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Companion-Technology: An Overview

Susanne Biundo · Daniel Höller · Bernd Schattenberg · Pascal Bercher

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Abstract Companion-technology is an emerging field of cross-disciplinary research. It aims at developing technical systems that appear as "Companions" to their users. They serve as co-operative agents assisting in particular tasks or, in a more general sense, even give companionship to humans. Overall, Companion-technology enables technical systems to smartly adapt their services to individual users' current needs, their requests, situation, and emotion. We give an introduction to the field, discuss the most relevant application areas that will benefit from its developments, and review the related research projects.

Keywords Artificial Companions · Companion-systems · Human-Technology Interaction

1 Introduction

Companion-technology denotes a novel, cross-disciplinary field of research that aims at a paradigm shift in human-technology interaction. It is motivated by two fundamental observations. First, technological progress in informatics and the engineering sciences provides us with technical systems and electronic services of continuously increasing complexity and functional "intelligence" in ever shorter innovation cycles. Second, quite often a considerable lack of comfort and convenience in use lets users feel overstrained and hindered from exploiting the offered functionality of these systems and services to its full extent. Companion-technology points the way out of this dissent by providing the means for a smart, adequate, and particularly user-tailored human-technology interaction.

Susanne Biundo · Daniel Höller · Pascal Bercher
Ulm University, Institute of Artificial Intelligence, D-89069 Ulm, Germany. E-mail: forename.surname@uni-ulm.de
Bernd Schattenberg
Büro für intelligente Technologie-Beratung, D-88471 Laupheim, Germany. E-mail: mail@berndschattenberg.de

Technical systems that conform to the Companion-paradigm should be able to smartly adapt their functionality to the individual user's requirements and current needs; adequately react to changes of context and changes of the environment that might impair an effective user-system interaction; be sensitive to the user's emotional state and disposition; and conduct helpful and informative dialogs. To this end, the systems need to be provided with advanced cognitive abilities and rich knowledge sources that build the basis for really advanced and effective user support.

So far, the notion of *Companion* together with technical systems has been used in various ways. Most prominently, the EU-funded COMPANIONS project focused on the development of Companion-systems as conversational agents, which give companionship to human users and accompany their owners over a (life-) long period [92]. Another prominent example are *Robotic Companions* as addressed by one of the pilot finalists of the European Flagship initiative "Robot Companions for Citizens". These biologically inspired systems were aimed at supporting humans in their daily activities [8].

However, up to now a systemized definition of the essence of Companion-technology or companionable systems is still lacking. The first attempt to come up with such a definition was made when establishing the interdisciplinary Transregional Collaborative Research Centre "*Companion*-Technology for Cognitive Technical Systems" [42,91,44]. Here, Companion-systems were specified as cognitive technical systems showing particular characteristics: competence, individuality, adaptability, availability, cooperativeness and trustworthiness. A precise definition of these characteristics together with specifications on how these characteristics could be achieved will be given in a forthcoming book [43].

This article presents the current state of the art in research and development towards Companion-technology. In Section 2 we introduce the research areas the contributions of which are essential for the realization of Companion-technology and review the application areas that will significantly benefit from its development. Section 3 gives a comprehensive overview of research projects that address Companion-technology in some way or another. At that, we do not only refer to currently active projects, but give a summary on the complete history of projects related to the field. Finally, we conclude with some remarks on open issues and further developments in Section 4.

2 Research and Application Areas of Companion-Technology

Companion-technology builds upon wide-ranging cognitive abilities of technical systems. The realization and the synergy of those are, since roughly one decade, investigated under the research theme of *cognitive systems* or *cognitive technical systems*. The theme is focused on capabilities such as environment perception, emotion recognition, planning, and learning, and their combination with advanced human-computer interaction. A first survey on cognitive technical systems was published by Vernon et al. [86], whereas Putze and Schultz give a more recent introduction [78]. Furthermore, there was also a special issue on *Cognition for Technical Systems* of the KI journal [35].

