

# Probabilistic Safety Verification of Future Air Traffic Management

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## Abstract

Despite advances in formal and probabilistic verification approaches, fault and event trees are still the dominant techniques used for safety risk analysis in aviation. However, the combination of concurrent, dynamic, and random effects that appear in air traffic cannot properly be captured by these classical techniques. In this lecture, it will be explained how safety risk modeling and analysis can be formulated as a problem of estimating the rare event probability of a large scale stochastic hybrid system. Subsequently it is explained how rare event estimation theory for diffusions can be extended to a large scale stochastic hybrid system (SHS), in which a large number of rare discrete modes may contribute significantly to the rare event estimation. Essentially, the approach taken is to develop a compositional model of the air traffic operation considered in the form of a large scale SHS; then to introduce a suitable aggregation of the discrete modes of this large scale SHS; and then to develop importance sampling and Rao-Blackwellization relative to these aggregations. The practical use of this approach will be demonstrated for the estimation of the mid-air collision probability for an advanced air traffic application.

## Further reading:

1. H.A.P. Blom, B. Klein Obbink, G.J. Bakker, Simulated safety risk of an uncoordinated airborne self separation concept of operation, ATC-Quarterly, March 2009.
2. H.A.P. Blom, G.J. Bakker, J. Krystul, Rare event estimation for a large-scale stochastic hybrid system with air traffic application, Eds: G. Rubino and B. Tuffin, Rare event simulation using Monte Carlo methods, J.Wiley, pp. 193-214, 2009.
3. M.H.C. Everdij and H.A.P. Blom, Enhancing hybrid state Petri nets with the analysis power of stochastic hybrid processes, Proceedings 9th International Workshop on Discrete Event Systems (WODES), Göteborg, Sweden, May 2008, pp. 400-405.
4. H.A.P. Blom, J. Krystul, G.J. Bakker, M.B. Klompstra, B. Klein Obbink, Free flight collision risk estimation by sequential Monte Carlo simulation, Eds: C.G. Cassandras and J. Lygeros, Stochastic hybrid systems, Taylor & Francis/CRC Press, 2007, chapter 10, pp. 249-281.
5. J. Krystul, H.A.P. Blom, A. Bagchi, Stochastic differential equations on hybrid state spaces, Eds: C.G. Cassandras and J. Lygeros, Stochastic hybrid systems, Taylor&Francis/CRC Press, 2007, chapter 2, pp. 15-45.
6. M.H.C. Everdij and H.A.P. Blom, Bisimulation relations between automata, stochastic differential equations and Petri nets, Journal EPTSC, forthcoming 2010.
7. M.H.C. Everdij, M.B. Klompstra, H.A.P. Blom, B. Klein Obbink, Compositional specification of a multi-agent system by stochastically and dynamically coloured Petri nets, Eds: H.A.P. Blom, J. Lygeros (eds.), Stochastic hybrid systems: Theory and safety critical applications, Springer, 2006, pp. 325-350.
8. M.H.C. Everdij, H.A.P. Blom, Hybrid Petri nets with diffusion that have into-mappings with generalized stochastic hybrid processes, Eds: H.A.P. Blom, J. Lygeros (eds.), Stochastic hybrid systems: Theory and safety critical applications, Springer, 2006, pp. 31-63.
9. M.H.C. Everdij and H.A.P. Blom, Piecewise deterministic Markov processes represented by dynamically coloured Petri nets, Stochastics, Vol. 77 (2005), pp. 1-29.