

INDRANIL ROYCHOUDHURY

CURRICULUM VITAE

Computer Scientist
Stinger Ghaffarian Technologies Inc., NASA Ames Research Center
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RESEARCH INTERESTS

- Fault diagnostics and prognostics of complex embedded systems
- Modeling, simulation, and analysis of hybrid and embedded systems

EDUCATION

Vanderbilt University, Nashville, Tennessee, USA August 2009
Ph.D. Computer Science (GPA: 3.98/4.0)

Vanderbilt University, Nashville, Tennessee, USA May 2006
M.S. Computer Science (GPA: 3.97/4.0)

Birla Institute of Technology and Science, Pilani, Rajasthan, India May 2004
B.E. (Hons.) Electrical and Electronics Engineering (GPA: 8.81/10.00)

PROFESSIONAL EXPERIENCE

SGT, Inc., NASA Ames Research Center, Moffett Field, California, USA December 2010 – Present
Computer Scientist

- Current research includes development of model-based and data-driven diagnostic and prognostic approaches, and development of electromechanical actuator testbeds for real-world implementation and evaluation of these approaches.
- Verification and validation of health management systems.
- Decision making using diagnostic and prognostic information.

SGT, Inc., NASA Ames Research Center, Moffett Field, California, USA August 2009 – December 2010
Computer Scientist, Post Doctorate

- Developed model-based and data-driven diagnostic and prognostic approaches for electromechanical actuators.
- Developed electromechanical actuator testbeds for real-world implementation and evaluation of these approaches.

Vanderbilt University, Nashville, Tennessee, USA Fall 2004 – July 2009
Research Assistant, Institute for Software Integrated Systems (ISIS)

- Modeled large scale hybrid systems using hybrid bond graphs and derived high-fidelity simulation models from them. These large hybrid systems include the Advanced Water Recovery System developed at NASA Johnson Space Center, and the Advanced Diagnostics and Prognostics Testbed at NASA Ames Research Center.
- Developed a methodology for distributed fault diagnosis of complex physical systems. Implemented algorithms to analyze the diagnosability of continuous systems and design distributed fault diagnosers that communicate a minimal number of measurements amongst themselves to generate globally correct diagnosis results through local analysis, without any central coordinator. These algorithms have been applied to the Advanced Water Recovery System.
- Developed a unified framework for diagnosing abrupt (fast) and incipient (gradual) parametric faults by combining a qualitative diagnosis scheme with a Dynamic Bayesian Network-based diagnosis approach.
- Developed an approach for improving the efficiency of inference of Dynamic Bayesian Networks (DBNs) by factoring the DBN into smaller factors such that each factor is conditionally independent from all other factors given the measurements that are communicated to it.
- Developed a distributed scheme for diagnosing abrupt and incipient faults by combining qualitative diagnosis schemes with inference algorithms applied to factored DBNs.

Mission Critical Technologies, Inc., NASA Ames Research Center, Moffett Field, California, USA Summer 2007
Intern, Intelligent Systems Division (Code TI)

- Developed high-fidelity hybrid models for the Advanced Diagnostics and Prognostics Testbed (ADAPT).
- Improved the efficiency of simulation software for hybrid bond graphs. Developed the VIRTUAL ADAPT simulator.

- Implemented the Fault Adaptive Control Technology (FACT) software as a test article for ADAPT. Performed diagnosis experiments using FACT on ADAPT.

Mission Critical Technologies, Inc., NASA Ames Research Center, Moffett Field, California, USA Summer 2006

Intern, Intelligent Systems Division (Code TI)

- Developed component-based hybrid models for the Advanced Diagnostics and Prognostics Testbed.
- Developed software to construct and execute hybrid bond graphs as MATLAB Simulink models.

Broadcom India Pvt. Ltd., Bangalore, Karnataka, India

Spring 2004

Intern, Firmware Group

- Implemented a Low Complexity MPEG 2 AAC Encoder.
- Generated worst-case audio streams for comprehensive testing of decoders.

Birla Institute of Technology and Science, Pilani, Rajasthan, India

Fall 2003

Teaching Assistant, Control Systems, Department of Electrical and Electronics Engineering

- Proctored student exams and tutorial sessions.

