06031 Abstracts Collection
Organic Computing - Controlled Emergence
— Dagstuhl Seminar —

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Abstract. Organic Computing has emerged recently as a challenging vision for future information processing systems, based on the insight that we will soon be surrounded by large collections of autonomous systems equipped with sensors and actuators to be aware of their environment, to communicate freely, and to organize themselves in order to perform the actions and services required. Organic Computing Systems will adapt dynamically to the current conditions of its environment, they will be self-organizing, self-configuring, self-healing, self-protecting, self-explaining, and context-aware.

From 15.01.06 to 20.01.06, the Dagstuhl Seminar 06031 "Organic Computing – Controlled Emergence" was held in the International Conference and Research Center (IBFI), Schloss Dagstuhl. The seminar was characterized by the very constructive search for common ground between engineering and natural sciences, between informatics on the one hand and biology, neuroscience, and chemistry on the other. The common denominator was the objective to build practically usable self-organizing and emergent systems or their components.

An indicator for the practical orientation of the seminar was the large number of OC application systems, envisioned or already under implementation, such as the Internet, robotics, wireless sensor networks, traffic control, computer vision, organic systems on chip, an adaptive and self-organizing room with intelligent sensors or reconfigurable guiding systems for smart office buildings. The application orientation was also apparent by the large number of methods and tools presented during the seminar, which might be used as building blocks for OC systems, such as an evolutionary design methodology, OC architectures, especially several implementations of observer/controller structures, measures and measurement tools for emergence and complexity, assertion-based methods to control self-organization, wrappings, a software methodology to build reflective systems, and components for OC middleware.

Organic Computing is clearly oriented towards applications but is augmented at the same time by more theoretical bio-inspired and nature-inspired work, such as chemical computing, theory of complex systems

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and non-linear dynamics, control mechanisms in insect swarms, homeostatic mechanisms in the brain, a quantitative approach to robustness, abstraction and instantiation as a central metaphor for understanding complex systems.
Compared to its beginnings, Organic Computing is coming of age. The OC vision is increasingly padded with meaningful applications and usable tools, but the path towards full OC systems is still complex. There is progress in a more scientific understanding of emergent processes. In the future, we must understand more clearly how to open the configuration space of technical systems for on-line modification. Finally, we must make sure that the human user remains in full control while allowing the systems to optimize.

Keywords. Emergence, self-organization, self-configuration, self-healing, self-protection, self-explaining, context-awareness

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2006/578

Developing OC Testbeds and Concepts

Kirstie Bellman (Aerospace Corp. - Los Angeles, USA)

The OC community should use biological ideas to draw inspiration from and to re-implement in technical systems. In the first part of the talk, the author describes some of the noteworthy phenomena that OC should pay attention to in biological systems, including: Self-organization and emergence (over different timescales and of different persistent structures, patterns, behaviors, symbol systems, processes, and 'cultures'); reflection processes, even of the system's own decision processes and resource management; the scalable integration capabilities of nervous systems, e.g. of 'top-down' and 'bottom up' processing, of diverse processing styles, and of perception and movement with decision processes; the ways in which limited components (slow, sloppy, inefficient) can have superb overall performance, and the attributes of non-rationale modes of intelligence such as has been suggested for emotional reasoning.

In the second part of the talk, the author describes their work on the iroom, an intelligent room consisting of sensors (cameras so far) controlled by both biologically realistic algorithms and traditional computational resources. She describes some of their work on integrating top-down processes (that monitor and control for the overall performance of the room) with bottom-up processes (that control the behavior of the semi-autonomous sensor controllers). The iroom is seen as a testbed for OC studies, this includes the ability to compare "biologically-inspired" approaches with traditional computational approaches and measure the benefits and applicability of both approaches.

Keywords: Iroom, biologically-inspired control of sensor nets, bottom up and top down integration

Designing Emergence with Evolutionary Algorithms

Jürgen Branke (Universität Karlsruhe, D)

Most technical systems envisioned in the organic computing initiative are assumed to be complex, consisting of a large number of interacting, self-organizing systems, and exhibiting emergent behavior. As is argued in this paper, the phenomenon of emergence poses new challenges to the design of organic computing systems. The usual "top-down" and "bottom-up" design paradigms have severe limitations when it comes to emergence. Instead, the use of evolutionary computation is advocated for the automated design of organic computing systems with emergent behavior. At the example of en-route caching it is demonstrated that evolutionary algorithms are indeed capable of designing local caching strategies outperforming human designed state-of-the-art strategies with respect to global (emergent) properties like average latency.

