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Project Final Report

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1.1 Executive Summary

Robot competitions have proved to be an effective instrument to foster scientific research and push the state of the art in a given field. Teams participating in a competition must identify best practice solutions covering a wide range of functionalities and integrate them into practical systems. These systems have to work in the real world, outside of the usual laboratory conditions. The competition experience helps to transfer the applied methods and tools to successful and high-impact real-world applications. By participating in robot competitions, young students are attracted to science and engineering disciplines. Through competition events, the relevance of robotics research is demonstrated to citizens.

The goal of RoCKIn ("Robot Competitions Kick Innovation in Cognitive Systems and Robotics") was to speed up the progress towards smarter robots through scientific competitions. Two Challenges have been selected for the competitions due to their high relevance and impact on Europe's societal and industrial needs: domestic service robots (RoCKIn@Home) and innovative robot applications in industry (RoCKIn@Work).

The RoCKIn project has taken an approach to boosting scientific robot competitions in Europe by i) specifying and designing open domain test beds for competitions targeting the two Challenges and usable by researchers worldwide; ii) developing methods for scoring and benchmarking through competitions that allow to assess both particular subsystems as well as the integrated system; and iii) organizing Camps whose main objective is to build up a community of new teams from reputed research labs, interested to participate in robot competitions.

Within the project lifetime, two Competition Events took place, each of them based on the two Challenges and their respective test beds: RoCKIn Competition 2014 (in Toulouse) and RoCKIn Competition 2015 (in Lisbon).

Three Camps were also organized, in 2013 (Eindhoven, together with RoboCup 2013), 2014 (Rome) and 2015 (Peccioli, at ECHORD++ Robotics Innovation Facility).

A significant number of dissemination activities on the relevance of robot competitions were carried out to promote research and education in the field, targeting the research community, in industry and academia, as well as the civil society. The potential future impact on Robotics research of the benchmarking methods developed and applied during the project lifetime was recognized by many researchers worldwide, and an article on the topic was published in the IEEE Robotics & Automation Magazine in 2015. The project was present in several scientific robotic conferences, fairs and major events, including the ICT 2015, where the prize for the best booth in the TRANSFORM area was awarded.

The lessons learned during RoCKIn paved the way for a step forward in the organization and research impact of robot competitions, contributing for Europe to become a world leader in this approach to developing research, education and technology transfer.

1.2 Context, Objectives and Activities Summary

Robot competitions have proved to be an effective instrument to foster scientific research and push the state of the art in a given field. Teams participating in a competition must identify best practice solutions covering a wide range of functionalities and integrate them into practical systems. These systems have to work in the real world, outside of the usual laboratory conditions. The competition experience helps to transfer the applied methods and tools to successful and high-impact real-world applications. By participating in robot competitions, young students are attracted to science and engineering disciplines. Through competition events, the relevance of robotics research is demonstrated to citizens. However, some limitations have emerged in the past as well-established robot competitions matured:

- the effort required to enter the competition grows and may present a barrier for the participation of new teams;
- a gap between benchmarking complete systems in competitions and benchmarking subsystems in research may develop and limit the usefulness of the competition results to industry.

The goal of RoCKIn ("Robot Competitions Kick Innovation in Cognitive Systems and Robotics") was to speed up the progress towards smarter robots through scientific competitions. Two Challenges have been selected for the competitions due to their high relevance and impact on Europe's societal and industrial needs:

- domestic service robots (RoCKIn@Home) and
- innovative robot applications in industry (RoCKIn@Work).

Both Challenges have been inspired by activities in the RoboCup community, but RoCKIn improved and extended them by introducing new and prevailing research topics, such as interaction with humans and networking mobile robots with sensors and actuators spread over the environment, in addition to specifying concrete scoring and benchmark criteria and methods to assess progress.

The RoCKIn project addressed the competitions limitations identified above by i) specifying and designing open domain test beds for competitions targeting the two challenges and usable by researchers worldwide; ii) developing methods for scoring and benchmarking through competitions that allow to assess both particular subsystems as well as the integrated system; and iii) organizing Camps whose main objective is to build up a community of new teams from reputed research labs, interested to participate in robot competitions.

Within the project lifetime, two Competition Events took place, each of them based on the two Challenges and their respective test beds:

- RoCKIn Competition 2014, in La Cité de L'Espace, Toulouse, 24-30 November 2014: 10 teams (7 @Home, 3 @Work) and 79 participants from 6 countries.
- RoCKIn Competition 2015, in the Portugal Pavilion, Lisbon, Portugal, 17-23 November 2015: 12 teams (9 @Home, 3 @Work) and 93 participants from 10 countries.

Organizing each of the Competition Events followed and improved established best practices for the organization of scientific competitions:

1. issuing the Call for Participation, requiring teams to submit an application consisting of a 4-pages paper describing the team research approach to the Challenge, as well as the hardware and software architectures of its robot system, and any evidence of performance (e.g., videos);
2. selecting the qualified teams from among the applicants;
3. preparing/updating and delivering the final version of the rulebooks, scoring criteria, modules and metrics for benchmarking about 4-5 months before the actual competition dates, after an open discussion period with past participants and the robotics community in general;
4. building and setting up the competition infrastructure through joint work with the venue staff and the IST-ID subcontractor Dr. Bredenfeld UG;
5. setting up the Motion Capture System for ground-truth data collection during benchmarking experiments, listing all data to be logged by the teams during the competitions for later benchmarking processing, and preparing USB pens to store that data during the actual runs of the team's robot system;
6. preparing several devices and software modules required by the competition rules (e.g., referee boxes, home automation devices (remotely-controlled lamps, IP camera, motorised blinds) and device network, factory-mockup devices (drilling machine, conveyor belt), objects for perception and manipulation, visitor's uniforms and mail packages, audio files and lexicon).
7. establishing a schedule for the competitions and their different components;
8. preparing the communication materials (brochure, leaflet, roller banners, banners, t-shirts, merchandising, schedule) for the media and general citizens and stakeholder (from academia and industry) visitors;
9. preparing materials for teams (bags, badges, schedule);
10. preparing guidelines plus questionnaires for the Experts Board and industrial visitors, so as to obtain feedback on the relevance of the competition Challenges and of the event organization;
11. establishing the adequate number of teams awarded per competition category and preparing trophies for the competition awards;
12. realizing the event, including the organization of visits form schools, and the availability of communicators who explain to the audience what is happening, using a simplified version of technically correct descriptions.

Three Camps were also organized:

- RoCKIn Kick-off Camp, in Eindhoven, the Netherlands, 28 June till 1 July 2013, during RoboCup2013: 12 participants. The Camp consisted of several lectures by the partners, on RoCKIn challenges and activities, covering subjects such as: principles for benchmarking robotics;

raising awareness and disseminating robotics research; as well as discussion on developing robotics through scientific competitions like RoboCup. In addition to the lectures, attendees got first-hand experience of demo challenges, tests, and hardware and software solutions during the RoboCup@Home and RoboCup@Work practical sessions.

- RoCKIn Camp 2014, in Rome, Italy, 26-30 January 2014: 19 teams (11 @Home, 8 @Work), corresponding to a total of 63 students and researchers from 13 countries. This Camp was designed to support the preparation of (preferably new) teams to participate in RoCKIn@Home and RoCKIn@Work competitions, and featured guest lectures by Michael Zillich, Norman Hendrich and Matthew Walter on vision-based pattern recognition, object and people detection, object grasping and manipulation, and Human-Robot Interaction in natural language, respectively.
- RoCKIn Field Exercise 2015, in Peccioli, Italy, at the ECHORD++ Robotics Innovation Facility, 18-22 March 2015: 42 participants divided in 9 teams (4 @Home, 5 @Work). The Field Exercise has been designed as a follow up of the previous RoCKIn Camp 2014, where most of the RoCKIn Competition 2014 best teams displayed their progresses and all participants improved their interaction with the RoCKIn scoring and benchmarking infrastructure.

Dissemination activities on the relevance of robot competitions were carried out to promote research and education in the field, targeting the research community, in industry and academia, as well as the civil society. This included, but was not limited to:

- a web page regularly updated;
- Facebook page and Twitter account also regularly updated, especially during major project events, such as the Camps and the Competitions;
- videos summarizing the RoCKIn Camp 2014, the RoCKIn Field Exercise 2015, the RoCKIn Competitions 2014 and 2015 were produced and made available online on the RoCKIn website and RoCKIn YouTube channel – targeting a general audience, to educate and raise awareness of RoCKIn;
- Nine publications in workshops, conferences and in the IEEE Robotics & Automation Magazine (about the scoring and benchmarking methods used and the project activities).
- Organization of several workshops on robot competitions, particularly three editions co-organized with the euRathlon Coordination Action and the EuRoC project at the European Robotics Forum (ERF) 2013, 2014, 2015 (with a new edition accepted for ERF 2016)
- Presence in several exhibitions and industrial fairs, such as RoboCup 2013 (Eindhoven), IEEE ICRA 2013 (Karlsruhe), IEEE/RSJ IROS 2013 (Tokyo), IEEE ICAR 2013 (Montevideo), ISR/ROBOTIK 2014 @AUTOMATICA 2014 (Munich), EuRoC Challenge Design Workshop (Munich, 2014), IEEE ICRA 2014 (Hong Kong), IEEE/RSJ IROS 2014 (Chicago), INNOROBO (Lyon), IEEE/RSJ IROS 2015 (Hamburg), ICT 2015 (Lisbon). The latter won the award for the best booth in the TRANSFORM area.
- Production and distribution of communication materials (leaflets, brochures, posters and banners) and merchandising (pens, travel mugs, t-shirts, key rings with the RoCKIn logo).

Two test beds were designed and built according to the rulebook open-source specifications, being available for research visits by worldwide groups interested to benchmark their approaches:

- RoCKIn@Home test bed at IST-ID.
- RoCKIn@Work test bed at BRSU.

The interest raised by the RoCKIn Competition events brought together institutional and commercial sponsorship, as well as the organization of co-located satellite events:

- major 2014 sponsors and associated institutions: LAAS/CNRS, Midi-Pyrénées Innovation, Toulouse Métropole;
- major 2015 sponsors and associated institutions: Institute for Systems and Robotics at Instituto Superior Técnico of the U. Lisbon, Lisbon Town Hall, SAPO, The Shadow Robot Company, Ciência Viva;
- euRobotics AISBL decided to move, for the first time, the communication centre of the European Robotics Week to La Cité de L'Espace and Toulouse in 2014;
- satellite events in 2014: *Les Journées Nationales de la Robotique Interactive* – organized by LAAS/CNRS (academic conference); Friendliness made in Midi-Pyrénées (networking event); Robotics EU Regions: Tell Me Who You Are (workshop); Meetings of euRobotics Technology Topic Groups;
- satellite events in 2015: ROBOT2015 – 2nd Iberian Robotics Conference; EU Robotics Clusters Workshop (for Portuguese companies); RoCKIn-RoboCup Meeting.

1.3 Main S&T Results and Foregrounds

An estimated number of approximately 100 participants took part in the different activities (Camps, Competitions) organized within RoCKIn's frame. Many of them were new to robot competitions. Thus **one of RoCKIn's top foregrounds is its contribution to raise the interest in Robotics through robot competitions**, notably in Europe. RoCKIn is one of the best known Robot Challenges and Competitions in our questionnaire about robot competitions (answers and results listed in Appendix B), immediately after the DARPA Robotics Challenge and RoboCup. Furthermore, the relevance of the Task and Functionality Benchmarks developed in RoCKIn is scored very high for all TBMs and FBMs in the same questionnaire.

RoCKIn is a Coordination Action. Thus, its main purpose is to carry out coordination and networking activities to promote research, programmes and policies in strategic directions, not to produce research itself. Nevertheless, **novel scientific and technological results are among the outputs from RoCKIn**:

- **Scoring methods and metrics** to evaluate and compare performance of different robot systems designed to solve given Challenges, both at the Task and Functionality levels[1].

[1] In RoCKIn, Tasks are executed by composing Functionalities (see subsection 1.3.1), e.g., Task "Bringing an Object to Granny Annie" requires "Navigation", "Object Localization" and "Object Manipulation" Functionalities.

- **Benchmarking methods and metrics** to study the impact of Functionality performance on Task performance.
- **Open source design specifications for the Test Beds and rulebooks** of each Challenge, which take into consideration the scoring and benchmarking requirements, together with problems whose solution requires pushing the state of the art in robotics research. The latter are also supported by available datasets from the RoCKIn team performances during the two Competition events and the RoCKIn Field Exercise 2015.

In the following subsections we highlight the main results in the above three topics, preceded by an introductory subsection where the RoCKIn benchmark concepts are introduced.

1.3.1 RoCKIn benchmarks

RoCKIn's **approach to benchmarking experiments** is based on the definition of two separate, but interconnected, types of benchmarks:

• Functionality Benchmarks, which evaluate the performance of hardware/software modules dedicated to single, specific functionalities in the context of experiments focused on such functionalities;

• Task Benchmarks, which assess the performance of integrated robot systems facing complex tasks that usually require the interaction of different functionalities.

Of the two types, Functionality Benchmarks are certainly the closest to a scientific experiment. This is due to their much more controlled setting and execution. On the other side, these specific aspects of Functionality Benchmarks limit their capability to capture all the important aspects of the overall robot performance in a systemic way. More specifically, emerging system-level properties, such as the quality of integration between modules, cannot be assessed with Functional Benchmarks alone. For this reason, the RoCKIn Competitions integrate them with Task Benchmarks.

In particular, evaluating only the performance of integrated system is interesting for the application, but it does not allow to evaluate the single modules that are contributing to the global performance, nor to put in evidence the aspects needed to push their development forward. On the other side, the good performance of a module does not necessarily mean that it will perform well in the integrated system. For this reason, the RoCKIn Benchmarking Competitions target both aspects, and enable a deeper analysis of a robot system by combining system-level and module-level benchmarking.

System-level and module-level tests do not investigate the same properties of a robot. Module-level testing has the benefit of focusing only on the specific functionality that a module is devoted to, removing interferences due to the performance of other modules which are intrinsically connected at the system level. For instance, if the grasping performance of a mobile manipulator is tested by having it autonomously navigate to the grasping position, visually identify the item to be picked up, and finally grasp it, the effectiveness of the grasping functionality is affected by the actual position where the navigation module stopped the robot, and by the precision of the vision module in retrieving the pose and shape of the item. On the other side, if the grasping benchmark is executed by placing the robot in a predefined known position and by feeding it with precise information about the item to be picked up,

the final result will be almost exclusively due to the performance of the grasping module itself. The first benchmark can be considered as a “system-level” benchmark, because it involves more than one functionality of the robot, and thus has limited worth as a benchmark of the grasping functionality. On the contrary, the latter test can assess the performance of the grasping module with minimal interference from other modules and a high repeatability: it can be classified as “module-level” benchmark.

Let us consider an imaginary, simplified RoCKIn Competition including five tasks (T1, T2, . . . , T5). Figure 1 describes such imaginary competition as a matrix, showing the tasks as columns while the lines correspond to the functionalities required to successfully execute the tasks. For the execution of the whole set of tasks of this imaginary RoCKIn Competition, four different functionalities (F1, . . . , F4) are required; however, a single task usually requires only a subset of these functionalities. In Figure 1, task Tx requires functionality Fy if a black dot is present at the crossing between column x and row y. For instance, task T2 does not require functionalities F2 and F4, while task T4 does not require functionality F1.