TEXMACO India Pvt. Ltd., Calcutta, West Bengal, India

Summer 2002

Intern

- Conducted an in-depth study of the various techniques for testing defects in welds.

SELECTED COURSEWORK

System-level Fault Diagnosis

- Focused on the theory, analysis, and application of a variety of algorithmic techniques for model-based diagnosis and diagnosability analysis in different modeling paradigms.
- *Project*: Surveyed hierarchical model-based fault diagnosis approaches. Analyzed the implications of a hierarchical TRANSCEND-based qualitative fault isolation scheme.

Independent Study: Distributed Fault Diagnosis Schemes for Discrete-Event Systems

- *Project*: Surveyed several distributed fault diagnosis schemes for discrete-event systems.

Modeling and Simulation

- Focused on a comprehensive study of modeling and simulation techniques for continuous and discrete-event systems.
- *Project*: Modeled and simulated the movement of a team of four robots in different formations. Developed formation and trajectory controllers that enable the robots to switch between formations without any collision.

Fundamentals of Hybrid and Embedded Systems

- Focused on the theory, analysis, and application of models of computation useful for specifying hybrid and embedded systems.
- *Project*: Modeled a multi-tank system, a benchmark problem for hybrid systems, as a hybrid automaton, and simulated the behavior of this system under normal as well as faulty operating conditions.

Model-Integrated Computing

- Focused on the theory, analysis, and application of domain-specific modeling languages and model-based program synthesis.
- *Project*: Developed a hybrid bond graph markup language (HBGML) for the exchange and reuse of hybrid bond graph models. Implemented a model translator in the Generic Modeling Environment for the Fault Adaptive Control Technology modeling paradigm to generate HBGML documents.

PUBLICATIONS

JOURNAL PAPERS

- [J1] **I. Roychoudhury**, M. Daigle, G. Biswas, and X. Koutsoukos, "Efficient Simulation of Hybrid Systems: A Hybrid Bond Graph Approach," *SIMULATION: Transactions of the Society of Modeling and Simulation International*, vol. 87, no. 6, pp. 467-498, June 2011.
- [J2] M. Daigle, **I. Roychoudhury**, G. Biswas, X. Koutsoukos, A. Patterson-Hine, and S. Poll, "A Comprehensive Diagnosis Methodology for Complex Hybrid Systems: A Case Study on Spacecraft Power Distribution Systems," *IEEE Systems, Man, and Cybernetics, Part A: Special Issue on "Model-based Diagnosis: Facing Challenges in the Real World"*, vol. 4, no. 5, pp. 917-931, September 2010.

- [J3] **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "Designing Distributed Diagnosers for Complex Continuous Systems," *IEEE Transactions on Automation Science and Engineering*, vol. 6, no. 2, pp. 277-290, April 2009.
- [J4] **I. Roychoudhury**, M. Daigle, G. Biswas, and X. Koutsoukos, "An Efficient Method for Simulating Complex Systems with Switching Behaviors Using Hybrid Bond Graphs," *Simulation News Europe*, vol. 18, no. 3-4, pp. 5-13, December 2008.

THESES

- [T1] **I. Roychoudhury**, "Distributed Diagnosis of Continuous Systems: Global Diagnosis Through Local Analysis," PhD Dissertation, Vanderbilt University, August 2009.

