

# Triennial Report

## IEEE RAS Technical Committee on Cognitive Robotics TC-CoRo

Chairs: Michael Beetz, Ayorkor Korsah, Jean Oh, Tetsunari Inamura, Alessandra Sciutti

Emeritus Chairs: Shingo Shimoda, 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. There is growing need for robots that can interact safely with people in everyday situations. This means they need to be able to understand what a person is doing, anticipate what they are going to do, and act accordingly. This is what the field of cognitive robotics addresses.

During the past three years the former co-chairs have progressively passed the role to **new five co-chairs** (three females, two males) from different areas of the world (Africa, Asia, Europe and USA) and of different seniority. The transition has been facilitated by the active support from the past co-chairs who now serve as emeritus co-chairs of the TC. In this period, we have created the opportunities for exchange of views with various fields of researchers to discuss the challenges and opportunities for cognitive robotics, by organizing and supporting workshops and conferences. We also tried to widen the knowledge and interest in cognitive robotics, by developing educational material and courses and also dissemination material for children.

As an exemplar activity, Shingo Shimoda organized an open on-line round table entitled *'What is the role of the next generation of cognitive robotics?'*<sup>1</sup> on December 21<sup>st</sup> 2020 involving members of the TC as panelists. The discussion ranged from the basic skills for cognitive functions to the implementation in the real world. As a follow up, the panelists produced **a review paper**, recently published<sup>2</sup>, which summarizes the panelists' insights on the role of cognitive robotics and the challenges ahead. The paper proposes information generalization, active sensing, prediction and language, as the necessary functions for future cognitive robotics.

Moreover, the discussion was kept active through the **organization or the participation in a series of events** aimed at fostering the debate and at targeting central issues of cognitive robotics. One of these was the *TransAIR Virtual Workshop on Cognitive Architectures for Robot Agents: Current Capabilities, Future Enhancements, and Prospects for Collaborative Development*<sup>3</sup> organized by M. Beetz in March 2021 and involving several chairs and members of the TC. Another relevant event was *the International Foundation for Robotics Research Colloquium*

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<sup>1</sup> The whole discussion is available online at <https://youtu.be/Q7dMo4dQqKw>

<sup>2</sup> Shimoda, S., Jamone, L., Ognibene, D., Nagai, T., Sciutti, A., Costa-Garcia, A., ... & Taniguchi, T. (2022). What is the role of the next generation of cognitive robotics?. *Advanced Robotics*, 36(1-2), 3-16. <https://www.tandfonline.com/doi/full/10.1080/01691864.2021.2011780>

<sup>3</sup> All the talks are available: <https://transair-bridge.org/workshop-2021>

on *Cognitive Robotics*<sup>4</sup>, a panel moderated by Giulio Sandini held on the 8th October 2020 addressing central questions such as “is cognition essential for robotics” and “which applications are doomed to fail without an approach based on cognitive robotics?”. To expand the area of cognitive robotics, Jean Oh co-organized a series of workshops on the topic of creativity in AI & robotics at ACM SIGGRAPH’21, IEEE Conference on Vision and Pattern Recognition (CVPR’21), Robotics: Science and Systems (RSS’21), and Inter-Society for the Electronic Arts (ISEA’20). Oh also co-organized workshops on the topic of using cognitive intelligence for autonomous driving and racing in International Conference on Machine Learning (ICML) and International Joint Conference on AI (IJCAI) in 2022.

We will continue to actively promote the discussion and the education on Cognitive Robotics, with new events. In particular the *2022 EASE Fall School for cognition-enabled robot manipulation*<sup>5</sup> will be held in Bremen in September. The school will become also an occasion for the first in-person meeting of the new co-chairs to extend the discussions on possible joint efforts for the future of the TC.

In continuity with past years the members of the TC have been active in the organization and technical supports of **IEEE International Conference on Development and Learning and on Epigenetic Robotics (ICDL)**, as this is another important activity to encourage the discussions on cognitive robotics in interdisciplinary form. Indeed, ICDL targets not only robotics people but also the researchers in the field of psychology and human science, with the joint goal of further understandings human development and learning systems, and of creating robots inspired by the human cognitive systems. Also, the participation in the Steering Committee of **IEEE Transactions on Cognitive and Developmental Systems (TCDS)** is an important contribution to encourage the discussions on cognitive robotics.

