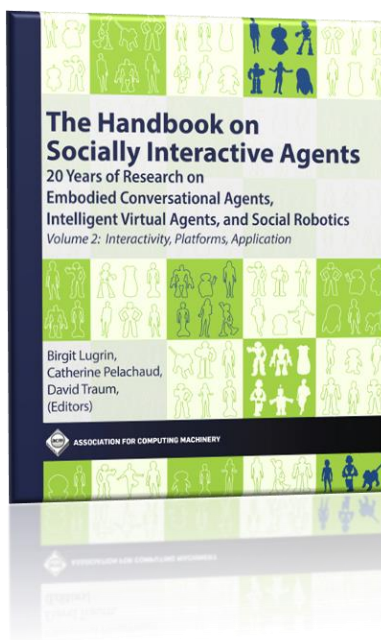# Preface

Birgit Lugrin

Author note:

This is a preprint. The final article is published in "The Handbook on Socially Interactive Agents" by ACM.
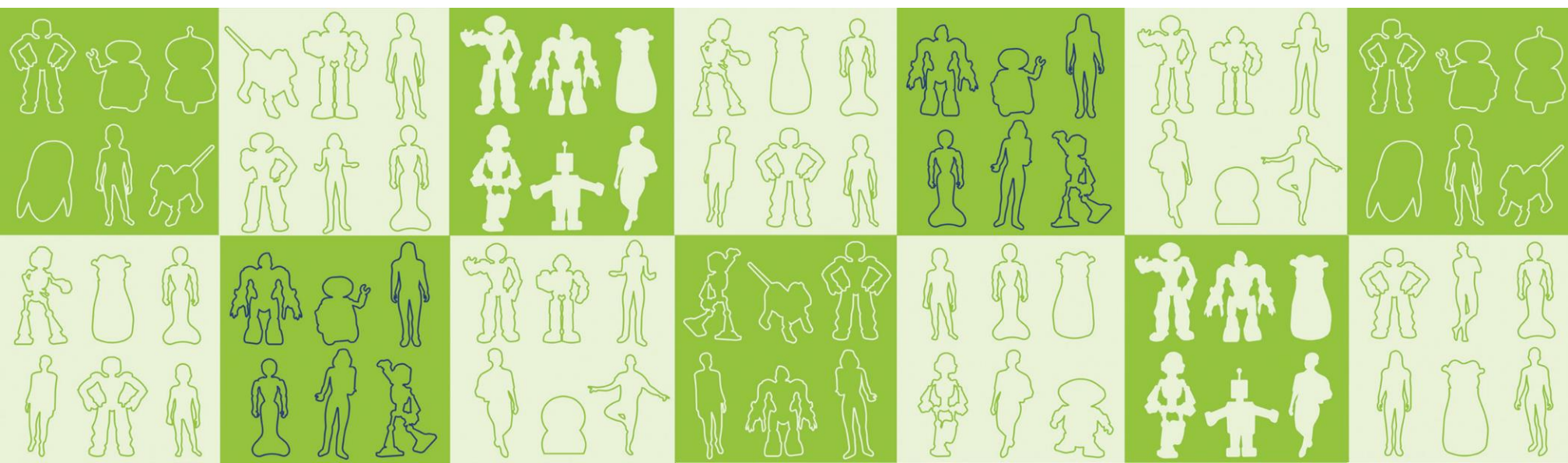
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Preface

Birgit Lugrin

This preface is a short version of the introduction chapter of this handbook [Lugrin 2021], which can be found in volume 1 [Lugrin et al. 2021]. Here, we repeat the definition of Socially Interactive Agents (SIAs), state the purpose of this book, and introduce its contents and terminology. It extends the introduction chapter by adding more details on the content of volume 2, including a new chapter that reports on interviews with leading experts on the current challenges of SIA research. For further information on the potential of or vision for SIAs, their origin, characteristics of embodiment, or suggestions on further readings, please refer to the chapter 1 "Introduction to Socially Interactive Agents" [Lugrin 2021] of volume 1 of this handbook [Lugrin et al. 2021].

