Robot League – A Unique On-Line Robotics Competition

Richard Balogh[1](✉) and Pavel Petrovič[2]

[1] Slovak University of Technology in Bratislava, Bratislava, Slovakia
richard.balogh@stuba.sk
[2] Comenius University Bratislava, Bratislava, Slovakia
ppetrovic@acm.org

Abstract. We have successfully organized seven years of a competition in building and programming robots in Slovakia named Robotická liga (Robot League) with the motto 'The joy of learning through solving and sharing'. The activity is deeply based in the didactic theory of Constructionism, we beleive it is one of the most genuine examples of organized constructionist activities utilizing modern on-line technologies. A side result is a set of about 80 challenges with solutions, a useful learning resource for both learners and teachers.

The competition has a unique format allowing the teams to compete remotely from their home, school or club. In other conventional competitions, the participants pay too much attention to their own performance, and the sharing and mutual learning aspect tends to be neglected.

Traditional competitions require a long preparation that culminates at a tournament, where things can easily go wrong, leading to frustrations. Our starting point was to benefit from the motivational vector that stems from competing while correcting those common disadvantages. The core of the activity lies in that it stimulates an exceptional level of creativity and provides an early and manifold feedback in a repetitive fashion. In this paper we present interesting example tasks, discuss their classification, our experiences and recommendations and feedback from the participants.

Keywords: Robotics competition · Constructionism · After-school activities

1 Introduction

Our interest in the field of robotics originates in our passion for technology. Technology gives the power to reach places we could not reach, make useful things that would have been impossible, to help each other, to liberate ourselves, it helps to learn about ourselves, and it allows building a green, fair, peaceful and creative society with optimal use of resources, maximizing the happiness and productivity as contrasted to maximizing the profit and resources drain. We believe in technology that will make a better future for all the mankind,

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wildlife and the planet as well. We were lucky to be ignited and inspired for this as youngsters in social settings. In clubs, schools, competitions, and through sharing of ideas in the magazines, books, and other literature. We feel that sharing and social settings are crucial part for spreading the spirit of the belief in technology. With this attitude in mind, we have spent considerable efforts preparing or participating in organization of various events, where sharing and learning took place, individually, or together [1–3]. Summer schools and summer camps provided opportunities for the young people not only to be exposed to the technology, but included up to 24 h presence of savvy experts who had answers to almost all the questions. In a two week well-organized technology camp, the motivated children often advanced in their skills and knowledge more than during a whole year of regular participation in an after-school club, each one of the two serving as a catalyst for the other. A successful approach used in these schools relied on project work with a specific goal to be accomplished - typically building or programming a robot or another device to perform a chosen task. Even though the children cannot stay in the camp all year round, they can still work on projects. Hence the competitions. And hence the huge challenges they need to face: now they lack the access to tools, knowledge and skills, the coach has to organize their work despite their variable skills and interests. In some competitions, a team of 3–10 children is required to build a single robot in a several months long season. How much are all the members going to advance through hands-on learning, if the robot is obviously going to be designed by the one or two most talented builders in the team? Likewise for the programming part. Only through personal involvement and one's own mistakes, trials and errors, tinkering and experimentation the valuable learning takes place. Yet, in a team of 10, this could happen only in case of a group of ideal children. It is not the case in most of the groups. Other competitions suffer from the problem of recurrence. The category is the same every year, or slightly changes only occasionally. The successful teams come back in the following season with even stronger robots, being a very hard competitor for the newcomers. After they eventually leave, the level in the contest stagnates or even declines. A partial remedy for this is a requirement to submit all the technical documentation and publish it on-line. Thus the teams in the next season can build up on the previous experiences even from other teams. A huge problem for many robot competitions is the high participation cost, placing an extra burden on team coaches who often fail to find the sufficient resources. And despite the high fees, the tournaments and their organizers are still dependent on the sponsors and their unpredictable mood and behavior. And finally, the creativity and narrow focus: yes, the soccer robots are all different, but at the same time, they are all the same. We are seeing the same ideas, designs, and algorithms over and over. Industry 4.0 is going to depend on creative prototyping and versatility. We should reflect on that. In 2013, after the autumn FLL season has finished, we were asked by the coaches if we could suggest an activity for their robot clubs during the idle spring season. Collecting on our experiences from different types of contests, we founded the Robot League.

