The ROSIN Education Concept

Fostering ROS Industrial-related robotics education in Europe

Alexander Ferrein, Stefan Schiffer, and Stephan Kallweit

Mobile Autonomous Systems and Cognitive Robotics Institute (MASCOR)
FH Aachen University of Applied Sciences, Aachen, Germany
{ferrein, s.schiffer, kallweit}@fh-aachen.de

Abstract. ROS Industrial (ROS-I) is an effort to deploy the Robot Operating System (ROS) for industrial manufacturing applications. The ROS-I activities are organised by the ROS Industrial consortium (RIC). With the EU-funded project ROSIN, which started in 2017, the ROS-I activities are further supported. The project will give out funds for developing ROS-I components. As a further important measure, the ROSIN project focuses on education measures for training a large number of students and industry professionals to become specialists in ROS-I. In this paper, we outline the broad ROSIN education programme, which consists of a series of summer schools, a professional academy and intends to provide the course contents in Massive Open Online Courses as well.

Keywords: Robot Operating System (ROS), ROS Industrial (ROS-I), Robotics Education, Professional Training, Summer School, MOOC

1 Introduction

The influence of robotic systems is steadily increasing, in the industry and the automation sector just as well as in areas such as mobile service robotics. The development of an intelligent robot application is a complex and time-consuming task that requires a lot of expertise in various fields. Hence, developers of such applications need to be well-trained.

Middlewares help in developing applications. One of the most well-known robotics middlewares is the Robot Operating System (ROS). The ROS Industrial (ROS-I) branch of the ROS project aims at extending ROS with features important for industrial manufacturing applications. In this paper we present the EU-funded ROSIN project that aims at fostering the use of high-quality ROS-based solutions in industry applications. We will focus on the educational activities planned and already started in the ROSIN project.

The rest is organised as follows. We start with a brief introduction of the background and some related work. In the next section, we present the core ideas of the ROSIN project. As this paper focusses on the educational aspects of the ROSIN project, we review other existing ROS education initiatives in Section 4, before we outline the ROSIN education activities in Section 5. We conclude with Section 6.

2 Background and Related Work

Robot middlewares are facilitating the robot application design. They come with tool support, they allow to debug the real-time software in a principled way and they open the opportunity to simulate the application in a 3D physical simulation environment. A number of middlewares from the academic sector are available. Since 2000, the Open Robot Control Software (Orocos) is developed. It is quite well known for its Kinematics and Dynamics Library and its Bayesian Filter Library. The Player project [6] which also started in early 2000 generated a widely used network server for cross-robot development which is often combined with Stage [5]—a 2D simulator for robot hardware. Other approaches like Urbi [1] are hardware dependant and belong more to the area of scripting languages. The framework Fawkes is used in competitions like RoboCup but is not widely deployed [8].

The aforementioned systems have in common that they are mostly used in academia. None of these frameworks have been intensively applied for industrial applications. In the above list, the very well-known middleware *Robot Operating System* (ROS) [9], which has celebrated its 10th anniversary in 2017, is yet missing. ROS is one of the most accepted frameworks for robotic applications world-wide and has a wide-spread community that supports it. The ROS-I [3] branch started in 2012, with industrial robotic applications in mind. These applications should benefit from components already available in ROS, such as, say, perception, navigation or path planning (e.g. [7]). Up to now, the acceptance of ROS-I in industrial environments is still low. This is despite the fact that ROS can help solving challenging future industrial robot applications.

To steer and to support the development of ROS for an industrial setting, the *ROS Industrial Consortium America* has been founded in 2013 at the South West Research Institute (SwRI). The goal of the consortium is to foster the development of the ROS-I core as well as ROS-I components for industrial robots. By using flexible and advanced techniques such as object detection, environment modelling or path planning so far deployed in mobile robotics mainly in academia, industrial robot applications can heavily benefit. This could also lead to cutting the costs for developing industrial robot applications by (a) making use of open-source software supported by a large community which allow commercial use without restrictions (through using BSD or Apache 2.0 license models), and (b) reducing the manufacturers' technology "lock-in" risk by providing standardised robot and sensor interfaces through ROS Industrial. In the meantime, there exists also a *ROS Industrial Consortium Europe* (RIC-EU), led by Fraunhofer IPA. Very recently, it has been agreed on founding the *ROS Industrial Consortium Asia Pacific*.

