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# White Paper: Key Performance Indicators in European Robotics Competitions

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# Content

# 1. Introduction and structure of the document

This document is intended to analyse the outcome of the RockEU2 events aimed at identifying proposals for the next competitions and challenges in EU, i.e, the workshop on robotics competitions and challenges at the European Robotics Forum 2017 and the "ERL Expert Forum on the Future of Robot Competitions", held in conjunction with RoboCup 2016 in Leipzig, whose discussed key topics are summarised in Section 2. On the basis of such topics, proposals have been drafted (described in Section 3). Public awareness/Scientific research/Technical advancement/Technology transfer to industry are the main areas influenced by robotics competitions. Four possible Key Performance Indicators for quantitatively assessing the impact of robot competitions on the progress of robotics have been then identified Section 4, i.e., KPI1: media coverage of robot competitions; KPI2: results of surveys directed at students applying to STEM schools; KPI3: incidence of recurring participation of research groups to competitions; KPI4: Participation of companies to competitions, including sponsorships. The Section 5 contains an additional discussion about KPIs and prospects.

The availability of sound scoring and proper benchmarking are additional key aspects for the implementation of successful future robotics competitions in EU: these topics are discussed in the deliverable D6.6.

# 2. Outcome from RockEU2 events about robotics competitions and challenges

## 2.1 Key findings

As reported in D6.2 deliverable, a workshop on robotics competitions and challenges has been organised in Edinburgh.

The session dedicated to teams has highlighted the main advantages and difficulties of the participation to robotics competitions and challenges, considering the two significant examples of ERL and EuRoC, respectively. Related to ERL, a positive feedback from teams is related to the introduction of local tournaments. With respect to major tournaments, they give relaxed environment for improvement and better cooperation among teams. Less stress has been noticed also with respect to RoboCup events. In addition, the availability of clear scoring mechanisms is very important; finally, the focus on benchmarking also supports research groups (e.g., ground truth for vision gives provides for research).

While the previous remarks are common for ERL-IR and ERL-SR, for ERL-ER presents some additional difficulties: differences with respect to the preparation phase are more relevant, due to the complexity of outdoor scenarios. On the other hand, creativity arising during the field tests is significantly higher than in laboratory settings. Related to EuRoC, the possibility of dedicated funding for teams has been noticed as the key aspect for guaranteeing high-quality teams during all phases of the challenges. In fact, also thanks to stable teams, noticeable and robust results have been achieved in the three challenges and will soon be ported to end-users' premises.

The panel discussion was based on both the inputs from teams presentations and on a list of recommendations for robotics competitions already drafted by the RockEU2 Consortium, shared among participants before the workshop, i.e.

1. Organisers of competitions should track advances both in science and technology (in collaborative projects, conferences, industry) in order to reflect them in new rules and scenarios. New challenges should be present every year.
2. Teams should use standard technology when available (not "reinventing the wheel"). This would allow to focus on architecture, control, strategy etc.. Forms of sponsorship could include in-kind contribution by companies: sensors, motors, grippers.
3. Robustness is among the main goals to be pursued.
4. Parallel events suggested for the ERL tournaments have to be used also for benchmarking and real comparison of results from EU-funded research projects, where consortia have to show robustness without long preparation and ad-hoc solutions.
5. Proposals for new EU projects should possibly include a budget for participation to competitions, or specific Coordination and Support Actions (CSAs) could be envisaged for such purpose. New CSAs may be proposed for dissemination and match-making towards demonstration of project results in really challenging scenarios.
6. Human-robot interaction in competitions is focused on cognitive interaction: safety of physical interaction is expected to be guaranteed as a primary functionality of the platform.
7. Among the different type of scores, it has been noticed that safety has to be guaranteed in any case: in case of physical HRI, collision or dangerous behaviours should be severely penalised.
8. Rehearsal camps and integration weeks before competitions should be encouraged also for improving team spirit.
9. In any case, the topic of dedicated funding for keeping some technical roles in the teams is crucial.
10. In order to attract industry, tasks have to represent an abstraction of the problems the industrial sector is interested to solve. Tasks must contain the core of a problem without focusing on details.

## 2.2 Outcome of the discussion and lessons learned

Based on these suggestions, the most relevant topics discussed were:

**1) Robotics research and competitions**

In order to demonstrate advances in technology, benchmarking and metrics are key instruments. The ERL has a strong scientific foundation and teams improve through years. Competitions allow the evaluation of an integrated systems, especially in non-standard cases (unstructured and non-repetitive environment as in traditional industrial robotics), comparing different approaches. The rate of success of a whole system has then to be evaluated. ERL can be beneficial to recognize the whole system research as science, provide that stable operation is guaranteed, while robustness and reliability are also related to the availability of stable technical teams. The design of tasks could be changed every year introducing some more “advanced” or “challenging” cases. In addition, competitions are interesting since they do not allow alteration of experiments.

