Triennial Report
IEEE RAS Technical Committee on Cognitive Robotics TC-CoRo

Chairs: Giulio Sandini, Matthias Scheutz, Shingo Shimoda, and David Vernon

1. Honest assessment of TC over past 3 years, goals for next 3 years, and feasibility of retiring the TC

TC-CoRo exists to foster links between the fields of robotics, cognitive science, and artificial intelligence (including computational intelligence and machine learning). The goal is to establish and promote the methodologies and tools required to make the field of cognitive robotics industrially and socially relevant. Since its establishment two years ago on 19 September 2014, TC-CoRo has been active on several fronts. In collaboration with the IEEE Computational Intelligence Society (CIS), it has **contributed to the launch of a new journal**: IEEE Transactions on Cognitive and Developmental Systems (TCDS), financially co-sponsored by IEEE RAS with a co-ownership of 20%. This is a significant development as it represents a shift in the focus of the predecessor journal, IEEE Transaction on Autonomous Mental Development, to include cognitive robotics. The co-chairs of TC-CoRo continue to actively support TCDS as associate editors and members of the steering committee. In keeping with the multi-disciplinary nature of TC-CoRo, it has supported the **organization thirteen workshops and conferences** that targeted the diverse areas underpinning cognitive robotics (see Sections 2 and 3 for details). TC-CoRo has supported **the Best Cognitive Robotics Paper Award** sponsored by Korean Robotics Society (KROS) in ICRA and IROS. This award encourages especially young researchers to advance the field of cognitive robotics. It has maintained the IEEE RAS **TC-CoRo website** as well as creating a dedicated external site (www.ieee-coro.org). This site provides access to a variety of resources to support research, teaching, and outreach. A wiki-based prototype of this resources page received over 35,000 visits prior to a recent migration to the website proper in July 2016. TC-CoRo has organized the **joint activities with other bodies** such as the European Society for Cognitive Systems (www.eucognition.org) and Biologically Inspired Cognitive Architecture Society (BICA). These activities are important to provide members of RAS TC-CoRo with opportunities for inter-disciplinary discussions. The **value of these activities** is reflected in the consistent growth in TC membership, from an initial cohort of 66 members, rising steadily to 120 members at time of writing, with global representation from America, Europe, Asia, and Australia. The relevance of these activities can be inferred from the strong emphasis placed by Industry 4.0 (also known as the Industrial Internet) on automation solutions that are highly cognitive and highly autonomous, enhancing collaboration between humans and machines, including next generation robots that work hand-in-hand and safely with humans.[1]

The goals for the next three years reflects the rapidly increasing societal demand for cognitive robotics, due in part to the emergence of new applications such as communication between drivers and autonomous vehicles, and between recipients of care and care-giving robots. Even in traditional settings, such as factory automation, robots and autonomous vehicle are coming into closer contact with humans, giving rise to a need for safe interaction. TC-CoRo will play a key role in connecting the academic seeds with industrial demands, creating opportunities for exchange of views on both sides and across disciplines. That said, cognitive robotics has not yet achieved the standing of a field of basic science and current academic

[1] Industry 4.0 - Challenges and solutions for the digital transformation and use of exponential technologies, Deloitte, 2014.

output is not yet sufficient to meet the pressing needs of application developers. To address this, in addition to its current activities in supporting IEEE TCDS and the organization of workshops, conferences, and awards, TC-CoRo will continue to provide opportunities for learning and discussing the scientific and engineering foundations of cognitive robotics, especially for the young researchers, with a view to establishing cognitive robotics as a scientific discipline in its own right.

Retiring TC-CoRo at this point in its development would waste the effort that has been invested over the past two years and, more importantly, it would preemptively destroy its potential to help foster a cohesive socially- and industrially-relevant engineering discipline.

2. List activities during past three years

TC-CoRo was established two years ago in September 2014. The following is a list of its activities in that period.

