RoboCup 2021 Worldwide: A Successful Robotics Competition During a Pandemic

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The COVID-19 global pandemic has challenged the entire academic community (and the whole world) to adopt new and creative ways of making progress. Most conferences have now organized at least one fully virtual event, often including keynote lectures, paper presentation sessions, poster sessions, and even social events. However, when the core of one's event is a collection of competitions among physical robots, what can be done when researchers are not able to travel? This article answers that question by recounting RoboCup 2021 Worldwide, a successful robotics competitions held during the summer of 2021.

Background

RoboCup (RoboCup website: www.robocup.org) consists of a robust international community of researchers in artificial intelligence (AI) and robotics who share the common goal of advancing the state of the art in these fields through scientific competitions [1]–[3]. Current RoboCup competition leagues can be grouped into four classes: RoboCupSoccer, RoboCupRescue, RoboCup@Home, and RoboCupIndustrial. In addition, RoboCupJunior and related educational activities are designed to reach out to grade school students and promote the dissemination of RoboCup advances.

From 1997 to 2019, RoboCup featured an annual international competition and symposium (as well as several regional and super regional competitions) bringing together hundreds of AI and robotics researchers from around the world. The 2020 international event was canceled because the COVID-19 pandemic happened too soon before the event to react. But with more time to prepare in 2021, the RoboCup Federation managed to accomplish what many people thought would not be possible: a successful RoboCup competition without anybody needing to travel.

This article describes RoboCup 2021 Worldwide—a fully remote event. The coauthors of this article chaired the event and worked together with many other dedicated RoboCuppers to conceptualize, define, and organize it, which kept the RoboCup community thriving during a global pandemic.

More specifically, we describe the main objectives of holding such an event, the challenges involved in doing so, how the community rose to the occasion, and the technological and organizational lessons learned that will be useful in future years, even after the pandemic resolves. In the end, we are pleased to report that RoboCup 2021 (RoboCup 2021 website: 2021.robocup.org) was a huge success! While this article focuses on the overall organization of RoboCup 2021, league-specific achievements and resources (including developed software, rulebooks, and so on) can be found on the league websites linked from the main RoboCup website. For example, Paetzel [4] describes the efforts in the Soccer Humanoid League to keep the community engaged during the pandemic, through virtual workshops and scientific and technical talks, while Laue et al. [5] describe the technical infrastructure and the results of a remote competition within the Soccer Standard Platform League (SPL).

Since RoboCup 2021, other international competitions have facilitated remote participation, such as the World Robot Challenge within the 2020 World Robot Summit in Japan (https://wrs.nedo.go.jp/en/wrs2020/challenge/), the SciRoc challenge (https://sciroc.org/2021-challenge-description/) in Italy, and RoboCup Asia–Pacific 2021 (https://2021.robocupap.org/eng/), taking inspiration from RoboCup, but also experimenting with new models of remote participation.

Based on our experiences reported in this article, we are confident that remote scientific competitions can be useful for introducing new methods for benchmarking algorithms and systems in AI and robotics based on remote participation of research groups in experiments carried out in standardized scenarios including common robots and environments. Such standardized installations will allow increased replicability, independence, fairness, and transparency and, thus, in general, have the potential to improve the quality of the benchmarking results.

The Competition Objectives

At the outset, we needed to decide on the main objectives of holding the competition. Was the main goal of the competition to be a compelling spectator event? To attract new members to the community?

It quickly became clear to us that the most important feature of a successful competition was to allow our existing RoboCup community to come together and remain engaged along with our

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common long-term scientific objectives. As such, we focused on curating an event that was most compelling for the team members in our various leagues. We therefore committed to

- creating rules of the competitions that would allow us to name champions in all the leagues, with trophies and awards
- facilitating a space for league meetings that would allow for discussions of future rules and elections of new technical committee (TC) members, organizing committee (OC) members, and executive committee members, and so on
- creating a space for people working on common research topics to come together
- holding our RoboCup Symposium as a traditional academic gathering with invited talks, peer-reviewed paper presentations, and poster sessions.

We recognized that the online format without any need for travel might also create an opportunity to draw in new participants who would not otherwise attend RoboCup. It could also be made appealing to spectators. But we decided to consider those aspects as secondary objectives to keeping the community engaged.