2) **Sustainability**

It is clear from teams that funding is a key aspect. Funded teams may keep a stable group of members. A possibility of funding may be sponsorship (considering the involvement of industry in designing the tasks) and the promotion of spin-off companies arising from teams.

3) **Focus on skills of participants**

Robotics competitions allow people to work together and improve both technical and soft skills. Promoting the participation of students to ERL teams is beneficial for the industry not only for the development of products, but also for the skilling of future professionals. Added skills in robotics thanks to competitions should be recognized through credits in the courses, special awards and certifications. The demonstrated role of competitions in educational robotics could contribute to the ERL framework.

4) **Dissemination and communication**

There is abundance of “bad advertising” of robots as “job stealers” and dangerous “war machines”. Competitions can bring robotics on the “positive side”: resources are needed to train scientists also for dissemination: in addition, a strategy is needed. The dissemination through “grand challenges” with big visibility can be complemented by visits to schools and universities to explain competitions. The current design of scenarios is also relevant: what is attractive for industry or research it is not always interesting or understandable for the public. Soccer robots are attractive and also contain a long-term strategy (RoboCup 2050).

# 3. Proposals

Based on the lessons learned from the current competitions and challenges, the following proposals have been derived:

1. **use competitions for science**, to check different paradigm approaches (soft vs hard etc.), to promote benchmarking at both component at system level (considering the concept of task and functionality benchmarks), with consistent scoring
2. **sustainability is the key aspects for keeping teams alive**: keep involving technology developers and end-users in order to maintain teams with industrial support
3. **excellence, imagination, fun** are keywords for the participation to competitions: make skills more visible through awards
4. **communication and visibility** of the ERL is very relevant for the competitions and for the whole EU robotics: plans are needed
5. **educational aspects** are crucial, starting from a possible ERL-junior up to dedicated classes at the University level

# 4. Identifying Key Performance Indicators for European robotics competitions

Given the previous qualitative indications, quantitative performance indicators are also expected for new competitions and challenges.

Differently from more focused initiatives (e.g., technology awards), robot competitions have a broad-spectrum influence on the whole robotics field. The impact areas for such influence are in fact many and diverse, the main ones being

- Public awareness
- Scientific research
- Technical advancement
- Technology transfer to industry

A consequence of this breadth of scope is to make the influence of competitions difficult to quantify. Most stakeholders consider competitions to have a positive impact on robotics, but no reliable way of measuring such impact is currently available.

Thus, the definition of quantitative Key Performance Indicators (KPI from now on) capable of reliably capturing the impact of robot competition would represent a useful tool.

A good starting point in the search for KPIs is the aforementioned list of impact areas, which can help in the identification of possible metrics for impact:

- Public awareness
    - Awareness of the fact that robot systems providing the functionalities demonstrated in the competition are available;
    - Awareness of the actual performance of such systems;
    - Awareness of the existence of jobs and careers focused on such systems;
    - Awareness of the potential for “excitement” and “fun” of such activities.

- Scientific research
    - Possibility to demonstrate the results of a research group in real-world scenarios;
    - Possibility to compare a group's results to those of others in the very same experimental setting;
    - Exposure to new ideas and approaches that can speed up progress in one's own research, in a way (i.e. via direct contact with researchers) that is often more effective than reading papers.
- Technical advancement
    - When a group has to compete with others, focus shifts from "proof of concept" to "performance": this in turn promotes the development of the most effective approaches to problems;
    - Again, comparing one's own realizations to other people's often provides new ideas, especially for what concerns key details that are too technical to be highlighted in the literature.
- Technology transfer to industry
    - By showcasing advanced technology in settings that are not under the control of the technology providers, competitions are good tools to understand what a technology is capable of in practice, and thus its worth as a product component;
    - Competitions are the ideal setting to compare competing approaches and choose the most effective;
    - The environment of a competition, with its pressure, is much more suitable than a laboratory to understand how robust a technology actually is.

