Annotated bibliography on (quantitative) model checking of Markov models[1]

Model checking DTMCs

- *A logic for reasoning about time and reliability*, H. Hansson and B. Jonsson, in Formal Aspects of Computing, vol. 6, pp. 512–535, 1994.

  Introduces the branching-time logic PCTL for DTMCs and presents several model checking algorithms for this logic. Shows that model checking until-formulas boils down to solving a linear equation system in the size of the DTMC.

- *It usually works: the temporal logic of stochastic systems*, A. Aziz, V. Singhal, F. Balarin, R. Brayton and A. Sangiovanni-Vincentelli, in P. Wolper (ed), Computer-Aided Verification, LNCS 939, pp. 155–165, Springer-Verlag, 1995.

  Considers PCTL and shows that model checking of this logic is decidable in polynomial time and space. Besides, it shows that PCTL* equivalence coincides with Larsen-Skou probabilistic bisimulation on DTMCs.*

- *Verifying temporal properties of finite-state probabilistic programs*, C. Courcoubetis and M. Yannakakis, in IEEE Symposium on Foundations of Computer Science, pp. 338–345, IEEE CS-Press, 1988.

Model checking CTMCs

- *Model checking continuous time Markov chains*, A. Aziz, K. Sanwal, V. Singhal and R. Brayton, in ACM Transactions on Computational Logic, vol. 1(1): 162–170, 2000.

  This paper is the initial proposal for a temporal logic for specifying performance properties over CTMCs, and shows that the model checking problem for this logic is decidable for rationale time bounds; it does not discuss model checking algorithms.

- *Approximate symbolic model checking of continuous-time Markov chains*, C. Baier, J.-P. Katoen and H. Hermanns, in J.C.M. Baeten and S. Mauw (eds), Concurrency Theory, LNCS 1664, pp. 146–162, Springer-Verlag, 1999.

  Contains the first full proposal for CSL, its formal semantics, and Volterra fixpoint characterisation for the probabilistic time-bounded until operator. Besides, it introduces the steady-state operator in the logic and discusses how to compute steady-state properties for non-ergodic CTMCs.

- *Model checking continuous-time Markov chains by transient analysis*, C. Baier, B.R. Haverkort, H. Hermanns and J.-P. Katoen, in E.A Emerson and A.P. Sistla (eds), Computer Aided Verification, LNCS 1855, pp. 358–372, Springer-Verlag, 2000.

  Describes how model checking of probabilistic time-bounded until-formulas can be done using transformations of the Markov chains, yielding a standard transient analysis problem. Besides, it shows that lumping preserves the validity of all CSL formulas.

[1] This bibiliography is not complete.

- *The use of model checking techniques for quantitative dependability evaluation*, B. Haverkort, H. Hermanns, and J.-P. Katoen, in Proceeedings 19th IEEE Symposium on Reliable Distributed Systems (SRDS), Nürnberg, Germany. IEEE Computer Society Press, pp. 228–238, 2000.

  Contains the case study of model checking a GSPN modelling a workstation cluster, as used in the tutorial.

- *A Markov chain model checker*, H. Hermanns, J.-P. Katoen, J. Meyer-Kayser and M. Siegle, in S. Graf and M. Schwartzbach (eds), Tools and Algorithms for the Construction and Analysis of Systems, LNCS 1785, pp. 347–362, Springer-Verlag, 2000.

  Describes a model checking tool for discrete-time and continuous-time Markov chains for checking steady-state as well as transient-state and path-based measures. The tool can be obtained from: `www7.informatik.uni-erlangen.de/etmcc/`.

Model checking combined with SPAs

- *Performance analysis := (process algebra + model checking) $\times$ Markov chains*, H. Hermanns and J.-P. Katoen, In K.G. Larsen and M. Nielsen (eds), Concurrency Theory, LNCS 2154, Aalborg, Denmark, 2001.

  Tutorial article about using stochastic process algebra for performance modelling combined with using model checking for performance analysis.

- *Towards model checking stochastic process algebra*, H. Hermanns, J.-P. Katoen, J. Meyer-Kayser and M. Siegle, in W. Grieskamp, T. Santen and B. Stoddart (eds), Integrated Formal Methods (IFM), LNCS 1945, pages 420–439. Schloß Dagstuhl, Germany, 2000.

  Describes an action-based variant of the logic CSL and model checking algorithms for stochastic process algebras where actions and delays are treated in a single prefix (such as PEPA, TIPP, and EMPA).

Symbolic model checking of Markov models

- *Symbolic model checking for probabilistic processes*, C. Baier, E. Clarke, V. Hartonas-Garmhausen, M. Kwiatkowska, and M. Ryan, in Automata, Languages and Programming, LNCS 1256, pp. 430–440, Springer-Verlag, 1997.

  Initial (theoretical) paper about symbolic model checking of DTMCs against the logic PCTL of Hansson and Jonsson. Is based on a representation of the probability transition matrix by means of multi-terminal binary decision diagrams (MTBDDs).