2.1 Research Areas

The upcoming research field of Companion-technology is cross-disciplinary in nature. Obviously, major constituents stem from sub-fields of AI. The supply of rich background knowledge together with the ability to reason about this knowledge is a necessary prerequisite for intelligent and user-tailored system behavior. Planning and decision making techniques enable systems to generate courses of action and to reflect and explain the effects of the respective acting. Thereby, depending on the application at hand, the system may either act itself or take the generated course to give recommendations for action to a human user. As soon as sensory input has to be processed in order to recognize environmental conditions, a user's emotional state or his or her disposition, reasoning under uncertainty becomes indispensable. In these cases, often techniques from machine learning and neural information processing are the methods of choice. Finally, natural language processing plays an important role for the exchange of information between the system and its user.

However, in order to design and conduct effective and adequate dialogs between a companionable system and its human user, advanced dialog management and human-computer-interaction techniques have to be employed and integrated with a system's above-mentioned cognitive abilities. They provide the possibility to choose among various dialog strategies and to interact via various media and modalities. With that, they enable a system to show a communication behavior that fits the user's current needs, the context of the application at hand, and the user's emotional state.

The field of affective computing originating from the work of Picard [74] is an essential contributor to Companion-technology as well. Combining aspects from informatics, psychology, and cognitive science, it is concerned with the recognition, processing, and even the simulation of human affects. Being able to dynamically recognize a user's emotional state helps a system to adapt its acting as well as its interaction and intervention strategies in an adequate way, thereby ensuring that a user gets not overburdened and preventing sudden dialog interruptions by the user.

Psychology and in particular the subfield of human factors investigate the interaction between humans and technical systems systematically and on an empirical basis. The results obtained here and the methodologies used are of particular importance for research, development, and evaluation of Companion-technology. Finally, a synergy with the field of neuro-biology results from neuro-imaging during human-machine interaction, which allows to draw conclusions regarding the benefit of particular such dialogs, for example.

2.2 Application Areas

Most technical systems are operated by human users. There is a wide variety of different application areas in which systems of different kind are used that may enrich their functionality and the system's user friendliness by Companion-technology. Here, we give a short overview about some of these application areas.

Robotics. A large area of research and development concerned with providing assistance to human users is the field of *Robotics*. Especially areas of application where robots interact directly with humans (see [54,58,46] for overviews) form an interesting field for the realization of Companion-characteristics. These areas range from (seemingly) smart toys with limited interaction capabilities, over service robots that perform tasks in household or elderly care, to systems in health care that support people with disabilities or in rehabilitation.

The field of domestic service robots (see [77] for an overview) ranges from single robots performing certain household tasks, like vacuum cleaning [55], over smart robotic environments like an assistive kitchen [36], to systems that are designed to support the user in a broad variety of duties [47,34,32].

A robot system that focuses on the social interaction in a bartender domain has been developed by Petrick and Foster [72]. Its behavior is based on AI planning and on its observations, which are based on vision and speech input.

Health and Elderly Care. Robots are also applied in health and elderly care. These robots can be categorized into *rehabilitation* or *therapy robots* and *assistive social robots* [48,67]. The former do not focus on human machine interaction [48] like e.g. intelligent wheelchairs and are thus not further discussed here. The latter category can be divided into robots that support a human in basic activities like eating or getting dressed as well as pet-like robots [48]. Here, the term "Companion" is used sometimes, but often in a literal sense (i.e., they provide companionship) and not like given above. Especially robots that support humans in their daily lives might benefit from Companion-characteristics. An overview of the field is given in [67]. A survey on the effects of robots in health and elderly care can be found in [48,37]. Examples for such robots are the robot seal "Paro" that is designed for psychotherapy [87,88] or the assistant robot described in [75] that supports elderly people by providing guidance and reminders.

There are also less robot-like intelligent devices that support humans in their daily lives. Systems support people suffering from dementia or other cognitive disabilities in activities of daily life, such as washing hands or brushing teeth, e.g. [76,45,71]. Other systems support people with disabilities, e.g. blind people ([51] gives an overview). Although these systems need less social abilities, situation and user adaptive behavior might help to optimize their capabilities.

