RoboCup Humanoid League RoboCup Humanoid League

Virtual RoboCup Humanoid Open Workshops: Welcome

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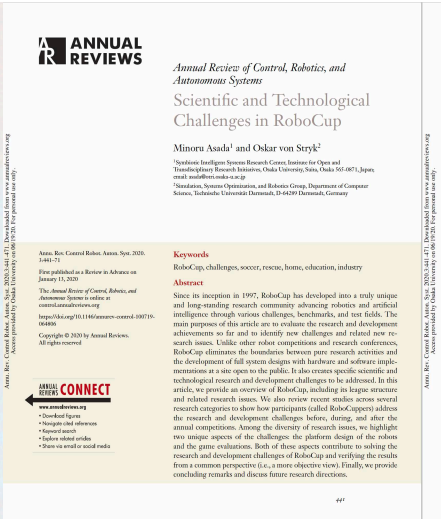
Introduction of myself

- President of the Robotics Society of Japan (2019~)
- Vice President of the Japanese Society of Baby Science (2020~)
- PI for JST RISTEX R&D Project “Legal Beings: Electronic personhoods of artificial intelligence and robots in NAJIMI society, based on a reconsideration of the concept of autonomy” (2017~)
- PI for NEDO Project on Innovative AI Chips and Next-Generation Computing Technology Development/ Development of next-generation computing technologies, entitled “Exploration of Neuromorphic Dynamics towards Future Symbiotic Society” (2018~)

Today‘s Two Topics

- A review publication: Minoru Asada and Oskar von Stryk. Scientific and Technological Challenges in RoboCup. Annual Review of Control, Robotics, and Autonomous Systems, Vol.3, No.1, pp.441--471, 2020.
- Introduction of my project: Exploration of Neuromorphic Dynamics towards Future Symbiotic Society



ANNUAL REVIEWS

Annual Review of Control, Robotics, and Autonomous Systems

Scientific and Technological Challenges in RoboCup

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Keywords

RoboCup, challenges, soccer, rescue, home, education, industry

Abstract

Since its inception in 1997, RoboCup has developed into a truly unique and long-standing research community advancing robotics and artificial intelligence through various challenges, benchmarks, and test fields. The main purposes of this article are to evaluate the research and development achievements so far and to identify new challenges and related new research issues. Unlike other robot competitions and research conferences, RoboCup eliminates the boundaries between pure research activities and the development of full system designs with hardware and software implementations at a site open to the public. It also creates specific scientific and technological research and development challenges to be addressed. In this article, we provide an overview of RoboCup, including its league structure and related research issues. We also review recent studies across several research categories to show how participants (called RoboCuppers) address the research and development challenges before, during, and after the annual competitions. Among the diversity of research issues, we highlight two unique aspects of the challenges: the platform design of the robots and the game evaluations. Both of these aspects contribute to solving the research and development challenges of RoboCup and verifying the results from a common perspective (i.e., a more objective view). Finally, we provide concluding remarks and discuss future research directions.

1. INTRODUCTION

Since its inception in 1997, by offering a publicly appealing yet formidable challenge (1–3), RoboCup has been a vehicle for promoting highly ambitious research in robotics and AI. One effective way to promote science and engineering research is to set a visionary and challenging long-term goal, and RoboCup was founded with such a long-term goal: by 2050, to have a team of soccer-playing robots defeat the most recent World Cup champion team. This goal was set at a time when humanoid robots were still confined largely to science fiction, as the Honda P2 humanoid robot was unveiled only in December 1996. Besides huge challenges for technology, RoboCup's vision also raises philosophical and societal questions (4).

This challenge has been successively expanded to address societal challenges by including major leagues for rescue robots, robots that perform services for humans at home, and robots that perform manufacturing tasks. The junior leagues, which target children in primary and secondary school as well as undergraduates under 19 years old, comprise robotic soccer, rescue robots, and creative on-stage performances by robots and humans. Generally, building teams of robots that perform services and operate in environments with a large amount of uncertainty (such as soccer games and rescue operations) can have significant social and economic impact, and reaching the specific 2050 goal would certainly be a major achievement in the science and engineering fields of robotics and AI.

