Calculi for Mobile Processes
— Bibliography and Web Pages —

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Abstract

With this note we present a quick overview on the work that has been done to collect (online) resources—an extensive up-to-date bibliography and a web page for further information—covering the area of calculi for mobile processes. Therefore, we quickly recapitulate the history of this area from our point of view, which is witnessed by the number of respective research papers in the field.

Introduction The π-calculus, originally introduced by Robin Milner, Joachim Parrow, and David Walker back in 1989 (published as [MPW92]) arose as a generalization of the algebraic process calculus CCS (see the textbook [Mil89]). In CCS, computation is carried out by independent processes that may synchronize with each other by means of hand-shaking, i.e. they may synchronize pairwise by making complementary use of so-called *channels*. In value-passing CCS, these synchronization channels are further used to carry *values* from one process (called the sender) to another process (called the receiver), where the values may be taken from some externally specified domain. In the π-calculus, the simple idea [Mil93] is to allow processes to exchange specific values—channel names themselves[1]—and, by that, to dynamically change their interconnection structures: processes become *mobile*.

[1] The π-calculus had various other predecessors that also tried to pursue the idea of using channels as data in communications, like in Engberg and Nielsen's ECCS [EN86] or with Astesiano and Zucca's *label expressions* [AZ84], but the π-calculus was the first to provide a convincing and elegant account of the idea by unifying the various syntactic categories of variables, channels, and values into just *names*.

Sometimes the objection arises that the π-calculus does not adequately express process *mobility* in a sufficiently explicit manner since it basically allows processes only to change their interconnection structures, even if it does so dynamically. However, the π-calculus has also been extended by Sangiorgi [San93] with the aim to incorporate more explicit notions of so-called *higher-order* mobility by allowing actual code, i.e. processes and abstractions thereof, to be transmitted in communications.[2] Interestingly, it turned out that higher-order mobility can be faithfully expressed within *first-order* mobility, as exemplified in the π-calculus. Thus, by *calculi for mobile processes*, we refer to mobility of arbitrary order.

The mechanism of name-passing, in combination with the paradigm of static binding—the scope of names may be dynamically extended by means of communication to include the receiver—turned out to

- be surprisingly expressive for a vast variety of programming idioms:
  - abstract data types,
  - λ-calculus, i.e. functional programming,
  - object-oriented programming,
  - imperative programming,
  - logic and concurrent constraint programming,
  - primitives for encryption/decryption;
- raise many interesting theoretical issues:
  - the role of substitution for the observational semantics of communication by name-passing, giving rise to variants known as ground, early, late, open, and hyper, which often do not coincide,
  - the proliferation and axiomatization of the various bisimulation, testing, and other process equivalences and congruences, ranging over the different styles of substitutions in the semantics,
  - the study of individual operators (e.g. replication, bound output, delayed input, mis-/matching, choice, explicit substitution) w.r.t. expressiveness, implementability and combinatory counterparts,
  - different modes of communication, e.g. asynchronous,
  - mobility-specific aspects in non-interleaving semantics,
  - the search for appropriate notions of modal and temporal logics,
  - denotational models and their categorical interpretation,

[2] Other calculi were also designed for that purpose, like Thomsen's CHOCS [Tho90].

  - rich notions of type systems for processes, both inherited from sequential (functional) programming notions, like arrays, records, subtypes, linear and polymorphic types, as well as original notions of type, like mutex (semaphor-like) and graphical notions and the distinction between local and remote channels;

- provide solid foundations for the design of high-level concurrent and distributed programming languages (e.g. Pict, Facile, Join, TyCO, HACL, and Oz) that are also suited as scripting languages for mobile agents;
- allow for applications in the range of mobile (and standard) telecommunication protocols, as well as cryptographic protocols;
- trigger a whole family of related calculi, where, in order to denote the various calculi, greek letters (and a zoo of indices) have meanwhile been replaced by colours or other physical phenomena.

This is, of course, not a complete list of all the work that has been done. Automated tools for analyzing mobile processes, e.g. for equivalence and model checking [VM94, FFG+97], have also emerged. It is often argued that the π-calculus is very much object-oriented in style (see also [HT91]), which is also witnessed by the programming languages built on top of it.

Online resources

`http://www.cs.auc.dk/mobility/`

provides access to most of the web pages of active researchers, research groups, and many other resources related to the area, like the above-mentioned programming languages and some introductory papers. Moreover, an extensive bibliography on calculi for mobile processes, administered by the authors of this note for use with BibTeX, can be found there as files `pi.bib` and `pi-bib.dvi`. Furthermore, the bibliography is regularly mirrored at

`http://liinwww.ira.uka.de/bibliography/Theory/pi.html`

where it provides the user with a very convenient service for online searching of the bibliography information. However, the web page on mobile processes will usually yield a slightly more up-to-date bibliography.

