Example annotated bibliography
Location-based process algebras

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References

[Boudol *et al.* 1991] G. Boudol, I. Castellani, M. Hennessy, and A. Kiehn. *A theory of processes with localities*. Technical Report 13/91, Computer Science, School of Cognitive and Computing Sciences, University of Sussex, 1991.

Aim: To extend CCS with the notation of location which leads to a semantic equivalence that distinguishes processes based on the location at which an action occurs.

Style/Type: technical report, theoretical.

Cross references: This report extends Calculus of Communicating Systems which was proposed by Milner [1989]. The approach taken is the same: syntax is given, operational semantics are defined and finally a bisimulation-type equivalence is defined, but transitions are labelled with action and location information, and bisimulation requires matching on both action and location string. The approach taken here allows any location to be generated by an action in comparison to the paper by Castellani [1995] where a more static approach is taken to locations.

Summary: The report proposes a syntax which differs from CCS in the addition of a location prefix operator $l :: P$ and an 'action at locality' operator $\langle a \text{ at } ux \rangle.P$. The operational semantics are modified so that each transition is labelled with both an action and a string of locations – the axiom for the action prefix operator is modified so that the resulting process is prefixed by the location at which the action occurred, and new rules are introduced for the location prefix operator and 'action at locality' operator. The definition of bisimulation is modified to include a relation over strings of locations - transitions match if their actions match and if their location strings are related. If the location relation is the identity relation then this bisimulation is called location equivalence. A number of expected results are proved, and an axiomatisation of the bisimulation relation is given by using appropriate normal forms. Location equivalence is shown to be incomparable to Darondeau and Degano's causal weak bisimulation. It is also shown that loose location equivalence, an earlier location-based equivalence developed by the same authors, equates more processes than location equivalence. Finally, a pre-order based on locations is introduced that orders processes in terms of how distrubted they are.

[Castellani 1995] I. Castellani. Observing distribution in processes: static and dynamic localities. *International Journal of Foundations of Computer Science*, 6(4):353–393, 1995.

Aim: To investigate distribution in CCS, by considering the use of locations statically (where locations are associated with processes) rather than dynamically (where locations are associated with actions).

Style/Type: journal article, theoretical.

Cross references: In Boudol *et al.* [1991], locations are dealt with dynamically, since whenever an action is performed, a location is associated with that action. Additionally, any location can be associated with an action which results in a transition for every possible location. This paper tries to reduce this multiplicity of transitions by taking a static approach to locations. This research extends CCS [Milner 1989].

Summary: The syntax of processes is the same as that of CCS but extended with a location prefix operator $l :: P$. The set of processes under consideration are called distributed processes, and are the same as CCS processes except that all parallel components are prefixed by locations, ie. all terms constructed with the parallel operator have the form $l :: P \mid m :: Q$. A consistent location association which is a relation over strings of locations captures the notion of independent locations, ie. those locations that can be matched in bisimulation. Bisimulation is defined in terms of a family of relations that are indexed by consistent location associations. Each relation in the bisimulation family is associated with the locations that have been matched on the transitions. Static location equivalence is defined in terms of these families of locations, and a pre-order is also defined. The notion of an occurence transition system is introduced, and a bisimulation equivalence is defined on these transition systems. Using this equivalence, it is shown that static location equivalence is the same as location equivalence [Boudol *et al.* 1991]. It is shown in an appendix that the occurence transition system bisimulation equivalence, is the same as local history preserving bisimulation which is based on local causality.

[Milner 1989] R. Milner. *Communication and concurrency*. Prentice Hall, Hemel Hempstead, United Kingdom, 1989.

Aim: To present a mathematical model of concurrency called Calculus of Communicating Systems (CCS) based on the notion of a process where behaviour is modelled in terms of a labelled transition system and processes with similar behaviour are equated by relations over these labelled transition systems.

Style/Type: textbook, theoretical.

Cross references: The process algebra presented here has been extended in a number of different ways to express different aspects of concurrent behaviour, such as location, causality, time and probability. Two articles that deal with location are Castellani [1995] and Boudol *et al.* [1991].

Summary: This book presents the theory of CCS in a textbook format. The presentation starts with simple examples of concurrent behaviour, briefly investigates when processes should be considered equal and then presents the transition semantics for processes. Both the basic calculus and the value passing calculus are presented – the value-passing calculus can be translated into the basic calculus. Next, various equational laws are explained and justified, after which strong and weak bisimulation equivalences are introduced together with more complex examples. The last part of the book covers more advanced topics such as defining a programming language using CCS, definition of new operaters and semantic equivalences, as well as specifications and logics. This is a good introduction to CCS and has useful exercises in each chapter.