Keywords: Emergence, organic computing, evolutionary algorithms

A System Level Design Methodology for Organic Systems-on-Chip

Oliver Bringmann (FZI Karlsruhe, D)

A successful design of Organic Systems-on-Chip (OSoC) needs a well-tailored design methodology that explores the effect how the OSoC can cope with malfunctioning subcomponents. This is becoming more and more important since nano-electronics reaches physical limits and results in a paradigm shift in the design and fabrication of electronic circuits. Therefore, the conservative worst-case-approach is no longer feasible and has to be replaced by new design methods. These new design methods and tools have to guarantee reliable and robust systems in spite of unsafe and faulty functions due to fabrication faults, soft errors and design errors. The presented OSoC design methodology follows the established platform-based design approach, where a pre-defined platform consisting of a set of architectural templates is optimized for a given application with respect to several design constraints like area, performance and power consumption. This presentation shows the extension of the traditional design process by adding an autonomic layer to the platform model and considering the reliability as an additional design parameter. The optimization of the reliability in the design process is based on combined analysis of activities, power consumption and the thermal distribution over time. As a result, each architectural alternative can be evaluated in order to find an optimized OSoC implementation consisting of less reliable subcomponents.

Keywords: Organic Computing, Electronic Design Automation, Systems-on-Chip

Self-Organization of Distributed Embedded Real-Time Systems — Conceptions and Architectures

Uwe Brinkschulte (Universität Karlsruhe, D)

The complexity of distributed real-time systems is increasing steadily. This trend will continue in the future. To handle this complexity, the "Organic Computing" paradigm proposes to enrich such systems with properties similar to living organisms. This means mainly to add attributes like self-organization, self-configuration, self-optimization, self-healing, self-protection and self-awareness.

The talk presents conceptions and basic architectures for the self-organization of distributed real-time systems. Starting from a basic middleware architecture, which is suitable for embedded real-time systems and allows dynamic real-time reconfiguration, self-x principles are added to this middleware. By the example of several projects, different self-organization techniques are proposed. For mobile robots, a technique based on cost-/utility functions and decision trees is introduced. On a reconfigurable hardware platform, the exchange of messengers is used to simulate a hormone system. For actor-sensor networks, clustering and the election of temporary leaders is used. Finally, for a distributed systems based on multithreaded processor cores decentralized control loops are proposed.

Keywords: Self-organization, distributed embedded real-time systems, middleware

Chemical Organization Theory as a Theoretical Base for Chemical Computing

Peter Dittrich (Universität Jena, D)

All information processing systems found in living organisms are based on chemical processes. Harnessing the power of chemistry for computing might lead to a new unifying paradigm coping with the rapidly increasing complexity and autonomy of computational systems. Chemical computing refers to computing with real molecules as well as to programming electronic devices using principles taken from chemistry.

The talk focuses on the latter, called artificial chemical computing, and discusses several aspects of how the metaphor of chemistry can be employed to build technical information processing systems. In these systems, computation emerges out of an interplay of many decentralized relatively simple components analogized to molecules. Chemical programming encompassed then the definition of molecules, reaction rules, and the topology and dynamics of the reaction space. Due to the self-organizing nature of chemical dynamics, new programming methods are required. Using a chemical implementation of an XOR, a FLIP-FLOP, and a controllable oscillator as examples, we show how chemical organization theory (Dittrich/Speroni 2005, arXiv:q-bio.MN/0501016) can serve as a theoretical base for chemical programming.

Finally, a road map for developing chemical computing into a unifying and well grounded approach is sketched.

Joint work of: Dittrich, Peter; Matsumaru, Naoki

Benefits of Bio-inspired Technologies for Networked Embedded Systems: An Overview

Falko Dressler (Universität Erlangen, D)

The communication between networked embedded systems has become a major research domain in the communication networks area. Wireless sensor networks (WSN) and sensor/actuator networks (SANET) build of huge amounts of interacting nodes build the basis for this research. Issues such as mobility, network size, deployment density, and energy are the key factors for the development of new communication methodologies.