The effort of pushing ROS Industrial recently gained more support. In the beginning of 2017, the H2020 project ROSIN funded by the European Commission was started. ROSIN has the goal to further push the ROS-I activities in cooperation with the ROS Industrial Consortium Europe. This is pursued by providing funds for ROS-I-related software projects, by improving the software quality developed in those projects, and by a broad education initiative for training software engineers with ROS-I. We will describe the ROSIN project in the following section in more detail.

3 The ROSIN Project

The Robot Operating System has gained much attention in the academic world and has become a de-facto standard middleware for mobile robotics applications. World-wide, many research institutes make use of this framework and provide their research work as open-source software modules. To this end, the process to develop a complex robotic application is much easier and less time-consuming today than it was 10 years ago because many important components of such a system are available as ROS nodes. However, many ROS components do not quite meet the requirements of industrial robotics applications in terms of real-time guarantees or software quality yet. The ROS-I effort—as mentioned above—was started to deploy ROS also for industrial robots. The benefits are that a larger developer community from different stakeholders can provide software solutions. Further, with ROS-I a form of standardisation of components, sensors and algorithms takes place.

3.1 Overview

The goals of the ROSIN project are to change the availability of high-quality intelligent robot software components especially for the European industry. To reach this goal, the criticism brought forward by the industry against ROS, in its current form, has to be addressed. The main points raised are:
- lack of (sufficient) real-time support;
- stability issues;
- no (software) quality guarantees of the framework, and
- a lack of professional training sites.

The ROSIN project's work programme addresses this criticism with three main focus areas. The development of relevant industrial software components in high-quality is supported by ROSIN with a funding from the European Commission. The consortium consists of the Robotics Institute of TU Delft, the Netherlands, the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA), Germany, the IT University of Copenhagen, Denmark, the Mobile Autonomous Systems & Cognitive Robotics Institute at FH Aachen University of Applied Sciences, Germany, Tecnalia Research & Innovation, Spain, and ABB AB, Sweden. The first measure of the ROSIN project is to fund so-called Focussed Technical Projects (FTPs, see Section 3.2). Second, with special tool support and dedicated training, the quality of the software developed in FTPs will be improved (Section 3.3). Third, the development and QA measures are flanked with a broad education initiative for current and future ROS-I software engineers (Section. 3.4). In the following, we describe these measures in greater detail.

3.2 Focussed Technical Projects

The idea of Focussed Technical Projects as promoted by the ROS Industrial Consortium (RIC) is to kick-start relevant and needed ROS-I capabilities. A full member of a RIC can champion a particular project and share the cost and effort with other RIC members who are interested in that particular capability. Under the guidance of the Consortium Manager, the SwRI, a network of interested developers start with the implementation of the component as soon as the funds are in place. The idea of FTPs is the fundamental concept to support developments within the ROSIN project. With funds allocated by the European Commission for ROSIN, the funding for FTPs is in place. Members of the ROSIN project board decide, which projects should be funded. It further monitors the progress of a respective FTP. The challenging goal of the ROSIN project is to give out funds for 50 successful FTPs over a time span of four years. For more information about how to apply for an FTP, please visit the ROSIN project's website.[1]