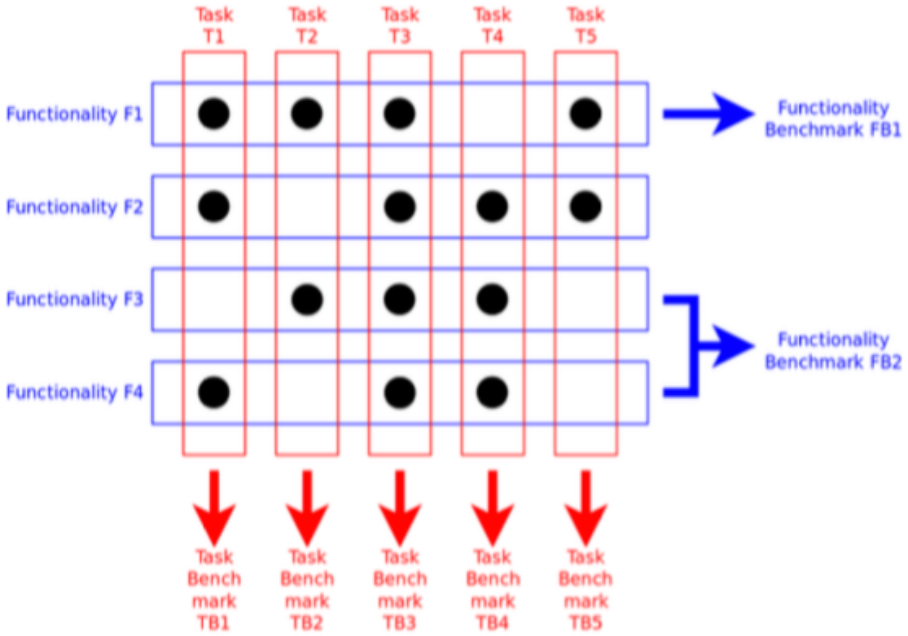

Figure 1 – Functionalities vs Tasks Matrix.

1.3.2 Scoring methods and metrics to evaluate robot systems performance

The **scoring framework for the evaluation of the Task Benchmarks** in the RoCKIn@Home and RoCKIn@Work competitions is the same for all Task Benchmarks of RoCKIn@Home and RoCKIn@Work, and it is based on the concept of performance classes used for the ranking of robot performance in a specific task.

The performance class that a robot is assigned to is determined by the number of achievements (or goals) that the robot reaches during its execution of the task. Within each class (i.e., a performance equivalence class), ranking is defined according to the number of penalties assigned to the robot. These

are assigned to robots that, in the process of executing the assigned task, make one or more of the errors defined by a task- specific list associated to the Task Benchmark. More formally:

- The ranking of any robot belonging to performance class N is considered better than the performance of any robot belonging to performance class M when M < N. Class 0 is the lowest performance class.
- Among robots belonging to the same performance class, a penalization criterion is used to define ranking: the robot which received less penalties is ranked higher.
- Among robots belonging to the same class and with the same number of penalties, the ranking of the one which accomplished the task in a shorter time is considered the highest (unless specific constraints on execution time are given as achievements or penalties).

Performance classes and penalties for a Task Benchmark are indeed task-specific, but they are grouped according to the following three sets (of which here we define the semantics; the actual content is specific to each Benchmark):

- set DB = *disqualifying behaviors*, i.e. things that the robot must not do;
- set A = *achievements* (also called goals), i.e., things that the robot should do;
- set PB = *penalizing behaviors*, i.e., things that the robot should not do.

Once the content of each of the previous sets is provided as part of the specifications of the relevant Task Benchmark, the following 3-step sorting algorithm is used to apply the RoCKIn scoring framework:

1. if one or more of the disqualifying behaviors of set DB occur during task execution, the robot gets disqualified (i.e., assigned to class 0, the lowest possible performance class), and no further scoring procedures are performed for it;
2. the robot is assigned to performance class X, where X corresponds to the number of achievements of set A which have been accomplished by the robot;
3. a penalization is assigned to the robot for each behavior of the robot belonging to set PB that occurs during the execution of the task.

One key property of this scoring system is that a robot that executes the required task completely will always be placed into a higher performance class than a robot that executes the task partially. In fact, penalties do not change the performance class assigned to a robot and only influence intra-class ranking.

It is not possible to define a single **scoring framework for all Functionality Benchmarks** as it has been done for Task Benchmarks in the previous chapter. These, in fact, are specialized benchmarks, tightly focused on a single functionality, assessing how it operates and not (or not only) the final result of its operation. As a consequence, scoring mechanisms for Functionality Benchmarks cannot ignore how the functionality operates, and metrics are strictly connected to the features of the functionality. For this reason, differently from what has been done for Task Benchmarks scoring methodologies and metrics are defined separately for each Functionality Benchmark of a Competition.

In RoCKIn, Functionality Benchmarks are defined by four elements:

- Description: a high level, general, description of the functionality.
- Input/Output: the information available to the module implementing the functionality when executed, and the expected outcome.
- Benchmarking data: the data needed to perform the evaluation of the performance of the functional module.
- Metrics: algorithms to process benchmarking data in an objective way.

Deliverable D1.2 – "General evaluation criteria, modules and metrics for benchmarking through competitions" provides more details and examples on scoring and ranking team performance in Task and Functionality Benchmarks, as well as methods to combine Task rankings to determine the competition winner.

1.3.3 Benchmarking methods

The availability of both Task and Functionality rankings opens the way for the quantitative analysis of the importance of single Functionalities in performing complex Tasks. This is an innovative aspect triggered by the RoCKIn approach to competitions.

To state the importance of a Functionality in performing a given task, RoCKIn borrows the concept of Shapley value from Game theory. Let us assume that a coalition of players (Functionalities in the RoCKIn context) cooperates, and obtains a certain overall gain from that cooperation (the Task Benchmark scoring in the RoCKIn context). Since some players may contribute more to the coalition than others or may possess different bargaining power (for example threatening to destroy the whole surplus), what final distribution of generated surplus among the players should arise in any particular game? Or phrased differently: how important is each player to the overall cooperation, and what payoff can (s)he reasonably expect? Or in the RoCKIn jargon: how important is each Functionality to the reach a given performance in a Task Benchmark?

Assuming that all scores are expressed according to the same scale, the Shapley values of the single functionalities can be calculated as:

$$\phi_i = \frac{1}{n!}\sum_{\pi}[v(C_\pi(i) \cup \{i\}) - v(C_\pi(i))]$$

where i is a functionality, n is the total number of functionalities, π is a permutation of the n Functionality Benchmark scores, $C_\pi(i)$ is the set of functionalities that precede i in the permutation π, and $v()$ is the score of the set of functionalities specified as argument.

The use of Shapley values is proposed as a post-competition analysis tool in RoCKIn. Nevertheless, other techniques, such as the Banzhaf power index or the Shapley-Shubik power index, could be used to perform the same kind of analysis and quantitatively evaluate the impact of Functionality performance in Task performance.

Deliverable D1.2 – "General evaluation criteria, modules and metrics for benchmarking through competitions" provides examples of application Shapley values to quantitatively evaluate the impact of Functionality performance in Task performance.

1.3.4 Rulebooks, test beds and datasets

The **RoCKIn@Home test bed** (see Figure 2) consists of the environment in which the competitions took place, including all the objects and artefacts in the environment, and the equipment brought into the environment for benchmarking purposes. An aspect that is comparatively new in robot competitions is that RoCKIn@Home is, to the best of our knowledge, the first open competition targeting an environment with ambient intelligence, i.e. the environment is equipped with networked electronic devices (lamps, motorised blinds, IP cams) the robot can communicate and interact with, and which allow the robot to exert control on certain environment artefacts.

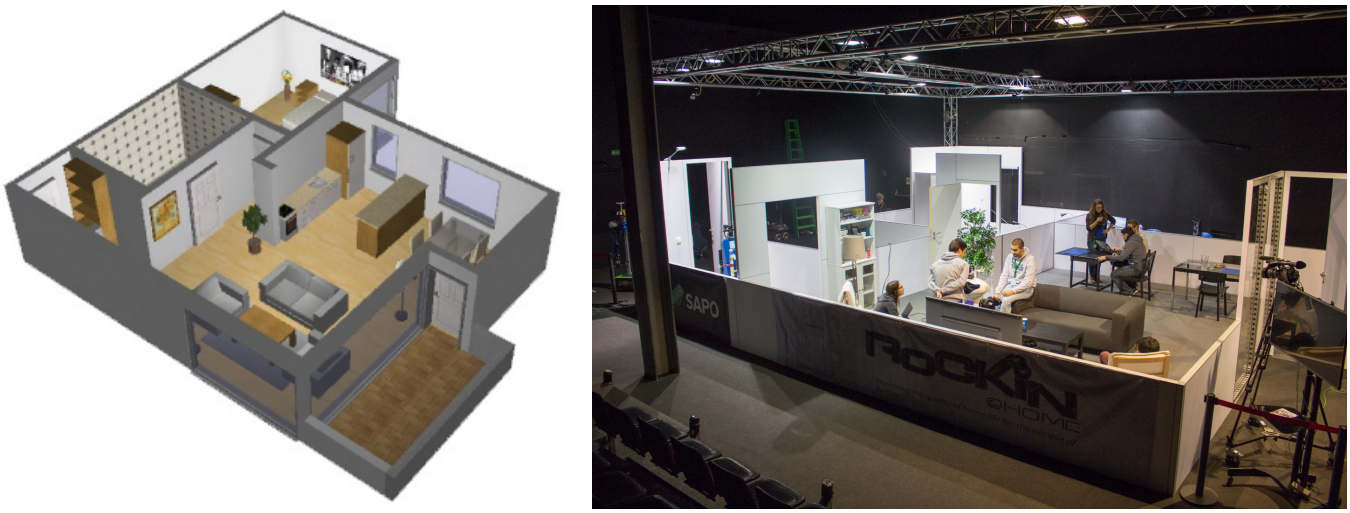

Figure 2 – RoCKIn@Home test bed, including the trusses for the MCS cameras on the right.

The RoCKIn@Home rulebook specifies in detail:

- The environment structure and properties (e.g., spatial arrangement, dimensions, walls).
- Task-relevant objects in the environment, split in three classes:
  - Navigation-relevant objects: objects which have extent in physical space and do (or may) intersect (in 3D) with the robot's navigation space, and which must be avoided by the robots.
  - Manipulation-relevant objects: objects that the robot may have manipulative interactions (e.g., touching, grasping, lifting, holding, pushing, pulling) with.
  - Perception-relevant objects: objects that the robot must "only" be able to perceive (in the sense of detecting the object by classifying it into a class, e.g., a *can*; recognizing the object as a particular instance of that class, e.g., a *7up can*; and localizing the object pose in a pre-determined environment reference frame.

During the benchmark runs executed in the test bed, a human referee enforces the rules. This referee must have a way to transmit his decisions to the robot, and receive some progress information. To

achieve this in a practical way, an assistant referee is seated at a computer and communicates verbally with the main referee. The assistant referee uses the **main Referee and the Scoring and Benchmarking Box (RSBB)**. Besides basic starting and stopping functionality, the RSBB is also designed to receive scoring input and provide fine grained benchmark control for functionality benchmarks that require so.

The **RoCKIn@Work test bed** (Figure 3) consists of the environment in which the competitions took place (the RoCKIn'N'RoLLIn medium-sized factory, specialized in production of small- to medium-sized lots of mechanical parts and assembled mechatronic products, integrating incoming shipments of damaged or unwanted products and raw material in its production line), including all the objects and artefacts in the environment, and the equipment brought into the environment for benchmarking purposes. An aspect that is comparatively new in robot competitions is that RoCKIn@Work is, to the best of our knowledge, the first industry-oriented robot competition targeting an environment with ambient intelligence, i.e. the environment is equipped with networked electronic devices (e.g., a drilling machine, a conveyor belt, a force-fitting machine, a quality control camera) the robot can communicate and interact with, and which allow the robot to exert control on certain environment artefacts like conveyor belts or machines.

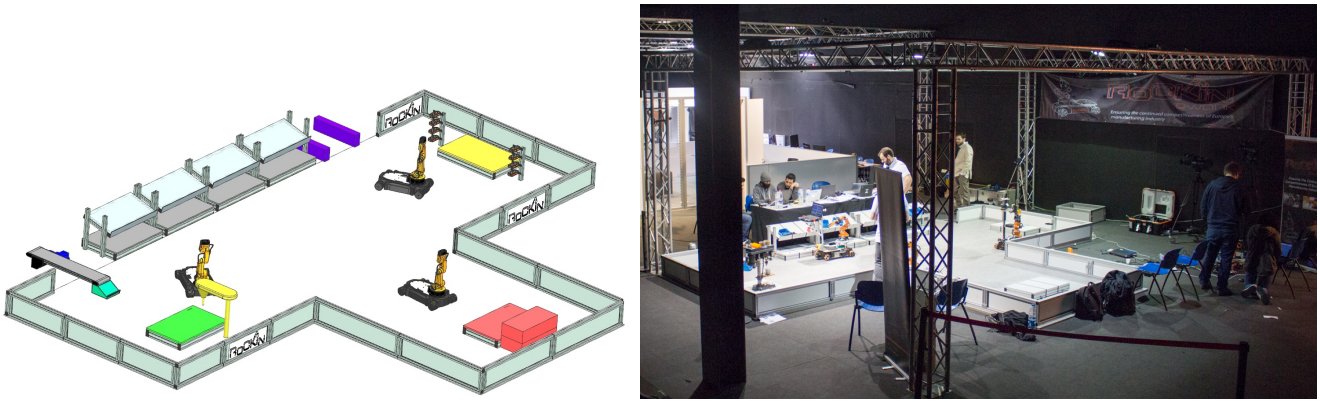

Figure 3 – RoCKIn@Work test bed, including the trusses for the MCS cameras on the right.

The RoCKIn@Work rulebook specifies in detail:

- The environment structure and properties (e.g., spatial arrangement, dimensions, walls).
- Typical factory objects in the environment to manipulate and to recognize.

The main idea of the RoCKIn@Work test bed software infrastructure is to have a central server-like hub (the **RoCKIn@Work Central Factory Hub** or **CFH**) that serves all the services that are needed for executing and scoring tasks and successfully realize the competition. This hub is derived from software systems well known in industrial business (e.g., SAP). It provides the robots with information regarding the specific tasks and tracks the production process as well as stock and logistics information of the RoCKIn'N'RoLLIn factory. It is a plug-in driven software system. Each plug-in is responsible for a specific Task, Functionality or other benchmarking module.

Both RoCKIn test beds include benchmarking equipment. RoCKIn benchmarking is based on the processing of data collected in two ways:

- internal benchmarking data, collected by the robot system under test;
- external benchmarking data, collected by the equipment embedded into the test bed.