Figure 1 illustrates how the number of RoboCup leagues has expanded since 1997. The first RoboCup had three soccer leagues [the Simulation League, Small Size League (SSL), and Middle Size League (MSL)] and has since expanded to five domains, each comprising several leagues: RoboCupSoccer, RoboCupRescue, RoboCupJunior, RoboCup@Home, and RoboCupIndustrial. In the following sections, we briefly explain the main research issues and their variations in each league. The number of participating teams increased rapidly in the first 10 years, but owing to

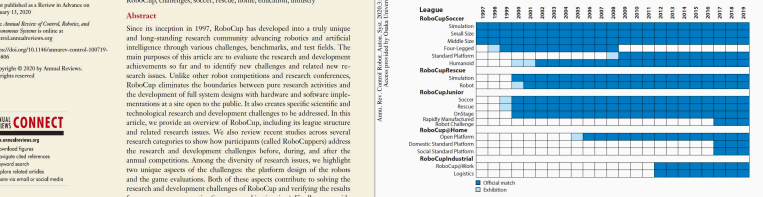

Figure 1

Expansion of RoboCup leagues since 1997. All leagues are currently active except for the RoboCupSoccer Four-Legged League, which was replaced in 2009 by the Standard Platform League.

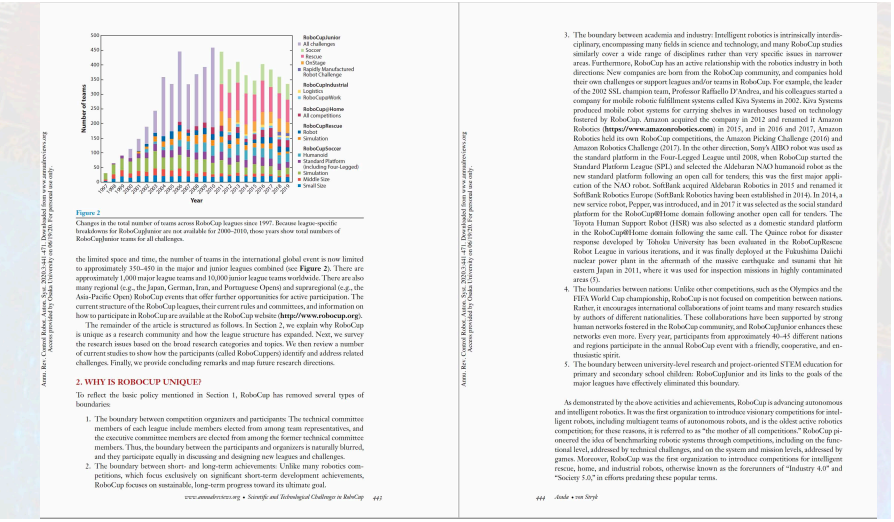

Figure 2

Changes in the total number of teams across RoboCup leagues since 1997. Because league-specific breakdowns for RoboCupJunior are not available for 2000–2010, those years show total numbers of RoboCupJunior teams for all challenges.

the limited space and time, the number of teams in the international global event is now limited to approximately 350–450 in the major and junior leagues combined (see **Figure 2**). There are approximately 1,000 major league teams and 10,000 junior league teams worldwide. There are also many regional (e.g., the Japan, German, Iran, and Portuguese Opens) and supraregional (e.g., the Asia-Pacific Open) RoboCup events that offer further opportunities for active participation. The current structure of the RoboCup leagues, their current rules and committees, and information on how to participate in RoboCup are available at the RoboCup website (**http://www.robocup.org/**).

The remainder of the article is structured as follows. In Section 2, we explain why RoboCup is unique as a research community and how the league structure has expanded. Next, we survey the research issues based on the broad research categories and topics. We then review a number of current studies to show how the participants (called RoboCuppers) identify and address related challenges. Finally, we provide concluding remarks and map future research directions.

2. WHY IS ROBOCUP UNIQUE?

To reflect the basic policy mentioned in Section 1, RoboCup has removed several types of boundaries:

1. The boundary between competition organizers and participants: The technical committee members of each league include members elected from among team representatives, and the executive committee members are elected from among the former technical committee members. Thus, the boundary between the participants and organizers is naturally blurred, and they participate equally in discussing and designing new leagues and challenges.
2. The boundary between short- and long-term achievements: Unlike many robotics competitions, which focus exclusively on significant short-term development achievements, RoboCup focuses on sustainable, long-term progress toward its ultimate goal.