Self-organization mechanisms promise to solve scalability problems — unfortunately by decreasing the determinism and the controllability of the overall system. Self-Organization was first studied in nature and its design principles such as feedback loops and the behavior on local information have been adapted to technical systems. Bio-inspired networking is the keyword in the communications domain. In this paper, selected bio-inspired technologies and their applicability for sensor/actuator networks are discussed. This includes for example the artificial immune system, swarm intelligence, and the intercellular information exchange.

Keywords: Bio-inspired networking, self-organization, wireless sensor network, sensor/actuator network

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2006/576

Assertion-Based Design and Observer/Controller Hardware

Hans Eveking (TU Darmstadt, D)

Assertions are properties asserted for a system. In the area of hardware design, assertions can be co-simulated, formally verified, transformed into a hardware monitor, or transformed into a hardware circuit conforming with the assertions. If hardware monitors are used for run-time tests of faulty hardware, then the coverage factor becomes crucial for improving the overall reliability. To resolve the obvious discrepancy between top-down specified functionality and the principle of self-organization as well as between locally specified behavior and resulting global behavior, two approaches are studied: the BlueSpec system by Arvind et al. and the generation of hardware from assertions.

Both techniques allow for rule-based, non-deterministic specifications which are "implementation-tolerant" design methods and possibly give room for self-organization methods.

Keywords: Assertion, coverage, observer/controller

Algorithmic Aspects of Large Sensor Networks

Sándor Fekete (TU Braunschweig, D)

In recent time, the study of wireless sensor networks has become a rapidly developing research area that offers fascinating perspectives for combining technical progress with new applications of distributed computing.

From an algorithmic point of view, the characteristics of a sensor network require working under a paradigm that is different from classical models of computation: absence of a central control unit, limited capabilities of nodes, and limited communication between nodes require developing new algorithmic ideas that combine methods of distributed computing and network protocols with traditional centralized network algorithms. In other words: How can we use a limited amount of strictly local information in order to achieve distributed knowledge of global network properties?

We propose not to use coordinates at all, but rather construct clusterings that describe the network topology. In a complex environment, the adjacency graph of these clusters is an extremely useful tool to describe the topological structure of a network.

Keywords: Self-Organization, Sensor Networks, Boundary Recognition, Network Topology

Joint work of: Fekete, Sándor; Kröller, Alexander; Fischer, Stefan; Pfisterer, Dennis

Self-organization principles in fine-grain parallel chip architectures

Dietmar Fey (Universität Jena, D)

Since Moore's law will still hold for the next decade we can expect soon integrated circuits with more than 1 billion transistor functions. On one side this enormous number offers a potential to integrate most powerful circuits within very dense room. On the other side it represents a complexity, which is hardly to manage with traditional centralized orientated structures. The easiest way to exploit this huge potential is to realize system-on-chip architectures consisting mainly of components which were integrated on a board before.

As a long-term solution organic computing architecture principles based on self-organizing and emergent structures are probably a much more promising approach. In particular fine-grain massively parallel chip architectures can profit from self-organization, which is the result of emergent behavior generated by local interchange of comparatively simple processing elements. To this class of architecture type belong so-called cellular nonlinear networks which are implemented under the name of visual or artificial retina processors. Furthermore highly parallel smart optical sensor processors, which are based on the Marching Pixels idea proposed by the author, belong to that class of fine-grain organic chip architectures. Last but not least more theoretical proposals for circuits consisting of artificial ants whose behavior is analog to that of transistors are to mention in this context. In the talk are presented the different and common mechanisms how emergent behavior is used in those circuit architectures.

Keywords: Organic Computing Chip Architectures, CNNs, Marching Pixels, Self-Organization, Emergence

Self-Organization in Sensor Networks

Stefan Fischer (Universität Lübeck, D)

Sensor networks have become a major research topic in the field of computer networks and distributed systems. Due to the fact that such networks usually operate in the real-world and, even more difficult, in a sometimes hostile environment, self-organization plays a major role when setting up and operating them. There simply is no system administrator available who can care for the network. In this talk, we present three projects that are currently being worked on at the Institute for Telematics at Lübeck University, namely SWARMS, SwarmNet, and AutoNomos.