The research area of Socially Interactive Agents aims to develop artificial agents that can interact via communication channels that come more natural to human interactants, by equipping the interface with a body that interacts multimodally by using verbal, para-verbal and non-verbal behaviours. With it, communication styles that are known from human face-to-face interaction can be transferred to the interaction with machines.

Socially Interactive Agents (see Figure 1 for examples) have been developed under different names in different research fields such as Intelligent Virtual Agents, Embodied Conversational Agents, or Social Robotics (see below for definitions of the respective terms). More than 20 years of research and development in these fields have drastically advanced the state of the art. For this book, we chose to use the term Socially Interactive Agents (SIAs) as it includes both physical and virtual embodiments, while highlighting their ability for social interaction, as well as the need to realize socially intelligent, autonomous behaviours.

We define SIAs as follows:

> *Socially Interactive Agents (SIAs) are virtually or physically embodied agents that are capable of autonomously communicating with people and each other in a socially intelligent manner using multimodal behaviours.*

In order to interact with humans in a socially intelligent manner, underlying concepts such as emotions, empathy or how to behave in a group are essential for SIAs to interpret. To be part of the interaction, observed input must be reasoned about, and decisions to be taken upon
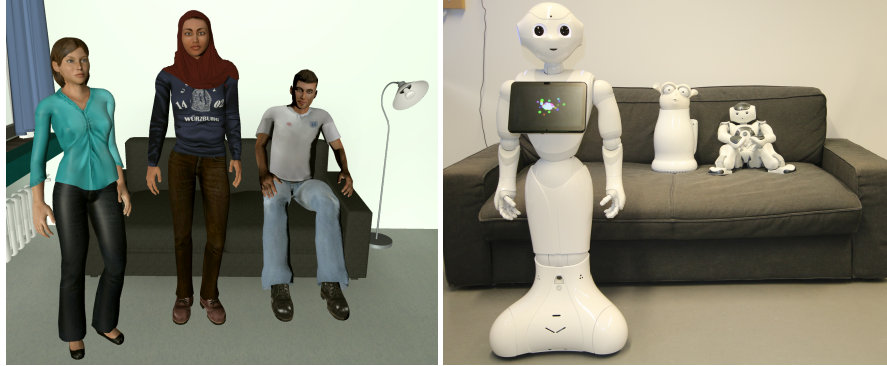
Figure 1   Examples of Socially Interactive Agents: Intelligent Virtual Agents (left) and Social Robots (right). SIAs in both figures are located in the same virtual vs. physical office space (reflected reality) [Eckstein et al. 2019], used for various research in the Media Informatics Lab of Wuerzburg University (left to right: two female agents and a male agent by Autodesk, partly adapted by features such as clothing style, Pepper by SoftBank Robotics, Reeti by Robopec, Nao by SoftBank Robotics)

that resemble a cognitive process. The SIA's (re)actions need to be externalized by natural language, expressive speech and non-verbal behaviours.

Thanks to extensive research, today prototypes including SIAs are used in many application domains helpful for individuals or today's society, with SIAs serving as companions or assistants in ageing support, health education, lifelong learning, or training of specific skills. On the long run, SIAs are envisioned to unobtrusively support humans in their daily lives.

A concern or fear that many researchers in the research area of SIAs are confronted with is the conception that these agents might be developed to replace humans, in the workplace or even in social relationships. It is very important to note here that a replacement of humans is not, and has never been, a goal in the development or research on SIAs. On the contrary, SIAs are developed to support humans and assist in situations where no human support can be provided or is not desired, and to offer additional functionalities or support in social domains. We want to further highlight that, particularly since SIAs enter social domains, development has to follow interdisciplinary approaches and methods, and needs to include, besides the technical knowhow, expertise in psychology, sociology and ethics.