The Competition Challenges

One of the most important aspects of any research competition is the rules. One generally wants them to both lead to interesting, exciting games and also encourage research innovations. Traditionally, RoboCup rules have been defined under the assumption that all participants would be physically present. However, in 2021, that was not the case. We thus challenged the league organizers to be creative in trying to define a new set of rules that would still achieve the previous objectives, without requiring any travel.

First, we identified two key features of traditional competitions that we sought to preserve.

1) In RoboCup competitions, there is a real-time aspect—the robots need to work at a particular moment.
2) In RoboCup competitions, there is uncertainty at the start of every game or event—at the start, everyone has a chance to win.

We thus instructed the league organizers to consider whether there are challenges that can be tackled in a physically decentralized manner, e.g., remotely in contestants' own laboratories with objective comparisons possible. We also asked participants to consider whether some details of the challenges could be revealed at the last minute to implement the real-time and uncertain aspects.

We asked participants to consider whether there was a way to hold real games or challenges in a way that was close to "normal." We expected that aspect to be most feasible for the simulation leagues, which could have teams upload their code to a centralized cluster to run the competition. We thought it might also be possible for the SPLs, in which all teams have the same physical robots, which could enable downloading code from other teams onto locally available robots.

We also broadened our notion of the competition beyond traditional games with teams playing against each other on a field or in a common arena. We thus considered whether there could be isolated challenges on perception (vision), movement (such as a robot getting down on its knees and then standing up quickly), navigation, manipulation, and cooperation, among other tasks.

For example, in soccer leagues, a "game" between two teams could consist of a designated configuration of robots and ball on the field with the objective being to score fastest, either using a live stream or with a video produced and submitted sometime shortly after the configuration is announced. As another example, in any of the leagues a vision stream could be sent to all teams with a need to segment and classify the relevant objects within a time limit.

While we expected that each RoboCup league would address these challenges in its own unique way, we also recognized that there would necessarily be some commonalities in the needs and requests of the leagues. As a result, we committed early to having some sort of central infrastructure that would allow for community meetings, a unified look and feel, and so on.

For both the individual league competitions and the centralized infrastructure, we expected that dealing with different time zones would be a challenge. For this purpose, we encouraged leagues to schedule preliminary round games such that teams from similar time zones would play against one another. We also addressed the different needs of the Major Leagues (generally graduate students and professors) and the Junior Leagues (generally high school students).

Finally, we needed to figure out a seamless way to merge the competitions with the symposium that could allow participants to take part in both aspects of the event. We thus scheduled the symposium talks and award ceremonies in the most convenient time slot for the Americas, Europe, and Asia/Australia (generally midday European time).

All in all, it was clear from the outset that there were many difficult challenges to address if the competitions were to fulfill the objectives listed in the section "The Competition Objectives." The following sections summarize our solutions to these challenges.

The Competition Organization

From the beginning, we knew that, to achieve a successful event, two kinds of communication infrastructure would be needed: one dedicated to the performance of the competitions and another one aiming at gathering the community to interact with each other. Moreover, we encouraged leagues to use additional communication channels and infrastructures for internal discussion and competition management.

RoboCup 2021 online was hosted by Underline (https://underline.io/events/108/reception), which provided both the virtual environment for the talks of the RoboCup Symposium, opening ceremony (https://youtu.be/fYOwURf-ItM), award ceremony (https://youtu.be/1gLXYsxlHs4), and sponsor booths and also the Gather Town (https://www.gather.town/) virtual space for social interactions among RoboCuppers, poster presentations, and videos of the competitions.

These platforms proved to be very appropriate for our goals of keeping the community engaged and, at the same time, running competitive challenges. The main issue was to align the requirements of RoboCup games (which are quite different from typical conferences) with such tools that are mostly designed for standard academic conferences.

The volunteer contributions of members of the RoboCup 2021 OC with the technical support of the Underline staff led to appropriately customized versions of the online platforms that enabled us to host a very successful online event. The OCs and TCs from each league provided content for these platforms (such as schedule, results, and videos) to make the games and challenges accessible to the participating teams as well as to the general audience.

