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Foreword

OC-Trust, this is an acronym representing a research cooperation that addressed one of the core challenges of the emerging digitalisation of almost every facet of our professional and private lives. How can we develop trust into the widely autonomous provisioning of digital functionality and associated services? We expect those services to know what we want them to provide, but we are not physically capable and do not want to programme those multitudes of devices explicitly. So, we increasingly depend on their capability to self-configure, self-optimise, self-heal and self-protect, to name a few of the many so-called self-* properties. But how do we know to what extent they will actually satisfy our expectations? They should be aware of our personal preferences, but will they respect our privacy? If agents act autonomously, how can their operating environment distinguish between trustworthy and malicious agents? This kind of almost contradictory questions and requirements is concerned with the trustworthiness of artefacts that are meant to be self-organising and widely autonomous but nevertheless capable to adapt to potentially changing requirements of their execution environment. Research initiatives like autonomic computing and organic computing have emphasised from the beginning that trustworthiness should be seen as one of the key requirements, but they more or less focused on the development of generic architectures and methodology for providing desired functionality and organic behaviour in the best possible way. So, the German priority programme on organic computing successfully addressed fundamental system concepts supporting controlled self-organisation, as summarised in the compendium on “Organic Computing – A Paradigm Shift for Complex Systems”. But it needed the additional initiative of research groups at Augsburg and Hanover to establish this complementary DFG research unit on “OC-Trust – Trustworthiness of Organic Computing Systems”.

Wolfgang Reif, the spokesperson of this research unit, continued his work on software design for organic computing systems but focused now on “Formal Analysis and Software Architectures for Trustworthy Organic Computing”. Christian Müller-Schloer, one of the core initiators of the organic computing research programme, and Jörg Hähner concentrated on top-down and bottom-up approaches to the “Generation of Self-organising Trust Communities”. Theo Ungerer, another
core member of the Organic Computing Initiative, investigated “Trust Relationships in Between the Autonomous Units of OC Systems”. Finally, since the interaction between man and machine is one of the key aspects of trustworthiness, Elisabeth André joined the research unit with her topic “HCI Design for Trustworthy Organic Computing”. Looking at the research unit’s record of meetings, workshops and special spring schools, it is obvious that they have been extremely active and productive. The TSOS workshop series on “Trustworthy Self-Organising Systems” as well as its successor, the SASOST Workshop, were essential for significant international recognition and provided a forum for exchange of ideas with other research groups. The “International Spring Schools on Trustworthy Self-Organising Systems” added specific input from international experts for the doctoral researchers in this research unit with a significant outreach to other research groups. This book now summarises the major results of this research unit on a topic that might prove to become most decisive for the public acceptance of technologies that are developed under a range of different, but highly related, headlines like “Internet of Things”, “Cyber Physical Systems”, “Industry 4.0” and “Smart City” (including energy and traffic systems as well as all kinds of citizen services), to name a few.

An interesting aspect of this book is the fact that it extends beyond the members of the research unit by including external experts on topics that are of interest for a more complete view on trustworthiness.

So, the DFG research unit OC-Trust not only generated a range of interesting concepts and results on trustworthiness of and within self-organising systems, but they also had a significant impact on the international research community and clearly showed the necessity and benefits of a transdisciplinary approach for a thorough understanding of the role of trustworthiness.

Karlsruhe, Germany Hartmut Schmeck
November, 2015
Preface

Our technological landscape is ever-changing. Interconnected devices interact with other devices as well as people in an increasingly autonomous fashion. This core idea manifests itself in several aspiring areas of technology – from the “Internet of Things” to “Industry 4.0”. It seems all too obvious that these entities cannot be controlled by individuals or even organisations but rather require sophisticated self-organisation mechanisms to implement various self-* properties without centralised control. This scientific challenge led to initiatives such as autonomic computing or organic computing that proposed important basic architectures, models and algorithms. Particularly in terms of robustness towards failures, these systems show the potential of outperforming conventional, rigid systems. When widening the scope of application of self-organising systems to critical domains that are more open and consist of heterogeneous participants, an essential question accompanies the more widespread adoption: How can we make these systems trustworthy?