In the SWARMS project, we work on the question of how to program huge collections of simple devices. For that purpose, we consider such collections to be a swarm, and the idea is to program the swarm as a whole and not the single devices. We present our idea of a distributed representation of the "swarm memory", the so-called virtual shared information space, and we show how applications based on this space can be programmed.

The second project, SwarmNet, concentrates on the idea of emergence. Here we are especially interested in the production of global knowledge by just executing local actions. We briefly present algorithms that allow the computation of global properties of a sensor network such as boundaries, crossings or streets just based on neighborhood information of single nodes. The presentation is brief because the project will be presented by Sandor Fekete in much more depth.

In AutoNomos, finally, we tackle a problem of traffic control on highways. Today, traffic data is centrally analyzed and then broadcast to all traffic participants by means of FM radio or sometimes GSM. The problem with this approach is that the information is often outdated and that it is not personalized, often leading to traffic problems just being shifted to other areas. Our idea is to let vehicles communicate directly to each other and set up information structures that identify certain traffic phenomena. The new thing is that these data structures live independently from their hosts (the vehicles), but are rather bound to the place where the phenomenon takes place. This creates a number of new challenges for data storage and communication, but it will help in creating much more up-to-date information which can be individually exploited.

Relevance of Organic Computing for System on Chip Architectures

Andreas Herkersdorf (TU München, D)

For at least another decade, integrated circuits based on standard CMOS technology will witness a continued capacity growth rate in the range of doubling the number of transistors per chip every 18 - 24 months ("Moore's law"). On the positive side, this capacity increase enables to integrate ever more complex and diverse functions on a single chip. On the negative side, System on Chip (SoC) designers face tremendous challenges to deal with the complexity of developing and testing such systems within reasonable time frames under economic constraints. Furthermore, due to transistor feature sizes approaching physical limits in the nanometer range, these devices become increasingly vulnerable for statistical variations in the manufacturing process and from the environment (soft-errors due to alpha-particle radiation). It is foreseeable that the current worst-case design approach is no longer feasible and has to be replaced by new design methods and architectures.

We proposes organic computing principles to be incorporated to hardware design methods and SoC architectures which ultimately allow SoC solutions to autonomously cope with various forms of defects (permanent, sporadic, timing and design faults) and determine optimal power/performance operation points. Our SoC architecture framework consists of two logical layers and suggests rededicating a part of the chip capacity to autonomous control and supervisor functions. The functional SoC layer contains CPUs, memories, interconnect buses, and special purpose coprocessors just like in a conventional SoC. The autonomic SoC layer contains monitors, evaluators and actuators to control the behavior of the functional elements in order to cope with unsafe and faulty functions. We differentiate two levels of control: Corrective actions are managed local to a functional element in case of low severity of the observed defect, i.e. the functional element has sufficient (redundant) means to deal with the situation. Global corrections and optimizations are triggered by communication among multiple autonomic elements to cope with situations that can no longer be resolved locally. The autonomic layer itself is interconnected to higher layer organic (middleware) software layers. The autonomic layer enables emergent system behavior which was not designed into the system during the design process.

We cooperate on this subject with University of Tübingen and FZI Karlsruhe who are investigating the design method and tools aspects of organic SoC.

Keywords: SoC, System on Chip, IC design method, IC architecture, IP core platform, fault tolerance, power/performance optimization

The Bias-Invariance Dilemma

Christian Igel (Ruhr-Universität Bochum, D)

When designing adaptive systems, appropriate specialization (bias) and invariance properties are important, partially conflicting objectives.

The "No-free-lunch" theorems imply that it is fruitless to design universal adaptive systems. That is, the systems have to be biased towards particular problem classes. In nature, such a bias stems from the evolved structures on which learning and self-organizing processes operate. In organic computing, simulated evolutionary structure optimization can create systems biased towards relevant problem classes.

Nonetheless, invariance properties are also desired. Not only because the performance should not vary strongly among possible application scenarios, but also because invariance allows for non-empirical statements about the feasibility of generalization from empirical performance evaluations. As an example, evolutionary algorithms for real-valued optimization possessing desired invariance properties are considered.