They also worked together to create an extraordinary virtual world in Gather Town with many areas and rooms where people could have meetings, discussions, or even linger for hours in a friendly environment with other participants. For example, in RoboCupJunior, the virtual world included a beach for relaxing and a room of virtual games for youngsters (see Figures 1 and 2).

The Competition Rules

Each of the leagues responded in its own unique way to the presented challenge of creating rules for a fully distributed competition, as described in the section "The Competition Challenges." In this section, we summarize a few of these responses.

The Humanoid League aimed to create a virtual world where all robots could be modeled and all soccer competitions could occur. It was successfully made in the Webots environment with features designed specifically for RoboCup Soccer games, such as a field with grass, realistic physics for ball kicking, and motor backlash. A short video of such games is available online (https://youtu.be/sYTp1X3nGuE). In the Small Size League, the virtual world and remote challenges worked well together. Teams competed in a simulated environment, but they also needed to show, in real time, some hardware performing in the team's laboratory with real robots.

The Soccer SPL came up with a very novel concept of distributed real robot games with remote participation. Six fields were installed in different geographical locations with standard dimensions. Teams then sent their code to the local hosts, who were able to run the code on their own robots. Challenges and one-versus-one robot games were successfully performed, requiring teams to address several technical challenges, including remote setup and calibration of the robots. An image of the Passing Challenge is shown in Figure 3. The far robot and the near robot needed to pass the ball back and forth without hitting the two robots in the middle, while staying within the square marked in green. More details about the competition format are available in [5], while videos of the games are available on the SPL YouTube channel (https://www.youtube.com/channel/UCmJWzHyCuBs8zaQcJfw077g).

The RoboCup@Home league opted for a competition based entirely in simulation. A simulation environment, based on Robot Operating System and Gazebo, was developed to reproduce an apartment-like scenario with the elements needed to run the tasks described in the rulebook (see Figure 4). The framework developed for the competition also included an automatic referee and scoring module, allowing for completely automated management of the competition runs. The simulation environment, released using Docker technology, proved to be very effective for competition organizers and usable for the teams. It could be very useful in the future for new teams, qualification purposes, and running specific challenges. Ongoing simulator development will focus on implementing advanced forms of human–robot interaction. More details are given in [6].

RoboCup@Home and RoboCup@Work jointly hosted the Virtual Robot Manipulation Challenge, supported by MathWorks. The focus of this challenge was to attract new teams by providing them a virtual machine already configured to run a manipulation task, MATLAB code to control the manipulation robot, and webinars and technical support for the teams to help them in developing the solutions. Similarly, RoboCup@HomeEducation targeted younger students with workshops, webinars, and remote technical support to perform simplified tasks.

Event Summary

The virtual event was a huge success. There were 12 Major Leagues, three Junior Leagues, and additional challenges aiming at bridging the Major and Junior sections. (Details are available at https://2021.robocup.org/participants/call-for-participation.) The event comprised 137 Major teams and 180 Junior teams from 43 Regions,

Figure 1. The main room in the RoboCup 2021 Gather Town virtual space.

