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Invited Talk: On the Concurrent Semantics of Transformation Systems with Negative Application Conditions

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Abstract: A rich concurrent semantics has been developed along the years for graph transformation systems, often generalizing in non-trivial ways concepts and results first introduced for Petri nets. Besides the theoretical elegance, the concurrent semantics has potential applications in verification and model checking, as witnessed by techniques like partial order reduction or the use of finite, complete prefixes of the unfolding.

In practice (graph) transformation systems are often equipped with Negative Application Conditions (NACs) that describe forbidden contexts for the application of a rule. The use of NACs increases the expressive power of rules, by reducing the number of rules needed to specify a system. In recent years several works addressed the problem of lifting the concurrent semantics developed for transformation systems to the case with NACs [LEOP08, HCEK10].

The talk will summarize some recent results which are the outcome of joint works with Reiko Heckel, Frank Hermann, Susann Gottmann and Nico Nachtigall. Essentially, we show that if the NACs are sufficiently simple (*incremental*) then the concurrent semantics lifts smoothly to systems with NACs, but the general case requires original definitions and intuitions.

We start discussing the definition of *sequential independence* for direct derivations with NACs [LEOP08], showing that unlike the plain case, it does not enjoy the fundamental property of being stable under switching of derivations. The consequence is that sequential independence does not induce a well-defined causal partial ordering on direct derivations, unless NACs are incremental. As shown in [CHH+12] a possible solution is to transform rules with arbitrary NACs into a set of rules with incremental NACs only. The resulting system is in general an over-approximation of the original one (it can have more derivations), and it can be exploited to identify the really independent direct derivations in the original system.

Next a step semantics for transformation systems with NACs is discussed (summarizing [CH13]), where several independent rules can be applied simultaneously to the same graph. Unlike the plain case, where the *parallel independence* of rules guarantees sequentiability in any order, in presence of NACs one should also check that no NAC of one of the rules is generated by any combination of applications of the other rules. If NACs are incremental, though, a static check is sufficient, simply comparing the NACs of each rule with the right-hand sides of the other rules. In this case, it is also shown that *canonical derivations* exist, that is maximally parallel

derivations where each rule is applied as early as possible.

Finally (deterministic) graph processes for derivations with NACs will be considered. It will be shown that the classical colimit construction that builds a process from a derivation diagram does not work properly with NACs, because isomorphic processes are obtained from derivations that are intuitively not equivalent. The same problem shows up with *inhibitor nets*, and the solution in the literature consists of enriching the process with some minimal additional information sufficient to distinguish among the non-equivalent derivations that it represents. We will discuss a similar and more general solution for derivations with NACs, suggesting that in the case of incremental NACs the solution coincides with the one proposed for inhibitor nets in [BP99].

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