External benchmarking data is generated by the RoCKIn test bed with a multitude of methods, depending on their nature. One of the types of external benchmarking data used by RoCKIn are pose data about robots and/or their constituent parts. To acquire these, RoCKIn uses a camera-based commercial motion capture system (MCS), composed of dedicated hardware and software. Benchmarking data has the form of a time series of poses of rigid elements of the robot (such as the base or the wrist). Once generated by the MCS system, pose data are acquired and logged by a customized external software system based on ROS (Robot Operating System): more precisely, logged data is saved as *bagfiles* created with the *rosbag* utility provided by ROS.

Pose data is especially significant because it is used for multiple benchmarks. There are other types of external benchmarking data that RoCKIn acquires: however, these are usually collected using devices that are specific to the benchmark.

Finally, equipment to collect external benchmarking data includes any server which is part of the test bed and that the robot subjected to a benchmark has to access as part of the benchmark. Communication between servers and robot is performed via the test bed's own wireless network.

During RoCKIn competitions and events, several datasets have been collected to be redistributed to the Robotics community for further analysis and understanding about the Task level and Functional level performance of robotics systems. In particular, data from the Object Perception (@Home and @Work) and Speech Understanding Functional Benchmarks was collected during RoCKIn Competition 2014 and RoCKIn Field Exercise 2015[2]. The datasets are available and will continue to be updated in the RoCKIn wiki at http://thewiki.rockinrobotchallenge.eu/index.php?title=Datasets.

Deliverables D2.1.3 "RoCKIn@Home Rule Book" and D2.1.6 - "RoCKIn@Work Rule Book" provide the full rulebooks for the two Challenges, including details of the RSBB and CFH "referee boxes" and pointers to the deliverables where details of the MCS and benchmarking system are available.

1.4 Potential Impact, Dissemination Activities and Exploitation of Results

RoCKIn impact in the upcoming years is expected to be mostly supported by the scoring and benchmarking methods, as well as the test bed specifications, developed during the project lifetime, as they progressively (fully or partially) migrate to new European (RoCKEU2[3]) and international (RoboCup) robot competitions. The research on benchmarking robot systems is also expected to be boosted by the introduced methods, as well as by exploiting RoCKIn major results and foreground: the RoCKIn rulebooks, test beds and datasets.

[2] At the time of writing the list of data collected during RoCKIn Competition 2015 is not yet complete.
[3] New European Horizon2020 ICT-Robotics Coordination Action, that will run from 1 February 2016 till 31 January 2018, where robot competitions will have a prominent role, including the two RoCKIn Challenges.

The dissemination activities will continue along similar lines to RoCKIn's: dissemination to the general public during competition events; dissemination to stakeholders (in academia and industry) through research articles (mostly on benchmarking, but possibly also targeting other research unveiled and motivated by robot competitions) in major journals and conferences.

We have questioned members of our Advisory Board on the **potential impact** of RoCKIn in several directions. The answers are compiled in Appendix A. Since they are prestigeful, well-respected and knowledgeable members of academia and industry, their answers should represent a good sample of the views of the international community. Here, we summarize each of the answers, associated to the topic we suggested to each member, based on his/her background, experience and/or role in the scientific/industrial community:

- Bruno Siciliano [*prospects for a research proposal around the topics of competitions following-up the RoCKIn experience*]: based on the success of the RoCKIn, euRathlon and EuRoC initiatives, "prospects are bright for the preparation of a proposal for a European Robotics League, aimed at designing robot competitions as benchmarking experiments, where scoring methods encourage reproducibility and repeatability of experiments and provide methods to measure performance (e.g., error between actual outputs vs ground-truth), while keeping the excitement of addressing a challenge and of competing with other teams to achieve the best solution to a common problem. Rules should foster developing functionalities that can be used and combined in the tasks. Algorithm and code-sharing repository of software modules per challenge should be developed. Data sets from the competitions should be made available, while teams should be forced to log their runs and provide their data sets."
- Bill Smart [*potential for US/EU collaboration in robot competitions using RoCKIn's model*]: "this is really two questions: (1) can we sustain a RoCKIn-like competition in the US?, and (2) can we interest people in an international event?". While the former may be difficult at the moment, due to several well-identified reasons, the second "is somewhat easier, assuming we have both US and EU versions of the competition. The easiest way in for this might be to have the top few teams from each continent get together to compete, so that the quality is high, and the cost is lowered (since there are fewer teams). (…) The idea of a strong ground-truth metricing facility and test-bed in the US might be a good starting point, and this is something that I'd be interested in helping out with, and hosting at Oregon State University. If we have this facility in place, perhaps with some funding to make it easier for people to travel here and use it, that might be a good catalyst for getting the competitions off the ground. Of course, this means finding funding for the effort, probably from NIST or NSF. I'd be interested in talking about strategies for this, if there is also interest from the RoCKIn organizers."
- Manuela Veloso [*the future impact of RoCKIn on RoboCup*]: "the RoCKIn competitions added [to the respective RoboCup leagues that served as their foundations] a complex vision motion-tracking system around the competition arenas, which enabled the extraction of the ground truth of the performance of the robot competitors. Such additional information proved to be very valuable and of use to the researchers to validate their algorithms and to provide an objective qualification to meet usual requirements of publications' reviewers. RoboCup will

consider this additional feature, learning from its impact in RoCKIn. RoboCup further hopes to build upon the participation success of RoCKIn and will reach out to RoCKIn teams to join the future RoboCup@Home and @Work competitions."

- Jon Agirre [*adequacy of @Work rules to future industrial robotics needs*]: "The initiative to have a robotic competition @Work is in my opinion very interesting to promote the evolution from a traditional industrial robotics to an emerging service robotics in manufacturing scenarios, where robots move, share the space and tasks with humans. This scenario has a huge potential in SMEs (thousands of companies all around Europe) but two aspects need to be addressed, the cost and the flexibility (at the set-up, easy programing methods, adaptability to changes at the product or at the production, ...). From what I saw and understood at the competition, the use of a perception system to detect objects including location is very interesting as a key functionality to achieve flexibility in manufacturing with robots. Perception is also a powerful tool to compensate the lack of accuracy of less specific robots and grippers."
- Oskar von Stryk [*potential for tech transfer of RoCKIn robot competitions*]: "There is a fundamental gap between academic robotics research and robotics applications. For the latter a high technology readiness level can only be achieved if complete robotic systems architectures are developed and evaluated in a strongly systems oriented manner. However, the involved efforts needed are often left out in academic research, although they are a pre-requisite for transferring research results to real robotics applications. Robotic competitions can fill this gap, as they give reward to participants' efforts for systems development through good results. RoCKIn has made very good contributions towards methodologies for robotic systems integration from a scientific viewpoint. As a consequence, this enables more systematic benchmarking in competitions for intelligent robots and for transferring a rather "hands-on" way of organizing robotic competitions to a more systems oriented research methodology. This pushes academic research towards methodologies for integration from a scientific standpoint. RoCKIn has also laid the basis for a yet not well addressed aspect of future intelligent personal robots in industrial and home environments: standardization and certification. (…) Meeting such standards with their robots, European robot manufacturers will be enabled to much better promote their high-tech robot developments in competition with other vendors on the international market."

The European Robotics League (ERL), whose foundations were laid out during discussions that took place during RoCKIn, will be a rich source of **dissemination** and **exploitation** of RoCKIn results. Its initial steps will be traced during the new RoCKEU2 European project, and can be summarized as follows. The ERL aims to become a sustainable distributed format (i.e. not a single big event) which is similar to the format of the European Football Champions League, where the role of national leagues is played by existing *local* test beds (e.g., the RoCKIn test beds, but also the ECHORD++ RIFs), used as meeting points for "matches" where one or more teams visit the home team for a small tournament. This format will exploit also arenas temporarily available during *major* competitions in Europe allowing the realization of larger events with more teams. According to this new format, teams could get "performance points" in a given challenge for each tournament they participate to, and they get ranked based on points

accumulated over the year. Teams will be encouraged to arrive 1-2 weeks before the actual competition/event so to participate in integration weeks where the hosting institution provides technical support on using the local infrastructure (referee boxes, data acquisition and logging facility, etc.). *Local* tournaments will take place in currently available test beds. *Major* tournaments will be part of RoboCup and other similar events. RoCKEU2 will provide a certification process to assess any new candidate test beds as RIFs for both challenges, based on the RoCKIn rulebook specifications and the implementation of the proper benchmarking and scoring procedures. This will enable the creation of a network of European robotics test beds having the specific purpose of benchmarking domestic robots, innovative industrial robotics applications and factory of the future scenarios.

The pool of ideas to **extend and exploit RoCKIn S&T results** is large and exciting. We will list here the most relevant ones, that came out from the three years of the RoCKIn experience, both from the consortium members and from the Experts Board members (whose full reports can be found as annexes of RoCKIn Deliverables D6.1 – "RoCKIn Competition 2014", and D6.2 - "RoCKIn Competition 2015"), Herman Bruyninckx (HB), Alessandro Saffiotti (AS) and Tijn van der Zant (TZ), organized by topics:

Overall:

- the benchmarking infrastructure, both software and hardware, is an impressive and distinctive feature of RoCKIn with respect to other existing robot competitions and challenges. It is now working smoothly, not interfering negatively with the teams' work, rather leading to a very intense and focused work atmosphere. Better benchmarking of existing robotic technology, rather than disruptive research in robotics should be the goal of RoCKIn. Leading the way to standardized, and preferably low cost, setups with automated software for the measuring and dissemination is the way forward for RoCKIn;
- the competition events have clearly pointed out RoCKIn's distinctive goals (with respect to other existing competitions or projects in Robotics): i) to systematically evaluate full robotic systems; ii) to benchmark key robotic functionalities; and iii) to foster scientific communication and cooperation. The research challenges posed by the rules are ambitious and well-balanced, as they should.

Benchmarking and Data Acquisition:

- the cost of the benchmarking infrastructure is high – solutions to minimize it (e.g., promoting local tournaments at the site of reference test beds where the equipment is available; touring the infrastructure through several sites in Europe) should be sought. Moreover, guidelines on how to set up the equipment and some standard software to work with the data would be very useful to boost technology transfer. It is recommended to provide a low cost hardware infrastructure with open source software, besides the current setup, to be used as a reference for other competitions and research laboratories;
- increase the value of *robustness* in FBM and TBM performance scoring – among other examples, the ability to deal with WLAN failures (or reduced bandwidth, or big latency) should be one of

the aspects that is tested in RoCKIn, since this is essential to real autonomy and deployability (namely in home scenarios), possibly giving a negative score to the bandwidth used;

- study further how testing single functionalities relate to the performance of the functionalities in complete tasks - making FBMs aligned with TBMs;
- "benchmarking procedures should cover not only geometric motion data but also dynamic features of navigation and manipulation" (HB);
- "I suggest to stimulate research groups to use the visual data or to use this for a Kaggle.com competition. The grounded data can be used for training the visual systems. This could lead to a setup where only 'normal' cameras are used. These visual systems are bootstrapped by the grounded system that is in use in the @Home scenario. For the test data set a part of the data is not published but is used to benchmark the trained visual systems. Once there are well trained visual systems that only 'normal' cameras are required the costs of the setup would be reduced by a large margin." (TZ);
- This is the time to advance towards the introduction of the semantic level, using semantic tags, i.e., "all data [*should*] be accompanied with semantic meta data that described the intention of the robot actions, as well as the progress that the robot is making in this intention, at least according to what its own executor process assesses as progress" (HB), including the logging of the associated tolerances regarding the error of what the robot accomplishes with respect to the desired goal(s).

Challenges:

- "Hopefully the technology of the benchmarking in the @Home setting can be transferred to the RoboCup Federation. Already in RoboCup there are discussions how to incorporate the measuring systems." (TZ);
- "There are interesting differences between the scoring system in RoCKIn@Home and the one in RoboCup@Home. The latter is much more subjective: roughly put, the given tasks must be completed in a way that is regarded as "satisfactory" by human judges. RoCKIn attempts at building a much more objective scoring system, and explicitly avoids subjective judgments. Two different philosophies about what and how to evaluate inspire these two scoring systems: one puts human's judgment and satisfaction as the ultimate goal, while the other seeks indicators that can be objectively measured. It would be interesting to compare these two approaches in a more extensive way. Perhaps one may find that the quantities measured in RoCKIn are effective indicators of human's satisfaction? Or perhaps one may find that these are two orthogonal dimensions and both of them should be considered? Maybe including additional user oriented metrics like acceptability, usability, or perceived utility?" (AS);
- include tests for FBMs and TBMs in more realistic world settings – on a related issue, establishing unexpected tests (e.g., restaurant test is turned into a supermarket test) will force the teams to reduce over-engineered approaches and focus on more general methodologies easy to customize to new tests - but this will come with the cost of being more difficult to benchmark results;

- there should be an extra emphasis on (graphical) user interfaces and on the teams providing real-time data to fill the slots of a dashboard displaying information to the attending public, e.g., information about the state of the robot actions such as grasping an object and whether the robot thinks it actually has successfully grasped it – this would force the teams to monitor and diagnose the performance of their robot systems and not only producing and storing data;
- A mixed-teams approach to solving some of the challenges would force improving the semantic level of the robots' code;
- the RoCKIn approach should be rebranded as a serious playground for open innovation, where several teams contribute with components that need to be integrated in a "standardized" manner to build up a successful "mixed team" – domotics companies, Internet of Things research groups, care technology providers, should be targeted and challenged to provide infrastructure and/or components;
- with the goal of reducing the size and increasing the objectivity of the rulebooks, start a community effort to develop a formal language to describe robotic scenarios, robotic tasks, and robotic benchmarks, e.g., the equivalent of PDDL, which allows people in the AI planning competition to describe domains and tasks in a compact but non-ambiguous way;
- make RoCKIn legacy sustainable after the project lifetime, by setting up an "European Foundation" composed of companies and institutions involved in affine areas and competitions.

Looking Towards Future Actions:

Future actions are already being taken so as to extend the project legacy past its lifetime:

- transferring the RoCKIn@Home and RoCKIn@Work rules and benchmarking methods to the new European Horizon 2020 Coordination Action RoCKEU2, that will start on 1 February 2016;
- promoting (under RoCKEU2) more regular and scientific-experiment-oriented competitions and reducing the cost of setting up the infrastructure, by creating a system of points awarded to teams that participate in local tournaments (head-to-head with the local team in one of the reference test beds) and in major tournaments (e.g., RoboCup, RoboCup German Open, Portuguese Robotics Open, RoboCup Dutch Open) – integrated in the existing league infrastructure for @Work and @Home;
- providing regular travel support to some of the teams willing to participate in the RoCKEU2 tournaments mentioned in the previous item;
- dialoguing with the RoboCup Federation and the RoboCup@Home and RoboCup@Work Technical Committees to discuss the transfer of some of the RoCKIn features (e.g., networked robot systems, benchmarking infrastructure, methods and metrics) to future RoboCup editions, under the RoCKIn/EC branding;
- promoting (under Horizon 2020 Research and Innovation Actions and other possible instruments) research progress on topics relevant to robotics at large, but mostly induced by needs found during the RoCKIn experience, e.g., methods and metrics to benchmark robot tasks and functionalities, including adding semantic meaning to data; real-time middleware for robot

systems; more dynamic and fault-tolerant methods for systems integration; better GUIs to display in real-time the information about the robot system performance.

