

Preface

It is not the question whether self-organising systems will arise, but how they will be designed and controlled.

One of the most fascinating endeavours in research consists of starting a new area of research, based on a visionary concept posing a range of challenges which can only be met by a collaborative effort. The priority research programme (“Schwerpunktprogramm”) SPP 1183 “Organic Computing” of the German Research Foundation (DFG) has been such an inspiring opportunity. This compendium provides an overview of the various results which have been achieved over a period of six years.

About eight years ago a presentation of a colleague on future trends for research in Artificial Intelligence at a “Perspectives Seminar” at Dagstuhl inspired us to initiate a series of workshops on challenges for future research in Computer Engineering, looking at a time frame of ten to fifteen years. The combination of a large collection of ideas led to a joint position paper of the Gesellschaft für Informatik (GI) and the Informationstechnische Gesellschaft (ITG) on a new research area which we called *Organic Computing*. Motivated by the increasing number of intelligent devices in our vicinity being aware of their environment, capable to interact, and relying on cooperation to satisfy their functional objectives we identified the urgent necessity of a new paradigm for system design. Such a paradigm should enable future systems to carry out certain tasks on their own, they should have properties like self-organisation, self-healing, self-configuration, self-protection, self-optimisation, and they should be able to adapt reasonably to changing requirements of their operating environment. In particular, they should adjust to human needs in a trustworthy way and should allow for explicit interference in case of undesired effects of self-organisation, leading to the—somewhat contradictory—requirement of *controlled self-organisation*. Considering the numerous examples of self-organisation in nature, it was obvious to look at the mechanisms behind the various ways of generating complex but robust behaviour from simple interactions in order to exploit bio-inspired concepts for the design of a new generation of technical application systems. In this way the notion of Organic Computing is associated with two different meanings: the need for intelligent systems showing “organic” behaviour and the potential use of bio-inspired concepts in their construction.

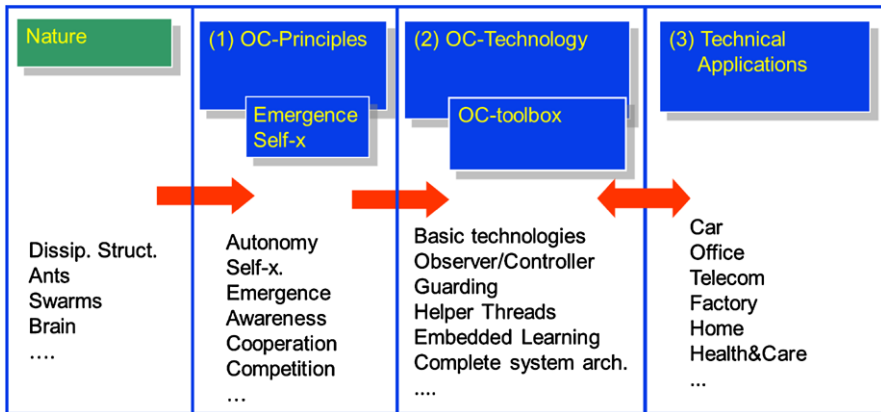


Fig. 1 Topical structure of the priority programme SPP 1183 “Organic Computing”

The concepts of Organic Computing are closely related to other research initiatives like ubiquitous and pervasive computing addressing the abundance of intelligent devices and the penetration of almost every aspect of our lives with information technology. The necessity of providing complex information processing and data management systems with self-* properties has also been the driving force of the Autonomic Computing Initiative by IBM using the biological principle of the autonomic (nervous) system as their paradigm for system design. Furthermore, independent from our initiative, Christoph von der Malsburg had used the notion of Organic Computing for his visionary concept of designing information processing systems inspired by principles of molecular biology and neuro-physiology.

Based on the ideas of the position paper our proposal to start a priority programme on Organic Computing was approved by the German Research Foundation in early 2004. The call for proposals for the first of the three two-year phases addressed the need for fundamental research on the effects of emergence due to self-organisation and on the design of system architectures and tools supporting the concepts of Organic Computing while keeping in mind the specific requirements of technical applications (see Fig. 1). In July 2005, the SPP 1183 “Organic Computing” started with 18 projects which had been selected by an international evaluation committee from 59 high quality submissions.

Semi-annual colloquia and various mini workshops supported a regular exchange of information between the projects and served to initiate and support cooperative work on various topics of joint interest like *self-organisation and emergence, architectures, applications, design methods*, and *bio-inspired methods*. In this way, a common understanding of essential concepts for the design of Organic Computing systems developed, which was deepened during the successive phases 2 and 3 of this programme. The programme’s third and final phase emphasised the need for a clear demonstration of the achievements of this fascinating research motivated by a visionary concept for future system architectures.

This compendium now combines presentations of major results from all of the projects that are or had been part of the priority programme. The contributions start with an overview of our work on *Theoretical Foundations* characterising essential properties of Organic Computing systems, looking in-depth at different aspects of emergence as a result of self-organisation, studying formal approaches to specify correct behaviour of adaptive systems, and highlighting ways of transferring behavioural patterns of biological systems (in particular of societies of ants) into Organic Computing systems. This is complemented with an assessment of the Organic Computing research methodology from a philosophical point of view.

One of the central objectives of the priority programme was to establish a toolbox of concepts and methods which are essential for the design and operation of Organic Computing systems. The chapters on *Methods and Tools*, *Learning*, and *Architectures* present an overview of the broad range of fundamental concepts that evolved within the research programme. Learning, in particular, is an indispensable part of Organic Computing, addressing the challenge to develop adequate behaviour even in unanticipated situations. As stated in the call for proposals, the potential and relevance of the new techniques and system architectures of Organic Computing should be demonstrated with respect to demanding application scenarios. Therefore, the chapter on *Applications* reports on the work on Organic Computing in areas like traffic, robotics, sensor networks, image processing, and parallel computing.

The compendium is concluded with an *Outlook* on research that originated from or was inspired by this priority programme. Finally, we address a number of insights and lessons learnt combined with potential future research questions—following the more general observation that “good research answers some questions while—and this is more important—posing new ones.”

Acknowledgement

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