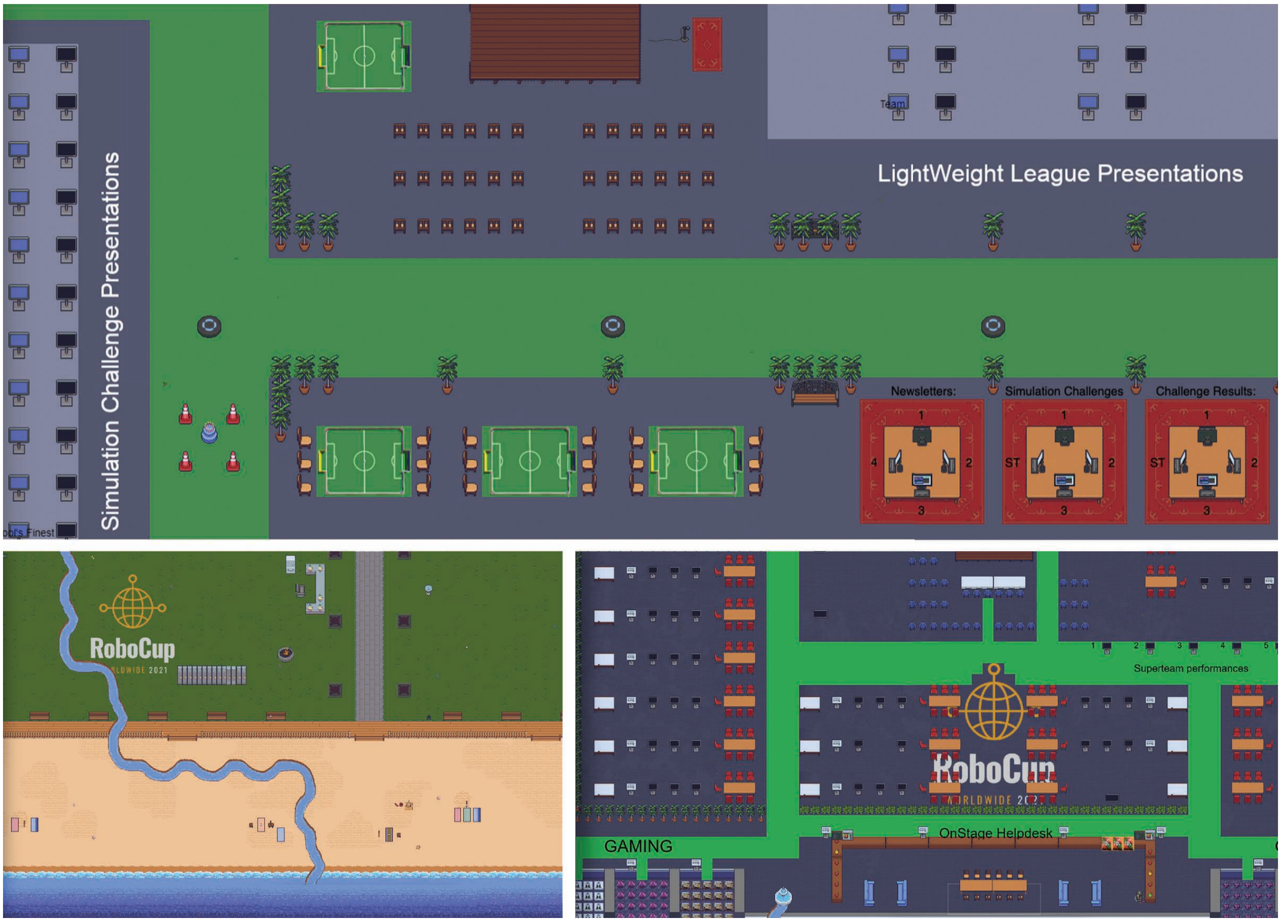

Figure 2. The environment and some spaces of RoboCupJunior in Gather Town.

with more than 2,000 participants from around the world (see Figure 5). Although the differing time zones were an incredible challenge for all, it did not prevent any team from fairly competing and showing their developments with virtual and remote robots.

The 24th RoboCup Symposium was held virtually on 28 June 2021 with the presentation of 19 papers reporting on novel contributions to the robotics field, an informative panel discussion on building a research career through RoboCup, some interactive sessions with the papers' authors in Gather Town, and a reflection on the past 25 years of RoboCup. It was organized by Rachid Alami (Laboratory for Analysis and Architecture of Systems-CNRS, France), Joydeep Biswas (the University of Texas at Austin), Maya Cakmak (University of Washington), and Oliver Obst (Western Sydney University, Australia).

It also comprised three invited talks from keynote speakers: Prof. Dieter Fox, from NVIDIA Research and the University of Washington, with a talk called "Toward Robust Manipulation in Complex Environments"; Prof. Jean-Paul Laumond, from CNRS, with a talk on "Robotics: The Science of Motion"; and Prof. Stefanie Tellex, from Brown University, with a talk titled "Towards Complex Language in Partially Observed Environments." Unlike most previous RoboCup events, some talks from keynote speakers happened in parallel with the main RoboCup event on the main competition days.

