Editorial

Towards intelligent social robots: Current advances in cognitive robotics

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1. Introduction

In 1950, Alan Turing described a now well-known thought experiment, which has now become known as the Turing test (Turing, 1950). While this has actually been adopted as a kind of benchmark for systems with some degree of AI, the original idea seems much more to be about the concept of intelligence being what we perceive it to be. If an unbiased human observer cannot tell the difference between human and machine in interaction then that machine can be claimed to posses some degree of intelligence. This puts interaction at the center of artificial intelligence.

However, in the past many approaches have rather taken a disembodied perspective (Dautenhahn, 2007). These had very little to do with interaction. For example, even the early artificial intelligence systems, which followed in close temporal proximity to Turing's work dealt with the problems posed to them by human programmers in isolation. One example was Newell and Simon's "General Problem Solver" (Newell, Shaw, & Simon, 1959).

Recent research in cognitive science and its allied disciplines, however, does strongly suggest that human cognition is not only very good at interaction but that interaction is indeed fundamental to human cognition. Culture and sociality may, indeed, create human cognition and intelligence. This finds support by a family of related theories, which puts interaction at the heart of human cognition, such as *The Social Brain Hypothesis* (Dunbar, 2003; Shultz & Dunbar, 2012) or the *Vygotskian Intelligence Hypothesis* (Moll & Tomasello, 2007). On the other hand, robots become more embedded into the social world that humans live in. Therefore, it seems to be an opportunity to reexamine whether artificial intelligence can actually profit from the social context, in which these new embodied agents will find themselves. Inspired by the cognitive science literature on the link between sociality and cognition, intelligent social robotics, hence, focuses on the social cognition aspect of robotics.

Robots are having an increasing omnipresent role in human social life, this requires them to be able to behave appropriately to the context of interaction and to have an accepted appearance for a human user. The problematic requirements of robot behavior and appearance for creating a successful long term human-robot relationship constitute major challenges in current cognitive science and robotics research. The complementary relationship between cognitive science and robotics defines the aspects of cognitive robotics research, which focuses on endowing robots with advanced cognitive abilities in order to perceive, reason, and behave autonomously in a similar intelligent manner to humans.

The use of robots side by side with cognitive science allows for modeling the hypotheses and theories of cognition so as to provide a clear conceptualization for cognitive functions considering the effect of the environment. This opens the door to several cognitive-social applications that require intelligent embodied robot behaviors, such as: modeling human learning and adaptation cognitive functions, defining the involved mechanisms in language and action development, understanding and generating multimodal affective behaviors, understanding a broad spectrum of cognitive developmental disorders (e.g., autism), and elderly assisted living, in addition to public interactive applications (e.g., receptionist robot, museum tour-guide robot, and tutor robot).

This special issue aims at shedding light on the intersection of cognitive science and robotics from the theoretical and technical aspects, covering the basic research and its applications. The recent advances and the future scope of cognitive robotics including the new methodologies, applied technologies, and robots are principal topics to be addressed in this special issue.

2. Summary of the special issue

In 1999, Dautenhahn and Billard (1999) coined the concept of ”social robots”, which refers to endowing embodied agents with high-level cognitive functions to engage in social interaction with human users. Developing such “intelligent social robots” takes robotics research to the center of artificial intelligence, neuroscience, and cognitive psychology research so as to cross the distance from human intelligence to artificial intelligence, where the fundamental target is to make robots able to perceive, think, and behave humanly and rationally in different contexts of interaction (Norvig & Russell, 2010).

During the last decades, researchers in both artificial intelligence and cognitive psychology were involved in developing theories of cognition to serve in building computational models that can make robots able to interact with human users in an intelligent manner, such as: situated and embodied cognition (Brown, Collins, & Duguid, 1989; Varela, Rosch, & Thompson, 1991), perceptual symbol systems (Harnad, 1990), and working memory (Baddeley & Hitch, 1974), which could give interesting insights into understanding the way humans think and behave.