Keywords: Adaptive systems, invariance, no-free-lunch, structure optimization, evolutionary computing

Design Aspects for Self-Organizing and Organic System Architectures

Wolfgang Karl (Universität Karlsruhe, D)

Future systems are complex in composition and behaviour, and this complexity is ever increasing. They are composed of an increasingly diverse set of dynamically interacting components. Additionally, systems are more and more used by nontechnical personal and therefore, they must be easy-to-use and fault-tolerant. For programmers, the systems must enable to easily build scalable applications. Missioncritical applications need guaranteed availability and real-time reactivity without user intervention. Thus, future systems' characteristics comprise growing complexity, increasing usability and reliability requirements, integration in highly dynamical environments with permanently changing situations, and high adaptability. This affords self-organizing and organic capabilities.

In this presentation, an architecture model for self-organizing and organic systems is introduced. This architecture model basically consists of an observer instance for flexible and adaptive introspection in order to acquire system-wide state information, to detect inefficiencies or mal functions. A controlling instance is responsible for tuning the system towards the desired metric of merit. There are several target functions towards an optimization: computing power, availability, energy-efficiency, or security. The architecture model serves as an basis for our work on general organic systems and provides a general template for the structured and interoperable design of organic systems.

The focus of our work is on the data acquisition techniques. Self-organizing and organic systems require a general and flexible monitoring infrastructure which is able to observe the system behaviour, to analyse and evaluate the gathered information at run-time, to detect the source, to correlate several events, and to compress the data semantically. The proposed monitoring infrastructure consists of a standardized and reconfigurable monitoring capsule, application specific analysis modules, and a monitoring interface. The capsules can be distributed over the hole system, are attached to the sensors which deliver the data as events, and will be dynamically loaded with analysis modules. The application specific analysis modules process the monitored data at the source, and analyze and filter the run-time data. The information delivered by the monitoring components will then lead the adaptive components which make up the control instance in order to adopt the system towards optimization objective.

Several case studies will demonstrate the application of the architecture model. For a NUMA architecture a flexible monitoring infrastructure is presented. This monitoring infrastructure observes the memory and communication behaviour. The gathered information is delivered to an adaptive component which automatically migrate pages in order to improve the data locality. A other case study presents an dynamically adaptive CPU which is target for Software Defined Radio (SdR) applications. Critical functions are provided as software routines and hardware descriptions which can be loaded into the reconfigurable logic. Depending on the environmental situation and the internal state a control instance decides about the actual implementation of the function.

Keywords: Architecture model, monitoring infrastructure

Reflective Architecture

Chris Landauer (Aerospace Corp. - Los Angeles, USA)

Biological systems have some remarkable properties that are not well-understood:

- interest, attention and noticing;
- reflection and self-modification;
- adaptation and robustness;
- exploration and search for problem-solving;
- generative processes;
- categories and classification;

– creation and use of symbols.

We expect technical systems that have more of these properties to be much more stable and effective in complex environments.

We have built systems that exhibit some of these properties, and are designing systems that are intended to exhibit the rest of these properties, in order to develop adequate design methods for building robust autonomous systems for complex environments. In order to understand and evaluate these technical systems, we need an architecture that supports very flexible use of disparate computational resources, comparisons of different resources for similar tasks and problems, and explicit instrumentation and modeling of those resources to help us study their use.

We describe *Wrappings*, a powerful Knowledge-Based integration method that we used to construct these reflective computing systems. These systems have complete models of their own behavior. They interpret those models to produce that behavior, and they can change the models to change the behavior. These systems observe their environment and the effects of their own actions and inactions in that environment. They construct, compare, evaluate, and modify models of their own capabilities and of the environment. They use these models to predict the effects of their own actions, to determine resource capabilities that they are missing, and to make context-, resource-, and intention-dependent decisions for actions to be taken.

These systems have very flexible and robust decision processes, and we have shown that they can function autonomously in certain complex environments. We believe that the Wrapping infrastructure provides a very promising approach to the construction of technical systems with some of these mysterious and interesting biological properties.

Keywords: Reflection, problem posing, wrapping, biological properties, computational semiotics

Joint work of: Landauer, Christopher; Bellman, Kirstie L.

Ercatons and Organic Programming

Falk Langhammer (Living Pages Research GmbH - München, D)

Organic programming (OP) is our proposed and already emerging programming model which overcomes some of the limitations of current practice in software development in general and of object-oriented programming (OOP) in particular. Ercatons provide an implementation of the model. In some respects, OP is less than a (new) programming language, in others, it is more. An "ercato machine" implements the ideas discussed and has been used to validate the concepts described here.