1.5 Contacts

The **RoCKIn consortium** is composed of the following partners (partner coordinator within brackets), [acronym]:

- Instituto Superior Técnico (Pedro U. Lima), project coordinator [IST-ID]
- Università di Roma "La Sapienza" (Daniele Nardi) [UNIROMA1]
- Hochschule Bonn-Rhein-Sieg (Gerhard K. Kraetzschmar) [BRSU]
- KUKA Roboter GmbH (Rainer Bischoff) [KUKA]
- Politecnico di Milano (Matteo Matteucci) [POLIMI]
- InnoCentive (Gergely Eredics) [INNO]

and has a board of Advisory members and External Experts (EEAB):

Advisory Board Members:

- Adam Jacoff, NIST, USA
- Bill Smart, Oregon State University, USA
- Bruno Siciliano, University of Naples Federico II, Italy
- Jon Agirre Ibarbia, Tecnalia, Spain
- Manuela Veloso, Carnegie-Mellon University, USA
- Oskar von Stryk, Technical University of Darmstadt, Germany
- XiaoPing Chen, University of Science and Technology of China, China

Experts Board (reports on the competition events):

- Alessandro Saffiotti, Örebro University, Sweden
- Herman Bruyninckx, University of Leuven, Belgium
- Tijn van der Zant, University of Groningen, The Netherlands

RoCKIn Logo and Contacts:

- Web: http://rockinrobotchallenge.eu
- E-mail: info@rockinrobotchallenge.eu
- Facebook: https://www.facebook.com/rockinrobotchallenge
- Twitter: @RoCKInChallenge

2 Use and Dissemination of Foreground

2.1 Section A: Scientific Publications and Dissemination Activities

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers (if available)	Is/Will open access provided to this publication?
1	Competitions for Benchmarking: Task and Functionality Scoring Complete Performance Assessment	*F. Amigoni*	*Robotics & Automation Magazine*	*No 33(3), Sept. 2015*	*IEEE*		*2015*	*pp. 63 - 61*		no
2	RoCKIn Innovation Through Robot Competitions	P. U. Lima	*Robotics & Automation Magazine*	No 21(2), June 2014	IEEE		2014	pp. 8-12		no
3	A Proposal for Semantic Map Representation and Evaluation	R. Capobianco	European Conference on Mobile Robots (ECMR)	2-4 Sept. 2015	IEEE	Lincoln, United Kingdom	2015	pp. 1-6		no
4	RoCKIn@Home: Benchmarking Domestic Robots Through Competitions	P. U. Lima	Int'l Conf. on Advanced Robotics (ICAR)	25-29 Nov. 2013		Montevideo, Uruguay	2013			no
5	Design and Development of a Benchmarking Testbed for the Factory of the Future	S. Schneider	Int'l Conf. on Emerging Technologies and Factory Automation (ETFA)	08-11 Sept. 2015	IEEE	Luxembourg	2015	pp. 1-7		no
6	To What Extent Are Competitions Experiments? A Critical View	F. Amigoni	Workshop on Epistemological issues in robotics	5 June 2014		Hong Kong	2014			no

			research and research result evaluation (ICRA 2014)							
7	The RoCKIn@Home Challenge	S. Schneider	Int'l Symposium on Robotics (ISR 2014)	02-03 June 2014	VDE	Munich, Germany	2014	pp. 1-6		no
8	The RoCKIn@Work Challenge	R. Dwiputra	Int'l Symposium on Robotics (ISR 2014)	02-03 June 2014	VDE	Munich, Germany	2015	pp. 1-6		no
9	Benchmarking Through Competitions	F. Amigoni	European Robotics Forum --	20 March 2013		Lyon, France	2013			no

TABLE A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
1	Website	InnoCentive	RoCKIn dedicated website	2013-2015		*Civil Society, Scientific Community, Industry*		World
2	Posters	InnoCentive		2013-2015		*Civil Society, Scientific Community, Industry*		
3	Flyers	InnoCentive		2013-2015		*Civil Society, Scientific Community, Industry*		
4	Roller banners	InnoCentive		2013-2015		*Civil Society*		
5	MUPIs	InnoCentive		2015		*Civil Society*		
6	RoCKIn merchandise: T-Shirts, pens, keyrings, sunglasses, travel mugs and bags	InnoCentive		2013-2015		*Civil Society*		

	Press Release	Innocentive	RoCKIn2015: A glimpse into the future of Europe's domestic and industrial robotics industry	2015		*Civil Society, Scientific Community, Industry*		
7	Online newsletter	InnoCentive		2013-2015		*Civil Society, Scientific Community, Industry*		
8	Social Networks	InnoCentive		2013-2015		*Civil Society, Scientific Community, Industry*		
9	Videos of RoCKIn Competitions and Camps	Innocentive		2013-2015		*Civil Society, Scientific Community, Industry*		
10	Five minutes pitches	InnoCentive		2013-2015		*Civil Society, Scientific Community, Industry*		
11	Questionnaire	InnoCentive	Progress Evaluation involving Academia, Industry and Policy Makers	2014		*Scientific Community, Industry, Policy Makers*		
12	Questionnaire	KUKA	Progress Evaluation involving Academia, Industry and Policy Makers	2015		*Scientific Community, Industry*		
13	*Five Presentations*	G. K. Kraetzschmar, M. Matteucci, L. Iocchi, P. U. Lima, G. Buchanan	RoCKIn Camp 2013	July, 2013	Eindhoven	*RoboCup participants, Camp students*		Netherlands
14	Presentation	F. Amigoni	Progresses in the RoCKIn project	13 March 2014	Rovereto	*European Robotics Forum participants (Scientific Community, Industry)*		Italy
15	Presentation	F. Amigoni	Benchmarking HRI in RoCKIn Competitions	Sep 2014	Chicago	*IEEE/RSJ IROS 2014 Workshop on Human2robot*		USA

						Collaboration in Standardization and R&D Activities (Scientific Community, Industry)		
16	Presentation	M. Matteucci	Driving Robotics Forward Through Collaboration, Benchmarking and Competition	June 2014	Hong Kong	*IEEE ICRA 2014 Forum on Robotics Challenges and Competitions (Scientific Community, Industry)*		China
17	Presentation	M. Matteucci,	Benchmarking: Learnings from RoCKIn	January 2014	Munich	*EuRoC Challenge Design Workshop (Scientific Community, Industry)*		Germany
18	Presentation	R. Bischoff	RoCKIn: Robot Competitions Kick Innovation in Cognitive Systems and Robotics	Nov. 2013	Tokyo	*IEEE/RSJ IROS 2013 Forum on New Horizon of European Robotics and Cognitive Systems (Scientific Community, Industry)*		Japan
19	Presentation	POLIMI	Robotics@Polimi Open Labs Event	Nov. 2013	Milano	*European Robotics Week (Civil Society)*		Italy
20	Presentation	R. Bischoff	Designing robot competitions RoboCup 2015 Ecosystem Summit with a benefit for the industry – The KUKA perspective	July 2015	Hefei	*RoboCup 2015 Ecosystem Summit (RoboCup participants)*		China
21	Presentation	R. Bischoff	Advanced control technologies for safe human-robot collaboration and	August 2015	Salvador	*IFAC Symposium on Robot Control – SYROCO 2015 (Scientific*		Brazil

			mobile manipulation			*Community, Industry)*		
22	Presentation	M. Matteucci	Do we really need to replicate experiments?	September, 2015	Hamburg	*IROS 2015 – Open Forum on Evaluation of Results, Replication of Experiments and Benchmarking in Robotics Research (Scientific Community, Industry)*		Germany
23	Presentation	P. U. Lima	RoCKIn: the Journey So Far and the Upcoming Final Competition	September 2015	Hamburg	*IROS 2015 – Workshop on Robot Competitions: What did we learn? (Scientific Community, Industry)*		Germany
24	Presentation	M. Matteucci	Benchmarking, experiments, and competitions	September 2015	Benicassim	*RAS Summer School on Experimental Methodology, Performance Evaluation and Benchmarking in Robotics (Scientific Community, Industry, students)*		Spain
25	Presentation	P. U. Lima	Robots Helping @Home and @Work	February 2015	Luxembourg	*DG Connect (Policy Makers)*		Luxembourg
26	Presentations	P. U. Lima and D. Nardi	Benchmarking and evaluation of intelligent robotic systems	December 2014	Örebro	*The Second Örebro Winter School on "Artificial Intelligence and Robotics" (Scientific Community, Industry, students)*		Sweden
27	Presentation	P. Miraldo	Practicals on evaluation of intelligent robotic systems	December 2014	Örebro	*Örebro Winter School on "Artificial Intelligence and Robotics" (Scientific*		Sweden

						Community, Industry, students)		
28	Presentation	F. Amigoni	Robotics Competitions as Experiments: a Critical Review	December 2014	Pisa	*AIRO 2014 Italian Workshop on Artificial Intelligence and Robotics (Scientific Community, Industry)*		Italy
29	Exhibition	InnoCentive	RoCKIn Project	March 2015	Vienna	*European Robotics Forum, Workshop on Robot Competitions, Challenges and Benchmarking – European Initiatives (Scientific Community, Industry)*		Austria
30	Exhibition	InnoCentive	RoCKIn Project	May 2015	Paris	*Innorobo (Industry)*		France
31	Exhibition	InnoCentive	RoCKIn Project	September 2015	Hamburg	*IEEE/RSJ International Conference on Intelligent Robots and Systems (Scientific Community, Industry)*		Germany
32	Exhibition	InnoCentive, IST-ID	RoCKIn-MOnarCH Projects	October 2015	Lisbon	*ICT Conference 2015 – Innovate, Connect and Transform (Scientific Community, Industry)*		Portugal
33	Popular press		RoCKIn 2015 Competition	Nov. 2015		*Portugal's major public station – RTP (Media, Civil Society)*		Portugal
34	Popular press		RoCKIn 2015 Competition	Nov. 2015		*ManotoTV (Media, Civil Society –*		United Kingdom

						Iranian communities)		
35	Invited post		RoCKIn's presence in ICT 2015	2015		*Digital Agenda for Europe blog (Scientific Community, Industry, Policy Makers, Civil Society)*		
36	Invited post		The history of RoCKIn	2015		*Digital Agenda for Europe blog (Scientific Community, Industry, Policy Makers, Civil Society)*		
37	Workshop	Pedro U. Lima, Alan Winfield	2nd Workshop on Robot Competitions: Benchmarking, Technology Transfer, and Education	2013	Lyon	*European Robotics Forum (Scientific Community, Industry)*		France
38	Workshop	Pedro U. Lima, Alan Winfield	3rd Workshop on Robot Competitions, Challenges and Benchmarking - Exploring the Synergies	2014	Roveretto	*European Robotics Forum (Scientific Community, Industry)*		Italy
39	Workshop	Pedro U. Lima, Alan Winfield, Bruno Siciliano	4th Workshop on Robot Competitions, Challenges and Benchmarking – European Initiatives	2015	Vienna	*European Robotics Forum (Scientific Community, Industry)*		Austria

2.2 Section B: Exploitable Foreground and Plans for Exploitation

TABLE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
-	-	-	-	-	-

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential Click on YES/NO**	**Foreseen embargo date dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable, commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved**
Exploitation of R&D results via standards	*@Home and @Work Test Beds*	*NO*	*N/A*	*Domestic robot systems; Industrial robot systems*	*M72.1.9 - Other research and experimental development on natural sciences and engineering*	*-*	*-*	*IST-ID (@Home), BRSU (@Work)*
Exploitation of R&D results via standards	*@Home and @Work Rulebooks, including scoring and benchmarking methods and metrics*	*NO*	*N/A*	*N/A*	*M72.1.9 - Other research and experimental development on natural sciences and engineering*	*-*	*-*	*-*
Exploitation of	*@Home*	*NO*	*N/A*	*Benchmark of*	*M72.1.9 - Other*	*-*	*-*	*POLIMI and the rest of*

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
R&D results via standards	*@Home and @Work Functionality Benchmark datasets*			*algorithms for object perception, speech understanding, robot navigation, mobile manipulator control*	*research and experimental development on natural sciences and engineering*			*the consortium.*

The exploitable foreground of the project consists mainly of:

- Two available test beds: @Home test bed at IST-ID, @Work test bed at BRSU. The test beds are based on open source specifications which are published in the rulebooks and can be used to replicate them in any other research lab or industrial site worldwide, thus becoming *certified test beds*. The goal is to create reference sites where researchers from all over the world, and particularly from European groups, can go to test their approaches to the challenges associated to each of the test beds (domestic robots interacting with humans and industrial robots acting in the factories of the future) and to benchmark them against other group results using RoCKIn scoring and benchmarking methods and metrics;
- Two rulebooks (one per Challenge), each of them based on a user story that enables future extension with new Tasks and Functionalities. The rulebooks specify ranges for competition arena dimensions, object types, networked devices; scoring and benchmarking metrics and methods; constraints on the robot systems to be used in the test beds and competitions; and organizational rules. They intend to act as a reference for the organization of scientific robot competitions whose results are replicable and comparable in different sites using *certified test beds*.
- Datasets for several RoCKIn@Home and RoCKIn@Work Functionality Benchmarks, namely Object Perception, Robot Navigation, Speech Understanding and Mobile Manipulator Control.

This exploitable foreground aims at pushing the state of the art in experimental robotics research, by creating benchmarks that can lead to future standards in domestic and industrial robots, datasets to benchmark algorithms and test beds to run the algorithms in a real scenario. Further research will certainly be necessary on these benchmark methods and metrics, and the open nature of the test bed specifications and

rulebooks aims to create conditions for a proliferation of *certified test beds* that can lead to the requirement of testing the results of the application of novel techniques and algorithms in the benchmark test beds, to compare them with past work, in scientific publications and/or for new commercial products.

For the moment no measures were taken to protect IPR concerning the test beds design and the rulebook specifications, but future developments may require such measures.

3 Report on Societal Implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*

Grant Agreement Number:	601012
Title of Project:	RoCKIn - Robot Competitions Kick Innovation
Name and Title of Coordinator:	Professor Pedro U. Lima

B Ethics

1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	0 Yes X No
2. Please indicate whether your project involved any of the following issues (tick box) :	***YES***
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	0 Yes 0 No
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator		1
Work package leaders		7
Experienced researchers (i.e. PhD holders)	1	11
PhD Students		6
Other		4

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**5**
Of which, indicate the number of men:	5

D Gender Aspects

5.	**Did you carry out specific Gender Equality Actions under the project**?	X ○	Yes No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
✓	Design and implement an equal opportunity policy	X	○	○	○	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
❑	Actions to improve work-life balance	○	○	○	○	○
X	Other:	Promoted inclusion of girls in competing teams, with some success (e.g., abou tone third of the participants in the RoCKIn Field Exercise 2015 were girls)				

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

X Yes- please specify: Open days for high school students, e.g., at POLIMI, IST-ID, as well as participation in Science Fairs, e.g., Lisbon Maker Faire 2015

○ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

X No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

X Main discipline: Electrical engineering, electronics

X Associated discipline: Mathematics and computer sciences

○ Associated discipline**Error! Bookmark not defined.**:

G Engaging with Civil society and policy makers

11a	**Did your project engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*	X ○	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

○ No

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

X Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	X ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- X Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- X Yes – as a **secondary** objective (please indicate areas below - multiple answer possible) – **IN BOLD**
- ○ No

13b If Yes, in which fields?