3. The boundary between academia and industry: Intelligent robotics is intrinsically interdisciplinary, encompassing many fields in science and technology, and many RoboCup studies similarly cover a wide range of disciplines rather than very specific issues in narrower areas. Furthermore, RoboCup has an active relationship with the robotics industry in both directions: New companies are born from the RoboCup community, and companies hold their own challenges or support leagues and/or teams in RoboCup. For example, the leader of the 2002 SSL champion team, Professor Raffaello D'Andrea, and his colleagues started a company for mobile robotic fulfillment systems called Kiva Systems in 2002. Kiva Systems produced mobile robot systems for carrying shelves in warehouses based on technology fostered by RoboCup. Amazon acquired the company in 2012 and renamed it Amazon Robotics (**https://www.amazonrobotics.com**) in 2015, and in 2016 and 2017, Amazon Robotics held its own RoboCup competitions, the Amazon Picking Challenge (2016) and Amazon Robotics Challenge (2017). In the other direction, Sony's AIBO robot was used as the standard platform in the Four-Legged League until 2008, when RoboCup started the Standard Platform League (SPL) and selected the Aldebaran NAO humanoid robot as the new standard platform following an open call for tenders; this was the first major application of the NAO robot. SoftBank acquired Aldebaran Robotics in 2015 and renamed it SoftBank Robotics Europe (SoftBank Robotics having been established in 2014). In 2014, a new service robot, Pepper, was introduced, and in 2017 it was selected as the social standard platform for the RoboCup@Home domain following another open call for tenders. The Toyota Human Support Robot (HSR) was also selected as a domestic standard platform in the RoboCup@Home domain following the same call. The Quince robot for disaster response developed by Tohoku University has been evaluated in the RoboCup|Rescue Robot League in various iterations, and it was finally deployed at the Fukushima Daiichi nuclear power plant in the aftermath of the massive earthquake and tsunami that hit eastern Japan in 2011, where it was used for inspection missions in highly contaminated areas (5).
4. The boundaries between nations: Unlike other competitions, such as the Olympics and the FIFA World Cup championship, RoboCup is not focused on competition between nations. Rather, it encourages international collaborations of joint teams and many research studies by authors of different nationalities. These collaborations have been supported by strong human networks fostered in the RoboCup community, and RoboCup|Junior enhances these networks even more. Every year, participants from approximately 40–45 different nations and regions participate in the annual RoboCup event with a friendly, cooperative, and enthusiastic spirit.
5. The boundary between university-level research and project-oriented STEM education for primary and secondary school children: RoboCup|Junior and its links to the goals of the major leagues have effectively eliminated this boundary.

As demonstrated by the above activities and achievements, RoboCup is advancing autonomous and intelligent robotics. It was the first organization to introduce visionary competitions for intelligent robots, including multiagent teams of autonomous robots, and is the oldest active robotics competition; for those reasons, it is referred to as "the mother of all competitions." RoboCup pioneered the idea of benchmarking robotic systems through competitions, including on the functional level, addressed by technical challenges, and on the system and mission levels, addressed by games. Moreover, RoboCup was the first organization to introduce competitions for intelligent rescue, home, and industrial robots, otherwise known as the forerunners of "Industry 4.0" and "Society 5.0," in efforts predating these popular terms.

RoboCup has removed several types of boundaries between:

- competition organizers and participants
- short- and long-term achievements
- academia and industry
- nations
- university-level research and project-oriented STEM education for primary and secondary school children

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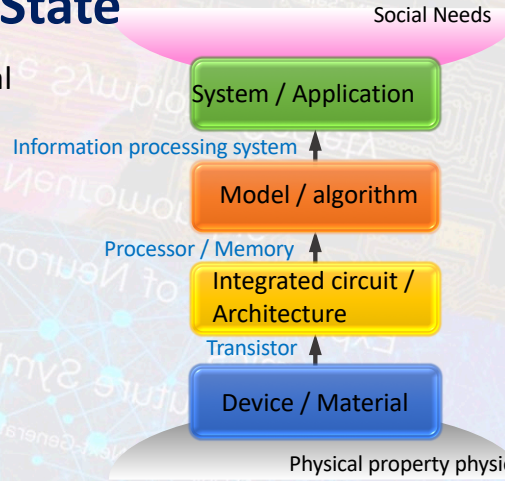
- Introduction of my project: Exploration of Neuromorphic Dynamics towards Future Symbiotic Society http://www.ams.eng.osaka-u.ac.jp/nedo-nmd/?lang=en