CONFERENCE PAPERS

- [C1] **I. Roychoudhury**, V. Hafiychuk, and K. Goebel, "Model-Based Diagnosis and Prognosis of a Water Recycling System," *Proceedings of the 2013 IEEE Aerospace Conference*, March 2013.
- [C2] **I. Roychoudhury**, M. Daigle, A. Bregon, and B. Pulido, "A Structural Model Decomposition Framework for Systems Health Management," *Proceedings of the 2013 IEEE Aerospace Conference*, March 2013.
- [C3] A. Bregon, M. Daigle, and **I. Roychoudhury**, "An Integrated Framework for Model-Based Distributed Diagnosis and Prognosis," *Proceedings of the Annual Conference of the Prognostics and Health Management Society 2012*, September 2012.
- [C4] M. Daigle, **I. Roychoudhury**, and A. Bregon, "A Distributed Approach to System-Level Prognostics," *Proceedings of the Annual Conference of the Prognostics and Health Management Society 2012*, September 2012.
- [C5] A. Bregon, M. Daigle, and **I. Roychoudhury**, "An Integrated Model-Based Distributed Diagnosis and Prognosis Framework," *Proceedings of the 23rd International Workshop on Principles of Diagnosis*, July - August 2012.
- [C6] S. Narasimhan, E. Balaban, M. Daigle, **I. Roychoudhury**, A. Sweet, J. Celaya, and K. Goebel, "Autonomous Decision Making for Planetary Rovers Using Diagnostic and Prognostic Information," *Proceedings of the 8th IFAC Symposium on Fault Detection, Supervision, and Safety of Technical Processes (SAFEPROCESS 2012)*, August 2012.
- [C7] M. Daigle, A. Bregon, and **I. Roychoudhury**, "Qualitative Event-based Diagnosis with Possible Conflicts Applied to Spacecraft Power Distribution Systems," *Proceedings of the 8th IFAC Symposium on Fault Detection, Supervision, and Safety of Technical Processes (SAFEPROCESS 2012)*, August 2012.
- [C8] A. Saxena, J. Celaya, **I. Roychoudhury**, S. Saha, B. Saha, and K. Goebel, "Designing Data-Driven Battery Prognostic Approaches for Variable Loading Profiles: Some Lessons Learnt," *Proceedings of the First European Conference of the Prognostic and Health Management Society*, July 2012.
- [C9] A. Saxena, **I. Roychoudhury**, C. Neukom, A. Huang, G. Pisanich, and D. Tran, "Evaluating the Impact of Unrestricted Operation of Unmanned Aircraft Systems in the National Airspace System," *Proceedings of AIAA Infotech@Aerospace*, August 2012.
- [C10] A. Saxena, **I. Roychoudhury**, J. Celaya, B. Saha, S. Saha, and K. Goebel, "Requirement Flowdown for Prognostics Health Management," *Proceedings of AIAA Infotech@Aerospace*, August 2012.
- [C11] **I. Roychoudhury** and M. Daigle, "An Integrated Model-Based Diagnostic and Prognostic Framework," *Proceedings of the 22nd International Workshop on Principles of Diagnosis (DX 2011)*, October 2011.
- [C12] A. Bregon, M. Daigle, **I. Roychoudhury**, G. Biswas, X. Koutsoukos, and B. Pulido, "Improving Distributed Diagnosis Through Structural Model Decomposition," *Proceedings of the 22nd International Workshop on Principles of Diagnosis (DX 2011)*, October 2011.
- [C13] M. Daigle, A. Bregon, and **I. Roychoudhury**, "Qualitative Event-based Diagnosis with Possible Conflicts: Case Study on the Third International Diagnostics Competition", *Proceedings of the 22nd International Workshop on Principles of Diagnosis*, October 2011.
- [C14] M. Daigle, **I. Roychoudhury**, S. Narasimhan, B. Saha, S. Saha, and K. Goebel, "Investigating the Effect of Damage Progression Model Choice on Prognostics Performance," *Proceedings of the Annual Conference of the Prognostics and Health Management Society 2011 (PHM 2011)*, September 2011. (Best Paper Award, Theoretical Paper Category)
- [C15] M. Daigle, A. Bregon, and **I. Roychoudhury**, "Distributed Damage Estimation for Prognostics Based on Structural Model Decomposition," *Proceedings of the Annual Conference of the Prognostics and Health Management Society 2011 (PHM 2011)*, September 2011. (Nominated for Best Paper Award)