3.3 Quality Assurance Aspects

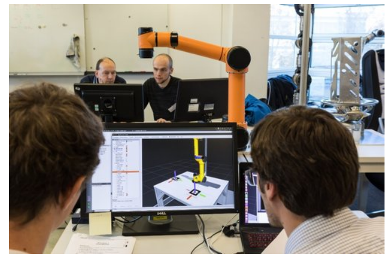
The ROSIN project proposal mentions three strategies how software quality of the newly established ROS-I components could be improved. The quality assurance strategy includes a *Community-based quality management process*. It will be established in such a way that it proposes quality standards which may or may not be obeyed, but it will leverage to force software developers to comply with the given quality standard. There will also be workshops and tutorials as well as some technical support. Within the ROSIN project, a *Continuous Integration infrastructure* will be provided allowing code reviews, error reporting and unit tests. Further, ROS-specific bug and quality trackers are to be developed within the ROSIN project. *Model-driven development* has been identified as a successful design and software production methodology. While there exist some description languages such as the Unified Robot Description Format (URDF) in ROS already, the concept of model-driven code generation will be strengthened to provide another means to assure the software quality. The component testing will also be improved including thorough testing of the ROS core. Besides test-based validation methods, also program-analysis based validation and regression methods will be applied to the developed ROS-I components.

3.4 Education

Even when a company agrees to use ROS-I as the middleware for their software developments, the major question remains where to hire employees with fundamental ROS-I knowledge. Despite the fact that many roboticists leaving varsity these days have been in contact with ROS before, profound and certified knowledge is desirable from a company's viewpoint. Therefore, a third pillar of

[1] http://www.rosin-project.eu/

(a) ROS Summer School 2016 held in Aachen, Germany



(b) ROS Industrial training at Fraunhofer IPA

Fig. 1: Impressions from ROS(-I) education events conducted by the authors.

the ROSIN concept foresees an education and training programme to impart in-depth knowledge of ROS Industrial. The different ROSIN education measures, which will be described in Section 5 in detail, will impart the required ROS-I knowledge, needed by the industry. The project comes with a number of measures, but is open to further educational ideas. Therefore, it is also possible to apply for funds to run additional ROS-I education measures.

4 World-wide ROS Training Activities

Even though ROS is quite well established and is the standard middleware for mobile robotics, the possibilities to receive professional training are limited. The academic world often uses ROS in the classroom, but the number of publicly available courses world-wide is less than ten. The well-established ROS Industrial Training by Fraunhofer IPA for Europe[2] or the one held at SwRI[3] in the USA are known to be of high quality. They usually host around 40 participants with the aim of building the bridge between ROS and ROS Industrial with a lot of practical contents.[4]

The ROS Summer School in Aachen[5] is well established and was already held five times. The last summer school had more than 50 participants out of 27 nations and went on for twelve days. The program is structured in a ROS introduction, basics, higher level applications of mobile robotics and a UAV session. A small introduction to MoveIt! is given for interested participants. The lectures and laboratory sessions are mixed equally with a high level of practical work with custom hardware. A more detailed description of the concept, the organisation and the financing of the Aachen ROS Summer School has been

[2] http://rosindustrial.org/news/2016/9/26/ros-industrial-training-and-conference-2016-schedule-now-online

[3] http://aeswiki.datasys.swri.edu/rositraining/indigo/Exercises/

[4] See, e.g., http://rosindustrial.org/news/2016/4/20/recap-ros-i-training-spring-2016.

[5] https://www.fh-aachen.de/en/faculties/mechanical-engineering-and-mechatronics/international-topics/ros/

described in [4]. Fig. 1a gives an impression of the Summer School held in Aachen last year. Fig. 1b from a training at Fraunhofer IPA.[6]

The number of novel ROS training activities increased over the last two years. For instance, in July 2015, a summer school was established in China, Shanghai, East China Normal University with over 200 participants for the first time. It is a four day event and consists mostly of lectures without any practical work with robots. In Turkey, at the Eskisehir Osmangazi University & Inovasyon Muhendislik a three day event was held for the 2nd time with ten participants focusing on ROS Basics, Simulation in ROS and ROS higher level applications. Lectures and laboratory sessions are equally split. In the UK, a ROS summer course is established in London, England, Middlesex at the University of London. It hosts eleven participants for five days and consists mainly of laboratory sessions, where the usage of Advanced ROS Packages and simulation is explained. The hardware deployed in this course is the well-known Turtlebot system.