The communications among the members and toward the community are maintained through a **moderated mailing list** ([All-coro-tc@ieee-coro.org](mailto:All-coro-tc@ieee-coro.org)), where relevant announces are shared among the members, and through the **website** (<https://www.ieee-ras.org/cognitive-robotics>), which collects several resources and links to noteworthy events and publications.

In addition to these major activities, we have supported the **organization of several conferences and workshops inside and outside RAS** in the past three years (a portion is listed below). The members are also active in promoting the TC in invited talks and **providing academic service as editor of journals** (such as Cog Sys Res, Front Rob and AI, Robotics and Autonomous Systems...) and as **program members in conferences and workshops**. A big effort has been dedicated to **expand the available education opportunities** on the topics of cognitive robotics. This has been done by Michael Beetz, David Vernon, Joern Syrbe with the creation of the course “Design and Implementation of Cognition-Enabled Robotic Systems”<sup>6</sup> and by David Vernon with the introductory course on cognitive robotics developed in 2020 with the support of the IEEE RAS CEMRA Program

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<sup>4</sup> The panel is available: <http://ifrr.org/cognitive-robotics>

<sup>5</sup> More information: <https://ease-crc.org/fall-school-2022/>

<sup>6</sup> Available on the German open KI Campus platform <https://ki-campus.org/courses/cognitionrobot-ub2021>

for Creation of Educational Material in Robotics and Automation<sup>7</sup>. Furthermore, **important books and book chapters on cognitive robotics** have been published by the members of the TC and by the co-chairs in the past three years (in particular Cangelosi, A. and Asada, M. (2021), Eds., *Cognitive Robotics*, MIT Press<sup>8</sup>, with the chapter "Cognitive Architectures" by David Vernon; and the entry "*Cognitive Robotics*"<sup>9</sup> by Sandini, G., Sciutti, A., and Vernon, D. (2021) in the Encyclopedia of Robotics, Ang, M., Khatib, O., Siciliano, B. (Eds.), Springer, Berlin, Heidelberg.)

The discussion on the topics of cognitive robotics is being brought forward also **through different initiatives**. With the aim of hosting and stimulating the convergence of various disciplines such as computer science, artificial intelligence, neuro & cognitive sciences, robotics, and social sciences Giulio Sandini founded in 2020 *the iCog Initiative*<sup>10</sup>, an open initiative started at IIT with the goal of advancing knowledge of human cognition by designing, building, and sharing a common cognitive architecture for an embodied artificial system. The initiative has fostered the discussion among many members of the TC, who have actively participated by giving talks and presentations. More recently, Michael Beetz led the formation of the *European Network of excellence centers in robotics (euROBIN)* building the EuRoCoRe (European Robotics Collaborative Repository) starting in July 2022 and funded by the European Commission. Moreover, the co-chair Tetsunari Inamura has released a cloud-based VR platform that allows human-robot interaction experiments using only software and has conducted online robotics competitions during the coronavirus pandemic, such as RoboCup AsiaPacific @home simulation in 2021. The platform has created a basis for a worldwide interactive robot competition without the need to transport robotic hardware, despite mobility limitations in recent years. He will also organize the Interactive Service Robot Competition in Cyberspace in IROS 2022 to expand opportunities for young students to practice and learn how to construct interactive robots.

The co-chairs have been also active in **disseminating the concepts of cognitive robotics to the wider public**, with a focus on children and with the intent of attracting more girls to STEM. This has been done with the creation of dissemination material such as the realization in Italy of a *virtual interactive online experience*<sup>11</sup> providing insights on the actual capabilities of current cognitive robots, with active participation in events for the public (such as Science Festivals and Maker Fairs) and in Germany with the creation of *free downloadable educational children book on cognitive robotics*<sup>12</sup>. Furthermore, a two-week enrichment programme for high school students

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<sup>7</sup> The material is freely accessible: <http://www.cognitiverobotics.net/>

<sup>8</sup> <https://mitpress.mit.edu/books/cognitive-robotics>

<sup>9</sup> [https://www.vernon.eu/publications/2021\\_Sandini\\_et\\_al.pdf](https://www.vernon.eu/publications/2021_Sandini_et_al.pdf)