Agriculture		Energy		Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and Monetary Affairs		Food Safety		**Research and Innovation**	
Education, Training, Youth		Foreign and Security Policy		Space	
Employment and Social Affairs		Fraud		Taxation	
		Humanitarian aid		Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- X European level
- ○ International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**2**
To how many of these is open access provided?	
How many of these are published in open access journals?	**0**
How many of these are published in open repositories?	**0**
To how many of these is open access not provided?	**2**
Please check all applicable reasons for not providing open access:	
X publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available X no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other: ……	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**0**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**
17. How many spin-off companies were created / are planned as a direct result of the project?		**0**
Indicate the approximate number of additional jobs in these companies:		

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	X	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
X	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*
Difficult to estimate / not possible to quantify	X

I Media and Communication to the Civil Society

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

X Yes ○ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the Civil Society?

○ Yes X No

22 Which of the following have been used to communicate information about your project to the Civil Society, or have resulted from your project?

X	Press Release	X	Coverage in specialist press
❑	Media briefing	X	Coverage in general (non-specialist) press
X	TV coverage / report	X	Coverage in national press
❑	Radio coverage / report	X	Coverage in international press
X	Brochures /posters / flyers	X	Website for the Civil Society / internet
X	DVD /Film /Multimedia	X	Event targeting Civil Society (festival, conference, exhibition, science café)

23 In which languages are the information products for the Civil Society produced?

X	Language of the coordinator	X	English
❑	Other language(s)		

Appendix A - Advisory Board Member Statements

DIETI UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II
DIPARTIMENTO DI INGEGNERIA ELETTRICA E TECNOLOGIE DELL'INFORMAZIONE

DR. BRUNO SICILIANO
PROFESSOR OF CONTROL AND ROBOTICS

14 December 2015

Brief Report following the RoCKIn final camp: Prospects for a research proposal around the topics of competitions

The European Commission has funded in FP7 three main challenges/competitions: euRathlon, EuRoC, RoCKIn.

euRathlon concluded with euRathlon 2015, in Piombino Italy; the world's first multi-domain (air, land and sea) multi-robot outdoor search and rescue competition. A total of 16 teams from 11 countries with ~40 robots competed, and collaborated in a simulated nuclear disaster scenario inspired by the 2011 Fukushima NPP accident. Leading up to euRathlon 2015 were two preparatory competitions with a focus on land and sea robots in 2013 and 2014, alongside 3 hands-on workshop/summer schools with the aim of building and supporting the European multi-domain search and rescue robotics community.

EuRoC launched 3 industry-relevant challenges: Reconfigurable Interactive Manufacturing Cell, Shop Floor Logistics and Manipulation, Plant Servicing and Inspection. The challenges have been structured in 3 stages, out of 102 teams subscribed for the first stage, there are currently 15 running the second stage (Realistic Lab) in the Consortium laboratories.

RoCKIn has recently concluded with the final camp I have attended. During three years of intense activity, two test beds (one on domestic robots, another on industrial robots) were designed and built, being now available for any researcher to go and benchmark their robot systems, as well as to replicate them at their labs; three camps where several students took part and learned about robot systems and the best practices in research competitions; contributions to benchmarking in robotics; and the organization of two successful competition events.

On the basis of the success of the above three actions, prospects are bright for the preparation of a proposal for a European Robotics League, aimed at designing robot competitions as benchmarking experiments, where scoring methods encourage reproducibility and repeatability of experiments and provide methods to measure performance (e.g., error between actual outputs vs ground-truth), while keeping the excitement of addressing a challenge and of competing with other teams to achieve the best solution to a common problem.

Rules should foster developing functionalities that can be used and combined in the tasks. Algorithm and code-sharing repository of software modules per challenge should be developed. Data sets form the competitions should be made available, while teams should be forced to log their runs and provide their data sets.

The European Robotics League is foreseen as an annual series of tournaments involving three challenges running in major competition sites already existing in Europe (e.g., possible suggestions are RoboCup German Open, Portugal Robotics Open, SAUC-E, ELROB, etc.), needing supporting funds for:

- getting the arenas and benchmarking infrastructure in place
- sending trained and experienced referees to the different tournaments, ensuring fair scoring
- providing team travel and development support

Bruno Siciliano
RoCKIn Advisory Board

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December 14, 2015

Potential for US/EU Collaboration in Robot Competitions using RoCKIn's model

The RoCKIn competition model has been very successful, pulling in teams from all across Europe and even from across the Atlantic. What's the potential for a US/EU collaboration for this sort of competition? I think that this is really two questions: (1) can we sustain a RoCKIn-like competition in the US, and (2) can we interest people in an international event. I'll address each of these in turn.

The big problems for a RoCKIn-like event in the US are interest and funding. The competition needs to be different enough from existing competitions (Robocup@home, ICRA) to raise people's interest. If it's not, then we're taking the (already small) number of teams that compete, and splitting them between yet another competition. If there's nothing novel about the new competition, then it will not get any interest. The key, I think, is to identify the elements of RoCKIn that are unique,and not part of any other competition: professional evaluation, strong ground-truthing, etc. Once we've done this, we still have to address the motivation issue: why should I bother participating in a competition when it doesn't directly benefit my career (tenure, promotion, graduation, etc)? We need to come up with something that "counts" if we want to attract more people: publication opportunities, funding, etc. Publication is relatively easy, since we can organize a special issue of a journal. However, it might be tricky to do this without resorting to very system-level papers. Perhaps we can do something that involves a comparison of approaches, and give joint authorship to the participaing teams (although this might lead to papers with many, many authors).

Another possibility is funding, perhaps from somewhere like NIST. However, providing funding to go to the competition is a net-zero proposition: I benefit the same if I go as I don't, assuming I can publish the work in other places. Perhaps the right mechanism is funding that requires you to participate and demo at this competition. The funding would allow some actual science to be done, which makes it more appealing, and the requirement makes people serious about the competition. I wonder if there might be a way to fund this through the US National Robotics Initiative.

The second question, that of an international event, is somewhat easier, assuming we have both US and EU versions of the competition. The easiest way in for this might be to have the top few teams from each continent get together to compete, so that the quality is high, and the cost is lowered (since there are fewer teams). In this case, we have the same problem of motivation (why should I bother), and the costs are higher (international travel). However, I think that if we have existing competition structures, then the international competition would be a relatively easy problem to solve.

In a related note, the idea of a strong ground-truth metricing facility and test-bed in the US might be a good starting point, and this is something that I'd be interested in helping out with, and hosting at Oregon State University. NaturalPoint, the company that supplies the tracking system is based in Corvallis, only a couple of kilometers from Oregon State, and might be convinced to help out. If we have this facility in place, perhaps with some funding to make it easier for people to travel here and use it, that might be a good catalyst for getting the competitions off the ground. Of course, this means finding funding for the effort, probably from NIST or NSF. I'd be interested in talking about strategies for this, if there is also interest from the RoCKIn organizers.

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Manuela M. Veloso
Herbert A. Simon University Professor

December 13th, 2015

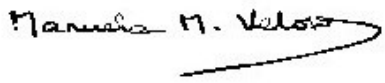
Professor Pedro Lima
Coordinator RoCKIn

Dear Pedro,

Here are my thoughts on the Future Impact of RoCKIn on RoboCup, following up on my role as Advisory Board member. Congratulations on the successful RoCKIn!

RoCKIn had two competitions, @Home and @Work, inspired by the previously long-established RoboCup@Home and the more recent RoboCup@Work. The RoCKIn competitions built upon the RoboCup competitions that served as their foundations, and added variants of the rules and setup. To wit, the RoCKIn competitions added a complex vision motion-tracking system around the competition arenas, which enabled the extraction of the ground truth of the performance of the robot competitors. Such additional information proved to be very valuable and of use to the researchers to validate their algorithms and to provide an objective qualification to meet usual requirements of publications' reviewers. RoboCup will consider this additional feature, learning from its impact in RoCKIN. RoboCup further hopes to build upon the participation success of RoCKIn and will reach out to RoCKIn teams to join the future RoboCup@Home and @Work competitions.

Sincerely,



Manuela M. Veloso
Herbert A. Simon University Professor

Donostia, 15th December 2015

Mr.Pedro U. Lima
RoCKIn project

Subject: RoCKIn – Robot competition 2015 in Lisbon

The initiative to develop a robotic competition @Work is in my opinion very interesting to promote the evolution from a traditional industrial robotics to an emerging service robotics in manufacturing scenarios, where robots move, share the space and tasks with humans. This scenario has a huge potential in SMEs (thousands of companies all around Europe) but two aspects need to be addressed, the cost and the flexibility (at the set-up, easy programing methods, adaptability to changes at the product or at the production, ...).

From what I saw and understood at the competition, the use of a perception system to detect objects including location is very interesting as a key functionality to achieve flexibility in manufacturing with robots. Perception is also a powerful tool to compensate the lack of accuracy of less specific robots and grippers. Additionally, according to teams' achievements, I guess that it is hard to perform manipulation tasks with didactic robots in a robust industrial way.

Some recommendations for future competitions : As a not expensive robot would not be able to perform a wide range of tasks, I would suggest to split the tasks and work from one side in manipulation and grasping with more robust devices and robotic systems, but static. Such a system would also allow working in many interesting functionalities related to flexibility. And from the other side, in an scenario similar to the proposed in the competition but simplifying as much as possible the manipulation aspects. In both cases, the achievement of robust implementations (accommodating the complexity of the task to the capabilities of the robotics systems available) must be pursued by young robotics engineers.

As a conclusion, I think that robotics solutions in industry will play a critical role in European economy and a competition as @Work is a great initiative to show also that robots and humans will share manufacturing environments.

Yours faithfully,

Mr. Jon Agirre Ibarbia

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TECHNISCHE
UNIVERSITÄT
DARMSTADT

Statement About the Coordinated Action "Robot Competitions Kick Innovation in Cognitive Systems and Robotics (RoCKIn)"

Dear Coordinators of RoCKIn,

Following your request, I would like to summarize my key findings made as a member of the RoCKIn advisory board.

There is a fundamental gap between academic robotics research and robotics applications. For the latter a high technology readiness level can only be achieved if complete robotic systems architectures are developed and evaluated in a strongly systems oriented manner. However, the involved efforts needed are often left out in academic research, although they are a pre-requisite for transferring research results to real robotics applications. Robotic competitions can fill this gap, as they give reward to participants' efforts for systems development through good results.

RoCKIn has made very good contributions towards methodologies for robotic systems integration from a scientific viewpoint. As a consequence this enables more systematic benchmarking in competitions for intelligent robots and for transferring a rather "hands-on" way of organizing robotic competitions to a more systems oriented research methodology. This pushes academic research towards methodologies for integration from a scientific standpoint.

RoCKIn has also laid the basis for a yet not well addressed aspect of future intelligent personal robots in industrial and home environments: standardization and certification. For example, it has taken the automotive industry decades of research and development to introduce a number of different standards to test and rate performance and safety. In addition, end-user organizations have developed a number of additional sophisticated test criteria for cars. For example, the German ADAC (Allgemeiner Deutscher Automobil-Club e.V., General German Automobile Club), which is the largest automobile club in Europe, test different dimensions of automotive performance with about 350 detailed static and dynamic (i.e. driving) criteria. On the results RoCKIn a suitable spectrum of test criteria for intelligent personal robots can be developed and established which enable a systematic evaluation and comparison of different robots available in the future. These will give not only the end-users better information on robot capabilities, but may as well develop to de facto standards for robots. Meeting such standards with their robots, European robot manufacturers will be enabled to much better promote their high-tech robot developments in competition with other vendors on the international market.

I am looking very much forward to the further outcomes of RoCKIn and I will be glad to answer any further questions.

With best regards,

(Dr. Oskar von Stryk, Professor of Computer Science, TU Darmstadt) Darmstadt, January 9, 2016.

Appendix B – Questionnaire to Scientific Community and Industry About RoCKIn

General questions about robot competitions

Branch

- ○ Academia / Research
- ○ Robot manufacturer
- ○ System integrator
- ○ End user
- ○ Sonstiges: _____

Position

- ○ Researcher
- ○ Developer
- ○ Project leader
- ○ Team leader
- ○ Sonstiges: _____

Do you know the following robotics challenges and competitions?

- ☐ DARPA Grand Challenge
- ☐ RoboCup
- ☐ euRathlon - An Outdoor Robotics Challenge for Land, Sea and Air
- ☐ RoCKIn - Robot Competitions Kick Innovation in Cognitive Systems and Robotics
- ☐ EuRoC - European Robotics Challenges
- ☐ ELROB - The European Land Robot Trial
- ☐ ARGOS Challenge - Creating the first autonomous robot for gas and oil sites
- ☐ MBZIRC - Mohamed Bin Zayed International Robotics Challenge
- ☐ KUKA Innovation Award
- ☐ Amazon Picking Challenge
- ☐ FIRST Lego League

Which other challenges and competitions are you aware of?

Meine Antwort

Have you ever participated in a challenge?

- ○ Yes
- ○ No

Do you consider challenges and competitions a useful tool to advance the fields of robotics?

	1	2	3	4	
not at all	○	○	○	○	fully agree

Which fields of robotics do you think are influenced the most by robotic competitions?

- ☐ Research
- ☐ Education
- ☐ Industry
- ☐ Sonstiges: _____

Do you think that challenges and competitions can create solutions for technology transfer from academia/research to the robotics industry?

	1	2	3	4	
not at all	○	○	○	○	fully agree

Are todays technical level of the teams and their solutions sufficiently advanced to solve todays robotics or manufacturing industry problems?

	1	2	3	4	
not all all	○	○	○	○	fully agree

In RoCKIn we developed functionality and task benchmarks. Please rate their usefulness from your point of view.

RoCKIn is an EU-funded project aiming to foster scientific progress and innovation in cognitive systems and robotics through the design and implementation of competitions.

To this end, RoCKIn has developed two Challenges:
RoCKIn@Work (Industrial Robots)
RoCKIn@Home (Domestic Service Robots)

It's project website can be found here:
http://rockinrobotchallenge.eu/

RoCKIn@Work

is set in the medium-sized RoCKIn 'n' RoLLIn factory, a scenario modelled after a typical industrial manufacturing line with different workstations, shelves and machines. The robot has to support a human worker with the assembly of a drive axles for a small mobile robot.

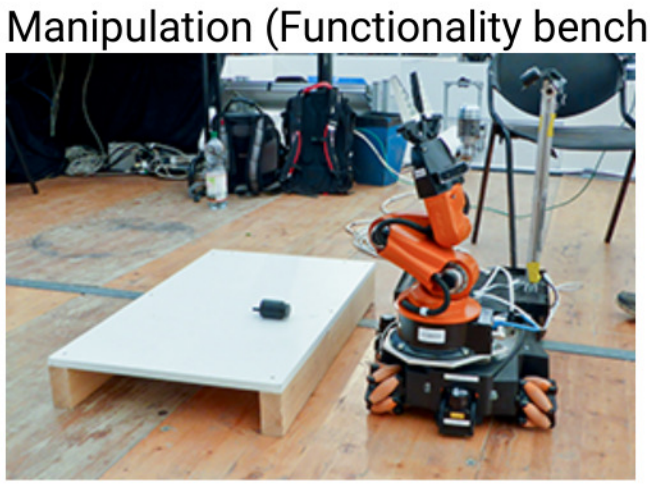
RoCKIn@Work competition environment

Object Perception (Functionality benchmark)

From a set of objects the robot has to detect, recognize and locate an object placed in front of it. Objects could be for example a tray, an axis or a bearing box.