As in previous years, papers presented in the RoboCup Symposium

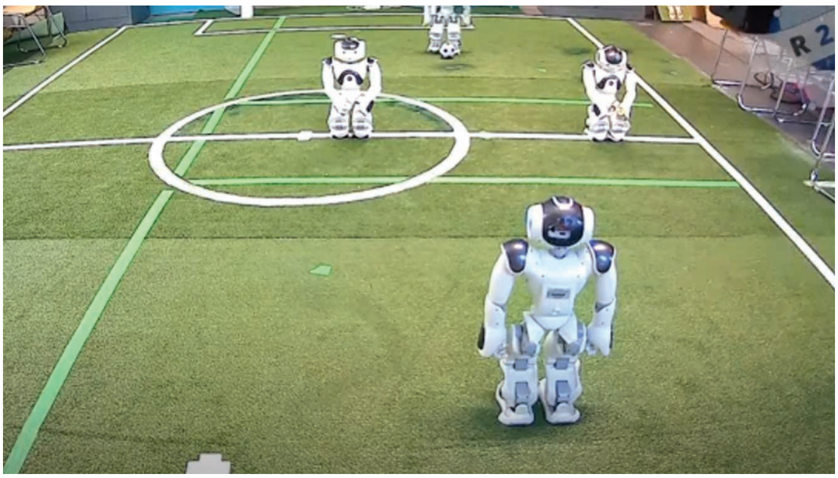

Figure 3. The RoboCup SPL Passing Challenge.

clearly show how RoboCup competitions spawn new scientific challenges and innovative solutions. For example, the RoboCup Symposium 2021 Best Paper Award [7] presented a creative idea to improve the behavior of soccer robots based on the analysis of noise coming from the audience during the game as a reinforcement signal.

A focal moment of all RoboCup events is the award ceremony. A recognition of the community's effort toward developing and researching intelligent robots is celebrated during this event with the awarding of trophies and certificates. However, shipping trophies all around the world was not practical. Instead, we decided to design a 3D-printable trophy shell that winning team members could print locally. We then created engraved metal plates with the team's name and the award to ship to the teams as an authentication of the 3D-printed trophy (Figure 6). The 3D printing file was distributed, and the plates were sent to all winning teams. All in all, we distributed more than 70 trophies to teams around the world.

Looking Forward

The biggest lesson learned from RoboCup 2021 is that it is indeed possible to run a successful international robotics competition with hundreds of participants without requiring anyone to travel from their home town. We expect that once the global pandemic abates, RoboCup will return to events with a physical copresence, both because of a desire to return to the traditional competition formats and also to reestablish personal relationships among participants. Nonetheless, in future events, we expect that some of the innovations from RoboCup 2021 will remain, such as the increased use of standard simulators, more automatic scoring systems, and the allowance for some remote participation.

As it does every year, RoboCup 2021 inspired us and, we assume, most of the other organizers and participants to continue working on the many open research challenges that remain if we are to achieve our long-term goals of robust, fully autonomous, multirobot systems for soccer, domestic service, disaster rescue, and industrial applications. One very salient challenge that was particularly apparent this year is the problem known as Sim2Real: enabling robot behaviors to be learned in simulation, with comparatively abundant computation and data, and then applied successfully in the real world [8]. While the development of new simulation environments was essential to the success of RoboCup

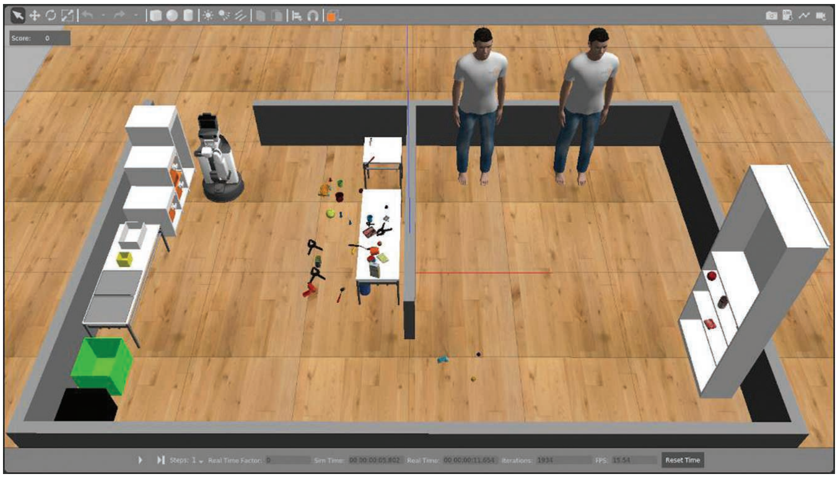
Figure 4. The RoboCup@Home 2021 simulation environment.