<sup>10</sup> <https://icog.eu/>

<sup>11</sup> "Trip in the mind of a robot" (in Italian) first presented at the Genoa Science Festival by IIT–  
<https://short.iit.it/contact>

<sup>12</sup> The collaborative research center EASE provides a free downloadable version in English and free class sets. in the book series "Finja Finds it Out Again!" and the title "the mysterious robot" for school pupils grades 3-6

from across Ghana and other parts of Africa, *the Ashesi Innovation Experience*<sup>13</sup> is annually organized, including a one-week hands-on robotics workshop. After the past years' suspension due to COVID, the co-chair Ayorkor Korsah will organize it in August 2022. To attract more women and girls to the cognitive robotics domain, the co-chairs participated to dedicated events. For instance, the co-chair Alessandra Sciutti organized a webinar on robotics within a program for Promoting STEAM disciplines for girls dedicated to primary schools organized by Regione Liguria in March 2021 which received extensive media coverage both online and on newscasts.

Considering the next three years, one of the most important challenges in cognitive robotics is the need to show adaptivity and learning over long-term interaction with the environment and with human partners. This requires a proper comprehension of how to balance the role of exploration-exploitation, how to enable prospection and internal simulation and how to build a proper memory system. The necessity of an architectural view of the robot cognition is stressed by the need of overcoming short-term (or one-shot) successful interactions, to achieve continuous and extended collaboration. Furthermore, a more comprehensive understanding of how enabling the robot to interact not only in dyadic settings, but rather in complex group scenarios is needed, for applications ranging from autonomous driving in human populated areas, to training and rehabilitation in groups and to collaborative robotics in industry. Addressing these challenges requires a strong multidisciplinary participation. Although **the number of TC-CoRo members continues to grow**, increasing of 31% with respect to the last report, we aim at disseminate further these topics. Hence, we plan for the next three year to keep the discussion on these topics active, ideally across different disciplines, through the support and the organization of events and of dedicated special issues. We will continue to update the website, but we will consider the opportunity to exploit also different channels of communications (such as twitter or instagram) to reach a wider audience. Additionally, we will continue to moderate and handle the mailing list, which provides the members with the opportunity to exchange news and announcements on the TC topics.

## 2. List activities during past three years

The activities related to section 2 and 3 are reported in the page <https://www.iecee-ras.org/cognitive-robotics/activities> of the website together. Here we report the elements separated in the two original sections.

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

#### *Supported workshops*

- Behavior-driven Autonomous Driving in Unstructured Environments (BADUE), IROS 2022
- Ergonomic Human-Robot Collaboration: How Cognitive and Physical Aspects Come Together, IROS 2022
- Robot Trust for Symbiotic Societies (RTSS), IROS 2022
- Social and Cognitive Interactions for Assistive Robotics (SCIAR), IROS 2022
- Workshop on Human Theory of Machines and Machine Theory of Mind for Human-Agent Teams, IROS 2022
- Artificial Intelligence for Social Robots Interacting with Humans in the Real World (intellect4hri), IROS

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<sup>13</sup> <https://ashe.si/aix>

2022

- Life-long Learning of High-level Cognitive and Reasoning Skills, IROS 2022
- Interactive Service Robot Competition in Cyberspace organized in conjunction with IEEE/RSJ IROS 2022. (<https://iros2022.org/program/competition/#toggle-id-2>)
- Workshop on Cognitive and Social Aspects of Human Multi-Robot Interaction, IROS 2021
- Workshop on Semantic Policy and Action Representations for Autonomous Robots (SPAR), IROS 2021

### **Courses and Schools**

- The IEEE RAS CEMRA Program for Creation of Educational Material in Robotics and Automation supported the creation of an introductory course on cognitive robotics in 2020.
- Online course: Design and Implementation of Cognition-Enabled Robotic Systems. Michael Beetz, David Vernon, Joern Syrbe. On the German open KI Campus platform (<https://ki-campus.org/courses/cognitionrobot-ub2021?locale=de>)
- 2021 EASE Fall School for cognition-enabled robot manipulation (<https://ease-crc.org/fall-school-2021/>) (virtual school)
- 2022 EASE Fall School for cognition-enabled robot manipulation (<https://ease-crc.org/fall-school-2022/>)

### **Relevant initiatives**

- iCog Initiative, founded by Giulio Sandini <https://icog.eu/>
- Michael Beetz led the formation of the European Network of excellence centers in robotics (euROBIN) building the EuRoCoRe (European Robotics Collaborative Repository) starting in July 2022 and funded by the European Commission.

