Guest Editorial Cognitive Agents and Robots for Human-Centered Systems

***Abstract*—A current challenge for artificial cognitive systems is to acquire the capability to freely interact with humans in such a way that the burden of learning and adaptation lies with the machine and not with the human. This special issue presents a variety of recent developments in artificial cognitive agents, embedded in human-centric environments, with a particular focus on robotic applications. It aims to capture potential multidisciplinary research directions in order to further expand artificial system capabilities in an open-ended process while socially interacting in real environments for the humans' benefit.**

***Index Terms*—Cognitive architectures, computational models, human-robot interaction, smart interactive systems, social robotics.**

I. Scope of this Special Issue

COGNITIVE agents are computational models inspired by human cognitive capabilities to exhibit effective behavior through perception, action, deliberation, communication, and through either individual or social interaction with the environment [item 1) of the Appendix.] These software programs are especially suited to control complex systems, such as robots, which are designed to provide services and proactively interact with people and other artificial agents in composite human-centric environments.

In this view, the current effort of the interdisciplinary community working in the area of cognitive agents and systems is to reach a level of cognition and motor intelligence that will provide autonomy in any environment (social or industrial), effective interaction with humans, and adaptation of their actions to an ever-growing range of open and dynamic situations [item 2) of the Appendix.] Cognitive agents are thus expected to be able to learn and predict perceptual and functional changes, that result as a consequence of human actions, replicate human activities taking into consideration their own capabilities and limitations and to develop the ability to function effectively in circumstances not explicitly planned when the system was designed [item 3) of the Appendix.]

A current challenge for artificial cognitive systems is to acquire the capability to freely interact with humans in such a way that the burden of learning and adaptation lies with the machine and not with the human.

This special issue offers a variety of recent developments in the topic with the aim to contribute to the multidisciplinary community working on cognitive and developmental systems in the identification of potential research directions, in order to provide artificial systems with the learning and behavioral capabilities in an open-ended process while socially interacting in real environments for the humans' benefit.

II. Contribution To the Special Issue

This special issue includes seven papers that present the human-centered development of cognitive systems in diverse scenarios, spreading light on the topic from multiple perspectives. Below, we briefly highlight the field of application and the main contribution of each paper.

Autonomous vehicles (also called self-driving or robotic vehicles) are indubitably one of the most promising applications of cognitive agents that could greatly benefit our society in the coming decades [item 4) of the Appendix.] They could potentially provide independent mobility for affluent nondrivers, reduced traffic and parking congestion, increased safety, and energy conservation and pollution reductions. These artificial drivers are expected to operate in urban environments in conditions without explicitly planned circumstances and dynamic environments. In the first paper, entitled *A Bio-Inspired Cognitive Agent for Autonomous Urban Vehicles Routing Optimization*, Vitello, Alongi, Conti, and Vitabile propose a bioinspired cognitive agent able to make optimized routing decisions thanks to the augmentation by the real-time information exchanged with other vehicles and the road sensor network to optimize traffic flows. The agent is based on metabolic networks (MNs) and makes use of vehicular ad hoc networks, which are formed by the interconnection of vehicles, control centers, and I/O urban data centers. The use of selected bioinspired analysis techniques, which are commonly employed to investigate the topological and functional features of an MN, allows the agent to analyze the structural aspects of a road network, find its extreme pathways and outline the balanced flow combinations. Experimental results coming from Palermo (Italy) urban road network show that the approach permits to find a better global routing optimization solution.

Human body motion and gesture analysis is a prerequisite procedure for understanding human activities, especially, in social contexts. The second paper, *Multilevel Body Motion-Based Human Activity Analysis Methodology* by Khoshhal, Dias, Peixoto, Metsis, and Nunes, proposes a general framework for the analysis of human body movements, taking into account possible interactions with the surrounding environment. This could be beneficial to human-centered cognitive systems, like social robots, for automatic understanding of

Digital Object Identifier 10.1109/TCDS.2017.2670787

human activity and social role identification and performing the appropriate interaction. The framework is composed of two levels: a Bayesian Network technique is used to implement the framework, while a mid-level body motion descriptor, using the Laban Movement Analysis system, provides a set of proper human motion-based features for linking low-level features to higher levels of human activities. The framework is tested using 3-D data from a motion capture device for the automatic estimation of human activities and behaviors, by exploring dependencies among different levels of feature spaces of the body movement.

