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Leïla Kloul
Gianluigi Zavattaro (Eds.)

Formal Techniques for Computer Systems and Business Processes

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Preface

This volume contains the proceedings of two international workshops EPEW and WS-FM held at the Université de Versailles Saint-Quentin-en-Yvelines, Versailles, France, 1–3 September 2005.

EPEW (European Performance Engineering Workshop) and WS-FM (International Workshop on Web Services and Formal Methods) were colocated to gather the researchers working across the spectrum of techniques for modelling, specification, analysis and verification of the behavior of computer systems and business processes.

This proceedings contains a selection of 20 research contributions, out of 59 submissions, which went through a rigorous review process by international reviewers. We therefore owe special thanks to all members of both program committees of EPEW and WS-FM and their sub-referees for the excellent work they did in the short time they had.

Additionally, this proceedings includes four invited papers, by Gianfranco Ciardo (University of California at Riverside), Peter G. Harrison (Imperial College London), Cosimo Laneve (University of Bologna) and Wil van der Aalst (Eindhoven University of Technology). These contributions brought an additional dimension to the technical and the scientific merit of these workshops.

Finally, our thanks go to the University of Versailles Saint-Quentin-en-Yvelines, its Laboratoire PRiSM and the CNRS for hosting the workshops and providing technical and financial support.

September 2005

Mario Bravetti
Leïla Kloul
Gianluigi Zavattaro

EPEW

The European Performance Engineering Workshop aims to bring together researchers working on all aspects of performance modelling and analysis of computer and telecommunication systems. Of the 32 regular papers submitted to EPEW 2005, after a rigorous review process, only 10 were accepted for presentation. We are very pleased with the quality of these papers and hope that you will find them interesting. The topics of this workshop are various and include queueing theory, bounding techniques, stochastic model checking, communication schemes analysis for high-speed LAN, QoS analysis in wireless ad hoc networks and optical networks analysis.

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WS-FM

The International Workshop on Web Services and Formal Methods aims to bring together researchers working on Web Services and formal methods in order to activate a fruitful collaboration in this direction of research. This, potentially, could also have a great impact on the current standardization phase of Web Services technologies. This second edition of the workshop (WS-FM 2005) featured 10 papers selected among 27 submissions after a rigorous review process. The main topics of the conference include: protocols and standards for WS (SOAP, WSDL, UDDI, etc.); languages and descripion methodologies for choreography/orchestration/workflow (BPML, XLANG and BizTalk, WSFL, WS-BPEL, etc.); coordination techniques for WS (transactions, agreement, coordination services, etc.); semantics-based dynamic WS discovery services (based on Semantic Web/Ontology techniques or other semantic theories); security, performance evaluation and quality of service of WS; semi-structured data and XML related technologies; and comparisons with different related technologies/approaches.

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Performance Engineering and Stochastic Modelling

Peter Harrison

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Abstract. Performance engineering has become a central plank in the design of complex, time-critical systems. It is supported by stochastic modelling, a brief history of which is given, going back to Erlang as long ago as 1909. This in turn developed according to successive new generations of communication and computer architectures and other operational systems. Its evolution through queues and networks is reviewed, culminating in the unification of many specification and solution techniques in a common formalism, stochastic process algebra. Recent results are given on the automatic computation of separable solutions for the equilibrium state probabilities in systems specified in such a formalism. A performance engineering support environment is proposed to integrate these methods with others such as response time analysis and fluid models, which are better suited to large scale aggregation of similar components in a continuous space.

1 Introduction

Performance engineering is about the development of efficient computer and communication systems by providing crucial performance analysis during the design phase. For several decades, computer and communication system design was left to 'experienced engineers' who used their knowledge and experience to successfully construct and 'optimise' both hardware and software architectures. These systems grew from simple stand-alone computers, through mainframes with virtual storage management and multi-access, to client-server systems organised as networks of clusters. More recently still we have distributed internet applications and the Grid. Increasingly from the late nineteen eighties/early nineties, the traditional ad hoc approach has been found inadequate in view of the complexity and sheer size of modern systems. This is hardly surprising in view of other engineering disciplines where the construction of an artefact is invariably preceded by the construction of a *model*, usually a mathematical model, upon which design decisions and parameterisations are based. In fact, the moves to 'structured programming', beginning in the 1970s, specialised programming languages and 'formal methods' defined the basis of software engineering which mirrors the conventional engineering paradigm.

