IEEE Robotics and Automation Society

Proposal for a new IEEE RAS Technical Committee on:
Cognitive Robotics[1]

1. Proposed Title

Technical Committee on COGNITIVE ROBOTICS (CORO)

2. Proposed Scope

Cognitive robotics is multi-disciplinary science concerned with the realization of adaptive robots that can interact safely with people, often by exploiting models based on biological cognition. Cognitive robots achieve their goals by perceiving their environment, paying attention to the events that matter, planning what to do, anticipating the outcome of their actions and the actions of other agents, and learning from the resultant interaction. Cognitive robots deal with the inherent uncertainty of natural environments by continually learning, reasoning, and sharing their knowledge.

A key feature of cognitive robotics is its focus on predictive capabilities to augment immediate sensory-motor experience and to allow a robot to anticipate future events relevant to the task being executed.

Cognitive robotics facilitates interaction between a robot and other cognitive agents, either through natural language or other interaction modalities. Being able to entertain models of other agents, a cognitive robot can anticipate people's intended actions, both during direct interaction (e.g. a robot assisting a surgeon in theatre) and indirect interaction (e.g. a robot stacking shelves in a busy supermarket).

In cognitive robotics, the robot body is more than just a vehicle for physical manipulation or locomotion: it is a component of the cognitive process. That is, cognitive robotics embraces embodied cognition, exploiting the agent's physical morphology, kinematics, and dynamics, as well as the environment in which it is operating.

Cognitive Robotics draws on many traditions in robotics, artificial intelligence, and cognitive science. Therefore, the CORO TC will embrace all scientific approaches concerned with modelling robot cognition, including those with roots in classical AI, with a focus on knowledge representation and reasoning, and other variants of cognitive science that focus on emergent self-organizing techniques based on connectionism and dynamical systems.

3. Motivation

The growing need for robots that are able to interact safely with humans in everyday situations has made evident how necessary it is for a robot to understand its environment and being able to anticipate the effects of its own and other's actions. This basically entails the merging of two streams of research: how to implement physical systems specifically designed for interaction with unconstrained environments and how to design control architectures taking explicitly into account the need to acquire and use experience. The first aspect usually refers mainly to robotics research while the second has its core activities in cognitive science and artificial intelligence. The merging of these two areas has brought about the so called field of "Cognitive Robotics" which in recent years has received significant funding in Europe, Japan and the USA (e.g. through the 7th Framework in Europe, the US-Robotics initiative in the USA, the JST ERATO projects in Japan). At this stage we feel that the field has developed very important tools in both areas (new actuators and sensors, multimodal perception and actions representation just to mention a few) and we believe that it is crucial for the overall field of robotics research to demonstrate how the "merging" of these tools can produce new scientific results as well as demonstrate the possibility of transferring them from the labs to the "real" world. It is in the merging of these competences that we see the real advantage.

For example, a robot acting safely in a human populated environment has to rely both on compliant actuation providing a "reactive" protection as well as on cognitive abilities providing the "predictive" contribution to safety. We do not see a viable solution to safe human-robot interaction without a synergy between these two aspects.

For this reason we think that a "stimulation" action, such as the one that can be implemented by a dedicated Technical Committee, aimed at a stronger and more stable interaction between robotics and cognition is very timely

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[1] The original proposal was prepared by (alphabetically): Minoru Asada, Martin Buss, George Lee, Yoshihiko Nakamura, Henrik Christensen, Giulio Sandini, Matthias Scheutz, Shingo Shimoda, David Vernon

and could help to build a critical mass of researchers in this multidisciplinary field and, consequently, expand RAS into this new area of research.
The TC-CORO could serve to coordinate the scheduling of major conferences, stimulate special sessions and workshops, promote journal issues and book publications, support student programs, organize focused events, and contribute towards the IEEE publications.