Purpose of the Book

The fields of intelligent virtual agents (IVAs) and social robotics (SRs) face similar research issues and challenges and are further developed in universities and research facilities across the world. Research on IVAs and SRs can highly benefit from one another and have con-

tributed to each other's advancement in the past. However, substantial work in both research fields is sometimes overlooked by researchers in the other area. This is partly due to the fact, that different wordings are used and there exists a large number of journals and conferences that publish works on SIAs, making it very difficult to keep a good overview (see chapter 1 "Introduction to Socially Interactive Agents" [Lugrin 2021] of volume 1 of this handbook [Lugrin et al. 2021] for a list of journals and conferences). Please note that while we intended to involve the communities of IVAs and SRs, the content of this book, or particular chapters, are of interest for other communities as well, for example for people working with voice assistants, conversational agents, virtual reality, game design, animation videos, assistive robots, or other types of systems containing autonomous agents.

The interdisciplinary nature of SIA research highly contributes to the very diverse venues where you can find relevant findings on SIAs. While researchers from the cognitive sciences bring expertise in underlying processes, communication, and interaction, computer scientists bring expertise in conceptualising computational models and implementation. Even within a single discipline, approaches, methods and wording can be used differently, complicating cooperation. In computer science, for example, many areas are involved in SIA research, such as artificial intelligence, human-computer interaction, robotics, computer graphics, or software engineering. Only through communication and research in interdisciplinary teams the field can be advanced. This constitutes one major challenge by itself, as researchers sometimes do not have enough insight into other areas (or even disciplines), and thus might not appreciate each others work enough.

We hope that this handbook will help raise the visibility of the research in the fields involved and further close the gap between the IVA and SR communities. This comprehensive handbook on Socially Interactive Agents (SIAs) summarizes the research that has taken place over the last 20 years. We are referring to this time period, since the first complete book on Embodied Conversational Agents ([Cassell et al. 2000], see above) appeared in 2000, although we are aware that research on this topic started before. By pointing out current challenges and future directions in the various topics involved, we hope to help directing future research and cooperation. In the book, we include views from an interdisciplinary perspective, containing theoretical backgrounds from human-human interaction, their implementation in computational models, their evaluation with human users, integration into applications, and ethical implications.

In a structured and easily accessible way, the book (hopefully) provides a valuable source of information on SIAs for research and education. Researchers in the research area of SIAs will find it a valuable overview of the field. Teaching staff will benefit from the handbook to structure courses for undergraduate or graduate students, and with it train the new upcoming generation of young researchers.

Particularly now, the public interest in SIAs is increasing. The book will also help professionals, and interested lay public readers, to get acquainted with the research area.

Structure of the Book

This handbook is split into two volumes, including 28 chapters that are grouped in five major parts, to cover the major topics in the area. For the book, we have relied on our connections to both fields, IVAs and SRs, providing a collection of surveys, each written by (an) acknowledged international expert(s) of their field.

Each chapter provides a survey that summarizes the theoretical background, approaches for implementation, history / overview of the topic, alongside with current challenges and future directions. All chapters discuss similarities and differences between IVAs and SRs and highlight important work of both fields. Where applicable, the chapters will follow a common structure to ensure internal consistency and facilitate understanding. In addition to the content of this handbook as outlined in volume 1, we have added a challenge discussion to the end of this volume as an appendix.

Volume 1

After the first chapter [Lugrin 2021] that introduces readers to the handbook, volume 1 [Lugrin et al. 2021] starts with **Part I "Establishing SIA Research"** that helps understand how research in this area is conducted and discusses the impact thereof on individuals and society.

Chapter 2 "Empirical Methods in the Social Science for Researching Socially Interactive Agents", by Astrid Rosenthal-von der Pütten and Anna M. H. Abrams [Rosenthal-von der Pütten and Abrams 2021], introduces the empirical methodology from the social sciences that is necessary for SIA research, particularly when it comes to research experiments including human participants.