The tools of performance engineering are *quantitative models* that predict metrics which reflect a view of performance. This view depends on who's interested. For the user it is some form of quality of service (QoS), often response

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time, reliability or availability. For the owner of a business that sells Grid resources, it is revenue, based more on the number of customers processed per day. Whatever the metric, the whole system needs to be modelled at an appropriate level of detail. There are several modelling techniques, each playing a vital role in different circumstances. An evolving, dynamic system can be considered as passing through a sequence of states that change upon the occurrence of events. Thus, discrete event simulation is the most natural and general modelling formalism since it is possible to mimic in an abstract model the dynamic behaviour of almost any system. The main issues in simulation are reliable interpretation of the simulation outputs, which are essentially sample paths of an underlying stochastic process, and run-time, which may be prohibitively long in detailed simulations and increase rapidly as tighter confidence bands are imposed.

Hence, where possible, analytical models are preferred, based on a mathematical analysis of the stochastic process that precisely describes the dynamics of the system being modelled. The trouble now is that further approximating assumptions must be made to achieve mathematical and numerical tractability. As a rule, the more tractable the model needs to be, the more approximations are necessary. Hence, when using approximate analytical models, validation must be done, often initially mutual validation between the analytical and simulation models. It is typical for an analytical model to be validated against simulation in simple scenarios, resulting in confidence in both models. Then either model can be used to make predictions in more complex cases. As complexity increases, one of the models will ultimately cease to be numerically tractable, but after validation, confidence is high in the surviving model. Indeed, it may be that it is best to validate a simulation in simple cases against an *exact* analytical model and then use that simulation to validate an approximate analytical model, which is the one intended for practical use.

Although analytical models produce precise predictions with respect to their assumptions and approximations, it is not always easy to interpret their output due to subtle properties like interdependence between, and even existence of, model components. Beware of such subtleties! For example, consider the following gamble. Two boxes are placed in front of you with a piece of gold in each. You can keep the gold from either box (your choice) and you have been told there is exactly double the amount of gold in one box than in the other, but you don't know which is which. You are allowed to open one box, look in and then decide which box's contents you want to keep. What should you do? If you find an amount x of gold in the box you open, you know there is either $2x$ or $x/2$ in the other, with equal probability by the symmetry of your random choice of box. So the average amount in the other box is

$$\frac{2x + \frac{x}{2}}{2} = 1.25x$$

Clearly, then, the best strategy is to choose a box at random, open it, and take the gold from the other box! What's wrong with that?

This paper is organised as follows. In section 2, a brief history is given of stochastic modelling, with a somewhat personal view. This begins with the early work of A.K. Erlang and progresses through queues and queueing networks of various kinds up to the present day, not forgetting the underpinnings of A.A. Markov. In section 3, relatively recent advances in the field of stochastic process algebra (SPA) are reviewed and it is shown how these combine many previous, apparently diverse, Markov models into a unified framework. The use of SPA is then argued as a basis for future performance engineering support environments, ideally to be integrated into software engineering support environments. The paper closes in section 6.

2 A Brief History

The origins of stochastic modelling, as applied to communication systems and operations research, is widely credited to A.K. Erlang, who was the first person to consider the problem of telephone networks quantitatively. By studying a village telephone exchange, he worked out a formula, now known as Erlang's formula, to calculate the fraction of callers attempting to call someone outside the village that must wait because all of the lines are in use. Although Erlang's model is a simple one, the mathematics underlying today's complex communication networks is still based on it in many ways. Erlang continued to investigate these problems and published perhaps his best known work "Solution of some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges" in 1917. Meanwhile, the theory underlying many of today's models, including those considered here, was being developed by A.A. Markov, the well known Russian mathematician, who began publishing in the area shortly after the turn of the 20th century; an interesting review of Markov's life and contributions is [1].

More recently, the focus of attention became Markovian networks of queues, with the famous product-form solutions of Jackson (open and closed networks) in 1963 and Gordon & Newell (closed networks) in 1967 [23,15]. These were generalised to multiple classes of customers, with class-dependent service and routing, and queueing disciplines other than first come first served by Baskett et. al. in 1974 and by Kelly at about the same time. Kelly used a different approach based on so-called *quasi-reversibility*, which is defined in terms of the reversed process of a stationary continuous time Markov chain (CTMC) and actually leads to further generalisations, for example to symmetric queues [24]. Interestingly, the reversed process is key to the unified methodology discussed later in this paper.

Various minor extensions were produced in the 1980s, more sophisticated individual queues were analysed and the focus shifted somewhat to approximate methods that required much less restrictive assumptions and so applied to more realistic scenarios. However, at the end of the 1980s, Gelenbe introduced the concept of the *negative customer*, which removes a customer (said to 'kill' one) from a queue rather than adds to it. This model was motivated by inhibitor signals in biological neural networks – these appear discrete in nature rather than continuously varying potentials. Surprisingly, the resulting Markovian network