Social interaction with robots and agents: Where do we stand, Where do we go?

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Abstract

Robots and agents are becoming increasingly prominent in everyday life, taking on a variety of roles, including helpers, coaches, and even social companions. A core requirement for these social agents is the ability to establish and maintain long-term trusting and engaging relationship with their human users. Much research has already been done on the prerequisites for these types of social agents and robots, in affective computing, social computing and affective HCI. A number of disciplines within psychology and the social sciences are also relevant, contributing theories, data and methods relevant for the emerging areas of social robotics, and social computing in general. The complexity of the task of designing these social agents, and the diversity of the relevant disciplines can be overwhelming. This paper provides a summary of a special session at ACII 2009 whose purpose was to provide an overview of the state-of-the-art in social agents and robots, and explore some of the fundamental questions regarding their development, and the evaluation of their effectiveness.

1. Introduction

Robots and agents are becoming increasingly prominent in everyday life: as companions, coaches, user interfaces to smart homes, household robots, or for lifestyle reassurance. In these roles, they have to interact with their users in a complex social world, and need to be able to develop and maintain long-term, trusting and engaging relationships.

Much research has been done on the characteristics and the development requirements for these types of social agents and robots. The relevant areas include all three of the core areas of affective computing (emotion recognition, emotion modeling, affective user modeling, and emotion expression), the emerging area of social computing, with its emphasis on the development of long-term relationships and methods for studying and evaluating relationships among humans and social agents and robots. Psychology and the social sciences also offer theories, data and methods relevant for the design, development and evaluation of social agents and robots, and their interactions with human users.

Given the breadth and diversity of the relevant disciplines, the complexity of the task of developing effective social agents, and studying and evaluating their relationships with humans, can seem overwhelming. This paper provides a summary of a special session at ACII 2009 whose purpose was to provide an overview of the state-of-the-art in social agents and robots, as well to explore some of the fundamental questions regarding their development.

The session focused on three core aspects of social agent and robot research: the modeling necessary for the development of agent architectures, methods for evaluation of the agent-user relationships, and the overarching problem of methodologies required to develop theories and models in general.

Emotions represent a key element in developing effective and engaging human-agent relationships. This is particularly the case for social emotions such as empathy. While much progress has been made in the recognition, modeling and expression of emotions, most of this work has focused on basic emotions. Advances in social agents will require an increased focus on social emotions, which are more difficult to recognize, model and express.

The session content was based in part on the FP7 project "Social Engagement with Robots and Agents" (SERA, http://project-sera.eu), whose objective is to make progress in the study of social interaction with social agents and robots. The project SERA set up a field study in which subjects interact with a robotic user interface (the Nabaztag - www.nabaztag.com), enhanced with some sensor and ASR technology in their homes, over the period of one week. Video data from the first round of the study with the "baseline system" were available in time for ACII. An extract was shown and contrast with a video of human-human interaction. The videos were made available to the panelists well before the conference for them to watch, analyse, and comment.

The panelists were researchers in the areas that directly contribute to the development of social agents, addressing several fundamental questions: (1) What do

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we know already about social interaction with agents and robots, and about the role of emotions in it? (2) How can existing theories and data be of use in advancing our knowledge? How should we study them to extend our knowledge of social interaction with robots and agents? Which additional data, experiments, disciplines and methods should be called upon? (3) Are existing approaches to affective modeling capable of modeling both episodic and pervasive emotions in social agents and robots? What additional requirements and methods may be required to model these emotions? (4) Do we know enough to model systems that build and maintain long-term relationships with users? Are existing theories sufficient to explain what happens in this kind of social interaction, and existing models sufficient to generate it? What types of additional theories and models would be required? What types of data would be required and what are the best means of obtaining such data? This paper presents the panelists' position papers, where they outline their views of the above issues.

2. Christian Becker-Asano

What is needed for artificial companions?