Organic programming is centered around the concept of a true "Thing". A thing in an executing software system is bound to behave the way an autonomous object does in our real world, or like a cell does in an organism. Software objects do not. Therefore, traditional software systems must be planned while with OP, software systems grow. This fact is traced back to be the root why current software development often fails to meet our expectations when it comes to large-scale projects. OP should then be able to provide the means to make software development achieve what other engineering disciplines have achieved a long time ago: that project effort scales sub-linearly with size.

With OP we introduce a new term because we hope that the approach we are pursuing is radical enough to justify this.

Keywords: Organic, software engineering

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Full Paper:
http://portal.acm.org/citation.cfm?id=1094868&coll=ACM&dl=ACM&CFID=63445337&CFTOKEN=67680763

Self-Organization and Controlled Emergence

Klaus Mainzer (Univ. Augsburg, D)

Complex computing systems begin to overwhelm the capacities of software developers and administrators. Self-organization has been a successful strategy of evolution to handle the increasing complexity of organisms with the emergence of novel structures and behavior. But, self-organization sometimes leads to uncontrollable growth and emergence of undesired side-effects. Therefore, in the factual evolution, hierarchies of controlling layers have been developed. A complex example is human self-consciousness which is still a challenge of philosophy of mind as well as cognitive science. What do we know and what can we learn from mental self-reflection and self-monitoring for controlled emergence in technology? In the theory of complex systems and nonlinear dynamics, self-organization and emergence can be mathematically defined. Actually, these concepts are independent of biological applications, but universal features of dynamical systems. Thus, we get an interdisciplinary framework to model self-organizing computational systems and to guarantee controlled emergence for many technical applications.

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Keywords: Self-Organization, Controlled Emergence

Controlling evolving self-assembling systems for the emergence of multiplication and artificial cells.

John S. McCaskill (Ruhr-Universität-Bochum, D)

Insights from theory and experiments on controlling the self-assembly and evolution of complex systems using a) genetic self-assembly and/or b) microfluidic complementation.

Keywords: Evolution, emergence, self-assembly, microfluidics

Swarming Bees, Specialising Ants and Helping Reconfigurable Components

Martin Middendorf (Universität Leipzig, D)

In our talk we review new results about the swarming behaviour of bees and discuss the role of self-organized emergence and partial central control mechanisms in this process. Then we present a model for response-threshold-reinforcement model for task selection in insects. In particular, we consider the emergence of spezialisation and differentiation between the individuals and how they depend on colony size. In the third part of the talk we present a self-organized worker-helper model for task selection where the helpers consist of reconfigurable components. Analytical and experimental results on the behaviour of this model are presented. We discuss the use of this model as a base model to study Organic Computing systems.

Quantitative Emergence

Christian Müller-Schloer (Universität Hannover, D)

Emergence and self-organization are key terms in Organic Computing. Although there exist many publications on the topic, unfortunately the terms are not well defined. Most definitions are verbal only, a quantitative approach, which allows to determine emergence practically, is missing so far.

This talk collects known definitions of emergence and self-organization. Then, it proposes a definition of emergence based on information-theoretical entropy. This definition allows a practical determination of emergence values of multi-element systems based on a goal-dependent selection of observable attributes. A collection of attribute emergence values comprises an emergence fingerprint, which can serve as a characteristic for certain states of order of an observed system.

The talk will derive this quantitative notion of emergence and exemplify it with examples from multi-agent simulations

Keywords: Emergence, organic computing, pattern self-organization, views, entropy

Modular Neurodynamics: Complexity Measures and Emergent Behavior

Frank Pasemann (Fraunhofer Inst. - St. Augustin, D)

In the context of a modular neurodynamics approach to (artificial) cognitive systems and related to the field of evolutionary robotics, complexity measures for neuromodules as parametrized dynamical systems are discussed with respect to their behavior relevance. Based on these measures emergent dynamics is defined, and its relevance for the description of emergent behavior of robots is outlined.

Keywords: Complex Systems, Dynamical Systems, Artificial Life, Evolutionary Robotics, Embodied Cognition

Multi-Agent Systems on Chip?

