UNIKASSEL
VERSITÄT

Distributed Systems Group

Research Profile

Prof. Dr. Kurt Geihs

Fachbereich 16 –
Elektrotechnik / Informatik

VERTEILTE SYSTEME

Wissenschaftliches Zentrum
für Informationstechnik-
Gestaltung

ITeG Research Center for Information System Design

March 2019

1 Motivation

This research profile is meant to provide a thematic framework for the research performed in the Distributed Systems Group in the Department of Electrical Engineering / Computer Science of the University of Kassel. Our intention is to send clear messages to the outside as well as inside: The group's external image is made more focused and more clear, while internally the research profile serves as an orientation aid for doctoral candidates looking for a PhD subject, and it promotes even more intensive collaboration between the doctoral students in the group.

Clearly, such a research profile will change over the years as technology evolves. By no means shall this research profile be unnecessarily restrictive and hamper the creativity of the group's research staff. Nor is it intended to imply a thematic monoculture such that only one type of technique or application domain or methodology would be the chosen subject of research. Research needs freedom and this should be preserved!

2 Research Objectives and Themes

The research activities of the Distributed Systems Group mainly belong to the thematic area practical computer science. Nevertheless, this requires very good knowledge of theoretical and conceptual fundamentals. Both aspects – practice and theory – are important and inseparable in our research methodology. Our goal is always to underpin and evaluate conceptual findings through a practical proof-of-concept in the form of a prototype.

The overarching theme for the research is Distributed Systems. Currently, the following characteristics are associated with the subjects of our research, whereby the term "actor" is to be understood in a general sense and may stand, for example, for "agent", "robot", "application" or "service":

Autonomous actors	The actors act autonomously, reacting to the actions of other actors and the changes in their runtime environment.
Cooperative, collective, team-oriented action	Particular attention is paid to systems in which several autonomous actors form a team that aims to achieve a joint task involving all team members.
Decentralized coordination	Generally, coordination of actors is decentralized: A central decision-making instance should be avoided because it represents a bottleneck and critical point of failure.
Dynamic execution context	The runtime environment changes dynamically. For example, mobile actors may encounter changing environment condistions, actors may leave and join a team due to failures or moving out of communication range, the quality of some service changes substantially, etc.
Adaptivity and reactivity	Contextual knowledge is used to react to significant changes in the environment and to adapt the team structure and behaviour to new situations.

Self-reflection	Actors have access to sensor data and system parameters, thus being able to monitor and reason about their own state and the state of the environment.
Common know-ledge-base	Actors have an explicit or implicit shared understanding about their environment. This common knowledge forms the basis of cooperative team behaviour. However, actors may have inconsistent views due to e.g. communication delays or diverging sensor values.
Heterogeneity	The world was, is and remains heterogeneous, and homogeneity is a rare special case in distributed systems. Heterogeneity appears in many aspects, e.g. in data formats, system platforms, programming languages, different types of robots in a team, etc.
Socio-technical concerns	The design of innovative ICT that is entangled with the users' daily life demands a socio-technical perspective that views the design of technical artefacts and their social embedding as a single inseparable task.

These characteristic features do not imply a focus on a particular application domain with specific characteristics of the actors, but they represent typical general characteristics of future application landscapes. We expect that these characteristics will be relevant for quite some time even with the rapid technological progress in information and communication technologies.

2.1 What is not included?

The aforementioned characteristics give a rough idea of the "workpieces" of our research. More details will follow in the next section. Before we would also like to point out what is not part of our research focus:

Hardware research	Although we design and build robots, research on hardware components is not one of the intended activities.
Single-actor systems	It follows from the above that systems in which no communication, interaction, collaboration, decentralization, etc. are to be found are of less interest to us.

2.2 Domains

Concrete application scenarios serve as test environments for the results achieved. Currently, the following scenarios are of particular interest:

Mobile cloud computing	Such application environments are characterized by dynamic changes in the context and the availability of resources and services, so that applications on mobile computers have to respond appropriately to these changes.
Service-oriented architectures	Service-oriented architectures require dynamic adaptation due to changes in the services or their quality of service. A particular area of interest is the support for automated evolution of (micro-)services in large service environments with multiple inter-dependencies.

Teamwork in multi-robot systems	Teams can be more than the sum of their parts. Since autonomous robots increasingly pervade our daily lives, it is an obvious thought that these robots around us will have to work collaboratively as a team pursuing a common goal.
Cognitive service robots	We investigate knowledge representation and reasoning techniques in order to equip service robots with common-sense knowledge and dynamic reasoning capabilities, such that robots can understand instructions by humans and collaboratively perform everyday tasks.

3 General Research Questions

The following research questions provide a frame for the project activities of the Distributed Systems Group.

How to achieve goal-oriented teamwork in multi-robot systems?
Examples of such teams are football robots, exploration robots, and search-and-rescue teams; the latter are an example of hybrid teams that will increasingly consist of humans and robots in the future.

How can a team of actors be equipped with collective self-* features such that the overall performance of the team is more than the sum of its parts?
Examples of such team properties are self-optimization and self-healing, where the collaboration of team members helps to improve the performance of individual actors and to compensate component failures in individual actors in a collective activity.

How to achieve optimal adaptation of distributed applications and systems to the dynamics of runtime environments?
Examples include cloud computing applications on mobile devices that flexibly react to changes in their execution environment and advanced service-oriented application architectures and platforms that are enabled to handle an on-the-fly coordinated evolution of services and applications in future large-scale service landscapes.

How can collective knowledge emerge from the potentially differing observations of individual actors and how is this knowledge modelled and evaluated in terms of collectively intelligent actions?
Examples for the need for such common knowledge bases can be found explicitly (or implicitly) in all scenarios where heterogeneous actors have a common task to accomplish. A common understanding of environmental constituents and their semantic dependencies is a prerequisite for joint coordinated action.

What kind of methodologies are appropriate for designing, building, and evaluating innovative ICT systems that are acceptable and accepted within the social context of their usage?
Context-aware mobile applications inherently pose questions related to normative concerns about data privacy, legal constraints, usability, adherence to ethical, cultural and religious norms, and many more. Such a value-oriented socio-technical design perspective requires interdisciplinary collaboration of different disciplines in order to come up with a sustainable and responsible system design.

4 Conclusion

Technological trends in hardware and software are leading to highly networked, inherently heterogeneous, decentrally organized autonomous systems whose various facets have created research and development challenges in realms such as Collective Adaptive Systems, Cloud Computing, Cyber-Physical Systems, Internet of Things, and Collaborative Multi-Robot Systems. All these research areas share a common underlying characteristic, i.e. they involve distributed computing in dynamic environments. The Distributed Systems Group aims to contribute to these developments in response to technological advances and evolving requirements but maintaining its general focus on distributed computing technologies.

It's all about effective teamwork …