If we believe that our products—robotic or virtual agents—will indeed have to fulfill the role of companions in our everyday life, then it is reasonable to think of the affordances that come with this type of social role, i.e. the type of (social) interaction the agents must be capable of. According to Merriam-Webster's online dictionary two possible definitions of the term "companion" are (a) "one employed to live with and serve another" or (b) "one that is closely connected with something similar". Following definition (a) a robot could function as someone's companion, if we could make this person believe that this robot (1) can *be someone* being employed in a household and (2) is *able to serve someone*. If we follow definition (b), (3) matching *similarity* and (4) establishing a tight *connection* between humans and robots seem to be the most important aspects.

An agent employed as a servant?

A dog of flesh and bones is much better at growing up alongside its human owner than AIBO (advertised as "Your artificial intelligent companion" on Sony's European AIBO website [25]). Thus, a *long term relationship* is less likely to evolve with any kind of robotic agent, if co-development is considered important. But regardless of being robotic or biological, dogs are not able to fulfill the role of butlers. An artificial butler, needs to have both a human-like appearance and sufficient social skills, including the ability to handle emotional signals regardless of the channels used to transmit them.

An agent providing services?

AIBO cannot provide much service. It can read out email, play music streamed over network and dance to it, and it follows simple verbal commands. Whereas a human butler could, for example, pick up the phone for me, say something like "Ahh, Mr. Smith!" while looking at me and waiting for my response. If then I shook my head, my butler would find a nice way to inform Mr. Smith that I am not available at the moment. Robotic or virtual agents would need a high degree of autonomy, understanding of social signals, and emotional skills to render such a service. In sharp contrast to this high-level social interaction, much simpler robots such as Roomba [13]are already treated as social actors in a household [14] probably because they provide a well-defined, practical service, i.e. vacuum cleaning. Remarkably, Roomba robots don't need heads or faces to be attributed a social role, but their autonomy might be a crucial factor.

An agent similar to humans?

The Roomba robots are only one extreme of designing sociable artifacts and their success seems to stem from their ability to do the one thing very well that they were designed for. Therefore, human owners probably don't expect their Roombas to possess any kind of social skills. If the defining factor of a companion is, however, *similarity* , then Roomba doesn't qualify. The android robot Geminoid HI-1 [23], for example, was explicitly designed as to resemble a real human. Its face is expressive enough to convey shifts of visual attention, and emotions such as surprise or amusement. It would be possible to let Geminoid act as an artificial butler,, in principle. If similarity in emotional expressivity is the key, then virtual agents have a lot to offer. MAX [1] [6], for example, is able to express a variety of simulated emotional states through facial expressions and tone of voice. Agents, of course, have the disadvantage of not sharing the physical space with us.

An agent connected with us?

There are at least two ways of understanding "connectedness": First, in the sense that sharing and manipulating the same physical world supports connectedness. The work on "presence" [23] relates to this understanding. Second, a more psychological view on "connectedness" deals with one's ability to feel or empathize with somebody else. We might start to accept the virtual butler as someone very similar to us only after a certain period of sharing our lives with him. Only if we come to believe that our butler is capable of experiencing emotions similarly to us, we might be able to connect with him in such a way that he becomes more than only our servant.

To decide on the direction of future research, we first need to state clearly which understanding of "companion technology" we have in mind. I am more interested in less application-oriented research and, thus, prefer research on robots that are similar to us in their outer appearances as well as their behaviors. But I see the necessity of doing research that takes the bottom-up approach of evaluating the power of simplistic robot designs to evoke social interaction in humans. Frequent, social interaction among researchers themselves, however, regardless of which approach they follow, is right now of utmost importance to advance this.

3. Kerstin Fischer

What do we know about (verbal) interaction with (speech processing) robots?

We know that users carry into interactions with robots an attention to the normative structures of interaction between humans. In particular, research in conversation analysis has shown that users attend to the turn-taking system in the way they attend to it in talk in interaction between humans [26][12], In many ways interacting with artificial communication partners is just like communicating with other humans.

We also know that the users' ideas about the functioning of the system determine the way they interact with it. If they hold the hypothesis that computers are particularly good formal thinkers, they may decide for instructions in degrees or meters, and use the compass as reference, even though this makes orientation in space very difficult for themselves [8]. The view of the robot as a social interactant determines users' linguistic behaviour considerably [9].