Intelligent Environments and Homes. Other application areas that aim at realizing customized assistance are those of intelligent environments [31] and in particular smart homes [59]. Systems in these areas should tailor their behavior to the current situation as well as to the preferences of the human user [31, p.4]. (Smart) homes often have more than one resident, hence adaptation to the current environment and the user's situation also becomes more complex. Smart homes are of particular interest as an application scenario for elderly care, as they allow to monitor and assist their elderly residents and, e.g., call an ambulance or notify other residents in case of an emergency. An important issue is the question on whether potential residents accept this technology in their daily life (see [52,56]); smart homes have been particularly investigated for patients [80]. For an overview of several smart home applications and smart home research we refer to [64,77,79].

Driver Assistance. Modern vehicles become increasingly smarter with a wide range of possible services [40,66,85]. In particular, we encounter a growing individualization of cars to its user. For example, they arrange the position of the driver's seat or adjust the radio's volume to the preferred level; they are equipped with many sensors that allow to automatically react to the environment (e.g. to break automatically) or to assist parking [89]. Individualization to a user's personal preferences and his current situation will also become important for autonomously driving cars, as one could imagine that the taken tour or speed depends on a combination of a user's personal preferences and his current stress level or emotional state.

Other Assistance Systems. Individualization to a specific user and its environment as well as the capability to behave rationally are important capabilities for smart *assistant systems* in various application fields such as elderly care. Due to its capability to automatically solve complex tasks, AI planning can also serve as the basis to improve the basic functionality of many technical systems, such as smartphones (see e.g. [41]). AI planning also serves as the basis in a prototypical system that provides automated assistance in the task of setting up a home entertainment system [38,39]. The system autonomously calculates a plan that solves the task and presents it as a sequence of detailed instructions that explain which cable needs to be plugged into which port of the respective device. Further, the system can generate AI plan explanations that - transformed into natural language - explain to the user the necessity of any presented instruction in question. The presentation of these instructions can also be adapted to different skill levels and preferences of different users [63,62].

Glodek et al. describe an intelligent ticket vending machine as an example application for explaining how information from various sources, such as sensors and a knowledge base, can be fused [57]. The ticket machine makes use of various sensors to observe the current situation and the user's emotional state in order to adapt its behavior accordingly. For instance, the system monitors whether the user is interacting with the system or with other people in front of the vending machine or talking with someone else using a cell phone. In such a situations, any spoken text or performed gestures are not interpreted as input to the system.

User assistance is also essential in any situation that involves great risks and/or where the cognitive load of the respective user is quite high. One such system, *ELP (Emergency Landing Planner)*, assists pilots in case of an emergency taking into account various factors like weather conditions, for example [69].

3 Research Projects in the Area of Companion-Technology

In this section, we focus on projects that are related in terms of the application's adaptation aspects and facets that aim at *advanced user assistance*, which means in particular: personal assistance systems, care of the elderly, and assistance for impaired or disabled persons. This is of course a very pragmatic and relatively fuzzy categorization of the enormous variety of approaches behind the presented research projects – it is thus a mere entry point to the field for the inclined reader.

3.1 History of Companion-Technology-like Projects

ACCESS (Assisted Cognition in Community, Employment and Support Settings) [2,65] was one of the first major joint research projects to address the issue of cognitive technical systems. Computer scientists and medical researchers at the University of Washington explored the impact of cognitive support for people suffering early stages of Alzheimer's disease. They combined techniques from Artificial Intelligence and Ubiquitous Computing in order to monitor the behavior of the patients and from that to assess their cognitive capabilities. While this research focused on establishing cognitive support, service robotics projects like *Nursebot* [25,82] at the University of Pittsburgh, Carnegie Mellon University, and University of Michigan, or *GiraffPlus* [17,50], funded by the European Community's Framework Programme Seven (FP7), aimed at directly assisting elderly people with cognitive tasks, for example helping them to remember medication schedules. The assistance functionality is thereby not embedded in a user's environment, but provided by an autonomous mobile platform that interacts directly with the patient. But robot Companions have not only been successfully deployed in elderly care scenarios, they are also very well and unbiased received by children, for example within the scope of the FP7 project *ALIZ-E* [4,68] on adaptive strategies for sustainable long-term social interaction. The autonomous system thereby assists in diabetes management during a long-term interaction with the child patient.