- Contribution to the launch of IEEE Transactions on Cognitive and Developmental systems, co-sponsored by RAS.
- Organization and Sponsorship of Workshops:
  1. Bio-inspired Social Robot Learning in Home Scenarios (IROS2016)
  2. Human-Robot Collaboration: Towards Co-Adaptive Learning Through Semi-Autonomy and Shared Control (IROS2016)
  3. Machine Learning Methods for High-Level Cognitive Capabilities in Robotics (IROS2016)
  4. Cognitive Robotics as Interdisciplinary Science (ICRA2015)
  5. Machine Learning in Planning and Control of Robot Motion Workshop (IROS 2015)
  6. Real-Time Cognitive Computing for Service Robots (IROS2015)
  7. Learning Object Affordances: A Fundamental Step to Allow Prediction, Planning and Tool Use? (IROS 2015)
  8. Tutorial on Cognitive Surgical Robotics (ICAR 2015)
- Award organization (Best Cognitive Robotics Best Paper award sponsored by KROS)
- We have been invited to prepare and submit a nomination for the most active TC

3. List of outreach activities outside the RAS

- Organization of 4th International Workshop on Artificial Intelligence and Cognition
- Special issue of “Cognitive Architectures for Artificial Minds” in the Cognitive Systems Research journal.
- Organization of RSS-2015 Workshop on Combining AI Reasoning and Cognitive Science with Robotics
- Organization of Workshop on “Neural-Cognitive Integration”, the 38th German Conference on Artificial Intelligence TU Dresden, Germany, 2015
- Co-organization of EuroAsianPacific Joint Conference on Cognitive Science

4. List of important publications over past 3 years in TC area

Papers in a sample of three areas are listed below; clearly there are many other important publications in the field of cognitive robotics.

Merging of physical and cognitive interaction

D. Song et. al., “Task-Based Robot Grasp Planning Using Probabilistic Inference”, IEEE Trans. Robotics,

2015
M. Deisenroth et. al., “Multi-Task Policy Search for Robotics”, IEEE International Conference on Robotics and Automation, 2014.
S. Shimoda et. al., “Adaptability of tacit learning in bipedal locomotion”, IEEE Transactions on Autonomous Mental Development, 2013.

Cognitive safety
J.R Hernández, et. al., “Synthesizing Anticipatory Haptic Assistance Considering Human Behavior Uncertainty”, IEEE Transactions on Robotics 31 (1), 180 – 190, 2015.
C. Schindlbeck et. al., “Unified Passivity-Based Cartesian Force/Impedance Control for Rigid and Flexible Joint Robots Via Task-Energy Tanks”, IEEE Int. Conference on Robotics and Automation, 2015.
P. Baxter et. al., “Cognitive Architecture for Human-Robot Interaction: Towards Behavioural Alignment”, Journal of Biologically Inspired Cognitive Architectures, 2013.

Publications on human motion understanding
D. Conti et. al., “Cognitive Robotics for the Modelling of Cognitive Dysfunctions: A Study on Unilateral Spatial Neglect”, IEEE International Conference Developmental Learning and Epigenetic Robotics, 2015.
M. Hirata et. al., “Hyperscanning MEG for understanding mother-child cerebral interactions”, Frontiers in Human Neuroscience, Vol.8, No.4, pp.618--623, 2014.
A. Sciutti et. al., “Investigating the ability to read others’ intentions using humanoid robots”, Frontiers in Psychology, vol. 6, (no. 1362), 1664-1078.

Robot Middleware
M. Beetz, et al., “OPEN-EASE —A Knowledge Processing Service for Robots and Robotics/AI Researchers”, International Conference on Robotics and Automation, 2015.

5. Number of members of each year in the past three years

TC-CoRo launched with an initial cohort of 66 members and since then it has almost doubled in size to 120 members (see http://www.ieee-coro.org/members for the names and date of joining of all members). This growth has been consistent and steady, with 70 admitted in 2014, 31 in 2015, and 19 so far in 2016.

6. Summary of top three technical innovations in the area during the past three years

The three outstanding innovations in the cognitive robotics field that we want to mention are

1. Merging of contact and non-contact interaction through cognition
2. Cognitive safety
3. Studies for understanding human communication with the goal of improving human-robot interaction

This selection is driven by the overall goal of TC-CoRo of building bridges between different research and academic communities. The development of robot middleware is also an important innovation in this field because this is now an indispensable for the effective implementation of the robot controllers with above functions.

7. Recommendations (and alternates) for new co-chairs

From 2016 onwards, one co-chair will retire and be replaced every year to ensure active and fresh operation TC-CoRo. We are in the process of inviting a new chair to represent the American region. Starting this year the role of corresponding co-chair will be taken on by Dr. Shingo Shimoda.