We have also found that users construe a partner model of their unfamiliar, artificial communication partner. Surprisingly, however, the robot's appearance plays a relatively unimportant role [8].

We also know that there are considerable interpersonal differences. While some users deal with the robot as a social actor [19][20], others refuse to do so even if the robot offers social communication to them [9].

Finally, since users actively engage in partner modelling, they readily make use of information presented by the robot implicitly and explicitly (Fischer forthc.). Moreover, they have been found to align with their artificial communication partner even more so than with other humans [4]. This, however, crucially depends on whether the robot is understood as a social interactant at all; users who regard the interaction as non-social do not align and resist any attempts to shape their linguistic behaviour.

How can existing theories and data be of use in advancing our knowledge?

There are several proposals on the market to frame the nature of social interaction with artificial communication partners theoretically (register theory, mindless transfer, evolutionary hypothesis, joint pretense, discursive practices, intercultural communication etc.), and I believe what we need is studies that help us distinguish between the different hypotheses.

Which disciplines and which methods should be involved? Which additional data, experiments, disciplines and methods should be called upon?

Wizard-of-Oz methodology is crucial to control the conditions in experimental settings. Useful as real life data may be, for scientific investigations data from interactions with implemented systems often depend too much on contingent factors. For some reason, the community seems to favour “real” data over controllable Wizard-of-Oz studies, which is really surprising given that the analogous data in psychology would be field observation versus controlled experiments.

In the area of verbal interaction with robots, at least linguistics, discourse analysis, social psychology, sociolinguistics, and sociology (especially ethno-methodology) need to be involved.

Regarding the methodological spectrum, I opt to use all methods we can get. Myself, I am using CA, comparative corpus elicitation and qualitative and quantitative corpus linguistics.

Do we know enough to model systems that build and maintain long-term relationships with users?

The main problem in the study of social interaction with robots I see lies in funding policies and the lack of reusable of resources, the pressure to construct running systems and therefore a focus on the “essential”, doable, which often does not leave enough time to include aspects of social interaction. These are, if at all, considered as add-ons to a system that first of all has to run.

4. Ana Paiva (with Iolanda Leite)

Emotional information exchange plays an important role in social interaction between humans, and many researchers believe that this also applies to human-agent interaction. Indeed, current research in synthetic characters considers emotional communication as one of the primary ways to achieve believability, as it helps to know that characters are aware and “care” about what happens in the world [2]. If tomorrow’s robots are going to be part of our world, they should have some emotional behaviour that allows them to communicate and respond in ways people can understand. Endowing robots with emotions can be very useful for a variety of reasons: (1) it facilitates human-robot interaction; (2) can provide feedback to the user, such as indicating the robot's internal state, goals and intentions; (3) can act as a control mechanism, driving behaviour and reflecting how the robot is affected by different factors over time [10]. The LIREC Project (Living with Robots and Interactive Companions, http://lirec.eu) aims to create a new generation of interactive and emotionally intelligent companions that are capable of establishing long-term relationships with users. Research focuses on both virtual agents and physically embodied agents such as robots. As part of one of the LIREC showcases, our group has been developing the behaviour of a social robot (Philips' iCat [5]) that acts as a chess companion. The iCat plays chess with children using an electronic chessboard. While playing with the iCat, children receive feedback from their moves through the robot's facial expressions, which are generated by an affective system influenced by the state of the game. Inspired by Scherer's classification of affective states [24], the iCat's affective system consists of two parts: *emotional reactions* and *mood*. Emotional reactions are triggered after every user's move, i.e., when the state of the game changes. Despite being of short duration, they are quite explicit. On the other hand, *mood* represents a background affective state, less intense but always present. The affective system is self-oriented or competitive, i.e., when the user plays a good move the iCat displays a sad facial expression and when the user plays a bad move the iCat displays positive reactions (for more details in the affective system please see [18]). We have adopted this approach instead of a more cooperative behaviour because, from our observations of children playing against each other in a chess club, such reactions are more consistent with what they might expect about their opponents.