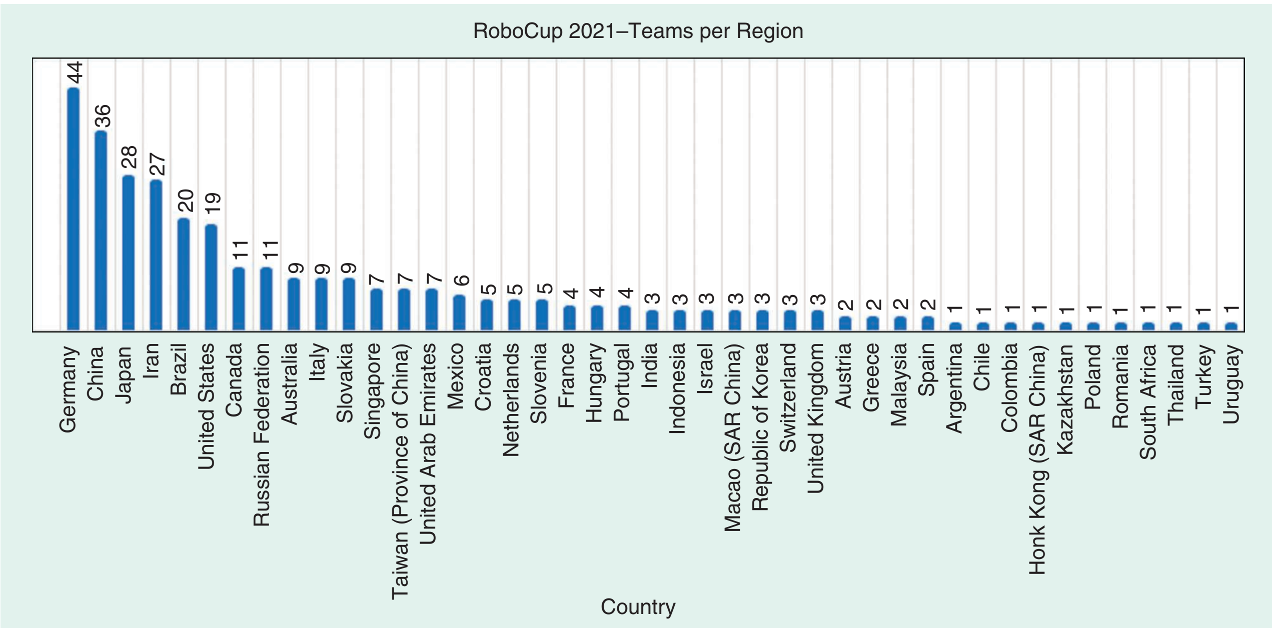

Figure 5. The participation of teams per Region in RoboCup 2021. SAR: Special Administrative Region.

Figure 6. The 3D-printed trophies for winning teams.

2021, our ultimate goal remains successful physical deployments. Additional open challenges include designing (efficient and affordable) robots with more agile bipedal locomotion, and the problem known as grounded language learning [9], a form of embodied cognition concerned with associating concrete sensory perceptions and behavioral primitives with relevant natural language tokens. Grounded language learning is particularly relevant to RoboCup@Home, where robots need to interact with users through spoken language.

In summary, we expect that all of the effort dedicated to preparing and running RoboCup 2021 will have long-lasting benefits. RoboCup teams will have more opportunities to participate in robotics competitions, and the whole AI and robotics scientific community will have better tools for benchmarking and the evaluation of new, innovative algorithms. The 2022 RoboCup competition is planned for July 2022 in Bangkok, Thailand, and the 2023 competition will be held a year later in Bordeaux, France. We hope to see you there!

Acknowledgments

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