4. Relationship to existing TCs

The relationship with existing TCs is a crucial aspect of this proposal not only within the RAS but also in relationship to TCs of the Computational Intelligence Society. As to the possible interactions, we stress the fact that we propose the CORO-TC as an attractor of different aspects of robotics AND cognitive science research. The goal is not to focus on individual aspects of cognitive science and robotics research but to stimulate activities aimed at merging these aspects in a big picture where the cognitive architecture and the robotic platform are integrated. Some of the on-going TCs in RAS are addressing aspects of cognition which are relevant for CORO-TC: learning in RAS-TC "Robot Learning"; cognitive aspects of manipulation in RAS-TC "Robotic Hands, Grasping and Manipulation"; cognitive skills for environment understanding in RAS- TC on "Autonomous Ground Vehicles and Intelligent Transportation Systems"; cognitive aspects of human-robot interaction in RAS-TC "Human-Robot Interaction & Coordination"; Motor cognition and learning in RAS-TC "humanoid robotics". It is worth stressing, however, that individually these TCs, although addressing important aspects of robot cognition, do not offer an arena where such aspects could be merged. With respect to the TCs of the CIS, the "Autonomous Mental Development" AMD-TC shares many aspects with CORO though AMD-TC mainly focuses on the mental aspect of cognition (robots are used as tools to demonstrate theories of mental development) and not on the study and implementation of the robotic platform per se. Collaboration with AMD-TC and CORO-TC can be beneficial to both TCs because some of the important technological and societal goals are similar.

With respect to the relationship between "cognitive robotics" and "robot learning" and the potential overlap in the activities of two distinct Technical Committees, we would like to remark some important differences and a few figures showing that, even if an overlap exists, it reflects a relatively small part of multifaceted structure of cognitive robotics. In short: we see cognitive robotics as a subject area of robotics which focuses on research and education activities in developing robots that "understand" their dynamic environment (with humans as part of the environment) and "interact" with the environment. Robot learning in general is a different field of research concerned with tools and techniques that enable robots to utilize their past experience to improve their current and future performance. In this sense any learning technique that can be used to improve the "understanding" and/or "interaction" capabilities of cognitive robots may indeed constitute an overlap. However, even if learning from experience is one essential aspect of cognitive robotics, it is by no means the only one. Others include the ability to anticipate the need for actions and predict the outcome of those actions and the actions of others (people and robots), the ability to adapt to changing circumstances by adjusting current and anticipated actions, and most especially the ability to understand the goals and intentions of other agents and to interact prospectively with them (i.e. to cooperate, collaborate, and communicate).
The fact that this existing overlap between robot learning and cognitive robotics can be considered relatively minor (even if important) is also demonstrated by a few statistics we computed on papers published recently in the major IEEE RAS conferences and publications and also by the keywords mentioned by the reviewers included in the RAS paperplaza database to define their areas of expertise.
The two tables below refer to the publications and were computed by searching the IEEE Xplore digital library. Table 1 and 2 were computed by searching the library with the Index Terms "cognit*" (to account for both "cognition" and "cognitive) and "learn*". Table 1 refers to papers published in the period 2010-2013 in the three major conferences while Table 2 refers to all IEEE publications containing the word "robot" as an Index Term.

Years 2010 -2013 (*)			
	cogni*	learn*	cogni* & learn*
ICRA	56	268	16
IROS	53	275	10
CASE	10	44	1
TOTAL	119	587	27

Table: 1. Number of papers referring to "learning", "cognition" and "learning AND cognition" published in the three major RAS conferences.

Years 2010 -2013 (*)		
cogni*	learn*	cogni* & learn*
812	2614	186

Table: 2. Number of papers containing the word "robot" as Index Term referring to "learning", "cognition" and "learning AND cognition" published by IEEE.

Table 1 shows that only 4.6% (27 vs. 587) of the papers listed with *Index Term* "learning" also were referring to "cognition" while this value is 7.1% if considering all IEEE publications containing the word "robot" as an *Index Term*. In both cases the overlap is very much acceptable.
As to the analysis of the RAS papercept database of reviewers, we computed the number of reviewers with the keyword "cogni" and/or "learn" among those defining their expertize. The results are shown in Table 3.

FROM PAPERPLAZA REFEREES	
5667	learning
2425	(cogniti AND NOT recognition)
908	learning AND (cogniti AND NOT recognition)

Table: 3. Number of reviewers from papercept database who included "learning" and/or "cogniti" among the keywords used to define their expertize.

In this case 16% of the researcher who claimed "learning" as one of their keyword's expertize also indicated "cognition" as a keyword which we consider an acceptable overlap.