2 Robot League

Our answer to above mentioned problems is a completely new, off-line, distance competition called Robot League. The competition has a unique format allowing the teams to compete remotely from their home, school or club. They spend as much time as they need to construct and program a robot, the only limitation is to upload their solution till the deadline on the competition web server.

2.1 Organization

We publish a set of tasks every two weeks. Each round consists of two different tasks, so the teams can choose which one is more attractive to them. They can solve both, and the better solution counts in the scores. The team has to upload their solution to the special competition web, where it is then evaluated by the jury of at least three independent reviewers. Their average ranking is then assigned to the team.

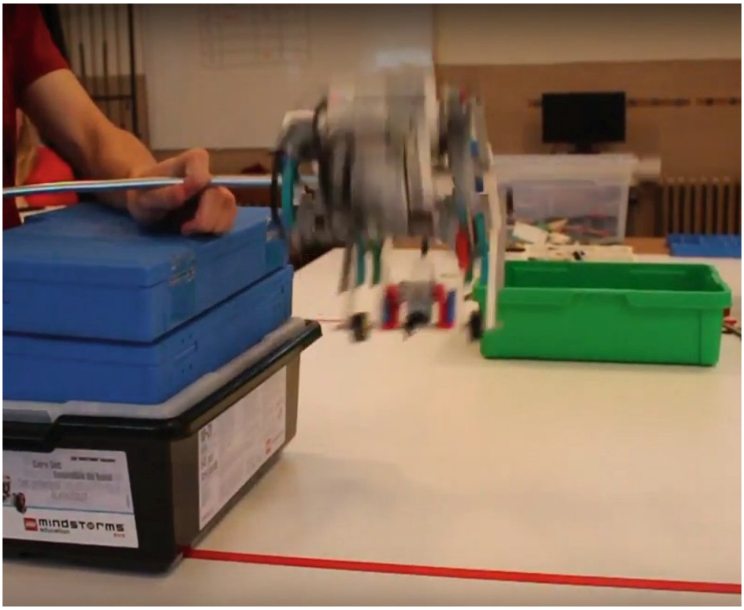

Fig. 1. Physical exercise of the M-Team's robot.

Teams work at home or in the after-school robot clubs. When they are finished with their solution, they typically use mobile phone to take pictures and record videos that they upload to YouTube service. Some teams use video editing software to add interesting effects or narrative, explaining the principles of their solution. Some teams add comments to their programs. Since the solutions are invisible before the task deadlines, and the YouTube videos are marked as unlisted, it is guaranteed that the teams work independently. The more keen on watching their peers solutions they become as they are made available. The organizers, and the coaches also take their part of the benefit from the learning process.

We have observed that once a team exceeds a certain threshold of their motivation, then they are highly likely to attempt to solve all the tasks in the season. In this way, we also hope to contribute to their regular work habit. One of the main benefits of these activities is that they initiate an interaction between the adults and young learners, which tends to be neglected today. Yet, some of the teams are completely independent and work on their own, without accepting any advises from adults.

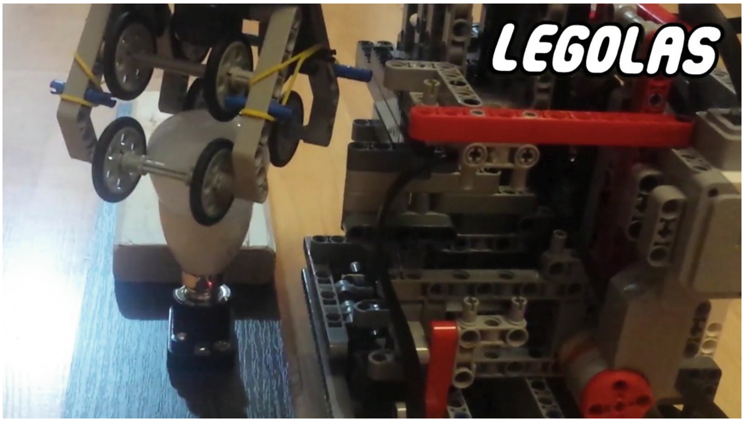

Fig. 2. Bulb replacement robot by the Legolas team.