	1	2	3	4	
not useful	○	○	○	○	very useful

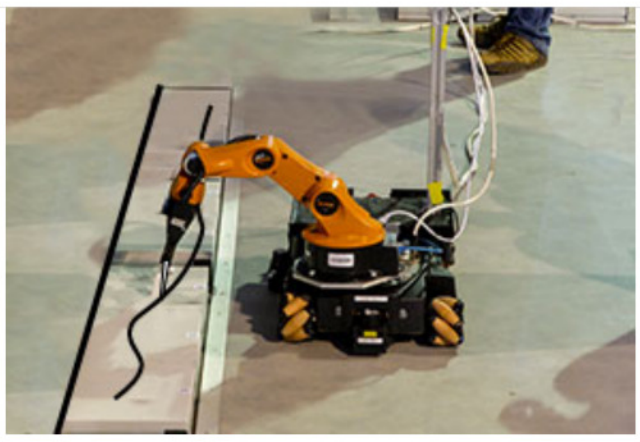
Manipulation (Functionality benchmark)



The robot has to identify the object in front of it, grasp and lift it and release it after a given time. The pose of the object in the gripper is not important, as long as the object is succesfully grasped.

	1	2	3	4	
not useful	○	○	○	○	very useful

Control (Functionality benchmark)



The robot has to follow a straight line/spline (without sensor feedback). Using a marker mounted on its end-effector an external system measures the path accuracy.

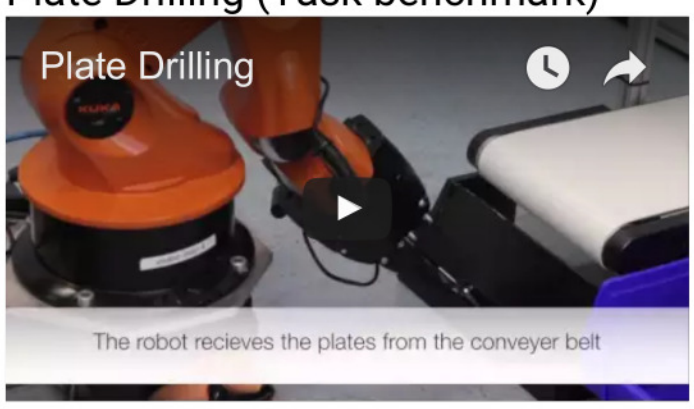
	1	2	3	4	
not useful	○	○	○	○	very useful

Assembly Aid Tray For Force Fitting (Task benchmark)

In this task the robot should collect a tray, a bearing box and a bearing. Bearing box and bearing have to be put into the tray and the tray has to be brought to the "Force Fitting Machine" for final assembly.

	1	2	3	4	
not useful	○	○	○	○	very useful

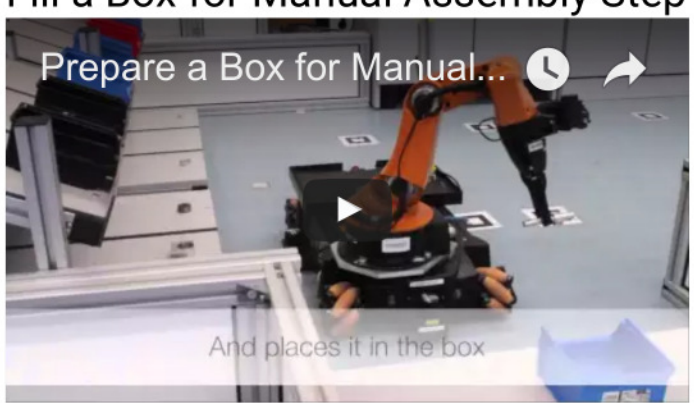
Plate Drilling (Task benchmark)



In this task the robot has to pick up a cover plate from a conveyor belt, conduct a quality check and perform one of three tasks according to the quality of the plate: perfect - collect; unusable - throw away; faulty - place inside drilling machine for rework.

	1	2	3	4	
not useful	○	○	○	○	very useful

Fill a Box for Manual Assembly Step (Task benchmark)



The robot has to navigate through a previously mapped area and avoid collisions with different types of unknown obstacles in unknown positions or people moving through the area.

	1	2	3	4	
not useful	○	○	○	○	very useful

Speech Understanding (Functionality benchmark)

The robot has to understand different speech commands. The commands are taken from a set of recognizable commands and can either be provided as prerecorded utterance or directly spoken by the user.

	1	2	3	4	
not useful	○	○	○	○	very useful

Getting to Know My Home (Task benchmark)

The robot is supposed to generate a semantic map of the apartment. How this is achieved is not specified, for example a team can guide the robot through the apartment, or the robot can explore it fully autonomously.

	1	2	3	4	
not useful	○	○	○	○	very useful

Welcoming Visitors (Task benchmark)

The robot has to answer the door, because Granny Annie is not feeling well. Depending on the visitor, eg. Deli Man, unknown person, Dr. Kimble or the postman, the robot has to show a different behaviour.

	1	2	3	4	
not useful	○	○	○	○	very useful

The robot has to navigate to different shelves, pick up objects and place them into a box as a preparatory step for manual assembly.

	1	2	3	4	
not useful	○	○	○	○	very useful

RoCKIn@Home

is set in a domestic environment, where the robot has to support the elderly lady Grannie Annie in her day to day activities.

Granny Annies apartment

Object Perception (Functionality benchmark)

From a set of objects the robot has to detect, recognize and locate an object placed in front of it. Objects could be for example a coffee mug, a knife or a gold-colored picture frame.

	1	2	3	4	
not useful	○	○	○	○	very useful

Navigation (Functionality benchmark)

Catering for Granny Annie's Comfort (Task Benchmark)

In this task the robot has to manage different day to day tasks. Granny Annie can call for the robot via her tablet computer. On arrival it can be given commands to, for example lift the shutters, tilt the window and switch of the lights. Another task may be to search for and bring back her reading glasses.

	1	2	3	4	
not useful	○	○	○	○	very useful

Open source and standard platforms in robot competitions

Do you consider it beneficial if teams use standard hardware platforms to compete on implementation level only?

	1	2	3	4	
not at all	○	○	○	○	fully agree

Do you agree that basic software functionality should be made available to the teams for allowing an easy entry to robot competitions?

	1	2	3	4	
not at all	○	○	○	○	fully agree

Do you agree that the software of all participating teams should be made public?

	1	2	3	4	
not at all	○	○	○	○	fully agree

Would you make your software publicly available if there was a special open source award at the before-mentioned competitions?

- ○ Yes
- ○ No

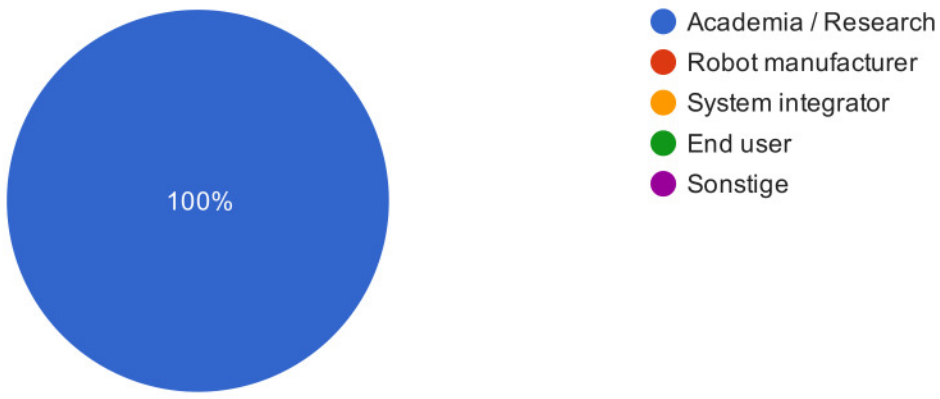
SENDEN

FRAGEN ANTWORTEN

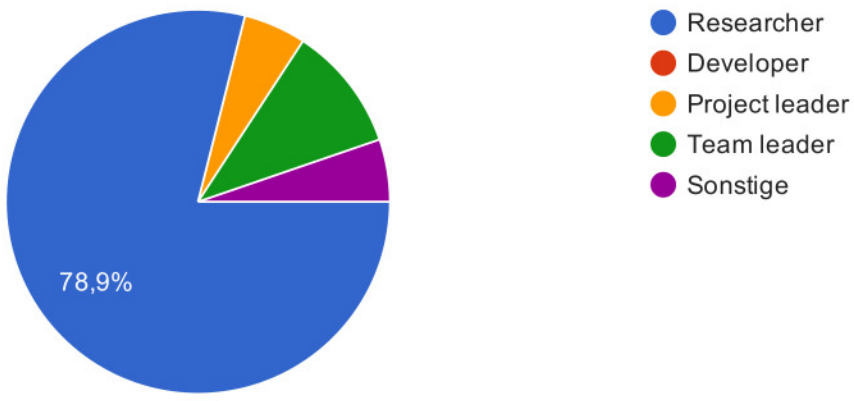
19 Antworten

Antworten möglich

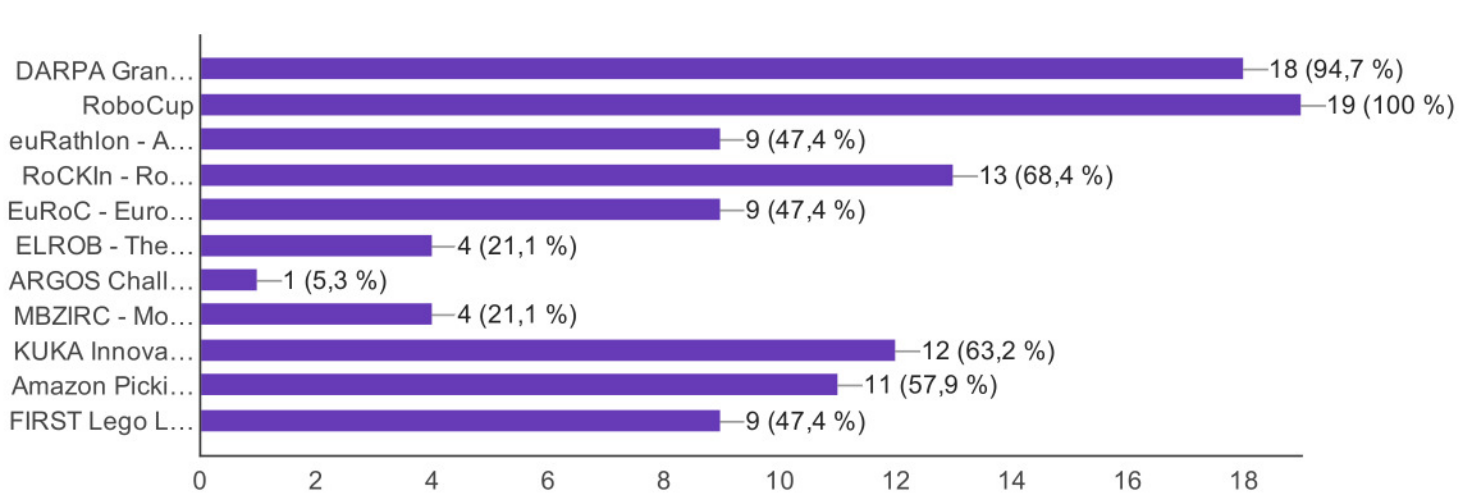
Branch (19 Antworten)



Position (19 Antworten)



Do you know the following robotics challenges and competitions? (19 Antworten)

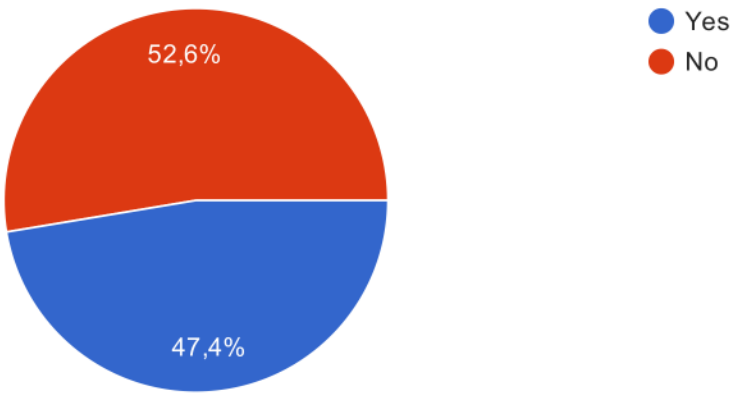


Which other challenges and competitions are you aware of? (6 Antworten)

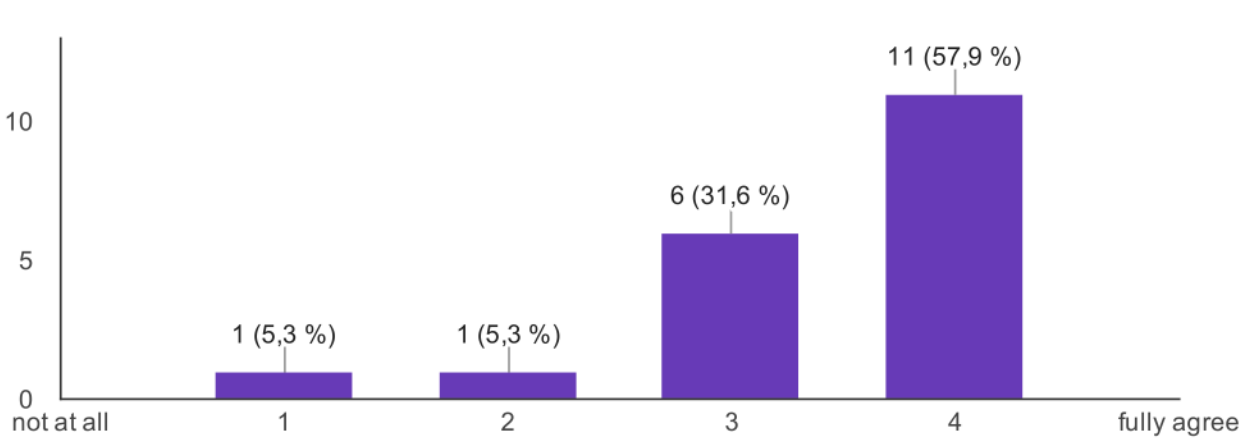
none
DLR Spacebot Cup
Darpa Robotics Challenge
Botball Educational Robotics Program
IEEE HRATC - Humanitarian Robotics and Automation Technology Challenge

