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# Simulator for Lotos to study the Independence and Causality of Events

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The standard interleaving semantics, by introducing all possible interleavings of all concurrent actions, creates choices and dependencies in the final transition system that do not really reflect a branching of the system behaviour. This is especially problematic for a simulation tool as the user of such a tool has to be bothered with making irrelevant choices. In this paper we use one particular causality based model, the *bundle event structure* model, in which the creation of unwanted choices and dependencies is avoided by moving towards a partially ordered set transition system. This forms the basics of an interactive simulation tool called *SLICE*. Simulations with this tool show that we can greatly improve upon simulation in an interleaving framework in terms of number of states.

## 1. Introduction

For the purpose of designing systems one does not only need a specification formalism, but also a semantical model to reason about specifications. In this paper we use the *bundle event structure* model[1, 2]. Event structures provide the opportunity to avoid the state space explosion caused by modelling all interleavings of concurrent processes by taking advantage of the intrinsic relations between events. The bundle event structure model defines two relations between events, namely bundles and asymmetric conflicts, that are used to model causal and conflict relations between events. Independence of events can then be defined as the absence of the above two relations. The approach taken by this paper is not to remove unwanted choices, i.e. by taking confluence properties into account, or to factor out unwanted choices in the transition system, i.e. by using dependency relations, but to avoid the creation of unwanted choices by moving towards a so-called partially ordered set transition system. Partially ordered sets (posets) are sets of events together with an ordering relation, often referred to as the *precedence relation*, over these events. A poset transition system is a transition system in which the transitions are labelled with partially ordered sets.

D. Hogrefe et al. (eds.), *Formal Description Techniques VII*

**1.1 Example (Poset transition system).**
Consider the behaviour $B = P[a, p_1, p_2] \;|[a]|\; Q[a, q_1, q_2]$ where

*process* $P[a, p_1, p_2]$ : *noexit* := $p_1; p_2; a;$ `stop` *endproc*
*process* $Q[a, q_1, q_2]$ : *noexit* := $q_1; (q_2;$ `stop` [] $a;$ `stop`) *endproc*

The labelled transition of $B$ is given by figure 1. It clearly shows the interleavings of the actions $p_1, p_2, q_1, q_2$, and a single transition labelled with $a$. The bundle event structure corresponding to $B$ is given in figure 2. It shows four bundles and a single symmetric conflict between $a$ and $q_2$.

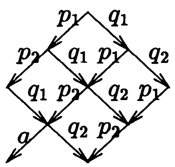


Figure 1. Transition system.

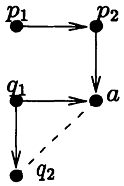


Figure 2. Bundle event structure.

We can build the transition system from the bundle event structure as follows: the events $p_1$ and $q_1$ do not depend on any other event and are not in conflict with any other event; therefore these events may happen in any order. We let these happen and obtain a new bundle event structure with only three events. Of these three events, the event $p_2$ does not depend on any other event, and the events $a$ and $q_2$ are in mutual conflict. Again, we let $p_2$ happen and obtain a new bundle event structure with only two events $a$ and $q_2$ which are in mutual conflict. This conflict however does reflect the branching of the system behaviour: the choice behaviour expression in process $Q$. Figure 3 gives one possible transition system derived this way. The next step is to combine the sequence of transitions $p_1$, $q_1$ and $p_2$ into one larger transition but somehow preserving the fact that $p_1$ must happen before $p_2$. This leads to a poset transition which is a transition labelled with a set of events together with a precedence relation which tells precisely which events must happen before which other events. The final transition system is depicted in figure 4. The arrow between $p_1$ and $p_2$ tells us that in this poset transition $p_1$ must occur before $p_2$. By combining transitions into larger (poset) transitions we have reduced the state space of the behaviour expression $B$ from 6 states to 4 states. The reduced transition system contains in general less information than the original transition system; for instance, from the poset transition system it is not clear that the system has e.g. trace $q_1q_2$.

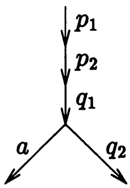


Figure 3. One of the transition systems.

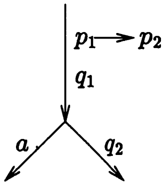


Figure 4. Poset transition system.

However, because the poset transition system contains all states corresponding to maximal traces, the poset transition does contain all deadlocking states. Furthermore, with the information that $q_1$ and $q_2$ are independent from $p_1$ and $p_2$ we can reconstruct the original transition system from the poset transition system.

The derivation of the poset transition system forms the basics of a tool called *SLICE* (Simulator for Lotos to study the Independence and Causality of Events).

Our approach bears a strong resemblance to the work of Valmeri[3] on *persistent sets*. A persistent set in a given state is the set of enabled transitions whose occurrences can not be affected by the evolution of the system by transitions outside the persistent set in that state. This strongly relates to our notion of *auto_init* set defined in the full paper. However, Valmeri uses the notion of "independent" transitions to factor out equivalence classes of sequences of transitions, whereas in our model such equivalence classes are avoided.

The full paper shows how to compute a transition system for basic LOTOS, provides some state space numbers and extends the transition system with data; it also gives some suggestions for further developments.

## Bibliography

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