The goal of the Collaborative Research Centre (CRC) 588 *Humanoid Robots - Learning and Cooperating Multimodal Robots* [18,53], funded by the German Research Foundation (DFG) at the Karlsruhe Institute of Technology (KIT), was to develop concepts, methods, and mechatronic components for creating humanoid robots. While assisting in household environments, the robot was supposed to grasp and acknowledge its human user's intentions in a natural, human-like, and multi-modal manner. The project had a specific interest in interactive learning, so in cooperatively interacting with a human user, the robot learned from that person new vocabulary, relevant objects in the household environment, and the execution of grasping and manipulation tasks. The research efforts thus focused on a broad variety of techniques like learning from observations, spontaneous speech recognition, and the like.

The relevance of robotic Companions as a means for assisted living on the European level became apparent by the selection of the *Robot Companions for Citizens initiative CA-RoboCom* [8] as one of the seven Future and Emerging Technologies (FET) Flagship Pilot finalists in 2012. The initiative's consortium aimed at developing biologically inspired robots that support humans in their daily activities and in particular in potentially dangerous situations. In order to provide this kind of support, their agenda also included developing adequate cognitive capabilities and addressing emotional aspects of companionship. CA-RoboCom proposed the adoption of autonomous systems on various levels of scale and organization, eventually realizing ubiquitous robotic assistance.

Establishing a new level of usability by providing Companion-like assistance in the realm of information technology was the goal of the following two German national "lead-project" initiatives, funded by the Federal Ministry of Education and Research (BMBF). *SmartKom* [30,90] followed the vision of automatically tailoring interactions with systems to the specific needs of the individual users. The barriers for novices in adopting information technology were to be minimized by providing more self-explanatory, respectively self explaining user interfaces. Key elements therefore were highly adaptive dialog-based interfaces, which combined natural speech, facial expression, gesture, and conventional graphical interfaces. In this way, the systems allowed for addressing all human senses in quasi-natural communication settings. The *EMBASSI project* [16,60,61] focused on assisting the operation of complex technical devices of everyday life, thereby providing access to their functionalities without any deeper technical knowledge required. This was achieved by establishing a flexible conversational-like dialog between the human user and the technical system, with the interfaces being based on psychological and ergonomic studies. In following this direction, the initiative developed intelligent assistance and anthropomorphic interfaces, combined with a corresponding architecture, infrastructure components, and protocol standards.

Focused on multi-modal dialog systems, the *SEMAINE (Sustained emotionally colored machine-human interaction using non-verbal expression)* FP7 initiative [29,83] followed the vision to provide these systems with a technology such that a human user is able to engage with them in an everyday conversation. The key element is to build an avatar with a rich facial expression, who reacts in particular on the user's non-verbal signals and traits of his or her emotional state. The communication, although no "real" content is understood, becomes believably emotionally colored. This "Sensitive Artificial Listener" is the underlying metaphor for SEMAINE's human-computer interface design.

Affective computing became a larger and more general research topic in the area of computer science and so it did in particular in realizing Companion-like functionality. In the mid-2000's, an FP6 project was funded that was exclusively dedicated to research on emotions in the course of man-computer interaction: the *Human-Machine Interaction Network on Emotion (HUMAINE)* [73]. Its members aimed at so-called *Emotion-oriented Systems*, that means, systems that are able to recognize emotions of human users, which can build an adequate representation of the underlying emotional states and processes, and that are capable of interacting on them. This includes research topics on emotion theory, signals, emotional aspects of interaction, emotions in cognition and actions, emotions in communications, and usability aspects of emotion-oriented systems.

After the network's completion, the HUMAINE consortium became the nucleus for *The Association for the Advancement of Affective Computing (AAAC)* [1], which is an active stakeholder in the field. Among others, the AAAC organizes the *Audio/Visual Emotion Challenge and Workshop*, the competition on emotion analysis methods on multi-modal corpora.

