Introduction and Summary

Model construction and modelling methodologies for parallel systems are more elaborated than the techniques which were used in the performance evaluation of classical computer systems. In a first step [1] we discussed, classified and compared the various candidate techniques.

There are various pros and cons, however; in particular, common to all these techniques is the problem of modelling- and evaluation complexity. In a second project phase we therefore investigated model properties, compared and simplified models, built complex models from smaller ones.

Due to the objectives of our research project we focus on Timed Petri Nets and Process Algebras and summarise our results in three contributions:

- Immediate Transitions in Parametric Stochastic Petri Nets

  Stochastic Petri nets (SPNs) are a modelling formalism in which state changes are represented by a set of nodes called transitions. State changes usually take places in finite time intervals and in SPNs transitions are associated with exponentially distributed stochastic delays. Generalized SPNs (GSPNs) allow the use of immediate transitions as well to model state changes that take negligible amounts of time to occur. SPNs and GSPNs are compared in order to investigate the actual role of immediate transitions. The comparison is based on the ability of the two formalisms to define models that can be "scalable" with respect to the initial marking. An intermediate model between (G)SPN structures and (G)SPN systems called "family" is used as a reference for the comparison. It is shown that GSPN families exist that do not have SPN counter-parts, so that the presence of immediate transitions makes GSPN models more scalable. An algorithm is given to reduce GSPN to SPN families in some restricted cases. The application of this structural reduction algorithm (when possible) allows a more efficient generation of the state space of GSPN systems.

- Structural, Temporal and Stochastic Properties of Unbounded Free-Choice Petri Nets

  In this paper, we show how a decomposition of a free choice Petri net into a "routing" network and marked graph subnetworks (i.e. linear subnetworks in the $[\max, +]$ setting) leads to new methods and algorithms to test structural as well as temporal properties of the net. The paper primalily focuses on the class of SI-free choice nets, defined in the paper. We show how this decomposition in linear subnets allows to:

  - (in the untimed case) check liveness in polynomial time;
  - (in the timed case) establish evolution equations which allow to represent the system as a coupling of two linear systems, one $(\min, +)$-linear, and the other $(+, \times)$-linear;
  - (in the stochastic case) check stability, i.e. the fact that the marking remains bounded in probability.

  The main tools for proving these properties are graph theory, exotic algebras and ergodic theory.

- Characteristic Equations for Markovian TIPP

  In this report we present the Stochastic Process Algebra MTIPP together with its operational semantics. In order to reflect different behavioural aspects we define a hierarchy of bisimulation equivalences and show that two of them are congruences. Finally we present characteristic equations for our central notion of equivalence, and show that these equations form a sound and complete axiomatisation for finite as well as infinite, regular processes. Theses equations characterise the behaviour of a MTIPP-processes on a syntactic level.

Performance modelling is necessary and helpful in all phases of parallel system design and their application. Different types of models may be adequate in different situations. Moreover, different techniques may be combined to make use of their special features. Transformation techniques, allowing one to pass over from one representation to another, are therefore most important. The fourth contribution allows for the first time to deal with this class of problems, it also investigates relations between different process algebraic approaches:

- Understanding Stochastic Process Algebras via their Stochastic Petri Net Semantics

  Recently several Stochastic Process Algebras have been proposed for performance modelling. At a superficial level they appear to be very similar, but there are subtle differences between them. In this paper three of these languages, PEPA, TIPP and Buchholz's MPA, will be compared on the basis of their SPN semantics. These semantics exhibit both similarities and differences in the three algebras, providing some insight into the relationship between the SPN and SPA approaches to performance modelling.

All four contributions show that considerable progress has been made in the theoretical foundation of the methods and their interrelations. They also show and stimulate further research in this challenging area.

Bibliography

[1] N. Götz, U. Herzog, and M. Rettelbach, editor. *Proceedings of the QMIPS-Workshop on Formalism, Principles and State-of-the-Art*, Erlangen, September 1993. IMMD.