## **3. List of outreach activities outside the RAS**

*In the program committee of:*

- IEEE International conference of Developmental and Learning and Epigenetics Robotics (ICDL-EpiRob)
- IEEE International Conference on Robot & Human Interactive Communication
- ICSR - International Conference on Social Robotics

*Associate editor of:*

- Cognitive Systems Research (Senior Editor)
- IEEE Transactions on Cognitive and Developmental Systems
- Robots and Autonomous Systems
- International Journal of Social Robotics
- Frontiers in Robotics and AI
- International Journal of Humanoid Robotics
- Interaction Studies
- Advanced Robotics

### **Workshop and Session organizations**

- Workshop on AI for Autonomous Driving, International Joint Conference on AI (IJCAI) in 2022
- Workshop on Safe Learning for Autonomous Driving, International Conference on Machine Learning, 2022
- Workshop on Adapted interaction with Social Robots (cAESAR) ACM UMAP 2022 and 2021

- IFRR Colloquium on Cognitive Robotics (International Foundation of Robotics Research) moderated by Giulio Sandini. (<http://ifrr.org/cognitive-robotics>). video lectures online.
- TransAIR Virtual Workshop on Cognitive Architectures for Robot Agents: Current Capabilities, Future Enhancements, and Prospects for Collaborative Development. 22nd to 28th March, 2021.
- Chef's Hat Cup Challenge competition 30th International Joint Conference on Artificial Intelligence (IJCAI2021)
- Workshop on affective shared perception (WASP) IEEE ICDL 2020
- Cognitive Robotics for Interaction (CIRCE) Workshop IEEE RO-MAN 2020
- RoboCup@Home Simulation (Open Platform League) RoboCup AsiaPacific in 2021
- Measurable Creative AI, ACM SIGGRAPH, Aug. 2021. (<http://mcreativeai.org/siggraph/>)
- Workshop and Exhibition on Robotics x Arts: Opportunities and Issues in Robotics Applied in the Arts. Robotics: Science and Systems (RSS), 2021.
- Interactive Workshop on Bridging the Gap between Subjective and Computational Measurements of Machine Creativity, Conference on Computer Vision and Pattern Recognition (CVPR). 2021.
- The Ninth Annual Conference on Advances in Cognitive Systems virtual, 2021.
- International Workshop on Artificial Intelligence and Cognition (AIC 2021)
- Workshop on Measuring Computational Creativity: Collaboratively Designing Metrics for Evaluating Creative Machines. Inter-Society for the Electronic Arts (ISEA). 2020.
- Latin American Summer School on Cognitive Robotics (LACORO), 2020.
- Artificial Intelligence for Improving Trustworthiness of Robots and Autonomous Systems, IRCE2020

### ***Special issues and Books editing***

- Second Edition of the Special Issue “Emerging Topics on Development and Learning” for IEEE Transactions on Cognitive and Developmental Systems (2022).
- Research Topic “Affective Shared Perception” for Frontiers in Integrative Neuroscience (2021)
- Book “Modelling Human Motion. From Human Perception to Robot Design” (2020), Springer International Publishing.
- Special issue on Semantic Policy and Action Representations for Autonomous Robots (SPAR), Journal of Robotics and Autonomous Systems, 2021-2022.
- IEEE Transactions on Cognitive and Developmental Systems: Special Issue on Artificial Intelligence and Edge Computing for Trustworthy Robots and Autonomous Systems.

### ***Dissemination activities to general public, for inclusion***

- Free downloadable educational children book on cognitive robotics in the book series “Finja Finds it Out Again!!” and the title “the mysterious robot” for school pupils grades 3-6. The EASE center provides a free downloadable version in English and free class sets.
- The Ashesi Innovation Experience (<https://ashe.si/aix>) is an two-week enrichment programme we run annually at Ashesi University for high school students from across Ghana and other parts of Africa. It includes a one-week hands-on robotics workshop. It will be held in August 2022.
- Virtual activity “Trip in the mind of a robot” (in Italian), (<https://short.iit.it/contact>) a video adventure providing insights on the actual capabilities of current robots with researchers’ explanations (first presented on Oct 2021)
- Invited webinar on Promoting STEAM disciplines for girls dedicated to primary schools of Regione Liguria organized by “Progettiamoci il futuro” and Regione Liguria, 8th March 2021 (Italian)
- Participation at the round table “Encounter with extraordinary European women in science” dedicated to secondary school students and organized by France Embassy and Institut français Italia. Rome, Italy, 11th February 2022. Also in streaming with about 2000 visualizations. <https://youtu.be/mU2JCi5pdsU?t=5037>