In 2006, the DFG established the excellence cluster *Cognition for Technical Systems (CoTeSys)* [15,33,49]. It was devoted to research in the areas of design, implementation, and analysis of information processing methods that constitute cognitive processes in technical systems [33]. In this long-term, interdisciplinary initiative technical systems have been modeled on the human brain with respect to learning and reliably performing complex activities, to adapt to changes in the environment and objectives, and the like. The project joined research in technical disciplines together with neurobiology and cognitive sciences in order to realize and evaluate technical solutions to perception in multimodal sensor feeds, to learning and knowledge acquisition, to behavior planning, organization and control, and to human-computer interaction models.

One of the most influential projects to the notion of Companion-technology is *COMPANIONS* [13,92], funded under the FP6 programme. It depicted Companion-systems as virtual conversational agents, which communicate with their users primarily via spoken language, but also employ touch-sensitive displays and others sensors. The research agenda of this project included many of the before-mentioned capabilities that are associated with verbal interaction: dialog management, speech recognition and synthesis, and emotion detection and elicitation. In addition to these technical issues, COMPANIONS also examined long-term aspects in the user-Companion relationship like the expanding engagement of users and the increasing demand for respecting their preferences and inclinations. With envisioning Companions to participate in everyday activities, the project also covered their philosophical and social implications. All these topics presented themselves to be even more relevant in application areas like fitness and health coaching or elderly care scenarios.

3.2 Currently Active Projects in Focus Areas

The majority of current projects that deal with pieces of Companion-technology employs the notion of an embodied, more or less anthropomorphic companionship, which in turn often translates into projects on autonomous robotic platforms to assist human users in their everyday lives. We will therefore start by focusing on a few representatives of this direction, which subsumes a vast number of methods and practical solutions.

Robotic companions become more and more socially engaging and in order to build or maintain a believable relationship, this requires them to adapt to the experiences they share with their human users. This personalization of autonomous platforms, together with all its technical and psychological issues is addressed by a number of cognitive robotics projects, for example the *MIT Personal Robots* projects [22] at the Massachusetts Institute of Technology or the researchers training initiative *Applications of Personal Robotics for Interaction and Learning (APRIL)* [5], funded under the Horizon 2020 Framework of the European Union (H2020). Their research centers around adaptation and learning mechanisms in technical systems, with which users prefer to interact in a natural, human-like fashion.

The H2020 project RAMCIP [28] addresses a specific kind of domestic service robot, a *"Robotic Assistant for MCI patients at home"*. The vision is to provide the autonomous system with higher-level cognitive capabilities such that it can pro-actively assist elderly people, patients suffering symptoms of beginning Alzheimer's disease, and the like. In these application domains, the right proportion of a level of discreteness and actual assistance provisioning is key, because the patients' autonomy must not be violated and the persons are supposed to be stimulated properly in order to stay as active as possible.

The aspect of the robotic Companion stimulating its user for medical purposes is also central to *Cognitive Development for Friendly Robots and Rehabilitation (CODEFROR)* [10]: The autonomous system is supposed to provide training and rehabilitation techniques for children with sensory, motor, and cognitive disabilities. It is another example of a target user group that heavily depends on natural and intuitive interfaces. In order to deliver adequate assistance concepts and mechanisms, this FP7 project focuses in particular on developmental issues of human cognition like the evolution of action representations, intentions, and emotions.

PAL, the *Personal Assistant for healthy Lifestyle* [26], builds upon some of the results of *ALIZ-E* (see above). It proposes the combination of a robotic platform, a virtual avatar agent, and a number of interactive health-related devices, which together constitute a health-related assistance system for young patients and their caregivers. Type 1 Diabetes Mellitus is a complex illness with serious risks, which on the one hand requires the patients to acquire and strictly adhere to specific habits within their diabetes regimen and which on the other hand demands for personalized and context-sensitive support in order to reduce the diabetes-associated risks persistently. It is the H2020 project's vision, that the robot and avatar serve as incarnations of the child's personal Companion, while the other system components support their parents and caregivers with respect to information sharing, regimen coordination and the like.