The Current State

- Technological hierarchical structure for the existing digital system construction

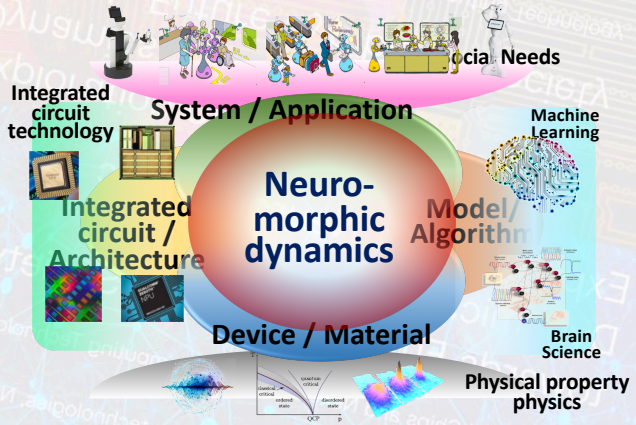


What is Neuromorphism?

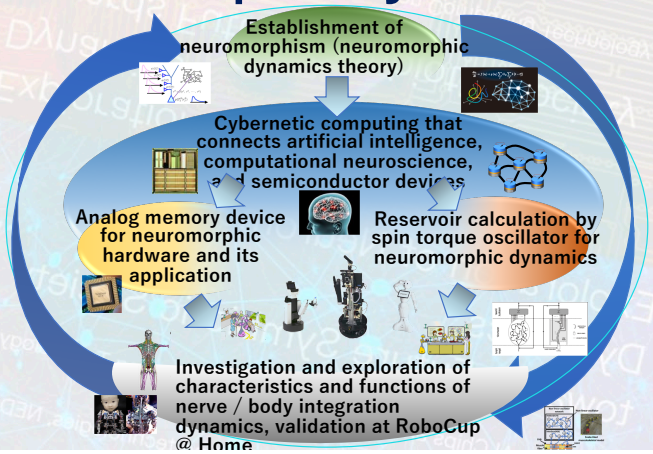
1. Grasp the essence inherent in the *neural mechanism of the brain and body*
2. Design and implement artifacts as its engineering realization
3. Obtain a new insight of the neural mechanism of the biological system through its process and results
4. Feedback to engineering reproduction. → 2

➢Philosophy of a new interdisciplinary approach by *mutually permeable dynamic circulation microscopically and macroscopically* in science and engineering

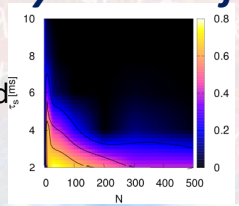
Goal image to be achieved

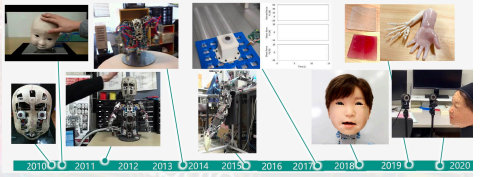


Neuromorphic dynamics



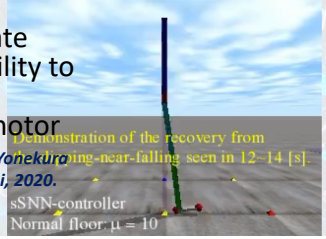
Efficient and diverse action generation by coupling dynamics of the body and the nervous system





Ishihara and Asada, 2011-20

Spike-induced ordering: Stochastic neural spikes provide immediate adaptability to the sensorimotor system, *Yonekura and Kuniyoshi, 2020.*



Connection between Physical Reservoir Computing and SoftRobotics:

- ➢ Future body for humanoids
- ➢ Energy-efficient processing

Acknowledgement

- Project members of NEDO project

http://www.ams.eng.osaka-u.ac.jp/nedo-nmd/

and more ...

- Lab. Members

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