5. Goals within 3 and 6 years

3 Year Goal: Promote the merging of cognitive sciences and robotics research into "cognitive robotics" by means of special sessions, workshops and tutorials at major R&A conferences (such as ICRA,IROS and CASE). Organize at least one special issue on "cognitive robotics" in a RAS journal to serve as a vehicle of the various aspects of cognition in robotics and as state-of-the-art in the field.
We also plan to propose a "Cognitive Robotics Grand Challenge" which could serve as a further stimulus to merge the multifaceted aspects addressed by CORO-TC.
In relation to specialized Journals it is our intention to investigate the possibility of establishing an IEEE Transaction "Cognitive Robotics"

The activities of the first 3+3 years will be implemented with the added objective of establishing a fruitful collaboration between the Robotics and Automation Society and the Computation Intelligence Society's Technical Committees mentioned in Section 4 by seeking areas of mutual interest and synergies.

Furthermore we plan to establish stable interdisciplinary relationships with non-IEEE societies interested more specifically in investigating aspects of human and animal cognition which may be relevant for robotics research such as the "Cognitive Sciences Society" (CSS), the "Cognitive Neuroscience Society" (CNS) and the "Society for Cognitive Rehabilitation" (SCR) just to mention a few.

At the end of the 6 years period we expect to have developed the identity of a CORO community and made evident (and fruitful) the links between all aspects of robotics contributing to cognition. Moreover we expect CORO to establish and promote the methodologies and tools required to make the cognitive robotics field industrially and socially relevant.

6. Proposed co-chairs

We are proposing 4 Co-chairs. However, considering the particularly multidisciplinary scope of the TC it may be better to organize the coordinating group so that a wider participation of persons is possible.

Prof. Giulio Sandini (Corresponding co-chair) - Robotics, Brain and Cognitive Sciences Department
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Dr. Shingo Shimoda (Asia Oceania) – Intelligent Behavior Control Unit
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Prof. David Vernon (Europe) – Informatics Research Centre
University of Skövde,
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7. Achievements of the co-chairs in the proposed field.

Giulio Sandini

Giulio Sandini is full professor of bioengineering at the University of Genoa and Director of Research at the Italian Institute of Technology where he leads the Robotics Brain and Cognitive Sciences Department, a multidisciplinary environment where research develops around the human being along three main research streams: i) the use and development of humanoid robots to study cognition; ii) the study human behavior with a focus on human sensorimotor coordination and learning in children and adults; iii) study human-machine interaction with emphasis on cognitive and physical interaction and communication. Through the advancement of science along these research steams, RBCS is developing protocols and tools for cognitive, sensory and motor rehabilitation.
Giulio Sandini past experience include research activities in neuroscience and clinical labs in Italy (Scuola Normale in Pisa) and abroad (Harvard Medical School in Boston) as well as coordination of research groups involved in robotics and bioengineering at the University of Genoa's LIRA-Lab. Since 1984 he has participated as PI in more than 40 EU-funded projects and coordinated several of them on topics related to Computer Vision, Biomorphic Microelectronics, Robotics and Neuroscience.

Specifically with respect to robot cognition Giulio Sandini has participated as Principal Investigator and coordinator in projects engaged in "cognitive science research". Among them the pilot initiative (2001-2004) of the EU on "cognition" as Principal Investigator of the project "Cognitive Vision Systems". He was the proposer and coordinator of the consortium of the project RobotCub which included 11 European and 5 non-EU research centers involved in different aspects of robotics and cognitive science. The technological goal of RobotCub was the design and construction of the humanoid robot iCub. iCub was the first full-fledged, "open source", European humanoid (possibly the first worldwide) specifically designed for collaborative research and is now one of the most used humanoid of similar complexity internationally with more than 25 systems being used worldwide by a community of researchers interested in Robot Cognition. When he founded the Robotics Brain and Cognitive Sciences department at IIT in 2006 Giulio Sandini established iCub as one of the leading robotic platforms of IIT and was instrumental in founding a department entirely dedicated to the development of the iCub platform. Currently the focus of RBCS department directed by Giulio Sandini is cognitive sciences with several ongoing projects on robot cognition.