More specifically, in 2009 the DFG¹ research unit “Trustworthiness of Organic Computing Systems” (OC-Trust) set out to develop methods to construct self-organising multi-agent systems that are deemed trustworthy by their users, by other systems interacting with them and by authorities and even organisations that certify and deploy systems in safety- or mission-critical environments. Positive aspects of self-organisation, such as increased robustness or other positive emergent effects, shall, however, not be sacrificed. The common denominator of the bundled research efforts is the scientific treatment of various facets of trust in technical systems. Trust manifests itself in the system design, e.g. by countermeasures against ill-behaving or little predictable agents, and helps to reduce the impact of such entities on the overall system performance. Among technical systems benefiting from trust management, one particular system class is selected to serve as a prominent representative. It can be roughly categorised as open, heterogeneous, self-organising, multi-agent systems and is visualised in Fig. 1. Systems in this class share several features that require individual attention:

¹German Research Foundation (Deutsche Forschungsgemeinschaft)
Fig. 1 Open self-organising multi-agent systems composed of heterogeneous agents. Examples thereof are detailed in subsequent chapters

- Components are represented by agents that interact via a self-organised communication and collaboration structure to, e.g. avoid excessive broadcasting and enable effective problem decomposition.
- The system interacts with other systems, and a single agent may even act on behalf of a larger subsystem in a systems-of-systems approach.
- Due to its deployment as an autonomous entity in a dynamic environment, uncertainty about interaction partners (and their possibly malicious intentions in the case of attackers) and exogenous factors is omnipresent – hence, the benevolence assumption is abandoned.
- Users are present “in the loop” and constantly interact with the software surrounding them – as long as they trust it.

Clearly, these diverse challenges require a collaborative effort that is reflected in the projects the research groups undertook and whose results of 6 years of research form the core of this book. Chapter 1 provides an overview of the properties of computational trust and its different uses. These are concretised in the subsequent chapters. Wolfgang Reif and his group (see Chap. 2) investigated methods that enable scalable, robust optimisation to control systems subject to strong environmental influences and physical constraints. Christian Müller-Schloer (see Chap. 4) and his team provided means to incentivise cooperative or to sanction malicious behaviour in a group of agents. In this context, Jörg Hähner (see Chap. 5) and his team devised mechanisms to form groups of agents that mutually trust each other. Theo Ungerer (see Chap. 6) established with his group how various self-* properties can be efficiently monitored and allowed for selective service placement in middlewares for parallel algorithms and distributed systems, in general. To accommodate the users’ interests, in particular its trust in a self-organising system,
Elisabeth André (see Chap. 3) and her team worked on explicit user trust models that capture the effects of system actions on the users’ experienced trust and take these factors into consideration. Measuring, formalising and interpreting various facets of trust as well as the incorporation of this knowledge into decision-making is a common theme that transcends all OC-Trust projects. Many of the concepts and algorithms were developed in close cooperation of the project partners, reflected by 35 joint publications. More than 20 internal project meetings over the course of 6 years offered room and time for the fundamental discussions that led to those results.

To illustrate the developed techniques and to instantiate the system class, three jointly used case studies were devised. All of them are based on the Trust-Enabling Middleware that offers communication interfaces and access to a generic infrastructure for application-specific trust metrics. The Trusted Desktop Grid deals with open, social agent environments that jointly process computing tasks. As a self-organised collaboration structure, the concept of trusted communities consisting of trustworthy agents is in the focus. Trust-based Autonomous Virtual Power Plants allow for a self-organised, robust and scalable control of a large number of power plants in a hierarchical way. Uncertainty introduced by volatile energy sources poses tremendous challenge to the system which has to keep supply and demand of power in balance at all times. Multi-user multi-display environments have users interact with a system on both public and private devices. With several participants at the same device, privacy and usability concerns become relevant when it comes to deciding which content should be shown. User preferences guide these decisions which are evaluated at runtime on a dynamic user trust model.