A primarily virtual avatar-based approach is followed by FP7's *Miraculous-Life for Elderly Independent Living* [20], which aims at unobtrusively supporting elderly people in their daily activities and safety needs. The avatar metaphor is chosen to allow the users to connect emotionally more easily. This is supported by providing the avatar with the capacity for behavioral and emotional understanding, allowing for interactions involving, e.g., facial expressions, gestures, and contextual information. This human-like company is expected to stimulate and motivate older people to stay active.

A universal "ease of use" and intuitive interfaces for technical systems in general is the goal for the DFG excellence cluster *Cognitive Interaction Technology (CITEC)* [9,81]. To this end, the researchers examine a variety of cognitive processes concerning interaction and communication, ranging from the integration of perception and motoric functions to mediation mechanisms for shared attention between human users and technical systems. They regard any communication with the systems as situational acts that require to coordinate speech, perception, and motoric action. As a consequence, learning and knowledge acquisition techniques in these areas become central research issues, as well as recognition, analysis, and goal-driven control of attention on objects in the environment as part of an emotional and social interaction.

One important aspect of Companion-technology is to provide systems with the means to enable and process a broad variety of input and output modalities. In this regard we find a large number of HCI-related projects that put emphasis on the sensory side. The *MIT Responsive Environments* laboratory [23] produces examples for augmenting the environment with a plethora of individual sensors and sensor networks. Building a coherent model of integrated sensory information is an ongoing challenge in this area. But the classical sensors for gathering visual and auditory information are not the only concerns of the community: *"Sensory Experiences for Interactive Technologies"* [70], a project funded by the European Research Council (ERC), aims for example at extending interactive technologies by integrating touch, taste, and even smell experiences. And although exploiting gestures as an input for systems is suggested by several research initiatives, the *BODY-UI (Body-based User Interfaces)* ERC project [7] studies the use of the body as a modality for input and output matters likewise. The aim is to understand how a user's cognitive processes are reflected by his or her body, and vice versa, and eventually how this can be exploited for creating natural interfaces. A *Corpus-Based Multimodal Approach to the Pragmatic Competence of the Elderly (CorpAGEst)* [14], funded under FP7, explores the use of speech and gesture modalities in particular amongst elderly people. The interaction patterns and their modalities are supposed to change with age and therefore this project's results may provide exploitable data for adapting assisting systems appropriately. On the subconscious level, a related topic is addressed by *Symbiotic Mind Computer Interaction for Information Seeking (MindSee)* [19] (FP7), which analyses EEG and discreet peripheral physiological sensors and combines them with available interaction context information. The project aims at exploiting these implicit cues of the user's perception and emotions in information retrieval applications. Similar topics are addressed from a different angle by the *ARIA-VALUSPA (Artificial Retrieval of Information Assistants - Virtual Agents with Linguistic Understanding, Social skills, and Personalized Aspects)* H2020 project [6]: The assisting avatar is to be realized as an anthropomorphic character that is capable of holding human-like multi-modal social interactions. Verbal and non-verbal cues are used to modify searches or filter results.

There are many more research initiatives in the field of human-computer interaction, which contribute to the ideas of accessibility in Companion-technology. For instance, the technical implementation of intelligent and reliable multimodal user interfaces is the driving force behind the DFG excellence cluster *Multimodal Computing and Interaction (MMCI)* [24,84]. This includes processing of natural spoken language, dialog management, image processing for three-dimensionally reconstructing scenes and poses, and the synthesis of virtual scenes and interacting avatars. But it also involves technical aspects for providing a solid and trustworthy system infrastructure.