Chapter 3 "Social Reactions to Socially Interactive Agents and their Ethical Implications", by Nicole Krämer and Arne Manzeschke [Krämer and Manzeschke 2021], looks at SIA research from a psychological and ethical perspective. It points to numerous studies demonstrating that people (unconsciously) react socially towards artificial entities, and that as soon as they display social cues, people can also be manipulated or socially influenced.

Part II "Appearance and Behaviour", deals with the impact of the looks of SIAs and the various aspects of multi-modal behaviour that need to be taken into account when convincing SIAs behaviour is modelled.

Chapter 4 "Appearance", by Rachel McDonnell and Bilge Mutlu [McDonnell and Mutlu 2021], argues that compared to voice assistants, embodied agents enable the use of appearance-based cues from human-human interaction, such as mutual gaze, that are known to improve social outcomes. The chapter shows that the appearance of an SIA can affect how people perceive, respond to, and interact with it.

Chapter 5 "Natural Language Understanding in Socially Interactive Agents", by Roberto Pieraccini [Pieraccini 2021], introduces natural language understanding as an essential part of

any interactive agent and highlights its complexity, particularly for SIAs that need to react to user initiated interactions across various application areas.

Chapter 6 "Building and Designing Expressive Speech Synthesis", by Matthew Aylett, Leigh Clark, Benjamin R. Cowan and Ilaria Torre [Aylett et al. 2021], gives an overview of definitions, methods and state-of-the art in expressive voices, and critically discusses when and where expressive speech is beneficial.

Chapter 7 "Gesture Generation", by Carolyn Saund and Stacy Marsella [Saund and Marsella 2021], discusses the complexity of communicative gestures and how they enhance communication in human-human conversation, and summarizes the research and their challenges in the transfer of this complexity in the implementation with SIAs.

Chapter 8 "Multimodal Behaviour Modelling for Socially Interactive Agents", by Catherine Pelachaud, Carlos Busso and Dirk Heylen [Pelachaud et al. 2021], extends the theme non-verbal behaviour by adding additional modalities such as gaze, smiles or social touch. Starting from introducing concepts from the social sciences, the chapter has a strong focus on the different computational models that can be employed for the implementation of multimodal behaviours.

Part III "Social Cognition - Models and Phenomena" investigates internal processes known from human cognition that are driving forces in human-human interaction, and demonstrates how they are addressed in SIA systems.

Chapter 9 "Theory of Mind and Joint Attention", by Jairo Perez-Osorio, Eva Wiese and Agnieszka Wykowska [Perez-Osorio et al. 2021], introduces the two crucial mechanisms of social cognition, and explains how they apply to the interaction between humans and SIAs from two angles: evoking human social cognition, and modelling artificial social cognition.

Chapter 10 "Emotion", by Joost Broekens [Broekens 2021], focuses on the computational representation of emotion and other related affective concepts such as mood, attitude, or appraisal and highlights how SIAs can make constructive use of them.

Chapter 11 "Empathy and Prosociality in Social Agents", by Ana Paiva, Filipa Correia, Raquel Oliveira, Fernando Santos and Patrícia Arriaga [Paiva et al. 2021], focuses on empathy and in particular on the related concept of prosociality (conducting positive and voluntary behaviour that should benefit others). With it, the authors provide a framework including the main variables needed to design prosocial agents, for individual or dyadic interactions, or at the society level.

Chapter 12 "Rapport Between Humans and Socially Interactive Agents", by Jonathan Gratch and Gale Lucas [Gratch and Lucas 2021], introduces rapport (a fine grained emotional communicational interplay) in the communication of humans and machines, by approaching it from a theoretical, computational and empirical side, and demonstrating its benefits.

Chapter 13 "Culture for Socially Interactive Agents", by Birgit Lugrin and Matthias Rehm [Lugrin and Rehm 2021], argues that implementing culture for SIAs can be beneficial not

only to raise their acceptance in certain user groups, but also to be able to teach about cultural differences, and foster cultural diversity.