The problem of the degree to which an adult can help the children solve the tasks is probably the largest we have encountered, but it is not specific to this contest. And there is no good solution to it except of wise coaches, which is something the organizers are not able to influence. Here we refer to an alternate approach used for instance in the Istrobot contest [3]: there is no age limitation, and the teams often consist of a father with a child, or similar. Such setup makes it possible for the young to learn even more in a project that gets completed to a level beyond his or her individual skills. Having this attitude and benefits in mind, it is even more questionable if it is beneficial to completely eliminate the help from elders.

Everything started in May 2013. During the first year we published a new task every week, however, the teams had time two weeks to solve it, thus they could already see the specification of another round while they were working on the previous one, and think in advance, let their ideas develop over time. Alternately, they could divide into dedicated groups, each solving one of the available tasks. The same principle remains till now, we just adjust the intervals of publishing new tasks to two weeks and we extend the solving period to four weeks.

Recently, we enjoy approximately 20 active teams and this is just enough to be able to evaluate all of them regularly. During the first years we tried to extend the period during the holiday time, but this was not successful attempt and most of the teams simply didn't work during the summer holidays.

During the years, it was necessary to develop a specific application to help maintaining the competition flow. Since the 2014 we use a specialized web application described in the Sect. 2.5.

The number of teams is summarized in Table 1. Not all the teams were working regularly, some of them just tried and didn't continue, some of them at least attempted to solve every single task. Last year, for example we have received and evaluated 151 unique solutions in total (on average 18–19 per round), however, not the quantity, but the endeavor, and the quality of the solutions were the most satisfying.

Table 1. Summary of participants since the origin of the competition, 2019 is estimate. Note: Teams 50 – Number of really active teams, i.e. teams solving at least half of tasks. 2019 – an estimation as the competition is not yet finished.

Year	2013	2014	2015	2016	2017	2018	2019
Number of tasks	10	10	10	10	8	8	8
Maximum score	30	30	30	30	24	24	24
Winners score [%]	75.3	94.5	95.9	89.7	99.0	99.5	*100*
Number of teams	6	18	26	24	20	19	*21*
Teams 50* [%]	33.3	38.9	61.5	62.5	75.0	78.9	*71.4*

2.2 About the Rules

In contrary to other robot contests, the Robot League focuses on constant and patient work on problem solving instead of single and energetic thrust culminating in a full stress. The contest is run in a friendly, open and trustful spirit with the main goal to have fun while learning something new.

The rules are kept as simple as possible with minimum limitations, see [4] or liga.robotika.sk for details.

The best teams in every round receive a diploma and a bag with spare plastic parts and sweets. A supportive NGO sponsor and the local distributor provide Lego Mindstorms robotics set to the overall winner with the highest score after all rounds. An average number of team members is 5–6, usually boys, with several pure girl teams (average team consists of 5 boys plus 1,75 girl). It is difficult to state exact numbers as some teams (especially school club) varied during the contest period. But the number of girls is higher than in most other contests, so we assume this type of design competition is also attractive for girls, but we didn't investigate this topic more deeply.

2.3 Tasks Classification

Our aim is to provide a wide variety of task types. One of our goals is to show examples of using robots in various curriculum-supporting scenarios, in subjects as Physics, Mathematics, Informatics, Art, or Biology, see [5–7] for more examples of inspiration. Tasks are being published in a random order as they are invented. Herein we classify them to different nondisjunct categories, see Table 2: *construction challenge* (C) is a task with a high demand on creativity in design and mechanical invention; *programming challenge* (P) requires non-trivial programming, sometimes use of data structures or files; *environmental interaction* (I) relies to somewhat larger extent on the interaction of the robot with its environment using sensors; *environmental manipulation* (M) requires the robot to successfully modify its environment; *Navigation* (N) needs strategies for moving the robot around its environment; *Measure* (E) tasks require measuring some physical properties using sensors; *Physics* (F) are tasks useful for discovering or demonstrating physics laws, or which need some physics insight; *Mathematical* (+) are tasks encouraging mathematical thinking; *Art* (A) are tasks focusing on artistic creativity; *Multi-robot* (2) are tasks with interaction of two robots; and *Static* (S) tasks have robots that do not travel in their environment.