Scope The bibliography should ideally cover every publication in the context of the π-calculus, its variants, descendants, simplifications, and extensions, including higher-order forms, and implementations. In general, the listed items should address mobility phenomena via the investigation of mathematically tractable calculi. So, the bibliography does not include just anything about process algebra (unless mobility is explicitly tackled) or mobile systems (unless a foundational calculus is involved).

Updates Any further items for inclusion and any corrections or updates of existing information should be reported to both `Bjorn.Victor@DoCS.UU.SE` and `uwe@cs.auc.dk` and will be included in future versions if they comply with the scope of the bibliography.

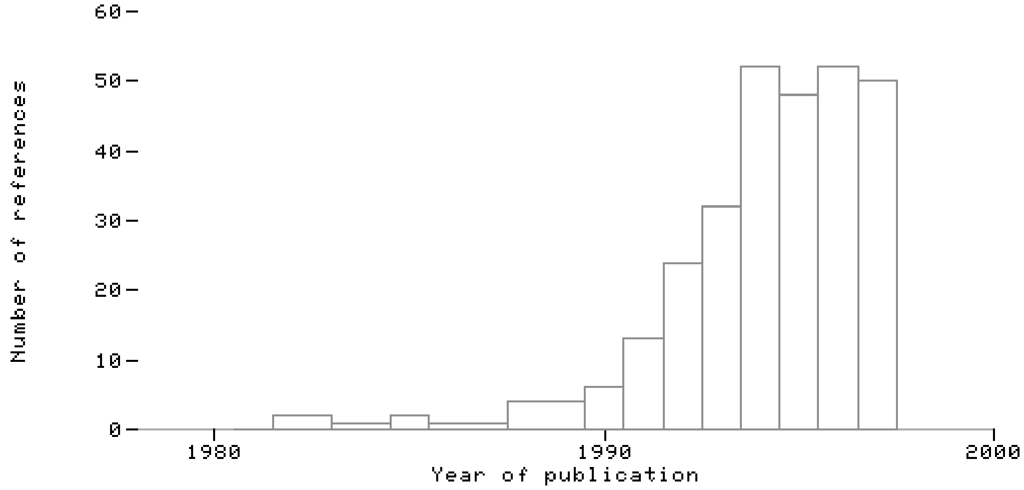
History The bibliography was initially created by Björn Victor in November 1994, and after a 'call for updates' on `concurrency@cwi.nl` it was merged with a similar bibliography collected by Uwe Nestmann. Ever since then we have worked with joint forces to keep the bibliography up-to-date. In March 1995 the bibliography was added to the *Collection of Computer Science Bibliographies* at `http://liinwww.ira.uka.de/bibliography/`, administered by Alf-Christian Achilles. In 1997, the home site of the bibliography was incorporated into the 'mobility pages'.

The 'mobility pages' were initially created at TU Eindhoven after a 'call for links' on `concurrency@cwi.nl` in November 1995 by Arie van Deursen, based on information (www-links) that he and Uwe Nestmann had collected. They moved (with Arie) to CWI in 1996 and then (with Uwe) to INRIA in 1997, and again (with Uwe) to BRICS/Aalborg in 1997.

Statistics `http://www.cs.auc.dk/mobility/` contains roughly 80 links to people doing research on mobile processes; it is currently accessed about 10 times every day from different locations outside the local domain.

As of 16 January 1998, the bibliography contained 289 references (among them 216 to articles) including 42 references to online publications, where the most recent reference dated December 1997. Figure 1 is thankfully taken from `http://liinwww.ira.uka.de/bibliography/Theory/pi.html`: it shows that after its birth in 1989, the π-calculus community continuously grew into its current state, where at least 40 research papers (the Proceedings need to be subtracted from the statistics) are published every year.

Figure 1: Number of references in `pi.bib` per year



TeXnics Unpublished papers, notes, and typescripts, are currently only included if some means for electronic retrieval is known; a `url`-field of the respective entry in `pi.bib` will then point to it.

The file `pi.bib` makes extensive use of cross-referencing by means of `crossref`-fields for use with BibTeX. The crossref'ed entries are supplied with `crossrefonly` in order to enable —using a special BibTeX-style available from the authors— that, like in the document `pi-bib.dvi`, crossref'ed Proceedings etc do not have to be listed themselves.

Pretty-printing of `pi.bib` and the generation of its citekeys is done by using BibTool (version `2.42`).

Several abbreviations are used by default in the current bibliography (mainly in order to reduce the size of the `dvi`-file), like e.g. writing *LNCS* instead of *Lecture Notes in Computer Science*. The alternative extensions are contained in `pi.bib` as `@COMMENT{...}`.

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