Another ROS training is held in Brazil, Sao Paulo, Centro Universitario FEI, but details about the number of participants are missing. The course takes five days and is structured in a ROS introduction, some basics, higher-level applications for mobile robotics. Lectures and lab sessions are offered but the goal is to have a more practical approach to ROS. It was held for the first time. In Austria, Maribor, TEDUSAR a ROS course is held with less than 20 participants for five days, focusing on RoboCup Rescue. This course concentrates on a ROS introduction, basics and higher-level applications for mobile rescue robotics. It is held for the 3rd time and consists of lectures and lab sessions. Another ROS course takes place in Australia, Kioloa, Australian Centre for Robotic Vision where the number of participants and the contents is not known. It seems to focus on ROS Vision. The list of summer schools shows that there are only a couple of ROS training facilities world-wide. The possibilities are increasing, but ROS Industrial – or even components like MoveIt! – are not yet covered by the mentioned courses.

5 Scope of Education Activities within ROSIN

One of the main objectives of the ROSIN project is to kick-start industrial robot applications based on the ROS middleware. With the aforementioned FTPs, interested developers and industrial partners could start interesting development projects. Another measure in ROSIN to facilitate ROS Industrial applications are educational activities.

5.1 Overview

In order to strengthen the ROS Industrial community it is also of utmost importance to educate and train current and future ROS-I software developers. Therefore, the ROSIN Education programme targets different end-user groups.

[6] http://rosindustrial.org/news/2016/12/16/ric-europe-event-recap-part-1-ros-industrial-training-and-conference-2016

These are, in particular, students and professional developers but also members of the broader ROS/ROS Industrial community.

For each of the end-user groups, the ROSIN Education programme provides specific training and education activities tailored to the needs of that particular group. Hence, the ROSIN education initiative includes the following different activities:

- ROS-I School offers *Classes* for students.
- ROS-I Academy offers *Trainings* for (industry) professionals.
- ROS-I MOOCs offers *Online Courses* for different stakeholders.
- ROS-I Market is a *Central Hub* where stakeholders can meet.

For the different end-users (students, professionals, community) tailor-made education activities exist which aim at optimally training the respective user group. The education programme for professionals also foresees some form of an accepted certificate which states the profound knowledge of the certificate holder in particular ROS-I topics. For self-studies, online courses will be provided (ROS-I MOOCs). Important for the success of the ROSIN project (FTPs as well as educational activities) will be to bring together people from academia and industry to work together on related ROS-I projects. For this purpose, the foundation of the educational activities will be the ROS-I Market, which will be a brokering platform where stakeholders from both sides can find respective peers. In the following, we describe the different activities in greater detail.

5.2 Education Measures

The ROSIN education concept is based on three main measures and a supplementary activities. A structural overview is depicted in Fig. 2a.

ROS-I School. The ROS-I School addresses university students and young professionals to get an entry to the ROS Industrial eco-system. In regularly held summer schools, participants could enrol for a one week teaching activity. The training will give good insights into currently used ROS-I software tools such as *Moveit!* or *Decartes*. As the activity aims at a very intense training, the number of admitted students per training event is rather limited. Therefore, the activities will be held several times per year to give a large number of interested students and young professionals the opportunity to participate in this educational activity. Further, we will also offer workshops and summer schools with varying topics. These are not only limited to teaching particular ROS-I components and tools, but will also allow to address how good software engineering works in order to improve the quality of future ROS-I components.

ROS-I Academy. As a second activity, the ROS-I Academy aims at establishing a ROS-I certified engineer programme to certify certain skills within the ROS Industrial software engineering eco-system, similar to MSE or CISCO certified engineers. The certified skills comprise basic knowledge in ROS Industrial, as taught in the ROS-I Schools activity, skills in code review and specialised ROS-I topics inspired by FTPs or based on different robot platform programming skills.