ECHORD++ PDTI: competitive solution design

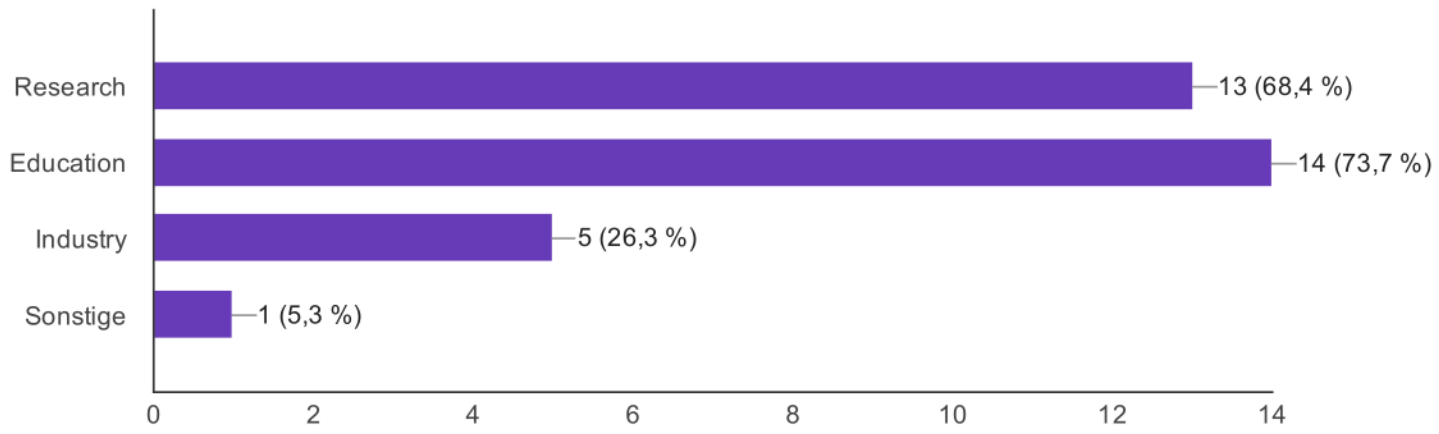
Have you ever participated in a challenge? (19 Antworten)



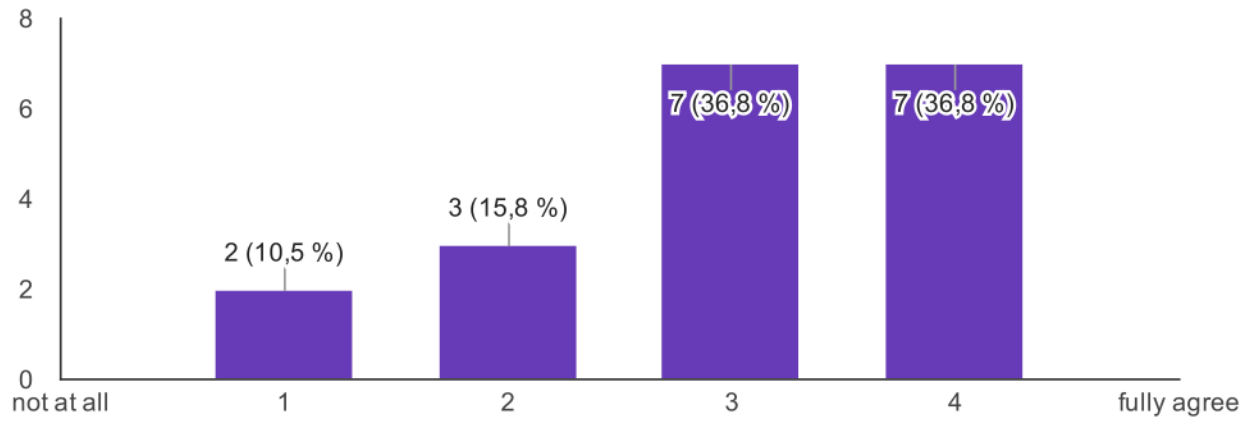
Do you consider challenges and competitions a useful tool to advance the fields of robotics?
(19 Antworten)



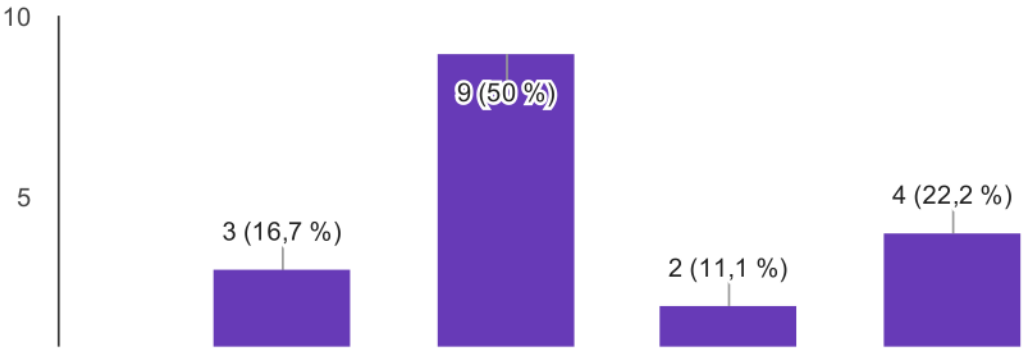
Which fields of robotics do you think are influenced the most by robotic competitions?
(19 Antworten)



Do you think that challenges and competitions can create solutions for technology transfer from academia/research to the robotics industry?
(19 Antworten)



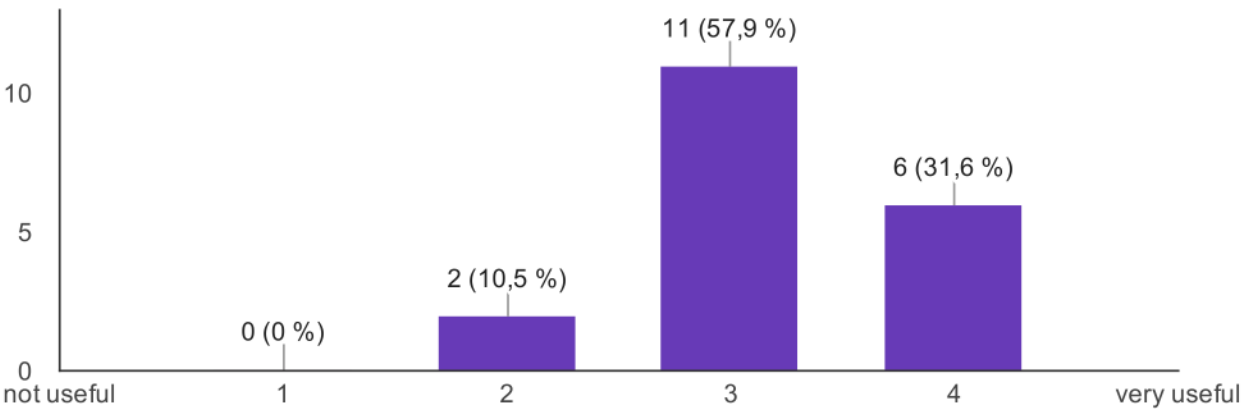
Are todays technical level of the teams and their solutions sufficiently advanced to solve todays robotics or manufacturing industry problems?
(18 Antworten)



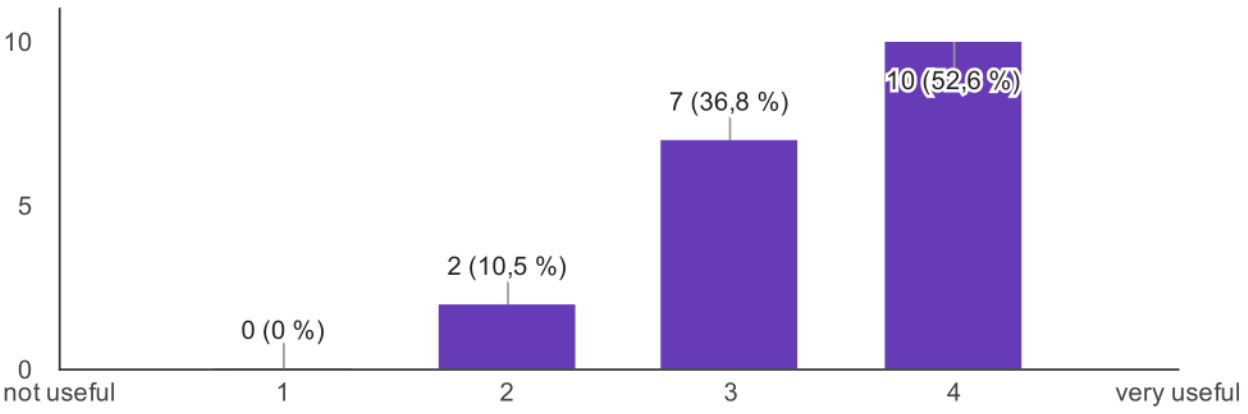
In RoCKIn we developed functionality and task benchmarks. Please rate their usefulness from your point of view.

RoCKIn@Work

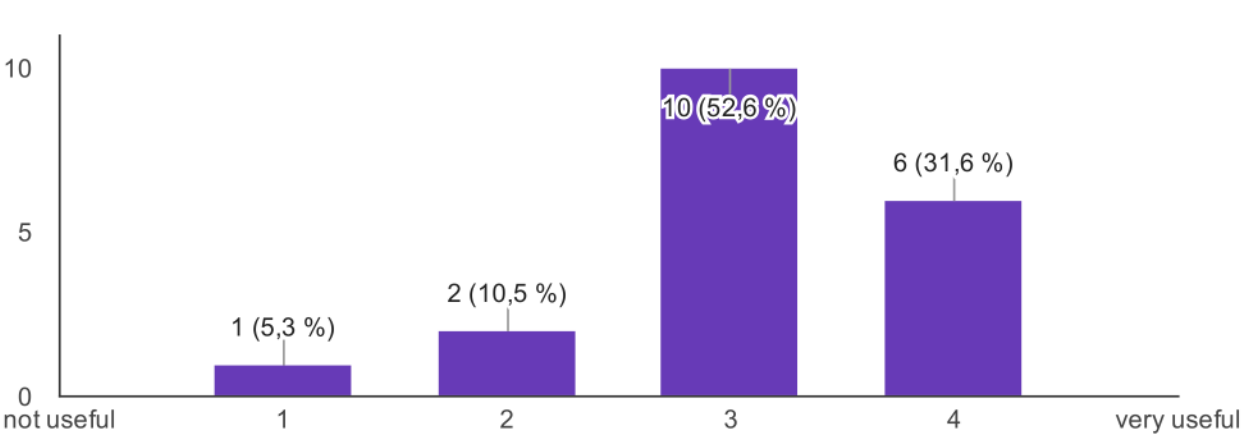
(19 Antworten)



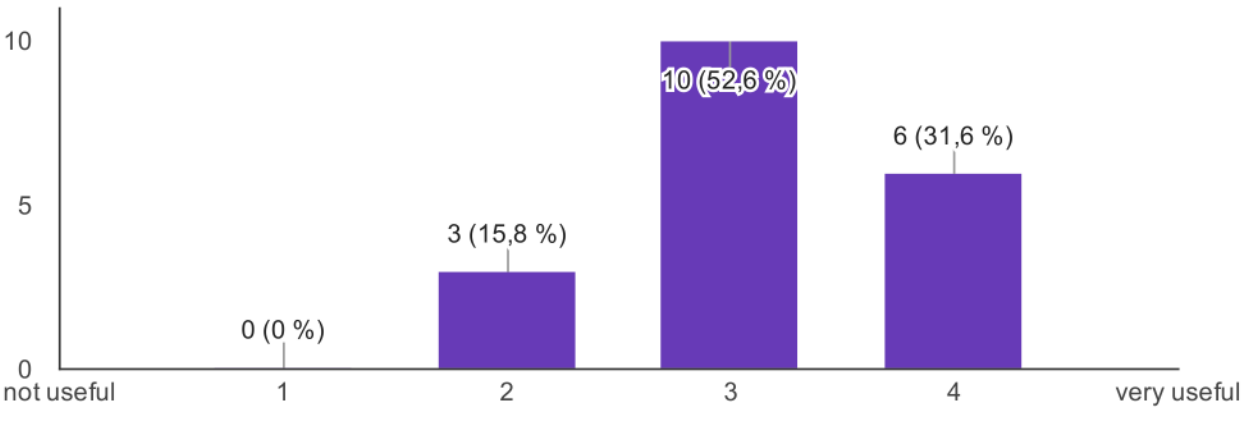
(19 Antworten)



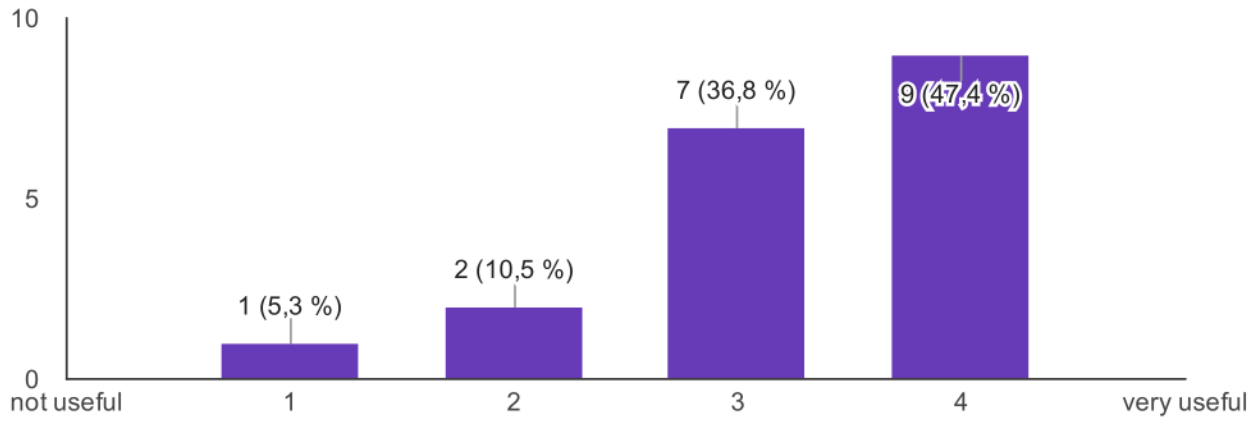
(19 Antworten)



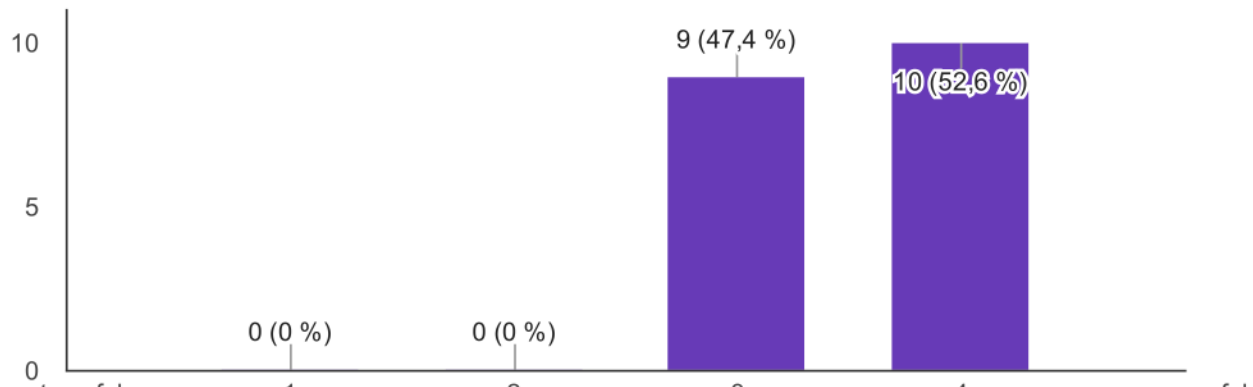
(19 Antworten)



