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

Chairs: Shingo Shimoda, Laurel Riek, David Vernon, and Giulio Sandini

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 primarily the links between the field of robotics and cognitive science and their relationship with artificial intelligence, medicine, and human sciences. The goal is to establish and promote the methodologies and tools required to advance the field of cognitive robotics and make it more industrially and socially relevant.

In 2017, TC-CoRo was selected as the recipient of the RAS Most Active Technical Committee Award. In the past three years, we have created the opportunities for exchange of views with various fields of researchers by organizing and supporting workshops and conferences. For instance, we organized the joint workshop in ICRA2018 with **Cognitive Robotics committee in Computer intelligence Society (Cogrob)** and discussed the role of AI in robot control. Organization and technical supports of **IEEE International Conference on Development and Learning and on Epigenetic Robotics** (ICDL) is another important activity to encourage the discussions on cognitive robotics in interdisciplinary form. In ICDL, not only robotics people but also the researchers in the field of psychology, rehabilitation therapy, human science etc. joined for further understandings of human's development and learning systems, and for creating robots based on human's cognitive systems. Participation in the Steering Committee of **IEEE Transactions on Cognitive and Developmental Systems** (TCDS) is also an important contribution to encourage the discussions on cognitive robotics. After three years since the journal's change of name TCDS has successfully got the impact factor in 2018. In addition to these major activities, we have supported the **organizations 32 conferences and workshops inside and outside RAS** in the past three years.

One of the most important trends on cognitive robotics derived from these activities is the discussions on full-fledged humanoid robot control. We think that time is ripe for summarizing the various type of individual cognitive skill to build autonomous humanoid robots with cognitive architecture. In order to strongly stimulate the discussion in this direction, we will organize **cutting edge forum entitled "Cognitive architectures for humanoids"** in IROS 2019 with the goal of assessing where we are today in our quest to build humanoid robots with cognitive abilities and human-level AI. On the other hand, in a complementary direction to the goal of achieving full autonomous control, a focus on partial (or supervised) autonomy is another trend of cognitive robotics, in which the robots move autonomously in limited settings, sharing its goals and behavior with humans. This has been tested in some novel application fields, creating the symbiotic interactions between human and robots. Rehabilitation and motion support for elderly and disabled persons are the potential fields for appropriate targets.

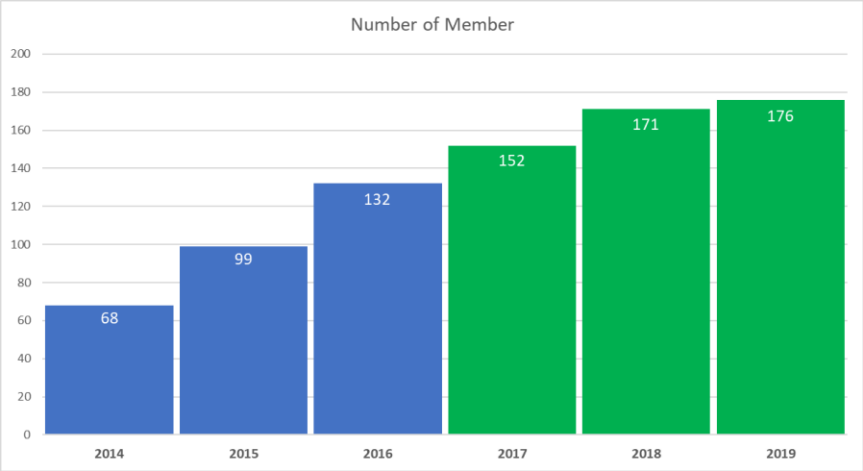

Fig. 1 TC-Coro Membership

The number of TC-CoRo members continues to grow (see Fig. 1), increasing 33% in the past three years,[1] from 132 at the end of 2016 to 176 at the time of writing. The ratio of work fields of CoRo member is Academic 79.8%, industry 20.2%. The membership application rate is slightly down for 2019 and this is something we intend to address by re-focusing our recruitment efforts (e.g. when giving talks at conferences and workshops) and by encouraging members to highlight the importance of cognitive robotics generally, and TC-CoRo, in particular.