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Matthias Scheutz

Matthias Scheutz is Full Professor of computer science and cognitive science in the Department of Computer Science and Adjunct Full Professor of psychology in the Department of Psychology at Tufts University (Medford, MA, USA). He is also the Director of the Human-Robot Interaction Laboratory and was the founding director of the cognitive science Ph.D. program. He has over 200 peer-reviewed publications in artifical life, cognitive science, artificial intelligence, and robotics, and has extensively contributed open-source software to the development of complex robotic architectures. He has been the PI or co-PI on many research grants funded by the US National Science Foundation and the US Department of Defense as well as grants in the EU.
His current research focuses on cognitive, affective, and reflective architectures for complex robots with natural language capabilities that can be instructed through situated dialogues.

In 2004, Matthias Scheutz was invited to participate in an EU Cognition workshop that subsequently led to the formation of EUCognition, three Coordinated Action programs funded by the EU from 2005 through 2014 to build the cognitive systems and robotics community (he was on the board of the first program). He also participated in various research projects directly related to cognitive systems in the US, including a Multi-University Research Initiative (MURI) project on effective human-robot interaction through natural language dialogue and dynamic autonomy. He is currently the PI of another large MURI project aiming to instill moral competence into autonomous robots for them to be able to handle morally charged situations in a satisfactory fashion in the future.

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- Run-time planner model updates via natural language instruction". 7th ACM/IEEE International Conference on Human-Robot Interaction, Boston, MA.

Shingo Shimoda

Shingo Shimoda is Unit leader at RIKEN Brain science institute – TOYOTA collaboration center, intelligent behavior control unit. Research target of the unit is the investigation of the control principle of biological control systems and the application of the control principle to control robots and understanding the human's motions. Especially, there are two main targets: 1) behavior adaptation to the unpredictable environmental changes through body/environment interactions and 2) Human behavior analysis based on neuro-synergy system.

Shingo Shimoda considered that cognition appears in the process of adapting behaviors to the surrounding environment and proposed the bio-mimetic learning architecture called tacit learning. Tacit learning can create the robot behaviors adapted to the environment from roughly defined behaviors through body/environment interactions. Even the unpredictable environmental changes occurred, tacit learning detect them through body/environment interactions and tune the behaviors automatically to the environment changes. Shingo Shimoda got CoTeSys Cognitive Robotics Best Paper Award in IROS 2010 applying tacit learning to the emergence of bipedal walking.

Behaviors of human beings can be considered as the environmental changes for the robot side viewpoint in robot-human interactions. Shingo Shimoda applied tacit learning to control the prosthetic devices to adapt these motions to the wearers' behaviors. In the process of adapting the prosthetic device motions to the wearers' behaviors, cognition played the dominant role because the prosthetic device should move according to the wearers' intentions. Shingo Shimoda is now under investigation to apply these adaptation and cognition techniques to propose the efficient rehabilitation method for post-stroke patients collaborating with TOYOTA and to the bipedal walking support by using exoskeleton robots as the member of EU project FP7.

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David Vernon

David Vernon is a Professor of Informatics at the University of Skövde, Sweden. He works on cognitive systems and computer vision and is particularly interested in cognitive architectures and modeling autonomy. He coordinated the inaugural *European Network for the Advancement of Artificial Cognitive Systems* (www.eucognition.org) as well as the *European Research Network for Cognitive Vision Systems* (www.ecvision.org). He was a leading member of the team that created the *iCub*, an open-source cognitive humanoid robot (www.icub.org) and he was the general chair of the sixth European Conference on Computer Vision (ECCV) in 2000.

Over the past 35 years, he has held positions at Westinghouse Electric, Trinity College Dublin, the European Commission, the National University of Ireland, Maynooth, Science Foundation Ireland, and Khalifa University in the UAE. He has authored four books, edited another three, and published over 100 papers in the fields of computer vision, robotics, and cognitive systems. He is a Senior Member of the IEEE, a Chartered Engineer of the Institution of Engineers of Ireland, and a past Fellow of Trinity College Dublin. He is an editor of the Springer series of *Cognitive* Systems Monographs (COSMOS), an associate editor of The Computer Journal, and a past associate editor of Cognitive Computation.

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9. Founding Members (alphabetically)

List to be extended if the proposal is accepted

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Henrik I. Christensen, Cognitive Robotics lab, Georgia Institute of Technology
C. S. George Lee, College of Engineering, Purdue University
Yoshi Nakamura, Department of Mechano Informatics, University of Tokyo