In close collaboration with industrial parties, the contents for the certified ROS-I engineering programmes will be selected. Further, the course will be accredited by some official relevant body in some form to ensure that the required skills will be taught and quality standards of the training are met. The number of participants per course will also be limited to ensure that each engineer gets a good hands-on experience with real hardware and gain good insights into ROS-I components. Also, a course concept where courses with different topics that build upon each other will be offered.

ROS-I MOOCs. To support the other two education activities, the ROS-I MOOC's objective is (1) to develop Massive Open Online Courses and (2) to provide a learning platform. Each participant of the ROS-I Schools or the ROS-I Academy could deepen their knowledge with this type of online courses in addition to presence courses held in ROS-I Schools or ROS-I Academies. Here, a number of different up-to-date topics will be presented ranging from ROS-I core over software engineering and software quality assurance topics (cf. Sect. 3.3) to single ROS-I components.

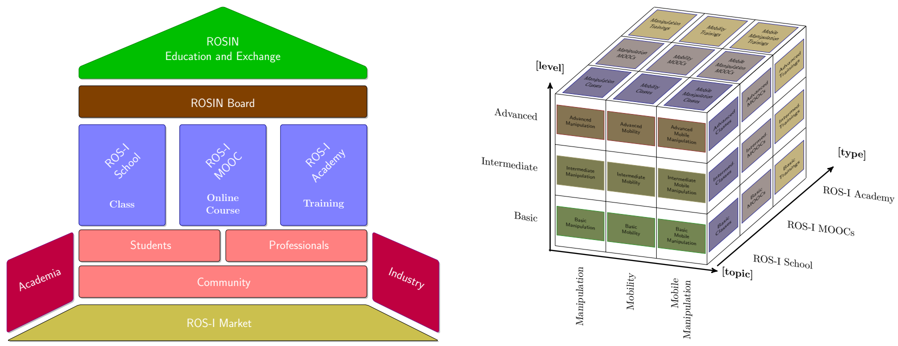
ROS-I Market. Finally, the ROS-I Market activity aims at providing a common internet platform to bring together the interested stakeholders of ROS-I. The objectives are to provide a brokerage platform, where industrial partners could post their needs for staff or development actions, developers could offer their expertise and students will be provided with internships at industrial or academic ROS Industrial stakeholders. The *ROSIN Education Board* will try and make matches between offers and demands from the different stakeholder's sides.

5.3 The Education Cube

The main educational activities are structured along three dimensions: topic, level of proficiency, and type of activity. We give a description of each dimension in the following.

Topic. The topics offered in ROSIN education measures are oriented towards industry needs. The first and foremost industrial applications are dealing with robotic *manipulation*. A second area then is *mobility*, dealing with mobile robots moving around an industrial site. Finally, the combination of these two forms the third area *mobile manipulation* where a robotic manipulator is moving around on a mobile platform.

Level. Each topic can be dealt with at different levels of proficiency. Beginners will start at a *basic* level, moving via *intermediate* proficiency to an *advanced* level. The levels will be oriented along the SOLO taxonmy, where basic corresponds to SOLO 2, intermediate to SOLO 3, and advanced to SOLO 4.



(a) The ROSIN education concept. (b) The ROSIN education cube.

Fig. 2: The ROSIN education concept and the education cube.

Type. Depending on the particular target group, we organise education in three bodies. The *ROS-I School* provides university level *Classes* for students. The *ROS-I Academy* offers vocational *Trainings* for industry professionals. Finally, for both groups mentioned above as well as for interested developers from the (broader) ROS(-I) community, a collection of *Online Courses* are present in the *ROS-I MOOCs*. Since the trainings in the ROS-I Academy and the classes in the ROS-I School are quite similar, we should and will not keep them too separated.

The structure of the educational activities along the three dimensions described above can be understood as a cube. The core instatiation of this education cube can be found in Fig. 2b.

Extending the Cube The core education cube can be extended along any of its dimensions.