Volume 2

This second volume of the handbook starts with this preface, which recaps the most important aspects and terminology of the introduction chapter. The chapters following in part IV (modelling interactivity) and V (areas of application), rely on the first three parts of volume 1 of the book by applying the outlined research methods, using knowledge on appearance, verbal, para-verbal and non-verbal behavior, as well as relying on underlying cognitive phenomena. Thereby some concepts, topics or concrete applications might be present in more than one chapter, while being discussed from different research angles and from multiple points of view.

Part IV "Modelling Interactivity" explains how interaction with human users or other SIAs is modelled, and how the many detailed aspects of multimodal, multiparty, adaptive interactivity are implemented.

Chapter 14 "Interaction in Social Space", by Hannes Högni Vilhjálmsson [Vilhjálmsson 2022], deals with the intricate social performance that inevitably takes place when SIAs and human users share the same social space (virtual or physical), regardless of their explicit intentions to connect with one another.

Chapter 15 "Dialogue for Socially Interactive Agents", by David Traum [Traum 2022], introduces several approaches to modelling the structure of extended verbal and multimodal interactions, with an emphasis on how different kinds of embodiment impact the communication affordances and requirements for SIA tasks.

Chapter 16 "The Fabric of Socially Interactive Agents — Multimodal Interaction Architectures", by Stefan Kopp and Teena Hassan [Kopp and Hassan 2022], presents different SIA architectures and gives an extensive overview on how SIAs can engage in dynamic and fluid social interaction, discussing different approaches to deal with multimodality and interactivity.

Chapter 17 "Multiparty Interaction Between Humans and Socially Interactive Agents", by Sarah Gillet, Marynel Vázquez, Christopher Peters, Fangkai Yang and Iolanda Leite [Gillet et al. 2022], looks into SIAs that interact with a group of people for which the complex group dynamics need to be understood, and highlights that the SIA can affect and even explicitly influence the group's dynamics.

Chapter 18 "Adaptive Artificial Personalities", by Kathrin Janowski, Hannes Ritschel and Elisabeth André [Janowski et al. 2022], focuses on how a SIA can automatically adapt its personality in accordance with the user's preferences, and with it make the interaction with them more enjoyable and productive.

Chapter 19 "Long-term Interaction with Relational Socially Interactive Agents", by Jacqueline M. Kory-Westlund, Cynthia Breazeal, Hae Won Park and Ishaan Grover [Kory-

Westlund et al. 2022], argues that strong relationships support people to achieve their goals in various domains, and that thus relational SIAs have the potential to scaffold humans in their long-term endeavours.

Chapter 20 "Platforms and Tools for Socially Interactive Agent Research and Development", by Arno Hartholt and Sharon Mozgai [Hartholt and Mozgai 2022], gives a practical introduction to the history of SIA platforms and tools directing to state-of-the-art technical solutions that support the development and implementation of SIAs.

Part V "Areas of Application" gives an overview of the major domains in which SIAs are employed, pointing to systems and research findings, highlighting the benefits of SIAs to individuals and society.

Chapter 21 "Pedagogical Agents", by H. Chad Lane and Noah L. Schroeder [Lane and Schroeder 2022], introduces work with SIAs in the domain of education, examining social aspects of teaching and learning and summarizing empirical research with pedagogical agents.

Chapter 22 "Socially Interactive Agents as Peers", by Justine Cassell [Cassell 2022], describes work that uses SIAs that are designed to work or play with children or teenagers at an eye-level, discussing the benefits of SIAs that look and act like peers rather than teachers, tutors, or parents.

Chapter 23 "Socially Interactive Agents for Supporting Aging", by Moojan Ghafurian, John Edison Munoz Cardona, Jennifer Boger, Jesse Hoey and Kerstin Dautenhahn [Ghafurian et al. 2022], is centred on work with SIAs located in the area of aging support that aim to improve older adults' quality of life and wellbeing. The chapter provides methods and suggestions to address the many challenges that arise when designing SIAs that should successfully assist the targeted user group.

