Stochastic Process Algebras: Past, Present and Future

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In the last decade a new formal approach to the integration of performance aspects in the modeling and analysis of concurrent systems has emerged with Stochastic Process Algebras (SPA for short). Like classical process algebras, they are algebraic languages endowed with a small set of powerful operators whereby it is possible to construct algebriac models from simpler ones. The main advantages of this approach are summarised with the motto: *integration* and *compositionality*. There are several forms of integration supported by SPA, including those illustrated below:

- *functionality and performance*: both aspects are to be described in the (unique) specification model, called integrated model. This has the advantage of ensuring coherence of the functional and performance (sub-)models as they both originate by projection from the same integrated model. Moreover, the integrated model is justified also because it allows the analysis of mixed properties (e.g., mean time to deadlock) and makes easier proof of functional properties for which the probabilistic aspect may be relevant.

- *(stochastic) process algebras and (stochastic) Petri nets*: the system, represented abstractly as a process term, can be automatically mapped to an equivalent (yet more concrete) representation in the form of a stochastically timed Petri net. The net representation may be advantageous from the analysis standpoint as, e.g., it often yields more compact state space; it is also useful whenever it allows for the application of efficient solution techniques to derive performance measures.

- *verification tools and performance evaluation tools*: having the two integrations above, it is possible to exploit many available tools for either functional (e.g., CWB) or performance analysis (e.g., MarCA). This can be easily achieved by simply generating the suitable inputs for the specific tools starting from the integrated model.

There are also several forms of compositionality, including those described below:

- *compositional modeling*: SPA provides a linguistic support to describe complex systems componentwise; each component is defined in isolation and then composed to the component it has to communicate with; this features is very useful for designers from a pragmatic point of view.

- *compositional manipulation*: process algebras are usually equipped with equivalence notions that are congruences w.r.t. the operators, hence supporting the substitution

of equals by equals in any context; in this setting, it is interesting to study which semantic congruences ensure that systems are equated if and only if they have the same functionality performing in the same (stochastic) time; it turns out that the integrated model is the right model on which solving this problem.

- *compositional solution*: in order to cope with the problem of state space explosion, aggregation and decomposition techniques have been investigated in order to efficiently solve the markov chains, possibly exploiting the compositional structure of terms.

In this talk we will provide a short historical perspective on the goals of the pioneers in this area, on the available results and on the challanges for the future. In this framewrok, I will mainly focus on the specific work done in Bologna with my co-workers Marco Bernardo and Mario Bravetti.