For the level of proficiency, for now we plan for three stages, namely basic, intermediate, and advanced. At a later point in time, however, a sufficient amount of participants will want to further deepen their understanding. Thus, introducing an *expert* layer on top of the existing levels might be appropriate. This level would then be corresponding to SOLO 5 in the SOLO taxonomy. Also, not all interested participant will meet the entry requirements of the basic education measures. As a consequence, we foresee *preparatory courses* that bring those individuals up to speed. While offering such prep courses as a MOOC will have the maximal coverage, given sufficient demand, special classes or trainings might be offered in the ROS-I School or the ROS-I Academy respectively.

Just as the scope of industrial robotic applications will broaden, so will the topics of our educational measures. Following industry needs, new topics will be accomodated and accounted for, such as *3D perception* or *machine learning*. Besides particular topics stemming for applications, also more general subjects like *continuous integration* or *software architectures* might be included.

The three types depicted in the core education cube are oriented towards the primary target groups. Eventually, to reach maximum impact, the educational measure could/should be franchised. This in turn requires training the instructors of such franchised educational activities. A *ROS-I Teacher Training* hence is a straightforward extension of the core cube.

5.4 Planned Course Contents

The overall training contents will focus on industrial applications. As an example, consider a standard pick-and-place scenario, where the individual positions of single objects are taught and later processed using a position list. This problem will be solved by using ROS-I standard components. The next step includes a flexible vision-based approach, where the positions of the objects to manipulate are no longer pre-specified with a teach-in. Instead, they are determined via standard tools available in the ROS environment such as OpenCV, PCL and the alvar functionality. This approach enhances the standard industrial pick-and-place procedure already by using concepts from mobile robotics such as perception and navigation. The next step includes collision avoidance with alternative path planning, in order to improve this application beyond the industrial standard. The basic concept of a collaborating robot will be used to attract the industrial users to the ROSIN activity. This setup focusses on the use of MoveIt! in combination with necessary training in setting up a serial kinematic with URDF, XACRO (XML Macros) and other description formats. Essential modules like the tf package will be explicitly explained for industrial serial kinematics which are still the most common robots for industrial use.

Fundamental knowledge of the topics mentioned above should enable the industrial user to cover numerous non-standard robotic applications using ROS-I. These applications can be as well supported using the funding possibility as FTPs. This way, the industrial users will be encouraged to make use of ROS-I for solving complex robotic tasks with open-source technology instead of going for proprietary cost intense solutions. The course contents above was just one example. During the project, we will further develop the concept including leading-edge components from successful FTPs. In general, training content will be aligned with prevalent industrial use cases. Currently, these are very often pick-and-place applications like sketched above. Another focus in the teaching activities lies on the quality of the developed software components. Therefore, workshops how to use state-of-the art development tools and methods (cf. Sect. 3.3) will be part of the initiative. Finally, the performance, stability and quality of the used software components will be evaluated during the ROSIN project.

Intended Learning Outcomes Upon reflection within the education board, we are trying to use the SOLO taxonomy [2]. Let us give an example of the goals formulated along the so-called Intended Learning Outcomes (ILO). Consider a basic manipulation training in the ROS-I Academy. The training covers a UR5 application with path planning and collision avoidance. After completing the training, the participant will be able to

- define their robot by using URDF, kinematic chain etc;
- configure the robot by setting parameters using the ROS reconfigure tools;
- visualize the robot by making use of rviz;
- make it move by deploying MoveIt!
- make it see by integrating additional cameras and recognizing objects using OpenCV;
- make it clever by combining motion planning and object recognition into an intelligent high-level control application;
- do something useful with ROS by finding task specific solutions to given application problems.

This was an example for a basic to intermediate ROS-I Academy training. Following SOLO taxonomy, for each different education level different ILOs will be in focus.

5.5 Educating Future Teachers

The ROSIN Education Board will set up a special education activity in order to educate future ROS-I instructors. To conduct education activities is not restricted to consortium members of the ROSIN project. The goal is rather to use the project as a multiplier to interest many other institutions to participate in ROS-I activities. However, a certain quality level of external education measures is required. The ROSIN Education board will ensure the quality of external education measures. This is done by offering special train-the-trainer courses within the ROSIN education measures.