Table 2. Classification of Robot League tasks.

Year/round	C	P	I	M	N	E	F	+	A	2	S	Year/round	C	P	I	M	N	E	F	+	A	2	S
2013	5	2	3	4	8						1	2017	5	2	2	6	7	1				2	5
2014	3	3	1	4	3		1		1		3	2018	6	3	3	3	6	3	1		1		7
2015	4	1	2	3	4		3		1		4	2019	9	4	1		5	2	1	1		1	9
2016	3	1	2	5	6	4	3	3			7	Total (96)	31	16	15	24	39	10	10	4	3	3	36

2.4 Example Tasks

In this section, we present few different tasks, each focused on a subset of competences. Formulation of the task is often very short, intentionally not specifying too much details. Solution is open-ended, leaving the final realization open just to the team creativity.

Pull-over. This is an example of task focused mainly on the mechanical construction and requires also some understanding of physics and mechanics. The task was to build a robot able to perform a pullover - a kind of gymnastic move performed on the high bar in which one pull its legs up and over the bar and its body rolls backward around the bar. To be honest, it was probably the most complicated tasks and no one was able to build the robot according to our vision. The closest one was M-Team, with two motors on legs, one for approaching the bar and last one for gripping the bar (see Fig. 1).

Bulb Exchange. The task specification is very short: build a robot that is able to replace a bulb in a table lamp. This requires creation of a mechanism for bulb grip, turning it an finding the right position. Many teams didn't think of complex solution, only one team designed also a bulb storage and their robot was able to store wrong bulb, take new one and replace it in the fixed lamp position (see Fig. 2). The gripper itself was able to adapt to different bulb diameters.

Spider Web. Task, inspired by Rodney Brooks bio-inspired robotics [8] asked to build a robot able to create simple spider net. Start of the fiber may be already fixed and the net has to be weaved using existing fixed objects (e.g. PET bottles, knitting needles etc.)

One of the best teams, RDS, created a plotter-like machine with the fiber bin and it was able to create not only the spider net, but almost any ornament (see Fig. 3).

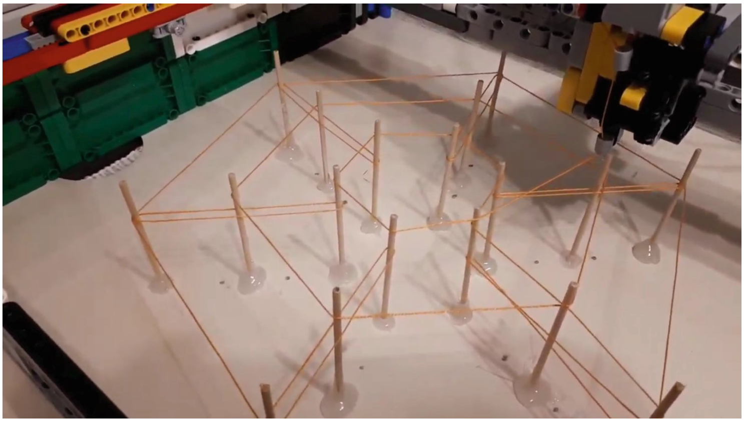

Fig. 3. Spider net by the RDS team.

Exchange Our Smiles. Some tasks are more focused on mechanical side, required just minimum programming, others are more challenging. An example of those is the task to find some randomly placed bricks in the front of the robot and to place them into the smiley shape. Robot should be able to work in many different starting configurations (see Fig. 4).