From the preliminary studies we performed, we realized that this scenario was well accepted by users. First [16], we evaluated the effects of the robot's affective behaviour in the user's perception of the game. The results indicated that the developed affective model enhanced the user's perception of the game. In another study [21], the iCat robot and a graphical version of the iCat were compared in terms of user's enjoyment. The experience was classified as more enjoyable by the users who played against the iCat physical robot.

However, as most of the interactions in previous studies did not exceed one hour, we cannot claim that the user's engagement with the robot was due to its behaviour rather than just a consequence of the novelty effect. Early studies have shown that the novelty effect of robots and agents quickly wears out and that people change their attitudes and preferences towards them over time [11][15]. As such, we conducted another study to disambiguate those questions, where the main objective was to evaluate if user's perceived social presence towards the iCat changes over time and, if so, identify which aspects of social presence are most affected [17]. Biocca [3] proposed a definition for social presence oriented to human-computer interaction: "is the degree to which a user feels access to the intelligence, intentions, and sensory impressions of another". We conducted an experiment where the iCat played chess with children at a chess club once a week, over a five week period. We measured social presence both by questionnaires and video analysis (all the interactions were video recorded). The results suggested that social presence decreased after five weeks of interaction, namely on three specific dimensions of social presence: attentional allocation (the amount of attention the user allocates to the robot), perceived affective interdependence (the extent to which the user's affective state affects and is affected by the iCat's affective state), and perceived behavioural interdependence (the extent to which the user's behaviour affects and is affected by the interactant's behaviour).

Considering the specific characteristics of this scenario, the valence of the feeling experienced by the user was chosen to measure the degree to which the user's affect is positive or negative [22], and user's engagement with the iCat was chosen to describe the level of social interaction established between them. The framework for perceiving the user should be robust enough to work in real world scenarios. For this reason, the inputs for the affect recognition system include not only automatic recognition of user's facial expressions and body cues, but also information related to the context of the interaction (in this case information about the chess game, such as captured pieces and which player has advantage in the game). In [7], more details on the affect recognition system can be found.

There are still many open issues to investigate in socially interactive agents and robots, especially over a long-term basis where the novelty effect fades away and problems related to repetitiveness in the interactions arise. We are particularly interested in exploring the role of affect in such interactions, in the attempt to keep the user engaged with the companion far beyond the novelty effect. To overcome such challenge, we need to start addressing questions such as: will the user notice significant differences when interacting with an agent capable of understanding his/her affective state, and respond to it in an appropriate manner? Which mechanisms concerning social relations, companionship, friendship, etc. are more appropriate for artificial companions? Is it possible to overcome the "long-term challenge" without recurring to a significant amount of pre-scripted behaviours?

5. Christian von Scheve

Evidence suggests that humans, when interacting with "believable" robots or agents, rely on social norms comparable to those prevalent in human social interaction – at least to some degree. This observation is in line with phenomena such as anthropomorphism or people treating computers (even the simplest) as social actors, part of which stem from attributions of agency and lifelikeness. Although more robust evidence is definitely needed, the idea that humans indeed rely on well-established social norms in agent/robot interactions entails profound consequences: When norms are activated by situational cues (not even necessarily in an interaction), this usually leads to *multilateral* behavioral expectations, regardless of the actual activation of the norm in every single interactant. This is mainly due to the fact that norms are experienced as *socially shared* beliefs regarding the appropriateness or inappropriateness of a behavior. Accordingly, humans relying on social norms when interacting with agents and robots will most probably expect analogous norm-adherence in agent behavior.

This raises a couple of important questions: What gives rise to the activation of what kinds of norms in human-robot interaction? How can agents and robots be endowed with capabilities of norm activation and norm compliant behavior? And how does this impact human-agent/robot interactions?

