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Six Themes for Future Concurrency Research

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Abstract

We list a few themes that might have attention in the coming few years in the area of concurrency research. We talk about widening the scope beyond computer science, about web services and grid computing, about hybrid systems, mobility and security, agents and games, and natural computing.

Keywords: concurrency, web services, grid computing, hybrid systems, mobility, security, agents, games, natural computing.

Introduction

Listing themes, subjects or areas of focus has become a trend in Dutch science and research management for computing sciences. Often these listings provide renamings of what people did before and after a conversion of terminology we all keep doing what we did. (E.g. some formal methods will be relabeled to 'the computer of the future'.) An underlying goal of these listings, however, is to give new focus to Dutch computer science research. We will also produce a listing of themes in this document, but with the sole purpose of guessing what people might do in the following years. In no way these themes should be considered a priority for their own sake just because we have listed them here. Interestingly, this detached approach makes writing the paper less 'scientific' because forecasting human behaviour is just

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not a part of computing science whereas managing their (research) behaviour might be. In any case, we intend not to rename themes in a futile way.

Dynamics and Interaction

Concurrency is about behaviour of interacting systems or entities. It has ways to describe dynamics and interaction, and can reason about these descriptions. Up to now, it is considered as an area of research in computer science, and it is applied to systems that are implemented in software, or in a combination of software and hardware. A development that we consider important, is the one where we see applications completely outside the realm of computer science. Most prominent is this in the area of life sciences, where concurrency theories are used in order to describe dynamics and interaction inside a living cell. But we see also applications in mechanical engineering and mechatronics, where concurrency theories are used to describe dynamics and interaction of manufacturing machines, production lines and automated factories. We consider this an illustration of the maturity of concurrency theories.

Grid Computing and Web Services

Grid computing and webservices are a big trend by any account. Both developments heavily depend on the design of novel protocols. The universal presence of security based protocols makes these protocols remarkably complex. As it stands, concurrency theory may be too simplistic to cover this new ground but if we have real faith in the strength of these techniques they will emerge in the analysis of the mentioned protocols as powerful tools. It is likely that projects aiming at this will be carried out throughout the world.

Hybrid Systems

Concurrency theory traditionally describes dynamics and interaction of discrete-event systems. Especially in applications in the area of embedded systems, there is a need to also model continuously evolving physical entities, usually described by means of differential equations. For modeling and analysis of such hybrid phenomena, discrete-event formalisms are extended in different ways with some form of differential (algebraic) equations. The most influential hybrid system model is that of a hybrid automaton. By now, these hybrid automata exist in many different flavours, with accompanying verification tools. Also hybrid process algebras exist. The challenge is to make the connection with the dynamics and control field, where there are representations such as piecewise affine systems, mixed logic dynamical systems or linear complementarity systems. In dynamics and control, the focus is on controller synthesis and analysis of properties such as stability and observability.

Mobility and Security

Research on mobility, and calculi to express mobility of systems, will continue. An important application area is in security, with the analysis of security protocols. Concerning security we expect that security aspects will be integrated with all other forms of communication and protocols. In this sense, security will cease to be an independent subject just as performance is a concern that always has to be taken into account. The integration of security features in known functionalities and their formal descriptions will lead to much future work. A significant part of this work will be carried out in the context of one of the (more or less algebraic) process theories.

Agents and Games

The theory of intelligent agents has developed rather separated from concurrency theory. We think we will see the use of concepts developed in concurrency theory in the further development of agent theory. Also, connections with game theory are important. Applications in gaming may lead to agent programming notations based on or significantly influenced by concurrency theory. Gaming agents will eventually be involved in extremely complicated communication protocols where these will represent entities that may seem real but at the same time need not obey the laws of physics. Travelling back in time is acceptable for a game, though a timed concurrency theory admitting such developments may be an elusive goal. Clearly, many other theories will find their way into the design of agents in games, but for the protocol side of it concurrency theories may hold a promise yet to be discovered when the increasing complexity of highly distributed games generates serious difficulties of that nature.

Natural Computing

Concepts from different areas of natural computing, in particular quantum computing and relativistic computing in time and space, will be connected to concurrency theory. Quantum computing turns out to be relevant in describing concurrency on a single chip, and relativistic aspects become important when describing communication with large delays as occur in space travel.

Caveat

Some people liked a small survey of future directions we wrote in 1996, see [1]. Here, we again speculate on a few possible directions. Others may very well have very different opinions concerning future directions, and indeed, more likely than not our selection of six themes will fail to highlight a development that will prove important in the coming years.

References

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