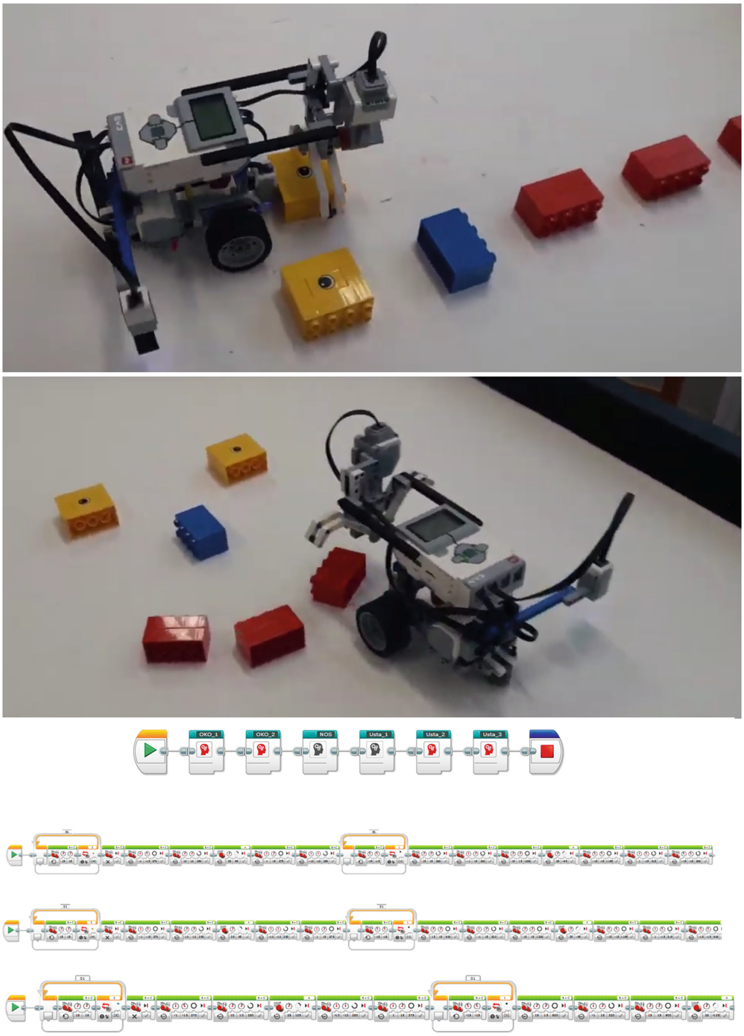

Fig. 4. Start and finish of the SiToMaFi team robot operation and the corresponding software in NXT-G programming language.

2.5 Supporting Software

In the first year, we have manually published the submitted solutions on-line, which even for 6 teams turned out to be a too demanding and time-consuming task. Later, students as part of the course Information Systems Development have specified, designed and implemented a web application as their team project. Currently, we are using the third complete rewrite, with new features added as the contest has been developing. The application allows the team leaders to register a new team at any time, view all past and current task specifications and submit and later edit a solution to a new task before the deadline. They provide a rich text description, upload pictures, programs or other attachments, and enter video links. Their solutions are nicely formatted and pictures are presented in a gallery, all integrated into the Robot League website. Judges can view the solutions, assign scores, and write their textual evaluation. Administrator then reviews and merges all the judges' comments, selects the best teams in each round, and makes the evaluation public. The resulting scores are computed automatically and shown in a table on the website. Organizers can enter their task descriptions with pictures and videos and maintain a pool of tasks to be used later in the contest, providing the starting and ending dates of the round. This system has simplified the organizers work and made it more convenient for the teams to adjust the presentation of their solution as they wish. The system currently supports Slovak, English and German languages, so that all tasks can be prepared in all three versions. It is open source and available at [9] (Fig. 5).

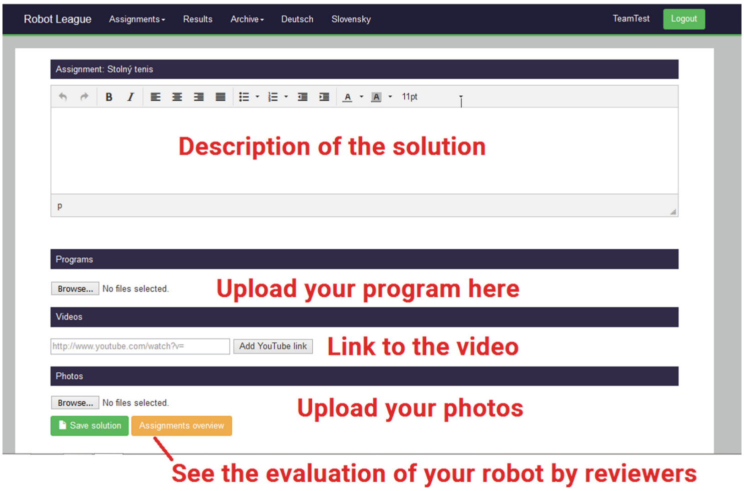

Fig. 5. The page for uploading a new team solution.