From here, a further step can be the identification of quantitative methods (if available) to quantify these mechanisms, such as those listed below:

- Public awareness
    - Awareness of the fact that robot systems providing the functionalities demonstrated in the competition are available + Awareness of the actual performance of such systems
        - ➔ **Media coverage of robot competitions**
    - Awareness of the existence of jobs and careers focused on such systems + Awareness of the potential for "excitement" and "fun" of such activities
        - ➔ **Results of surveys directed at students applying to STEM schools**
- Scientific research
    - Possibility to demonstrate the results of a research group in real-world scenarios + Possibility to compare a group's results to those of others in the very same experimental setting + Exposure to new ideas and approaches that can speed up progress in one's own research, in a way (i.e. via direct contact with researchers) that is often more effective than reading papers
        - ➔ **Incidence of recurring participation of research groups to competitions**

- Technical advancement
  - When a group has to compete with others, focus shifts from "proof of concept" to "performance": this in turn promotes the development of the most effective approaches to problems
    - ➔ **Proper ranking based on significant performance indicators**
  - Again, comparing one's own realizations to other people's often provides new ideas, especially for what concerns key details that are too technical to be highlighted in the literature
    - ➔ **Progressive standardisation of some features may be recognised in following competitions**
- Technology transfer to industry
  - By showcasing advanced technology in settings that are not under the control of the technology providers, competitions are good tools to understand what a technology is capable of in practice, and thus its worth as a product component + Competitions are the ideal setting to compare competing approaches and choose the most effective + The environment of a competition, with its pressure, is much more suitable than a laboratory to understand how robust a technology actually is
    - ➔ **Participation of companies to competitions, including sponsorships**

To sum up, we have identified via this process four possible Key Performance Indicators for quantitatively assessing the impact of robot competitions on the progress of robotics. Here is a list of them, also including the assumptions they are based upon:

- **KPI1**: media coverage of robot competitions (basic assumption: an increased and/or more pervasive media coverage corresponds to higher impact)
- **KPI2**: results of surveys directed at students applying to STEM schools (basic assumption: a higher number of applicants citing robot competitions as personal interest corresponds to higher impact)
- **KPI3**: incidence of recurring participation of research groups to competitions (basic assumption: a higher number of teams that, after participating to a competition, decide to participate again –to the same or other- corresponds to a greater impact)
- **KPI4**: Participation of companies to competitions, including sponsorships (basic assumption: more numerous and/or more "official" and/or more significant participations correspond to a greater impact)

Of the four KPIs above, KPI1 and KPI2 require significant effort to be applied: the first, because it requires a comprehensive survey of all available media; the second, because it requires that a suitable survey is prepared and, most importantly, accepted by the majority of relevant schools.

On the other hand, KPI3 and KPI4 are only based on public data associated to the competitions themselves: they could therefore be computed, with limited effort, either by the organizers of such competitions or by interested external parties. As such, KPI3 and KPI4 are possible KPI candidates for European robotics competitions.

Of course, as any other metric, KPIs are bound to capture only a part of the phenomenon they assess, possibly diminishing or distorting it to the point where any significance is lost. In the case of KPIs for robot competitions, unfortunately, this risk is especially present: in fact, the effects of competitions on their impact areas are mostly indirect, and thus difficult to isolate from other phenomena. Indeed, KPI3 and KPI4 can be expected to suffer from high noise due to external factors influencing the participation to competitions, both for researchers (e.g.: trends in scientific research, availability of funding) and for industry (e.g.: market trends, state of the economy, dynamics internal to companies). As a consequence, the actual relevance of KPI3 and KPI4 (or other alternatives) as useful Key Performance Indicators should be carefully assessed and not taken for granted.

# 5. Details on KPIs and prospects

In order to provide hints on future prospects, the KPIs are further specified in the following

**KPI1: media coverage of robot competitions**

How many reports (Articles/day, month, year)
Percentage of positive, negative, neutral reports
Presence of relevant keywords in the press

Coverage of the medium (local/national etc.)
How are competitions portrayed (positive/negative)
How is robotics portrayed (positive/negative)
What communication channels Like/share on social media

**KPI2: results of surveys directed at students applying to STEM schools**

Number of school involved
Number of countries involved
Participation of Ministry of Education
Results: Awareness of the type of competitions
How are competitions portrayed (positive/negative)
Knowledge about compeititons is correct/inaccurate
Relationship between interest in competition and interest in STEM

**KPI3: incidence of recurring participation of research groups to competitions**

Statistics about participation (number of tournaments, number of people, results)
Statistics about budget
Statistics about the presence of specific courses/curriculum in autonomous robotics
Statistics on career of the involved students

Survey on relevance of awards and visibility (positive/negative opinions)

**KPI4: Participation of companies to competitions, including sponsorships**

Statistics about participation (which leagues, which tournaments, whole league, other competitions)
Budget
Sponsorship vs. participation in teams
Share of SMEs with respect to total (number and budget)
Share of companies already active in EU projects
Share of robotics companies wrt other companies (end-users)
Technical personnel of the companies with previous experience in competitions
Survey on estimated return (positive/negative opinions)

In sum, a positive outcome resulting from the monitoring of KPIs will impact the following identified goals:

1. increasing sustainability
2. making skills visible
3. demonstrating in the field research results in autonomous robotics
4. contributing to a positive promotion of robotics science and technology
5. using robotics in STEM education