Chapter 24 "Health-related Applications of Socially Interactive Agents", by Timothy Bickmore [Bickmore 2022], addresses another area of major societal importance, and highlights the potential of SIAs that have shown to have a positive impact on voluntary changes in health behaviour.

Chapter 25 "Autism and Socially Interactive Agents", by Jacqueline Nadel, Ouriel Grynszpan and Jean-Claude Martin [Nadel et al. 2022], reviews work that uses SIAs to study or help improve the social skills of people with autism spectrum disorder. The chapter highlights the improvements that have been achieved throughout the last two decades and that, following a multi-disciplinary approach, more can be expected in the future.

Chapter 26 "Interactive Narrative and Story-telling", by Ruth Aylett [Aylett 2022], introduces narrative and storytelling as fundamental human capabilities, and outlines how SIAs are used in character- or plot-based systems, highlighting the great challenge of interactivity in this domain.

Chapter 27 "Socially Interactive Agents in Games", by Rui Prada and Diogo Rato [Prada and Rato 2022], discusses the complexity in which SIAs have been used in games, and introduces their different roles alongside with their contributions to gameplay.

Chapter 28 "Serious Games with Socially Interactive Agents", by Patrick Gebhard, Dimitra Tzovaltzi, Tanja Schneeberger and Fabrizio Nunnari [Gebhard et al. 2022], focuses on serious games that can partly be seen as a means to an end to achieve certain goals in various domains (such as education or health-behaviour change) using specific methods from games and interactive narratives. Thus the chapter focuses on learning gain as well as individual experience during game play.

Appendix A holds a "Challenge Discussion on Socially Interactive Agents", organized and edited by Birgit Lugrin and Catherine Pelachaud [Lugrin et al. 2021], that contains interviews with international experts of their fields who are all authors of this book, discussing the major challenges SIA research is facing today, pointing out potential future directions, and inviting other communities to join our journey. Interviewees were (in alphabetical order) Elisabeth André, Ruth Aylett, Timothy Bickmore, Cynthia Breazeal, Joost Broekens, Kerstin Dautenhahn, Jonathan Gratch, Stefan Kopp, Jacqueline Nadel, Ana Paiva, and Agnieszka Wykowska.

Appendix B holds short CVs of all authors and editors of this second volume of the handbook.

Terminology

Since research on SIAs is manifold and researchers are coming from different disciplines and research areas, a number of terms exist that can be found in the literature. In the following, we aim to shed light on the terminology (in alphabetical order), and highlight their origin and different foci, albeit you might find some of the definitions being quite similar:

Agent *"An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators"* [Russell and Norvig 2009]. This very classic and well known definition looks at agents from the perspective of Artificial Intelligence (AI), highlighting the autonomy of the artificial entities. Those agents can be, but are not necessarily, embodied. Examples include softbots, thermostats, robots or humans.

Avatar An avatar represents a game unit that is under the player's control [Kromand 2007], which is usually the graphical representation of the user in the virtual environment [Trepte and Reinecke 2010]. Unfortunately, this term is often confused with virtual or robotic agents in communities other than SIAs. Note that an avatar is not behaving or interacting autonomously with a user, but representing the user in the virtual or real world. The term embodiment also has a different meaning concerning avatars, and describes the physical process to substitute

(parts of) a person's body with a virtual one by the deployment of virtual reality (VR) hard- and software [Spanlang et al. 2014].

Embodied Conversational Agent *"Embodied conversational agents are computer-generated cartoonlike characters that demonstrate many of the same properties as humans in face-to-face conversation, including the ability to produce and respond to verbal and nonverbal communication"* [Cassell et al. 2000]. The term was defined by Cassell and colleagues in their same named book on the topic in 2000. The authors highlight the importance of the combination of the multi-modal interface, with a software agent and a dialogue system, to assure natural conversation. While the original focus was on virtual embodiments, the term also allows robotic embodiments, and is used in both fields.