- [C16] E. Balaban, S. Narasimhan, M. Daigle, J. Celaya, **I. Roychoudhury**, B. Saha, S. Saha, and K. Goebel, "A Mobile Robot Testbed for Prognostics-Enabled Autonomous Decision Making," *Proceedings of the Annual Conference of the Prognostics and Health Management Society 2011 (PHM 2011)*, September 2011. (Nominated for Best Paper Award)
- [C17] E. Balaban, A. Saxena, S. Narasimhan, **I. Roychoudhury**, and K. Goebel, "Experimental Validation of a Prognostic Health Management System for Electro-Mechanical Actuators," *Proceedings of the AIAA Infotech@Aerospace*, March 2011.
- [C18] S. Narasimhan, **I. Roychoudhury**, E. Balaban, and A. Saxena, "Combining Model-Based and Feature-Driven Diagnosis Approaches - A Case Study on Electromechanical Actuators," *Proceedings of the 21st International Workshop on Principles of Diagnosis (DX 2011)*, October 2010.
- [C19] M. Daigle, **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "An Event-based Approach to Distributed Diagnosis of Continuous Systems," *Proceedings of the 21st International Workshop on Principles of Diagnosis (DX 2011)*, October 2010.
- [C20] M. Daigle and **I. Roychoudhury**, "Qualitative Event-based Diagnosis: Case Study on the Second International Diagnostic Competition," *Proceedings of the 21st International Workshop on Principles of Diagnosis (DX 2011)*, October 2010.
- [C21] E. Balaban, A. Saxena, S. Narasimhan, **I. Roychoudhury**, K. Goebel, and M. Koopmans, "Airborne Electro-Mechanical Actuator Test Stand for Development of Prognostic Health Management Systems," *Proceedings of the Annual Conference of the Prognostics and Health Management Society (PHM 2010)*, October 2010.
- [C22] **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "Distributed Diagnosis in Uncertain Environments Using Dynamic Bayesian Networks," *Proceedings of the 18th Mediterranean Conference on Control and Automation (MED 2010)*, June 2010.
- [C23] A. Saxena, **I. Roychoudhury**, J. R. Celaya, S. Saha, B. Saha, and K. Goebel, "Requirements Specifications for Prognostics: An Overview," *Proceedings of the AIAA Infotech@Aerospace*, April 2010.
- [C24] **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "Using Factored Bond Graphs for Distributed Diagnosis of Complex Systems," *Proceedings of the 9th International Conference on Bond Graph Modeling and Simulation (ICBGM 2010)*, pp. 11-18, April 2010.
- [C25] **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "Factoring Dynamic Bayesian Networks Based on Structural Observability," *Proceedings of 48th IEEE Conference on Decision and Control (IEEE CDC 2009)*, December 2009.
- [C26] **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "Distributed Diagnosis of Dynamic Systems Using Dynamic Bayesian Networks," *20th International Workshop on Principles of Diagnosis (DX 2009)*, June 2009.
- [C27] **I. Roychoudhury**, M. Daigle, G. Biswas, X. Koutsoukos, A. Patterson-Hine, and S. Poll, "Comprehensive Diagnosis of Complex Electrical Power Systems," *7th IFAC Symposium on Fault Detection, Supervision, and Safety of Technical Processes (SAFEPROCESS 2009)*, June 2009.
- [C28] **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "Efficient Tracking for Diagnosis Using Factored Dynamic Bayesian Networks," *7th IFAC Symposium on Fault Detection, Supervision, and Safety of Technical Processes (SAFEPROCESS 2009)*, June 2009.
- [C29] **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "Comprehensive Diagnosis of Continuous Systems Using Dynamic Bayes Nets," in *Proceedings of the 19th International Workshop on Principles of Diagnosis (DX 2008)*, Blue Mountains, Australia, pp. 151-158, September 2008.
- [C30] **I. Roychoudhury**, M. Daigle, G. Biswas, and X. Koutsoukos, "Efficient Simulation of Hybrid Systems: An Application to Electrical Power Distribution Systems," in *Proceedings of the 22nd European Conference on Modeling and Simulation (ECMS 2008)*, pp. 471-477, June 2008.
- [C31] S. Poll, A. Patterson-Hine, J. Camisa, D. Nishikawa, L. Spirkovska, D. Garcia, D. Hall, C. Neukom, A. Sweet, S. Yentus, C. Lee, J. Ossenfort, **I. Roychoudhury**, M. Daigle, G. Biswas, X. Koutsoukos, and R. Lutz, "Evaluation, Selection, and Application of Model-Based Diagnosis Tools and Approaches," *AIAA Infotech@Aerospace 2007 Conference and Exhibit*, May 2007.
- [C32] S. Poll, A. Patterson-Hine, J. Camisa, D. Garcia, D. Hall, C. Lee, O. Mengshoel, C. Neukom, D. Nishikawa, J. Ossenfort, A. Sweet, S. Yentus, **I. Roychoudhury**, M. Daigle, G. Biswas, and X. Koutsoukos, "Advanced Diagnostics and Prognostics Testbed," in *Proceedings of the 18th International Workshop on Principles of Diagnosis (DX 2007)*, pp. 178-185, May 2007.