Thomas Preußer (TU Dresden, D)

Multi-agent systems offer dependability through the potential for self-organization, self-optimization and self-healing. The key ingredient in these systems is the delegation of tasks or even the trading of services and sub-contracting. These mechanisms lead to the formation of built-in or ad-hoc hierarchies, and they depend on the availability of redundancy and parallelity. Agents originating in AI have been being adopted in software engineering as the evolutionary successor of the object-oriented paradigm. Proposals for tools like AgentUML are widely available. We suggest that it is worth thinking about adopting ideas of multi-agent systems also in hardware and analyze the potential of special infrastructure provided for these systems in hardware. Realizing that the available chip complexity is becoming harder and harder to utilize in more and more complex computing cores, a shift towards many but simple cores seems favorable and offers a natural platform for multi-agent systems. Specific infrastructure for these systems can be provided through available technology: service lookup (CAM), data communication (packet-switched network on chip) and local bid selection (distributed minimum on open-drain structures).

Keywords: Multi-agent systems, hardware infrastructure

Controlling self-organizing systems

Hartmut Schmeck (Universität Karlsruhe, D)

Organic Computing evolved as a vision for tomorrow's Informatics, taking into account the challenges imposed by numerous intelligent devices interacting dynamically in potentially unlimited networks, being confronted with applications that have to behave robustly and trustworthy but at the same time should adapt flexibly to unforeseen changes in the environment. System design will have to cope with the various aspects of self-organisation as an inevitable and at the same time desirable property in order to manage the growing complexity of the systems in the human environment. The observer/controller feedback loop has has been suggested as an essential component of system architecture to guarantee an acceptable behaviour of self-organized systems which might suffer from unexpected global behaviour due to effects of emergence. Standard notions and tools of Control Theory might be sources for inspiration; at least, it offers formal definitions of controllability and observability. For nonlinear industrial processes Model Predictive Control is a powerful and widely accepted methodology which might be transferable to the control of self-organized technical systems. In organic computing these systems will be highly distributed, therefore one should consider different types or degrees of control distinguished with respect to the way of influencing the system, ranging from changes in the environment and changes of the communication system to reprogramming of the components of the system. As an example of an observer-controller architecture the organic traffic control is presented which indicates the necessity of having at least two levels of control.

Keywords: Self-organization, emergence, observability, controllability, nonlinear control

Computationally Intelligent Technical Systems with Emergent Behavior – Philosophical Considerations and Their Implications on Organic Computing

Bernhard Sick (Universität Passau, D)

Philosophy of mind investigates the emergent behavior of complex systems since a long time. However terms such as "weak" or "strong" emergence are hardly applicable to organic computing systems. Organic Computing requires new definitions that define emergence in the sense of collective self-organization, in the sense of non-programmed functionality, in the sense of interactive complexity, or in the sense of unpredictability, for instance.

Keywords: Organic computing, emergence, self-organization

Joint work of: Buchtala, Oliver; Sick, Bernhard

Fast Recurrent Learning with the Backpropagation-Decorrelation Rule and Intrinsic Plasticity

Jochen Steil (Universität Bielefeld, D)

The talk discusses the backpropagation-decorrelation learning rule, which is a new approach to learning for fully recurrent networks comprised of a static dynamical reservoir and a trainable readout neuron with feedback into the reservoir. It is argued that the emergent dynamics in the reservoir provides highly efficient dynamic features, which can even be improved by adding a second long term mechanism of intrinsic plasticity for the reservoir neurons, which thereby tend to optimize their local information transmission. Some preliminary results showing a complex interaction between the global error propagation and the local intrinsic plasticity are given, in particular the intrinsic plasticity can help to reduce overfitting dramatically.

Cognitive Systems in the European IST Programme

Hans-Georg Stork (European Commission Luxembourg, B)

Presentation of the current IST Cognitive Systems programme, projects funded under that programme, and future plans (for Cognitive Systems in the 7th European Framework Programme (FP7)).