The important role that cognitive robotics plays in understanding human cognition lies in providing the ability to examine hypotheses of cognition empirically through mechanistic embodiment for related theories of cognition (D’Mello & Franklin, 2011) so as to replicate human-like intelligence. However, to meet this target efficiently, a primary open challenge to address is how to quantify this “human-like intelligence” level. The philosophy of artificial intelligence describes this human-like level of intelligence by the ability of robots to solve the same problems that human users can solve by thinking. However, this raises other open questions, such as how can robots have mental states and consciousness as human users? Yet, a stubbornly elusive challenge for building intelligent social robots is meta-cognition, where robots need to build knowledge about how to employ specific learning strategies according to the situation of interaction and the environment (Metcalfe & Shimamura, 1994). However, this point is still being considered as a pure artificial intelligence challenge without real applications in robotics. In this special issue, we take a step forward towards bridging between different disciplines of cognitive science and robotics research with the objective of shedding light on current and future challenges in cognitive intelligent robotics.

Tsardoulias et al. (2017) propose the cloud-based RAPP framework that enables robotic devices to deploy robotic applications so as to reduce the computational load on robots. The developed robotic applications according to this paradigm allow social robots to adapt to several situations and scenarios. The study shows the efficacy of the RAPP paradigm in fulfilling the needs of end users as well as for developers.

Choi and Kwak (2017) discuss the concept of identity and presence in robot-mediated communication with remote humans. The study shows that both the robot identity level and the number of remote senders had an effect on the presence of the remote sender, in addition to both the telepresence and presence of the robot.

Wiltshire, Warta, Barber, and Fiore (2017) take a closer look at social cognition. The authors’ aim is to provide a set of recommendations with the aim of facilitating robots to become more capable of complex social interactions. For this purpose, they examine possibilities to facilitate the development of the perception, motor control, and an overall cognitive architecture for artificial cognitive systems of the future.

Parisi, Tani, Weber, and Wermter (2017) investigate how robust multimodal representations can naturally develop in a self-organizing manner from co-occurring multisensory inputs. They propose a hierarchical learning architecture with growing self-organizing neural networks for learning human actions from audiovisual inputs.

Schadenberg, Neerincx, Cnossen, and Looije (2017) discuss the effect of adapting the difficulty of a child-robot game on the motivation of the child to meet the challenge of the game. They propose a Bayesian-based user modeling module that adjusts the game difficulty to the level of the child's skills. The study shows that the Bayesian-rating module was able to measure the level of the child's performance during the game with the social robot.

Gonzalez, Pulido, and Fernandez (2017) introduce their NAOTherapist, a cognitive architecture for automated planning to perform rehabilitation sessions for pediatric patients with upper-limb disorders. These patients suffer from cerebral palsy or obstetric brachial plexus palsy and the NAOTherapist uses three levels of automated planning to assist these patients in the rehabilitation sessions. The social interactive robot takes on the role of a therapist in a hands-off rehabilitation, which allows training by imitation.

Looije, Neerincx, and Hindriks (2017) present an extension of the situated Cognitive Engineering (sCE) methodology: a formal template that describes the relations between support objectives, behavior change theory, design specifications and evaluation outcomes, called situated Design Rationale (sDR) and the method to obtain this. The sDR supports design of functionalities and evaluation before an experiment and reason about the effects and decisions afterwards.

Biswas and Murray (2017) present a number of experiments with robot companions, in which they model human-like cognitive biases. They focus on selected biases: misattribution, empathy gap, Dunning-Kruger, a humorous effect and self-serving bias. These biases are modeled and then tested in interaction with human subjects. The result is a discussion of how these effects of biases, which are prominent features of human cognition, can be useful in human-robot interaction.

Maniadakis, Hourdakis, and Trahanias (2017) present their work on timing, which is a crucial aspect of human-robot interaction. They integrate a planner into a simulated multi-robot scenario, in which one robot takes on the role of a human and one robot takes on the role usually fulfilled by a robot. Timing is then modeled using a representation of time intervals as fuzzy numbers. The authors evaluate their model by showing a collaboration between two simulated robots, in which they prepare a salad collaboratively.

Schneider, Goerlich, and Kummert (2017) present a framework for interaction with robots in assistive scenarios. The authors focus on reusability in socially assistive robots (SAR). They present an interactive system, which uses motivational instruction patterns, and they evaluate it in a sports scenario. In this scenario, the software design principles interact with social context and the physicality of the robot.

Aly, Griffiths, and Stramandinoli (2017) define metrics and benchmarks for different aspects of human-robot interaction, and discuss the outcome of an annual workshop that focuses on recent advances in cognitive robotics. Besides, they provide a summary of an interactive discussion session between the workshop participants and the invited speakers about different issues related to cognitive robotics research.

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