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Communicating and Mobile Systems: the π-calculus,
Robin Milner, Cambridge University Press, Cambridge, 1999, 174 pages, ISBN 0-521-64320-1

The π-calculus is a well-known and influential model of concurrency. It is simple – the grammar that describes the processes has just a few constructs, each with a clear operational intuition – and has an elegant theory, yet it is very powerful. Its amazing expressive power is due to the ability of describing *mobile systems*. These are concurrent systems whose structure can change, both because processes can be created and can die, and because the linkage structure among existing processes can change. It is remarkable, for instance, that references (in the sense of imperative languages), objects (in the sense of object-oriented languages), and functions can all be described as π-calculus processes. The possibility of describing different computational models, both sequential and concurrent, and the rich theory make the π-calculus an ideal semantic basis for languages and systems that combine features from different models, for instance concurrent imperative object-oriented languages.

Thorough and intense studies of the π-calculus over the past 10 years have allowed us to understand important concepts of concurrency theory – in particular, of mobile systems – such as types and behavioural equivalences.

From a marketing point of view, Milner's *Communicating and mobile systems*: *the π-calculus* is justified by two important reasons: it is the first textbook on the π-calculus; it is a superb introduction to the fundamental principles of concurrency theory. The first point is just a fact. I should explain, however, the second. In today's information society, concurrency is more and more important. Students should therefore be exposed, already at the *undergraduate* level, to the basic concepts of its theory. For this, Milner's book stands out as a wonderful instrument. (The book is indeed the outcome of Milner' s lectures to undergraduates in Cambridge.) Undoubtedly, Milner was the right person to endeavour the task of writing such a text. Milner has an extraordinary communication skill, something clear to anybody who has ever read one of his papers or books, or has seated at one of his talks. Furthermore, Milner has been a leading researcher in the area of concurrency theory for the past 30 years. The π-calculus, and the earlier calculus of communicating systems (CCS), for instance, are contributions of his [1,3].

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These two marketing justifications are reflected into the two parts, of about the same length, in which the book is divided. The first part begins with automata theory. An automaton, here, is viewed as a process, whose possible interactions with the outside world are described by the transition graph of the automaton. Milner discusses why certain aspects of the classical theory of automata are to be rejected when automata are thought as processes. Examples are language equality as the notion of equivalence, and the reduction from non-deterministic automata to deterministic automata. He also discusses the advantages of defining processes by means of an algebra. Thus bisimilarity, as the notion of behavioural equivalence on processes, and a calculus of processes, CCS, are gradually introduced. CCS is very roughly π-calculus without mobility (more precisely, with only a very limited form of mobility: processes can still be created and can die dynamically). Other important concepts of concurrency theory, such as labeled transition systems, and co-inductive and algebraic techniques for reasoning on processes, are put forward.

The second part of the book is where the π-calculus is actually presented, preceded by a lucid discussion of what is mobility. Some components of the π-calculus theory, such as bisimilarity and the reaction rules, are a development of the CCS theory in the first part; other components, most notably types, are new. Having seen CCS in the first part, the reader will find it easy to understand the π-calculus theory and the examples.

The book achieves a very good balance between theory and examples. Every new concept is introduced and motivated by means of examples. The informal explanations are always enlightening, for instance in unraveling the connection between different concepts.

The book does not go very deep into the theory of π-calculus (or CCS). This is a inevitable price for being such an excellent introductory book, suitable also to undergraduates. The content of the π-calculus chapters is similar to that of an earlier tutorial paper by the same author [2]. The algebraic theory, the types, the modeling of objects and functions are only briefly discussed. (The π-calculus allows a large spectrum of types, much as in the λ-calculus; this constitutes one of the most striking differences between π-calculus and CCS). Variants of the calculus (such as the asynchronous π-calculus, nowadays widely used) and alternative styles for the definition of bisimilarity are not touched. (The style of bisimilarity is not just a notational choice: different styles, such as the *early* and *late*, give rise to different equivalence relations.)

A minor technical point that I found a bit puzzling is that, although the different styles of bisimilarity for the π-calculus are not discussed, strong bisimilarity is given in the late style, while weak bisimilarity is given in the early style. As a consequence, since the late is strictly included in the early, there are processes with exactly the same number of transitions that will be weakly bisimilar, but not strongly bisimilar.

In summary, *Communicating and mobile systems*: *the π-calculus* is an extremely good book. Highly recommended, especially to students and researchers that do not know concurrency theory, or know something of concurrency theory but do not know the π-calculus. This book, as the previous ones by Milner, will undoubtedly fascinate and amuse the reader.

References

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[3] R. Milner, J. Parrow, D. Walker, A calculus of mobile processes (Parts I and II), Inform. and Comput. 100 (1992) 1–77.

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