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

From: [https://www.ieee-ras.org/cognitive-robotics/resources#relevant\\_publications](https://www.ieee-ras.org/cognitive-robotics/resources#relevant_publications)

##### Relevant Publications

- Shimoda, S., Jamone, L., Ognibene, D., Nagai, T., Sciutti, A., Costa-Garcia, A., ... & Taniguchi, T. (2022). What is the role of the next generation of cognitive robotics?. *Advanced Robotics*, 36(1-2), 3-16.
- Taniguchi, T., Yamakawa, H., Nagai, T., Doya, K., Sakagami, M., Suzuki, M., ... & Taniguchi, A. (2022). A whole brain probabilistic generative model: Toward realizing cognitive architectures for developmental robots. *Neural Networks*, 150, 293-312.
- Cangelosi, A. and Asada, M. (2021), Eds. , *Cognitive Robotics*, MIT Press
- Sandini, G., Sciutti, A., and Vernon, D. (2021) "Cognitive Robotics" in *Encyclopedia of Robotics*, Ang, M., Khatib, O., Siciliano, B. (Eds.), Springer, Berlin, Heidelberg.
- Vernon, D. (2021). "Cognitive Architectures", in *Cognitive Robotics*, Cangelosi, A. and Asada, M. (Eds.), MIT Press.
- Ueda, S., Nakashima, R., & Kumada, T. (2021). Influence of levels of automation on the sense of agency during continuous action. *Scientific reports*, 11(1), 1-13.
- Di Cesare, G., Vannucci, F., Rea, F., Sciutti, A., & Sandini, G. (2020). How attitudes generated by humanoid robots shape human brain activity. *Scientific Reports*, 10(1), 1-12.
- Taniguchi, A., Hagiwara, Y., Taniguchi, T., & Inamura, T. (2020). Improved and scalable online learning of spatial concepts and language models with mapping. *Autonomous Robots*, 44(6), 927-946.
- Tangiuchi, T., D. Mochihashi, T. Nagai, S. Uchida, N. Inoue, I. Kobayashi, T. Nakamura, Y. Hagiwara, N. Iwahashi, and T. Inamura. (2019). "Survey on Frontiers of Language and Robotics." *Advanced Robotics*, 33 (15-16), 700-730.
- Fischer, T., & Demiris, Y. (2019, issued in 2020). Computational modeling of embodied visual perspective taking. *IEEE Transactions on Cognitive and Developmental Systems*, 12(4), 723-732.

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

From: <https://www.ieee-ras.org/cognitive-robotics/members>

The numbers of members in the past years are the following:

- 2014: 68;
- 2015: 99;
- 2016:132;
- 2017:152;
- 2018:171;
- 2019: 182;
- 2020: 200;
- 2021: 227;

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

From: <https://www.ieee-ras.org/cognitive-robotics/resources#innovations>

##### Top three technical innovations (2020-2022)

The top three outstanding innovations in Cognitive Robotics in 2020-2022 are:

1. Focus on an architectural approach to human – robot interaction to support autonomy and long-term interactions.
2. Advances in the integration of machine learning and model-based approaches in cognitive robots
3. Progress in language understanding and acquisition in real-world environments.

**Diverse members in their field of interest who are willing to serve as distinguishing lecturers and leading roles at our conferences, in our publications, and at our outreach events.**

The Technical Committee for Cognitive Robotics has nominated three Distinguished Lecturers, through the

dedicated forms:

- **Prof. Friederike Eyssel** – Bielefeld University, Germany
- **Prof. Katia Sycara** – Carnegie Mellon University, USA
- **Prof. Yukie Nagai** – The University of Tokyo, Japan

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

The current co-chairs have all recently taken their role, with the support of the Emeritus co-chairs. Hence they plan to continue for the next three years.