3 Discussion

Although we have some experiences and we believe this competition format is better than other in many ways, still some questions remains open.

Should the rules be limited in the same way as the FLL competition rules? After the requests from the participants, we have allowed to use an alternate software. Teams have then happily used NXC, Robot C, and MonoBrick software. It may also open further doors to creativity when we allow the use of additional components, not strictly limited to LEGO parts. Wider base here can later be limiting when teams start to prepare for regular FLL competition.

Children can easily forget some important limitations (this sensor was allowed, so why we can't use it now?), but FLL rules tend to be clear and the teams know they must check them thoroughly. Currently, we restrict these to be supportive objects only, for instance gymnastics rings, lighthouse, or an umbrella fabric. Some teams use 3D printing for making them. We keep the limitation to LEGO kits to address the issue of common platform and equal opportunities. However, we are considering a completely new parallel contest with Arduino platform and 3D printed designs. *Is there an "optimal" time interval for solving the tasks?* Are four weeks sufficient? Usually the clubs meetings are organized once a week, so they may need more time to discuss and solve the task. Currently, each round consists of two tasks. This leaves 4 tasks open for solutions at any time. A typical robot club has 6–15 members and thus the leader can split the children into groups of 2 or 3, each solving a different task. This makes the organization of work much more smooth, and manageable as contrasted for instance to running an FLL team with 10 children who are to build and program only a single robot in the span of four months. We believe leaving more time for a round would result in teams finding other activities, loosing focus. Lifting this time constraint could harm the efficiency and the skills of setting the priorities. It is a league after all. *Is the age limitation 9–16 years appropriate?* In FLL, we found that young teams from elementary schools have very hard time competing against 15–16 years old students of secondary schools. In fact, it is almost impossible for them to win, provided such a team with sufficient skills takes part. In our league, we try to design tasks, which can be solved by younger students too, if they try hard enough. A successful solution leads to full score – almost every round has some. Thus a focused younger team with full dedication can outperform older teams. Yet, they learn from each other by watching the solutions of other teams approaching the challenges from a different perspective. *Can the evaluation system be improved?* We also considered the idea of taking the 3 or 5 best tasks from all. The positive effect of giving teams a chance to skip a couple of tasks would result in too many teams having the full score. It could harm the motivation, and the habit of regular work. When communicating with teams, we try to give emphasis on learning, sharing, and having fun participating and that we are happy for all their solutions, even partial ones. Finally we provide a qualitative feedback from a team leader of one of the successful teams: *I have to say that our boys enjoyed the competition very much and not only this year. We have summarized our whole year last Tuesday, and Robot League is among the most interesting activities we do. We have a couple of new members this year, and they were immediately excited by the League and joined. Boys were looking at solutions of other teams after the deadline, and sometimes they could see a way they were considering, or were unable to complete, and it was super that they could see it from a different angle or in a different variation.*

4 Conclusions

During the seven years with the organization of creative constructionist robotics on-line competition, we have collected enough experiences and individual evidence for recommending it to others.

It was focused on young people in Slovakia aged 9–16, with 8–10 tasks each year. Its main aim is to support creative and design thinking of the pupils. We have experienced a growing interest and a positive feedback from the participants. In the 2019 we start to spread the competition in Austria too and we are open to a global international participation. Participation in the contest is free and easy, emphasizes learning, and creativity, it does not include stress and frustrations from failures at tournament day – which are inevitable in on-site single-day events. The amount of sharing ideas that takes place in this contest is among its strongest advantages. We efficiently utilize modern media – such as YouTube videos and a dedicated web application that allows the participants, referees, and organizers to maintain the contest automatically on their own without any other assistance from a system administrator.

Instead of increasing the size of this single competition, we would like to encourage leaders and organizers of robot competitions around the world to organize their own local versions. The software is open-source and can be found at Github repository [9]. We can provide assistance with its deployment. The prospective organizers can get inspired by the tasks solved in previous years of our competition. We would be honoured to provide consultations when starting new local contests.

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