSUM	149
6.10	MDG showing state-based model slice computed for the slicing criterion $[CA_F, S_{21}, D_M = {attrib_d1 = aaa, attrib_d2 = 1, attrib_f1 = 1, attrib_f2 = 2, attrib_f3 = 3, attrib_e1 = aba}] during the execution of phase 2 of SDSUM$	150
6.11	MDG showing state-based model slice computed for the slicing criterion $[PC_{c}, S_{12}, D_{M}]$	
	$ \left\{ \operatorname{attrib}_{a} = -1, \operatorname{attrib}_{a} = xxy, \operatorname{attrib}_{c} = 3, \operatorname{attrib}_{c} = 5 \right\} $ during the	
	execution of phase 2 of SDSUM	150
6.12	Schematic design model of the prototype tool <i>ArchliceDE</i>	151
6.13	Increase in average run time of SDSUM with increased model sizes	153
6.14	Increase in execution time of SDSUM with increase in model size	153
6.15	Increase in memory requirement of SDSUM with increase in model size	156
6.16	Memory requirement during execution of SDSUM	157
6.17	Comparison of SDSUM backward and forward model slice sizes listed in Table 6.11	159
6.18	Impact on average SDSUM slice size with changing $D_M$ in the slicing criteria. (a) Change in average slice size with increase in number of slicing criteria used with parameter $D_M = \_NULL\_$ (b) Change in average slice size with increase in number of slicing criteria used with parameter $D_M = \_FEW\_$ (c) Change in average slice size with increase in number of slicing criteria used with parameter $D_M = \_ALL\_$ (d) Comparison of average slice sizes obtained in (a), (b), and (c).	161

6.19 Summary of experimental results for DSUAM and SDSUM algorithms. (a) Comparison of increase in average run time with increase in model size, (b) Comparison of increase in execution time of phase 1 with increase in model size, (c) Comparison of increase in execution time of phase 2 with increase in model size, (d) Comparison of increase in average memory requirement with increase in model size, (e) Comparison of increase in memory requirement in execution of phase 1 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size, (f) Comparison of increase in memory requirement in execution of phase 2 with increase in model size.

An example UML model. (a) Classes depicted using a class diagram (b) An interaction	
$I_1$ depicted using a sequence diagram	L
Classes depicted using a class diagram	2
Interaction I <sub>1</sub> depicted using a sequence diagram	;
Interaction I <sub>2</sub> depicted using a sequence diagram 173	;
	An example UML model. (a) Classes depicted using a class diagram (b) An interaction   I <sub>1</sub> depicted using a sequence diagram 171   Classes depicted using a class diagram 172   Interaction I <sub>1</sub> depicted using a sequence diagram 173   Interaction I <sub>2</sub> depicted using a sequence diagram 173

## **List of Symbols**

	М	A UML model
	$G_{\mathrm{M}}$	A model dependency graph of a UML model M
	CL	A class in a UML model
	I	An interaction in a UML model
	SM	A state machine in a UML model
	AT	An attribute node
	PR	A parameter node
	RT	A return node
	IT	An interaction node
	SC	A slicing criterion
	Si	All scenarios in an interaction $I_i$
	${\tt S_i}(\overleftarrow{m})$	Messages before $m^{th}$ message transfer in an interaction $I_i$
	$\mathtt{S_i}(\overrightarrow{m})$	Messages after $m^{th}$ message transfer in an interaction $I_i$
	$I_i(k)$	$k^{th}$ message in an interaction $I_i$
	$S_{ij}$	$j^{th}$ scenario in an interaction $I_i$
	MEI	Model elements in an interaction
	ME <sub>SS</sub>	Model elements in a static slice
	ME <sub>DS</sub>	Model elements in a dynamic slice
	$D_{M}$	Model data
	$S_{m}$	An object's present state
	S <sub>n</sub>	An object's next state

## **List of Abbreviations**

ADL	Architecture Description Language
PDG	Program Dependency Graph
MDG	Model Dependency Graph
CA	Class Access
PC	Predicate Class
AO	Operation Access
SAMS	Static Architectural Model Slice
SSUAM	Static Slicing of UML Architectural Models
DAMS	Dynamic Architectural Model Slice
DSUAM	Dynamic Slicing of UML Architectural Models
SDSUM	State-based Dynamic Slicing of UML Models
UML	Unified Modelling Language