Intelligent Virtual Agent *"Intelligent virtual agents are interactive digital characters that exhibit human-like qualities and can communicate with humans and each other using natural human modalities like facial expressions, speech and gesture. They are capable of real-time perception, cognition, emotion and action that allow them to participate in dynamic social environments"* [IVA 2019]. This term focuses on communicative, digital characters and is mainly used by researchers that are affiliated with the IVA conference series. An important fact lies on the character's intelligence that allows them to dynamically interact, as opposed to scripted behaviour.

Socially Assistive Robot Socially Assistive Robots were defined in [Feil-Seifer and Matarić 2005] as robots that share characteristics with assistive robots, in particular to provide assistance to users, but distinguish by their focus on social interaction while assisting people.

Socially Intelligent Agent *"The field of socially intelligent agents is characterized by agent systems that show humanstyle social intelligence"* [Dautenhahn et al. 2002]. The term was coined by Dautenhahn in the late 1990' and highlights the specific social intelligence of the agent, relying on *"deep models of human cognition and social competence"* [Dautenhahn 1998] which needs to comprise strongly interdisciplinary approaches. Different embodiments of these agents are possible, virtual or robotic.

Socially Interactive Robot Socially interactive robots were defined as *"robots for which social interaction plays a key role "* [Fong et al. 2003] in order to *"distinguish these robots from other robots that involve "conventional" human–robot interaction, such as those used in teleoperation scenarios"* [Fong et al. 2003]. This term was defined after the definition of socially intelligent agents, to highlight the need for social interaction.

Socially Interactive Agent The term socially interactive agents extends the term socially interactive robot, by allowing virtual and physical embodiments. This term was used by the AA-MAS (autonomous agents and multiagent systems) community and conference series, where they are described as *"capable of interacting with people and each other using social communicative behaviors common to human-human interaction. Example applications include*

social assistants on mobile devices, pedagogical agents in tutoring systems, characters in interactive games, social robots collaborating with humans and multimodal interface agents for smart appliances and environments"[AAMAS 2019].

Social Robot *"Social (or Sociable) robots are designed to interact with people in a natural, interpersonal manner [...] They will need to be able to communicate naturally with people using both verbal and non-verbal signals. They will need to engage us not only on a cognitive level, but on an emotional level as well in order to provide effective social and task-related support to people"* [Breazeal et al. 2016]. Social robotics is distinguished from robotics through its socially interactive focus with applications in domains such as education, ageing support or entertainment. This term is dominantly used by the social robotics community and the same named conference series and journal.

Virtual Character The term Virtual Character focusses on a virtual representation of a figure along with its animations. *"Virtual characters in animated movies and games can be very expressive and have the ability to convey complex emotions"* [McDonnell et al. 2008]. Note, that they do not necessarily have to be intelligent or interactive, c.f. characters of a movie. Thus, the term is often used by researchers that focus on the character's appearance, graphics, animation or background story.

Virtual Human *"Virtual Humans are artificial characters who look and act like humans but inhabit a simulated environment"* [Traum 2008]. The term focusses on the human-like appearance and behaviour and is frequently used by US American authors and research groups. Research on virtual humans often relies on highly realistic graphical representations of the characters and their animations.

Please note, that the terms introduced above are the ones most commonly used. Other variations, e.g. affective embodied agent, companion robot, conversational robot, relational agent, social embodied agent, socially intelligent robot, socially intelligent virtual agent, virtual agent, and so on, are also found in the literature and address similar research topics.

For the scope of this book, we use the term **Socially Interactive Agents** (SIAs) when we talk about both kinds of embodiment, virtual or robotic. We chose this term as we think it highlights the socially interactive nature as well as the intelligent background of the agent. In occasions where we discuss virtual representations of SIAs solely, we use the term **Intelligent Virtual Agent** (IVA). At occasions where we discuss robotic representations of SIAs solely, we use the term **Social Robot** (SR).

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