- PROBVERUS*: probabilistic symbolic model checking*, V. Hartonas-Garmhausen, S. Campos and E.M. Clarke, in Formal Methods for Real-Time and Probabilistic Systems, LNCS 1601: 96–111, Springer-Verlag, 1999.

  Considers the implementation of the algorithms presented in the previous paper and contains some first experimental results.

- *Symbolic model checking for probabilistic processes using MTBDDs and the Kronecker representation*, L. de Alfaro, M. Kwiatkowska, G. Norman, D. Parker and R. Segala. in S. Graf and M. Schwartzbach (eds), Tools and Algorithms for the Analysis and Construction of Systems, LNCS 1785: 395–410, 2000.

Deals with symbolic model checking algorithms for MDPs using multi-terminal BDDs, and the usage of Kronecker representations for the generation of MTBDDs. Contains experimental results for (qualitative) reachability properties.

- *Faster and symbolic CTMC model checking*, J.-P. Katoen, M.Z. Kwiatkowska, G. Norman and D. Parker, in L. de Alfaro and S. Gilmore, editors, Process Algebra and Probabilistic Methods, LNCS 2165, 2001.

  Presents a variant of (backwards) uniformisation where calculations are carried out for a set of states simulataneously. Besides, presents symbolic model checking algoriths for CSL model checking of CTMCs, their implementation and experimental results.

Model checking of (discrete) Markov decision processes

- *Automatic verification of probabilistic concurrent finite state programs*, M.Y. Vardi, in IEEE Symposium on Foundations of Computer Science, pp. 327–338, IEEE CS Press, 1985.

- *The complexity of probabilistic verification*, C. Courcoubetis and M. Yannakakis, Journal of the ACM, volume 42, number 4, pp. 857–907, 1995.

  These two papers treat model checking linear-time temporal logic over both DTMCs and MDPs.

- *Model checking of probabilistic and nondeterministic systems*, A. Bianco and L. de Alfaro, in P.S. Thiagarajan (ed), Foundations of Software Technology and Theoretical Computer Science, LNCS 1026, pp. 499–513, Springer-Verlag, 1995.

  Considers PCTL model checking of MDPs and shows how model checking reduces to solving a linear optimisation problem.*

- *Model checking for a probabilistic branching time logic with fairness.* C. Baier and M.Z. Kwiatkowska, in Distributed Computing, volume 11, pp. 125–155, 1998.

  Deals with model checking algorithms for MDPs and focusses on the role of fairness (to resolve non-determinism) in these techniques.

- *On algorithmic verification methods for probabilistic systems*, C. Baier, Habilitation thesis, University of Mannheim, 1998.

  Overview of quantitative model checking (logics, algorithms and complexit analysis) of discrete-time probabilistic models such as DTMCs and MDPs. Includes a treatment of symbolic model checking and various notions of probabilistic bisimulation relations.

- *Probabilistic model checking: formalisms and algorithms for discrete and real-time systems*, C. Courcoubetis and S. Tripakis, in Lecture Notes NATO Summerschool on the Verification of Digital and Hybrid Systems, 1997 (to appear).

  Overview of model checking DTMCs, MDPs and the qualitative analysis of generalised semi-Markov processes.

Model checking Markov reward models

- *On the logical characterisation of performability properties*, C. Baier, B.R. Haverkort, H. Hermanns and J.-P. Katoen, in U. Montanari, J.D.P. Rolim, and E. Welzl (eds.), Automata, Languages, and Programming (ICALP), LNCS 1853, pp. 780–792, Springer-Verlag, 2000.

Extends the model checking approach for CTMCs towards Markov reward models with state-based rewards; presents the duality theorem as treated in the tutorial.

- *Temporal logics for the specification of performance and reliability*, L. de Alfaro, in R. Reischuk and M. Morvan (eds), 14th Annual Symposium on Theoretical Aspects of Computer Science, LNCS 1200, pp. 165–176, Springer-Verlag, 1997.

  Introduces the logics pTL and pTL^* that contain an operator to express bounds on the average time between events, and presents model checking algorithms for these logics. The model that is used is a MDP with a simple cost function that is either 0 or 1.

- *Computing minimum and maximum reachability times in probabilistic systems*, L. de Alfaro, in J.C.M. Baeten and S. Mauw (eds), Concurrency Theory, LNCS 1664, pp. 66–81, Springer-Verlag, 1999.

  Considers MDPs with costs (rewards) and presents algorithms to compute the minimum (or maximum) probability of reaching a given set of states, and to compute the minimum (or maximum) expected time to reach such set.

- *How to specify and verify the long-run average behavior of probabilistic systems*, L. de Alfaro, in 13th IEEE Symposium on Logic in Computer Science, IEEE Press, pages 454-465, 1998.

  Deals with the automatic verification of long-run average properties of semi-Markov decision processes where with each action the average delay of that action is associated.