Operation Research Methods in Petri Net–Based Analysis of IT Systems

Szilvia Gyapay

Petri nets are widely used as an underlying framework for formalizing and verifying IT system models. Based on their easy-to-understand graphical representation, rich mathematical background, and precise semantics, they are appropriate to model IT systems, e.g., production systems with quantitative properties.

The production of desired materials can be formulated as a reachability problem of its Petri net model, which can be analyzed by linear algebraic techniques (solving linear inequality systems). However, traditional reachability analysis techniques can result in a state space explosion, while the much more efficient numerical methods (often with polynomial runtime) for invariant computations give either sufficient or necessary conditions only [1].

Process Network Synthesis (PNS) algorithms are widely used in chemical engineering to estimate optimal resource allocation and scheduling in order to produce desired products from given raw materials. By means of PNS algorithms [2], sufficient **and** necessary conditions for solution structures are determined defining the entirely solution space, and the search of optimal solutions (with respect to functions interpreted over the state space) is provided [3]. Moreover, PNS algorithms that exploit the specific combinatorial features of PNS problems can be applied to Petri nets in order to give more efficient mathematical methods for their analysis.

The current paper presents efficient semi–decision and optimization methods for the reachability problem based on the strong correspondence between Petri nets and Process graphs. PNS algorithms, *Maximal Structure Generation* (MSG), *Solution Structure Generation* (SSG) and *Accelerated Branch and Bound* (ABB) algorithms can be adapted to solve the reachability problem of Petri nets (formulating as a mixed integer linear programming problem). We show that the ABB algorithm can be used to solve scheduling problems efficiently, and can be extended for other Petri net analysis, e.g., to determine T-invariants of a Büchi net [4].

References

[1] A. Pataricza. Semi-decisions in the validation of dependable systems. In Proc. IEEE DSN'01, The IEEE International Conference on Dependable Systems and Networks, pages 114–115, 30.June–4.July 2001.

[2] F. Friedler, J. B. Vajda, and L.T. Fan. Algorithmic approach to the integration of total flowsheet synthesis and waste minimization. In M. M. El-Halwagi and D. P. Petrides, editors, Pollution Prevention via Process and Product Modifications, volume 90 of AIChE Symposium Series, pages 86–87, 1995.

[3] J. B. Vajda, F. Friedler, and L.T. Fan. Parallelization of the accelerated branch and bound algorithm of process synthesis: Application in total flowsheet synthesis. Acta Chimica Slovenica, 42(1):15–20, 1995.

[4] J. Esparza and S. Melzer. Model checking LTL using constraint programming. In Proceedings of Application and Theory of Petri Nets, 1997.