(19 Antworten)

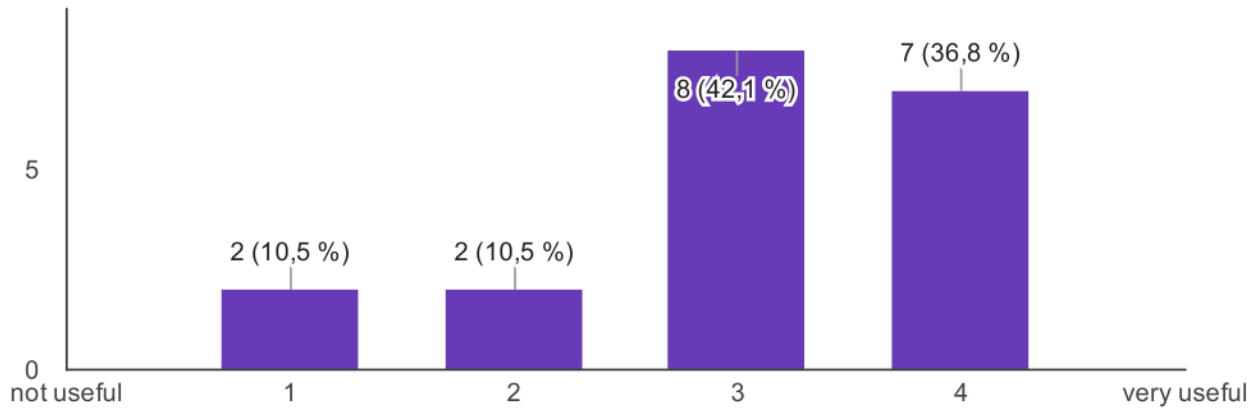


(19 Antworten)

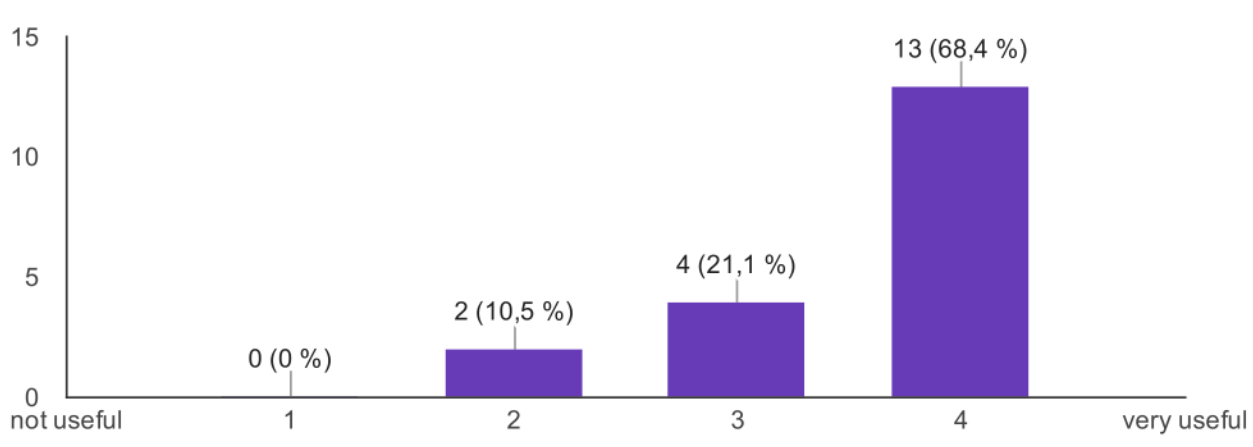


RoCKIn@Home

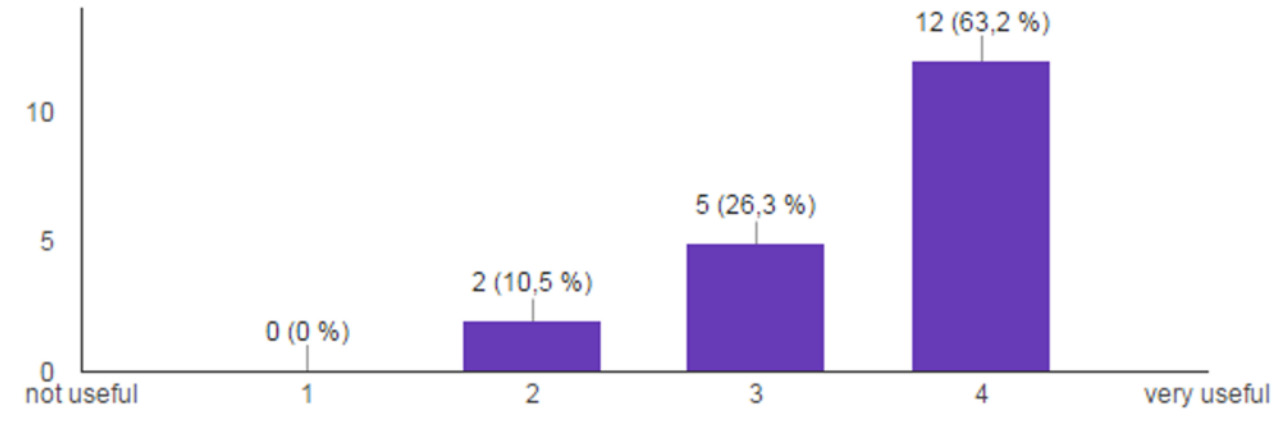
(19 Antworten)



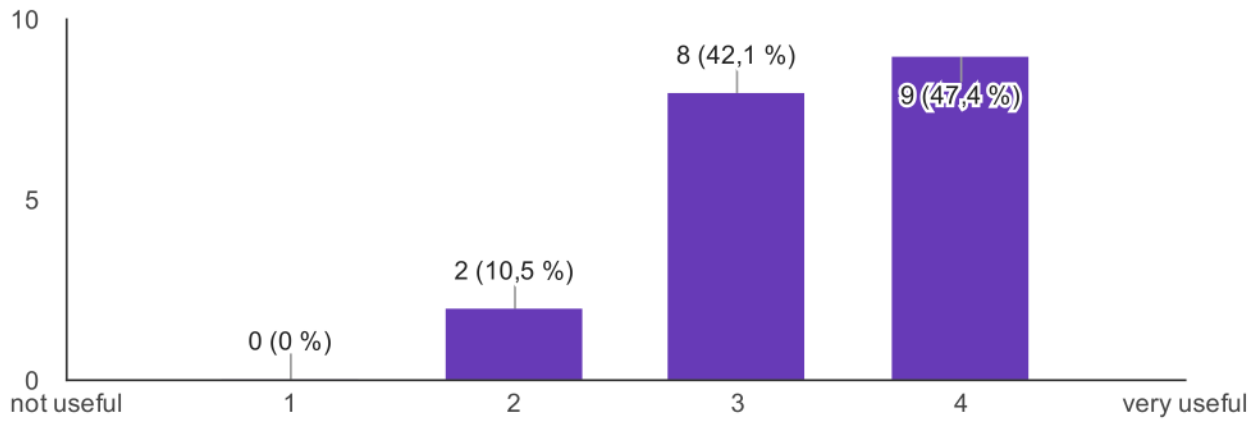
(19 Antworten)



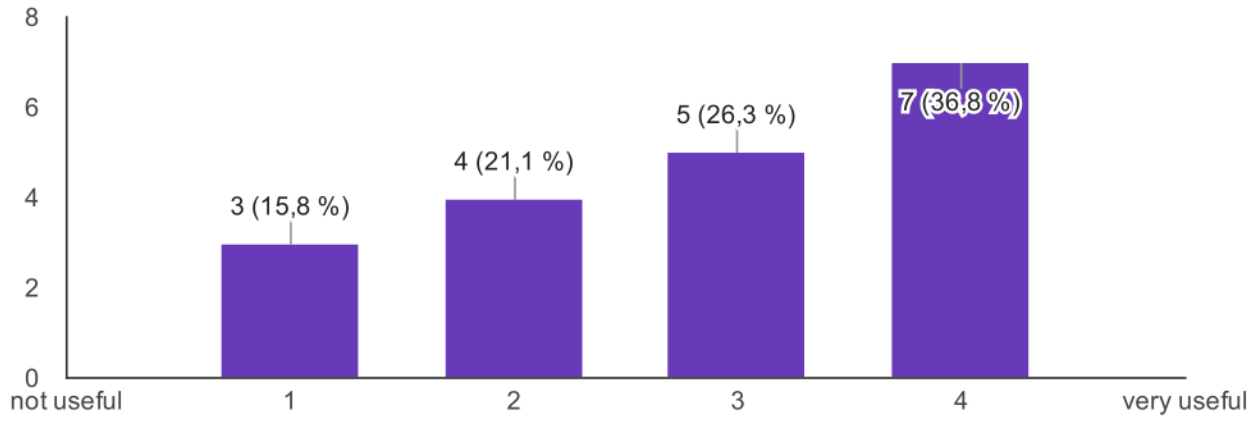
(19 Antworten)



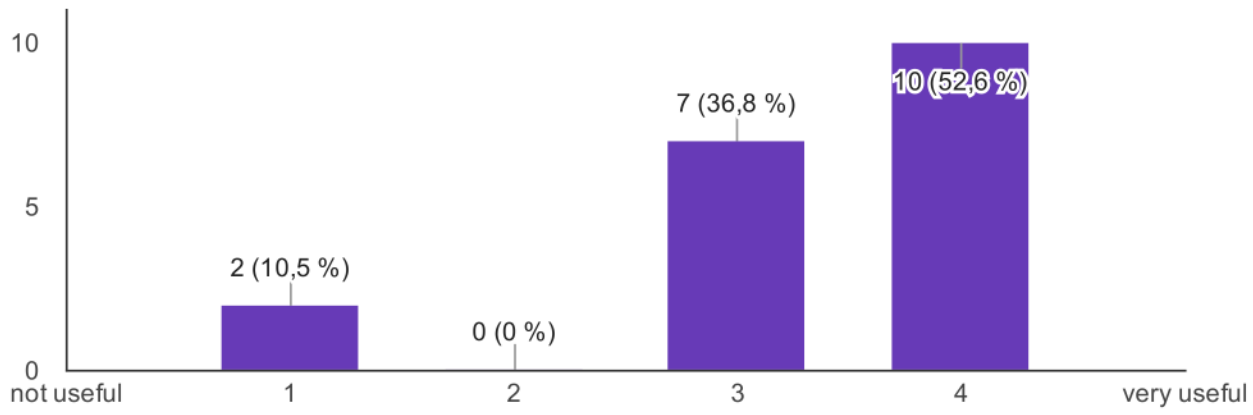
(19 Antworten)



(19 Antworten)



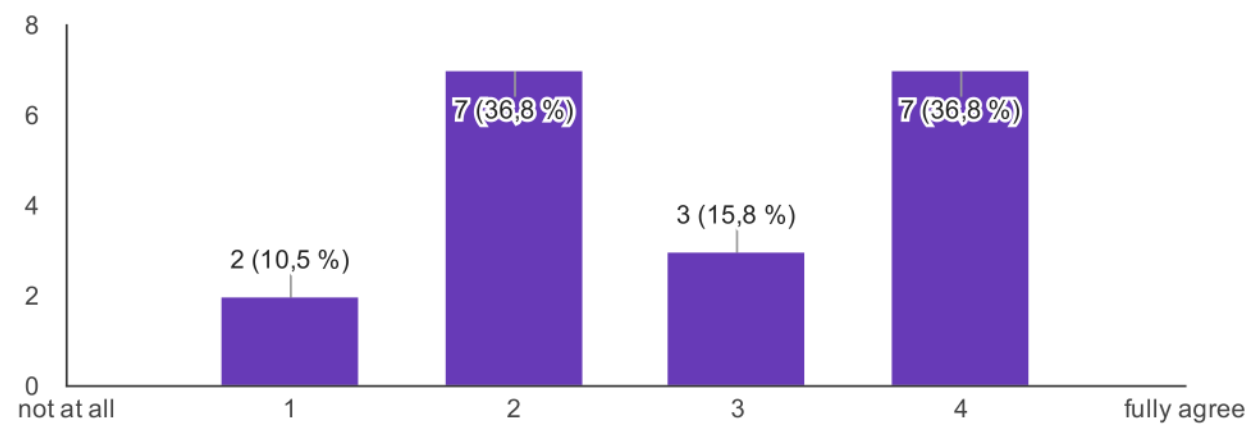
(19 Antworten)



Open source and standard platforms in robot competitions

Do you consider it beneficial if teams use standard hardware platforms to compete on implementation level only?

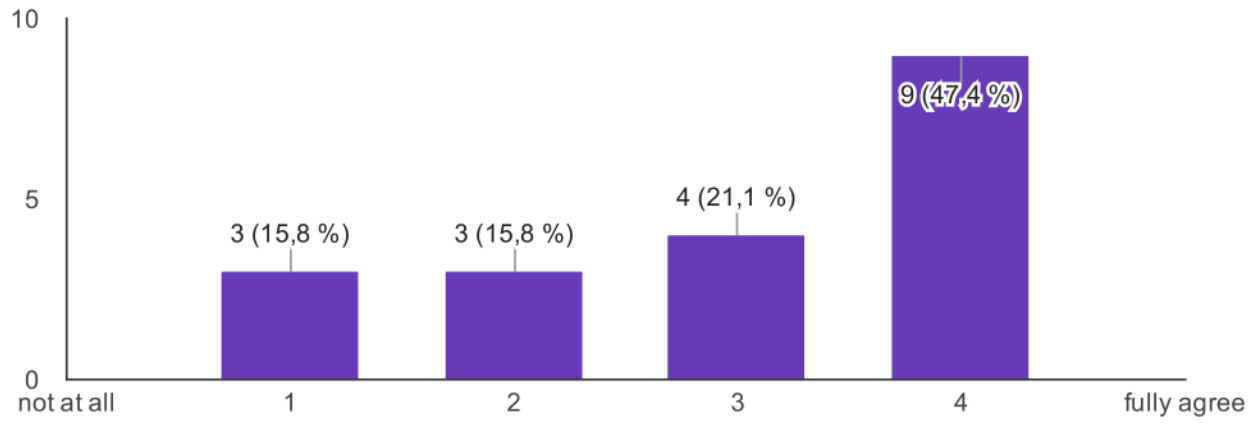
(19 Antworten)



Do you agree that basic software functionality should be made available to the teams for allowing an easy entry to robot competitions?

(19 Antworten)

Do you agree that the software of all participating teams should be made public? (19 Antworten)



Would you make your software publicly available if there was a special open source award at the before-mentioned competitions?
(19 Antworten)