One road to dealing with these questions lies in the manifold interrelations of social norms and emotions. Traditionally, norms are assumed to be cornerstones in the emergence and reproduction of social order. This capacity is usually broken down to their compelling nature in guiding or even constraining social action, thereby structuring social interaction and ultimately corroborating social order. However, the exact nature of these "mind-gripping" characteristics remains largely unknown. After several years of either postulating the mysterious (though intuitively plausible) "internalization" of norms or framing norm-oriented action as a specific kind of rational action, more recent approaches acknowledge the role of affect and emotion in norm compliance and enforcement. This role can be elaborated – even if only conceptually – with regard to different kinds of norms. Here, I will focus on injunctive and descriptive norms.

As for injunctive norms, i.e. norms that pre- or proscribe certain actions based on socially shared expectations, it has been shown that transgressing or perceiving transgressions of injunctive norms reliably elicits strong affective reactions. These negatively valenced affects (moral emotions) are said to sanction one's own norm-violations (shame, guilt), motivate punishment of transgressors (anger, disgust, contempt), or constitute – in the form of facial expressions – punishment in its own right. This effect seems to hold for different normative domains, from strict moral obligations to informal social conventions. It can thus be assumed that this "affect signature" of injunctive norms is a response to *social evaluation* and promotes behavior in accordance with what others frame as "appropriate."

Less obvious is the role of emotions in behavior conforming to descriptive norms, i.e. norms reflecting perceptions of what people *actually do*, but without entailing judgments of appropriateness or inappropriateness (except for the appreciation of conformity). Descriptive norms are thus rather based on *social information* than on social evaluation. They often conflate with injunctive norms or may be a precursor to them, but can well be unrelated or even in opposition to them. Although descriptive norms have been shown to be highly effective in influencing behavior, direct evidence on the role of emotions is still rare. One way to elucidate their role is to take conformity to descriptive norms as a form of habitualized and deeply socialized behavior. Framed this way, there is reason to believe that emotions indeed promote behavior that is (a) perceived to be performed by a majority and (b) has been instilled during socialization. Although speculative, the mechanisms in operation here are supposed to be closely tied to the role of emotion in information processing (e.g., affect-as-information, memory recall, fast-and-frugal heuristics, etc.).

In view of humans interacting with agents capable of generating, expressing, or even recognizing emotions, one might speculate that humans indeed attribute (or even expect) emotional reactions to own normative violations and at the same time react emotionally upon perceived normative transgressions. That is, an agent recognizing emotions from a human is well advised – at least in terms of "believability" – to interpret them as reactions to the normative status of its behavior in terms of social evaluation and to react correspondingly, inter alia on an emotional level. For instance, by expressing shame and thereby indicating that agent and human indeed share a set of normative beliefs, one would expect a significant contribution to stable relationship formation. In a similar vein, agents endowed with affective capabilities might be designed to override decisions promising high immediate (short-term, utilitarian) gains in favor of norm-compliance.

A similar role could be assigned to conformity to descriptive norms. In view of agent behavior, one crucial question concerns the reference group or "the majority." Here, two possibilities are suggestive: On the one hand, agents could take humans as a reference group and learn what is usually done and what not. On the other hand, agents might refer to other agents' successful behavior and take it as a model. This, however, would presuppose inter-agent/robot communication. Behavior adhering to descriptive norms might then become a goal in itself, i.e. a normative goal coupled with a conformity motive. The way agents' affective capabilities can be tied to this goal is again related to their information processing architecture and does not in principle differ from the assumptions underlying the affective "override" mechanism mentioned above, which has been discussed for quite some time in the emotional agents literature.

6. Conclusions

This paper summarized a special session panel held at ACI 2009, whose aim was to address some fundamental issues in the design and development of social agents, and the methodologies for evaluating their interactions with humans. The panelists' position statements highlighted key challenges and in effect defined a research agenda in this emerging area. These included: understanding of the possible types of human-agent relationships, and more interaction among the researchers (Becker-Asano), understanding of humans' individual differences in interactions with social agents, thorough evaluation of existing theories of human-agent interactions, and a better understanding of the appropriateness of different evaluation methodologies

(Fischer), importance of emotional communication for believability, and a sense of social presence (Paiva & Leite), and a better understanding of the roles of social norms, and their interactions with emotions, in establishing effective relationships (von Scheve).

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