One of the most important goals of TC-CoRo for next three years is the support of expanding the application targets of cognitive robots and systems. The social demands for cognitive robots and systems are rapidly increasing and changing. Indeed, the commercial failure of some social robot companies increasingly points to the need for a cognitive capacity in order to foster acceptance and engagement by users. As we prepare for robots to enter our homes, equipping cognition-enabled robots with the ability to carry out everyday activities will also become increasingly relevant. The quest for autonomous cars offers an ideal testbed to investigate the problems of joint action linked to negotiating shared roads with human users (car drivers, cyclists and bikers besides pedestrians. Human-robot anticipatory sharing of environment is a central aspect of social interaction involving cognitive skills. Many cognitive architectures such as the organization of unmanned shops and the operations by AI speakers like Alexa of Amazon and Google assistant can change our lifestyle. Not only the extension of the current trends mentioned above to reflect to these social demands, further advancements of cognitive skill and architecture are required. The stronger networks with other fields including academic and industry are also necessary. TC-CoRo will play the role both in encouraging the deeper discussions on cognitive robotics and in connecting these discussions with other fields. Furthermore, we will continue to make additional resources for cognitive robotics available on the TC-CoRo website (www.ieee-coro.org).

[1]Since this report is being prepared mid-year, these numbers reflect do not reflect the second half of 2019. The final membership numbers for the period 2017-2019 are likely to be higher.

2. List activities during past three years

Workshop Organization in ICRA and IROS

28 workshop organization and support. Followings are an example of the workshops:

- ✓ “Semantic Policy and Action Representations for Autonomous Robots”, IROS2017, IROS2018, IROS2019
- ✓ “The Robotic Sense of Touch”, ICRA2017
- ✓ “New horizons in cognitive robotics and AI”, ICRA2018
- ✓ “Active touch for perception and interaction: How nature inspires robotics", ICRA2018
- ✓ "Workshop on Cognitive Whole-Body Control for Compliant Robot Manipulation (COWB-COMP)", ICRA2018
- ✓ “Robots for Assisted Living”, IROS2018
- ✓ Autonomous Dialogue Technologies in Symbiotic Human-Robot Interaction", IROS2018
- ✓ "Towards Intelligent Social Robots: From Naive Robots to Robot Sapiens", IROS2018
- ✓ “Task-Informed grasping (TIG-II)”, RSS 2019
- ✓ “Next Generation Robotic Surgery: Seamless integration of Machine Learning, Knowledge Representation and Robotics within the operating rooms”, ICRA2019
- ✓ “Deep Probabilistic Generative Models for Cognitive Architecture in Robotics”, IROS2019
- ✓ Cutting edge forum on “Cognitive architectures for humanoids - where are we in our quest to achieve human-level AI in robotics?”, IROS2019

Steering of IEEE Transaction on Cognitive and Developmental Systems (TCDS)

3. List of outreach activities outside the RAS

Technical support of Conference organization

- ✓ IEEE International conference of Developmental and Learning and Epigenetics Robotics (ICDL-EpiRob)
- ✓ International conference on NeuroRehabilitation (ICNR)
- ✓ International Conference on Intelligent Functional Reconstruction of Hand (IFRH)

Workshop and Session organizations in International Conferences

- ✓ The Development of the Self: from self-perception to interaction under uncertainty, ICDL2017
- ✓ Continual Unsupervised Sensorimotor Learning, ICDL 2018
- ✓ Challenges in Autonomous Robot Evolution, ALife 2019
- ✓ World-wide consensus of NeuroRehabilitation, ICNR 2018

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

Cognitive Robot Control

- T. Taniguchi, et. al., “Symbol Emergence in Cognitive Developmental Systems: a Survey”, IEEE Transactions on Cognitive and Developmental Systems, 2018
- D. Vanderelst, et. al., “An architecture for ethical robots inspired by the simulation theory of cognition” Cognitive Systems Research, 48. pp. 56-66, 2018
- M. Hayashibe et. al., “Synergetic Learning Control Paradigm for Redundant Robot to Enhance Error-Energy Index”, IEEE Transactions on Cognitive and Developmental Systems, Vol. 10, Issue 3,pp. 573-584, 2018

Supervised Autonomy

- H.-L. Cao et. al., "Robot-Enhanced Therapy: Development and Validation of a Supervised Autonomous Robotic System for Autism Spectrum Disorders Therapy", IEEE Robotics and Automation Magazine, Vol. 26, No. 2, pp. 49-58, June 2019.