Keywords: European research funding, IST Programme, Cognitive Systems

Information, Homeostasis, and Dynamics - a View from Neuroscience

Jochen Triesch (Univ. California - San Diego, USA)

The brain is an information processing device and one of its paramount goals is to maintain homeostasis of its internal activity. At the same time, it seems plausible that the brain has evolved to optimize its information processing in terms of energy consumption, processing speed, space requirements and other criteria. In this talk I will present recent progress in modeling homeostatic mechanisms that maximize the information processing capacity of individual neurons and how they can give rise to efficient representations of external stimuli. I will then discuss how such homeostatic mechanisms may operate in recurrent cortical circuits to contribute to creating dynamics of high complexity.

Keywords: Brain, cortex, information theory, intrinsic plasticity, synaptic plasticity, recurrent neural network

Organic Computing Middleware

Theo Ungerer (Universität Augsburg, D)

The talk introduces a ubiquitous middleware called AMUN - Autonomic Middleware for Ubiquitous eNvironments - AMUN fulfills demands of Organic Computing for smart environments, i.e. adapt to changing environments at runtime, self-configuring, self-optimizing, self-healing, and self-protecting. Another property for ubiquitous systems is the context awareness and the anticipation to react accordingly to current and future conditions. The investigation of the middleware focuses currently on self-configuration, self-optimization, and self-protection.

Keywords: Organic middleware, smart environments, self-x properties

Full Paper:
http://www.informatik.uni-augsburg.de/en/chairs/sik/research/middleware/

Robustness in embedded system design

Klaus Waldschmidt (Universität Frankfurt, D)

Robustness will be an important feature in future embedded systems. Robustness increases the trust in electronic devices, will reduce the design complexity and enhances the performance. For the design of robust embedded systems, an understanding of robustness and especially formal measures and metrics are necessary. These metrics have to be integrated in the complete design and refinement process. following the ABC philosophy.

This contribution discusses some of these approaches and their embedding in a robust design procedure. As a possible approach for robustness evaluation in modern SoCs and NoCs, a semi-symbolic representation of deviations and tolerances of analog components is presented. The approach is based on affine arithmetic and allows for efficient calculations and simulations with intervals. The benefits are that it keeps track of the functional correlation of different signals in a system, and that different deviations can be charged against each other. Because of this property it is possible to analyze systems with feedback, linear as well as non-linear ones.

Keywords: Robustness

Feature-driven Emergence of Model Graphs for Object Recognition and Categorization

Rolf Würtz (Ruhr-Universität Bochum, D)

The first part of the talk reviews correspondence-based recognition techniques, which rely on self-organized mappings between images, and have been successful for facial recognition.

These techniques encounter difficulties when applied to general objects, because of the variability of structure. On the other hand, relatively good results can be achieved with purely feature-based techniques, which completely disregard spatial arrangement, if only enough feature types are used. This is compatible with feedforward recognition in the brain, and recognition/categorization experiments show that reaction times can be as short as to only allow for a forward pass.

We then present a feature-based feedforward network based on the information contribution of the single feature types to the decision at hand. Due to its speed this is very well suited to quickly rule out most irrelevant matches and only leave the ambiguous cases to be processed by a correspondence-based method, which is more accurate but also more time consuming. In the course of this model graphs emerge that describe the analyzed object well.

We report the results of experiments testing the complete system on standard databases for object recognition and categorization. The method achieved high recognition rates on identity, object category, pose, and illumination type. Unlike many other models it can also cope with varying background, multiple objects, and partial occlusion.

Keywords: Graph matching, recognition, categorization, computer vision, self-organization, emergence

Joint work of: Westphal, Günter; von der Malsburg, Christoph; Würtz, Rolf P.

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Abstraction and Instantiation as Essential to Organic Computing

Christoph von der Malsburg (Univ. Bochum & Frankfurt Inst. for Adv. Studies, D)

The complementary processes of abstraction and instantiation will be discussed as crucial for reaching the goals of organic computing. In the human mind, these mechanisms are central to such activities as recognition of objects, of activities and situations, generation of movement, speech acts, problem solving and the writing and debugging of programs. The abstraction and instantiation processes

must evidently be based on general mechanisms that can react to but are independent of semantic contents. Identifying and implementing these mechanisms must be the holy grail of organic computing and more generally of artificial intelligence. Taking invariant object recognition in the visual system as well-studied paradigm, I will discuss some of the issues involved and some components of a solution.

Keywords: Abstraction, instantiation, generalization, invariant recognition, graph matching