- [C33] A. Moustafa, M. Daigle, **I. Roychoudhury**, C. Shantz, G. Biswas, S. Mahadevan, and X. Koutsoukos, "Fault Diagnosis of Civil Engineering Structures using the Bond Graph Approach," in *Proceedings of the 18th International Workshop on Principles of Diagnosis (DX 2007)*, pp. 146-153, May 2007.
- [C34] M. Daigle, **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "Efficient Simulation of Component-Based Hybrid Models Represented as Hybrid Bond Graphs," in *Proceedings of Hybrid Systems: Computation and Control (HSCC 2007)*, vol. 4416, pp. 680-683, Apr 2007.
- [C35] **I. Roychoudhury**, M. Daigle, G. Biswas, X. Koutsoukos, and P. J. Mosterman, "A Method for Efficient Simulation of Hybrid Bond Graphs," in *Proceedings of the 8th International Conference on Bond Graph Modeling (ICBGM 2007)*, pp. 177-184, Jan 2007.
- [C36] **I. Roychoudhury**, G. Biswas, X. Koutsoukos, "A Bayesian Approach to Efficient Diagnosis of Incipient Faults," in *Proceedings of the 17th International Workshop on Principles of Diagnosis (DX 2006)*, pp. 243 - 250, June 2006.
- [C37] **I. Roychoudhury**, G. Biswas, X. Koutsoukos, and S. Abdelwahed, "Designing distributed diagnosers for complex physical systems," in *Proceedings of the 16th International Workshop on Principles of Diagnosis (DX 2005)*, pp. 31 - 36, June 2005.

TECHNICAL REPORTS

- [R1] M. Daigle, **I. Roychoudhury**, G. Biswas, and X. Koutsoukos, "Efficient Simulation of Hybrid Models Represented as Hybrid Bond Graphs," *Technical Report ISIS-06-712*, Institute for Software Integrated Systems, Vanderbilt University, Dec 2006.
- [R2] M. Daigle, **I. Roychoudhury**, G. Biswas, X. Koutsoukos, A. Patterson-Hine, and S. Poll, "A Comprehensive Diagnosis Methodology for Complex Hybrid Systems: A Case Study on Spacecraft Power Distribution Systems," *Technical Report ISIS-08-908*, Institute for Software Integrated Systems, Vanderbilt University, Dec 2008.

PRESENTATIONS

- "An Integrated Model-Based Diagnostic and Prognostic Framework," *22nd International Workshop on Principles of Diagnosis (DX 2011)*, Murnau, Germany, October 2011.
- "Using Factored Bond Graphs for Distributed Diagnosis of Complex Systems", *9th International Conference on Bond Graph Modeling and Simulation (ICBGM 2010)*, Orlando, FL, April 2010.
- "Comprehensive Diagnosis of Continuous Systems Using Dynamic Bayes Nets," *19th International Workshop on Principles of Diagnosis (DX 2008)*, Blue Mountains, Australia, September 2008.
- "Diagnosing ADAPT: An Application of the Fault Adaptive Control Technology," MCT/NASA Ames Internship Presentation, NASA Ames Research Center, Moffett Field, CA, September 2007. (with M. Daigle)
- "Modeling and Simulation of the Advanced Diagnostics and Prognostics Testbed," MCT/NASA Ames Internship Presentation, NASA Ames Research Center, Moffett Field, CA, September 2006. (with M. Daigle)
- "Designing Distributed Diagnosers for Complex Systems," *16th International Workshop on Principles of Diagnosis (DX 2006)*, Monterey, CA, June 2005.