Certainly, the research unit did not work in isolation on these fundamental topics but rather built on top of established theories, models and algorithms and extended the literature substantially. This fact is reflected by the structure of this book which includes three invited contributions by selected experts from the domain of trust in multi-agent systems. Jeremy Pitt (see Chap. 7) discusses formal models of several social processes for open distributed systems and, in a sense, removes the restriction on the social concept of trust otherwise so prominent in this book. Cristiano Castelfranchi and Rino Falcone (see Chap. 8) add various other factors to the discussion on trust in self-organising, sociotechnical systems. Natasha Dwyer and Stephen Marsh (see Chap. 9) conclude the book by asking the interesting and relevant question whether a digital environment empowered users to proceed on their own terms.

These contributions are witness to the fact that the research unit enjoyed great visibility in the scientific community and put serious efforts into the dissemination of its results. Papers that resulted from the projects were regularly presented at international conferences such as the IEEE International Conference on Self-Organising and Self-Adaptive Systems (SASO), the International Conference on Autonomic Computing (ICAC) or the International Conference on Architecture of Computing Systems (ARCS), to name a few. Especially at SASO, nine editions of workshops on topics related to OC-Trust were held, comprising the workshops on trustworthy self-organising systems (TSOS), sociotechnical concepts (SASO$^T$) and
quality assurance for self-organising systems (QA4SASO). These workshops turned out to be valuable regular additions to the programme of SASO and led to fruitful discussions. But of course, until sound publications can be written, doctoral students need to be exposed to and guided towards recent scientific work. It is for this cause that the research unit conducted two spring schools on “trustworthy self-organising systems” and three gender workshops to invite prominent researchers and foster future cooperations. Furthermore, due to this encouraging culture, several doctoral researchers were already invited to personally serve in programme committees or panels at both conferences and workshops. Additionally, the 10th edition of SASO will be held in Augsburg in 2016 with demonstrations of the OC-Trust projects.

Besides these community-oriented activities and OC-Trust-internal cooperations, some of the results emerged from collaborations with external partners. Especially papers at the frontiers of trustworthy self-organising systems that could benefit from input from other disciplines were written with OFFIS at the University of Oldenburg, the Imperial College London, the Max-Planck-Institute in Tübingen and the KU Leuven. Interesting meetings took place with NEC Laboratories, the University of Calgary, the University of Duisburg-Essen and the LMU in Munich. Additionally, invited talks at the Stadtwerke Munich, Phoenix Contact, the SORules workshop in London and the Helmholtz centre in Munich showed increased interest from both industry and academia. Wolfgang Reif and Christian Müller-Schlöer furthermore spent sabbatical terms at NICTA in Australia and Telecom ParisTech, respectively, to work intensively on related topics. All shall be mentioned to value their feedback that influenced and shaped the research unit.

Results of OC-Trust found their way into three courses at the universities of Augsburg and Hanover. Therefore, motivated students were well-prepared to conduct their own research in self-organisation in their thesis works. Many of those results found their way into proper publications. Finally, 13 doctoral researchers found challenging questions to complete their dissertations in the research unit. It is due to their continuous efforts that the project succeeded the way it did, in answering some questions but asking many important new ones. As a starting point for new directions, a Dagstuhl seminar on “Social Concepts in Self-organising Systems” was initiated by the research unit in December 2015. We are confident that the achieved results presented in this book show great promise for both research and applications and look forward to an increasing number of trustworthy self-organising systems in our future environment.

Finally, many thanks go to the contributing authors, in particular of the invited contributions that enriched the book tremendously. We are indebted to the German Research Foundation for sponsoring the research unit OC-Trust (FOR 1085).

Augsburg, Germany
January, 2016

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