Cognitive Robotics for Everyday Activities

- M. Beetz, D. Beßler, A. Haidu, M. Pomarlan, A. K. Bozcuoglu, and G. Bartels. Knowrob 2.0 – a 2nd generation knowledge processing framework for cognition-enabled robotic agents. In IEEE International Conference on Robotics and Automation, ICRA 2018, pages 512–519. IEEE, 2018.
- T. Tangiuchi, et. al., "Survey on frontiers of language and robotics", Advanced Robotics, 2019

Cognitive Safety

- L. Jamone, et. al., "Affordances in psychology, neuroscience and robotics: a survey", IEEE Transactions on Cognitive and Developmental Systems 10(1):4-25, 2018

Robot Middleware and software

- D. Camilleri, et. al., "iCub-HRI: a software framework for complex human–robot interaction scenarios on the iCub humanoid robot", Frontiers in Robotics and AI, Vol 5, 2018

Robot Cognition in Healthcare Settings

- K. Iwatsuki, et. al., "Magnetoencephalographic evaluation for the myoelectric hand prosthesis with tacit learning system", NeuroRehabilitation, 44(1):19-23, 2019
- B. Woodwarth, et. al., "Preference Learning in Assistive Robotics: Observational Repeated Inverse Reinforcement Learning" In Proceedings of Machine Learning for Healthcare (MHLC), 2018.
- Riek, L.D. "Healthcare Robotics". Communictions of the ACM, Vol. 60, No. 11. pp. 68-78. 2017
- B.D. Argall, "Autonomy in Rehabilitation Robotics: An Intersection.", Annual Review of Control, Robotics, and Autonomous Systems, 1, 441-463, 2018.

Cognitive Architectures

- J. E. Laird et. al., "A standard model of the mind: Toward a common computational framework across artificial intelligence, cognitive science, neuroscience, and robotics." AI Magazine, 38(4):13–26, 2017.
- I. Kotseruba et. al., "40 years of cognitive architectures: core cognitive abilities and practical applications", Artificial Intelligence Review, 2018.
- G. Sandini, et. al., "Social Cognition for Human-Robot Symbiosis—Challenges and Building Blocks", Frontiers in Neurobotics, Vol. 12, 2018.

Development and Learning

- N. Sünderhauf, et. al., "The limits and potentials of deep learning for robotics.", International Journal of Robotics Research, 37(4-5):405–420, 2018.

Interdisciplinary Papers

- T. Morita, et. al., "Self-face recognition begins to share active region in right inferior parietal lobule with proprioceptive illusion during adolescence", Cerebral Cortex, Vol.28, pp.1532--1548, 2018.
- M. Itkonen, et. al., "Quantifying the Difference Between Intention and Outcome in Driving

Performance", Transportation Research Part F: Psychology and Behaviour, Volume 62, pp. 126-134, 2019
- Sciutti et. al., "Humanizing Human-Robot Interaction: On the Importance of Mutual Understanding." IEEE Technology and Society Magazine, 37(1), 22-29, 2018.
- Sciutti et. al., "Interacting with Robots to Investigate the Bases of Social Interaction", IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2017 10.1109/TNSRE.2017.2753879

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

2017: 152

2018: 171

2019: 176 (August 2nd, 2019)

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

Top three outstanding innovations in Cognitive Robotics in the past three years are

1. Cognitive motion control and sensor data analysis for full autonomous control.
2. Cognitive human – robot interactions.
3. Advances of interdisciplinary discussions

For autonomous control, we encouraged the discussions of novel control algorithms and sensory analysis such as whole-body control, Learning and active touch (Workshops in ICRA and IROS). The cutting edge forum "Cognitive architectures for humanoids" will organize for summarizing the advances in this direction.

Human activity understanding is one the most challenging problems for robots. Cognitive human-robot interactions are discussed for encouraging the discussions of symbiotic interactions between human and robots in our daily life including the sociality of robots and cognitive safely.

Interdisciplinary discussions were very actively conducted in the past three years encouraging the use of robotic technology in healthcare settings, including surgery, rehabilitation, cognitive training, social communications, and so on.

7. Recommendations for new co-chairs to replace existing co-chairs

Dr. Alessandra Sciutti, Istituto Italiano di Tecnologia, COgNiTive Architecture for Collaborative Technologies Unit, Italy; replacement for Giulio Sandini in 2020.