Cognitive developmental robotics is the "interdisciplinary approach to the autonomous design of behavioral and cognitive capabilities in artificial agents (robots) that takes direct inspiration from the developmental principles and mechanisms observed in natural cognitive systems (children)" [item 5) of the Appendix,] [item 6) of the Appendix.] Following this approach, Pierris and Dahl presented a study on *Learning Robot Control Using a Hierarchical SOM-Based Encoding*, which is the third paper of this special issue. The paper contributes by extending the hierarchical self-organizing map-based encoding algorithm that is based on the constructivist learning architecture and derived from a computational model of infant cognition [item 7) of the Appendix.] Two novel features are introduced: 1) a novel skill acquisition feature in the complex domain of learning a double tap tactile gesture between two humanoid robots; and 2) the capability to recall past observations and reproduce rhythmic patterns. Two experimental simulations show how a complex behavior emerges from the automatic reuse of distinct oscillatory swimming demonstrations of a robotic salamander.

While artificial intelligence was moving its first steps, Alan Turing argued that "it is best to provide the machine with the best sense organs that money can buy, and then teach it to understand and speak English. That process could follow the normal teaching of a child. Things would be pointed out and named, etc." [item 8) of the Appendix.] Applying this vision to intelligent agents and robots, people should be able to naturally and intuitively teach them how to perform tasks and the machine behavior could be customized by end-users with no machine learning expertise. In this direction, the fourth paper [item 4) of the Appendix,] *Learning From Explanations Using Sentiment and Advice in RL* by Krening, Harrison, Feigh, Isbell, Riedl, and Thomaz discussed a cognitive agent that learns to play the famous Mario Bros. game using natural language explanations by a human teacher. The contribution focuses on the development of an object-focused advice methodology for reinforcement learning in which human advice is tied to objects instead of specific states and is generalized over the object's state space. In addition, the methodology uses a sentiment analysis to improve performance by filtering explanations into the advice of what to do and warnings of what to avoid. Authors also suggest that the method of interaction should be carefully designed to ease the cognitive load of the human teacher in order to improve the quality of his advice.

With the increase of robotic platform availability and applications, the supervision of collaborative semiautonomous multirobot teams is getting the attention of the robotic community in order to find solutions that can enable the human operator to efficiently control many robots without increasing their workload. This is particularly relevant in proximate interactions or of the necessity of freeing operator's hands. In the fifth paper, titled *Supervisory Control of Multiple Robots Through Group Communication*, Rossi, Staffa, and Rossi propose that communicating with robots by group utterances may be a viable way to scale up the number of robots in a multirobot system supervised by a human operator. A simulated environment is used to experimentally analyze the humans' interaction effort and the robot's effectiveness while increasing the number of robots involved in a joint task, in the two cases where the commands are issued towards single or grouped robots.

A cognitive system that interacts with humans is expected to be flexible and demonstrate the ability to execute structured cooperative tasks while reacting to unexpected events and behaviors of the human counterpart. In the sixth paper, *Flexible Task Execution and Attentional Regulations in Human-Robot Interaction*, Caccavale and Finzi present a framework that integrates cognitive control, executive attention, and hierarchical plan execution. In the proposed approach, the execution of structured tasks is guided by top-down (task-oriented) and bottom-up (stimuli-driven) attentional processes that affect behavior selection and activation, while resolving conflicts and decisional impasses. Experimenting on the framework in different case studies, the authors show that multiple concurrent tasks can be effectively orchestrated and interleaved in a flexible manner; moreover, in a human-robot interaction setting, they test and assess the effectiveness of attention manipulation for interactive plan guidance.

The article by Ma and Su titled *Aesthetics Evaluation for Robotic Chinese Calligraphy* completes this special issue. Authors investigate how robots can be capable of the highly abstract and perceptual problem of producing handwritten Chinese characters. The proposed learning strategy for a robotic controller is based on aesthetics evaluation for online stroke planning. The effectiveness of the proposed strategy is validated in a simulation on a database containing 400 calligraphy references, and verified though an experimental comparison of robotic Chinese calligraphy with and without the proposed aesthetic evaluation is performed with an NAO robot.

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APPENDIX
RELATED WORK

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Dr. Di Nuovo is the Coordinator of the H2020 MSCA-IF CARER-AID (Controlled Autonomous Robot for Early Detection and Rehabilitation of Autism and Intellectual Disability), and he was involved many research projects (e.g., FP7 ITALK, ROBOTDOC ITN, FP7 ROBOT-ERA) on the HRI multimodal interfaces. He has been involved in several Conference Committees, such as HM 2016, as the General Chair and FUZZ-IEEE 2017, as the Publication Chair. He is an Associate Editor of the *Cognitive Systems Research* journal and he was a Lead Guest Editor of special issues in renowned journals, such as *Adaptive Behaviour* and the *International Journal of Social Robotics*.

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