Further examples of the many different facets of interaction issues are the questions that arise from building up a shared understanding of complex contexts from basic concepts when *Communicating with Computers* [11], a program funded by the US Defense Advanced Research Projects Agency. Its vision follows the notion of human users being involved in a symmetric communication with a system when collaboratively developing solutions to given problems, including the language to actually communicate about that problem. Of course, the area of affective computing contributes by bridging the gap between human emotions and information technology - from the large number of projects we refer to the *MIT Affective Computing group* [21] and the before-mentioned *AAAC* [1]. These initiatives provide methods to sense and elicit emotional user states and are in particular suitable for detecting and handling enjoyable, stressful, or otherwise particularly meaningful episodes during an interaction. With a focus on providing natural access to assisting technology over a variety of devices, the *AIDE (Adaptive Multimodal Interfaces to Assist Disabled People in Daily Activities)* H2020 project [3] targets the needs of impaired persons. Here, the challenge lies in a shared-control paradigm for assistive devices, ranging from wearables to pervasive installations. As one final facet in our overview, we mention the European Union's FP7 *Prosperity 4All* initiative [27], which deals with the need for establishing an adequate ecosystem that enables developers to economically build self-personalizing interfaces and their corresponding hardware.

The issues of a universal notion of Companion-technology are comprehensively dealt with by the Transregional Collaborative Research Centre *Companion-Technology for Cognitive Technical Systems* [12,42,91,44,43]. This interdisciplinary initiative, funded by the DFG, systematically investigates cognitive capabilities and their implementation in technical systems. This is done while focusing on a set of key characteristics such as individuality, adaptability, availability, cooperativeness, and trustworthiness. Realizing these so-called Companion-characteristics by the integration of various cognitive processes in technical systems is intended to open a new dimension regarding human-technology interaction. Since the resulting Companion-systems will provide their technical functionality by taking into account the entire current and past situation of the user, including his or her emotional state as well as environmental conditions, these systems will finally be perceived and accepted as competent and empathetic assistants.

4 Conclusion

Companion-technology is an exciting field of research at the interfaces between AI and informatics, the engineering sciences, and the life sciences. It imposes a number of challenges on the disciplines involved and requires close cross-disciplinary co-operation. Among the main issues to be addressed are a consistent interlocking of information processing procedures to actually connect the sensory input levels of a prospective companionable system to its logical planning and decision making levels and vice versa; the design and conduction of comprehensive empirical studies to carefully explore both users' demands on the interaction and dialog capabilities of future technical systems and the effects of these capabilities once they are actually implemented; and finally the development of procedure models and tool support to enable the take-up of the technology in business and industry.

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Susanne Biundo is a professor of Computer Science at Ulm University and the Director of the DFG-funded Transregional Collaborative Research Centre *Companion-Technology for Cognitive Technical Systems* SFB/TRR 62. She led the *European Network of Excellence in AI Planning* and acted as the Co-chair of various international AI conferences. Susanne Biundo was elected ECCAI Fellow in 2004 and was a founding member of the Executive Council of ICAPS, the *International Conference on Automated Planning and Scheduling*. Her research interests are in AI Planning, Automated Reasoning, Knowledge Modeling, and Cognitive Systems.

Daniel Höller received his M. Sc. in Computer Science from Bonn-Rhein-Sieg University of Applied Sciences in 2013 and joined the Institute of Artificial Intelligence at Ulm University afterwards. He is interested in Automated Planning and currently working on his Ph. D. on Plan and Goal Recognition in the context of the SFB/TRR 62.

Bernd Schattenberg is a freelance developer and consultant for AI planning and scheduling (P&S) technology since 2013. Before that, he was a Research Assistant at the Institute of Artificial Intelligence of Ulm University, where he received his Ph.D. in 2009. He coordinated the *European Network of Excellence in AI Planning* and the Transregional Collaborative Research Centre *A Companion-Technology for Cognitive Technical Systems* SFB/TRR 62. His interests include knowledge engineering methods, mixed-initiative aspects, and novel application areas of hybrid P&S.

Pascal Bercher received his diploma in Computer Science from the University of Freiburg, Germany. He is now working on his Ph.D. in the SFB/TRR 62 at the AI Institute of Ulm University. His area of research focuses on hierarchical task network (HTN) planning, Partial-Order Causal-Link (POCL) planning, and the fusion thereof, called hybrid planning. His thesis is concerned with theoretical foundations, planning heuristics, and practical applications of these planning paradigms.