PROFESSIONAL SERVICE AND SOCIETIES

Reviewing

- JOURNALS:

- SIMULATION: Transactions of The Society for Modeling and Simulation International
- SCS Simulation Modeling Practice and Theory
- IEEE Transactions on Control Systems Technology
- IEEE Transactions on Instrumentation and Measurement
- IEEE Transactions on Systems, Man and Cybernetics, Part A: Systems and Humans
- International Journal of Modeling, Simulation, and Scientific Computing
- International Journal of Robust and Nonlinear Control

- International Journal of Prognostics and Health Management
- CONFERENCES AND WORKSHOPS:
 - Annual Conference of the Prognostics and Health Management Society, 2012
 - First European Conference of the Prognostics and Health Management Society, 2012
 - 8th IFAC Symposium on Fault Detection, Supervision, and Safety of Technical Processes
 - 22nd International Workshop on Principles of Diagnosis
 - Annual Conference of the Prognostics and Health Management Society, 2011
 - 21st International Workshop on Principles of Diagnosis
 - 20th International Workshop on Principles of Diagnosis
 - Annual Conference of the Prognostics and Health Management Society, 2009
 - 7th IFAC Symposium on Fault Detection, Supervision, and Safety of Technical Processes
 - 2009 American Control Conference
 - 14th IEEE Real Time Embedded Technology and Applications Symposium
 - 19th International Workshop on Principles of Diagnosis
 - 18th International Workshop on Principles of Diagnosis
 - 17th International Workshop on Principles of Diagnosis

Conference Organization

- Annual Conference of the Prognostics and Health Management Society, 2013, **Technical Program Committee Member** and **Proceedings Co-chair**
- 24th International Workshop on Principles of Diagnosis (DX 2013), **Program Committee Member**
- 4th International Diagnostic Competition (DXC 2013), **Organizing Committee Member**
- Annual Conference of the Prognostics and Health Management Society, 2012, **Proceedings Co-chair**
- 21st International Workshop on Principles of Diagnosis (DX 2010), **Workshop Organizing Committee** and **Proceedings Editor**
- 18th International Workshop on Principles of Diagnosis (DX 2007), **Workshop Organizing Committee** and **Webmaster**

Membership

- Member of the SAE HM-1 Integrated Vehicle Health Management Committee
 - Requirements for IVHM working group
 - V & V and certification of IVHM working group
- Member, PHM Society, 2009 - Present
- Member, IEEE, 2009 - Present
- Graduate Student Member, IEEE, 2007-2008

HONORS AND AWARDS

- **ISRDS Team Recognition Award** for *Outstanding contributions to the Ames Prognostics Center of Excellence and to the Prognostics Community*, SGT Inc., 2012.
- **Best Paper Award, Theoretical Paper Category**, “Investigating the Effect of Damage Progression Model Choice on Prognostics Performance,” Annual Conference of the Prognostics and Health Management Society, 2011.
- **Winner**, Diagnostic Problem I, 3rd International Diagnostic Competition, 2011. Work in collaboration with M. Daigle, NASA Ames Research Center, and A. Bregon, University of Valladolid, Spain.
- **Research Assistantship**, Vanderbilt University, 2004-2009.

SOFTWARE IMPLEMENTATIONS

MOTHS Tool Suite: A tool suite for the **MO**deling and **Tr**ansformation of **Hy**brid bond graph models for **Sim**ulation. Includes model translators for the automatic translation of hybrid bond graph models created in the Fault Adaptive Control Technology (FACT) modeling paradigm into MATLAB Simulink models. Part of the FACT release. Developed in collaboration with M. Daigle. (<http://macs.isis.vanderbilt.edu/software/MOTHS>)

Related papers: [J1, J4, C30, C34, C35, R1]

VIRTUAL ADAPT: A high-fidelity simulation environment for the Advanced Diagnostics and Prognostics Testbed (ADAPT) at NASA Ames Research Center, developed using the MOTHS tool suite. Currently used by researchers as a portable alternative to ADAPT for ADAPT-related projects. Adds the capability of injecting a variety of faults via software in ADAPT. Used for experimental user interaction studies for the Advanced Caution and Warning project at NASA Ames Research Center. Developed in collaboration with M. Daigle.

Related papers: [J1, J2, J4, J3, C30, C31, C32, C34, C35, R1]

TECHNICAL SKILLS

C, MATLAB/Simulink, Generic Modeling Environment (GME)