In this measure, we need to distinguish between teachers and training instructors. This is because with teachers we can already assume a certain level of didactical proficiency. With instructors for professional trainings that might not be the case.

5.6 Measures Conducted by the ROSIN Consortium

Within the ROSIN project, a number of education activities will be carried out by the ROSIN consortium members. The Mobile Autonomous Systems & Cognitive Robotics Institute (MASCOR) will conduct eight editions of the ROS-I school at their premises in Aachen, Germany. The Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) will offer two kinds of professional training activities. The first one will be a basic training course teaching the fundamentals of ROS-I. This activity shall take place every two months. There will be also more advanced courses every three month. The workshops will take place either at the IPA training facilities or at MASCOR. Some workshops will also be held at the consortium member TECNALIA in Spain. The courses will also be accredited in the course of the ROSIN project. Further, the consortium members will set up online courses at an appropriate platform (e.g. EdEx, Moodle, or Coursera). At a later stage, an additional programme will be dedicated to train future ROS-I trainers.

6 Conclusion and Future Work

In this paper, we presented the ROSIN project, in general, and its ROS Industrial-related robotics education activities, in particular. The ROSIN project aims to foster the acceptance and quality of ROS Industrial-based solutions in industry and academia. To this end, the ROSIN project features a set of educational activities to increase the number of ROS Industrial literate people among students and professionals alike. Tailored offers for the different end-user groups accommodate for particular interests. In so-called ROS-I Schools, students receive training in developing high-quality applications using ROS Industrial. Similarly, the ROS-I Academy aims at training and later also certifying professionals in developing industrial-strength solutions with ROS Industrial for industrial applications. ROS-I MOOCS are meant to offer any interested party improving their ROS Industrial proficiency with online training. Finally, the ROS-I Market offers a central platform for cooperation and exchange between all stakeholders. The education activities are also open for third-parties who can propose additional ROS-I education measures and who can apply for funds through the ROSIN project from the European Commission.

Acknowledgements

The ROSIN project has received funding from the European Unions Horizon 2020 research and innovation programme under grant agreement No 732287.

References

1. Baillie, J.C., Demaille, A., Nottale, M., Hocquet, Q., Tardieu, S.: "The Urbi Universal Platform for Robotics". In: SIMPAR 2008, Venice(Italy) (2008)
2. Biggs, J.B., Collis, K.F.: Evaluating the quality of learning: the SOLO taxonomy (Structure of the Observed Learning Outcome). Academic Press, New York (1982)
3. Edwards, S., Lewis, C.: ROS-Industrial – Applying the Robot Operating System (ROS) to Industrial Applications. In: ICRA/ROSCon, St. Paul, Minnesota (2012)
4. Ferrein, A., Kallweit, S., Scholl, I., Reichert, W.: Learning to program mobile robots in the ros summer school series. In: Proceedings of the 6th International Conference on Robotics in Education (RIE-15) (2015)
5. Gerkey, B., Vaughan, R.T., Howard, A.: The Player/Stage Project: Tools for Multi-Robot and Distributed Sensor Systems. In: ICAR 2003, Coimbra, Portugal (2003)
6. Gerkey, B.P., Vaughan, R.T., Støy, K., Howard, A., Sukhatme, G.S., Mataric, M.J.: Most Valuable Player: A Robot Device Server for Distributed Control. In: IROS 2001, Wailea, Hawaii (2001)
7. Michieletto, S., Tosello, E., Romanelli, F., Ferrara, V., Menegatti, E.: ROS-I interface for COMAU robots. In: Proc. SIMPAR. pp. 243–254. Springer (2014)
8. Niemüller, T., Ferrein, A., Beck, D., Lakemeyer, G.: Design Principles of the Component-Based Robot Software Framework Fawkes. In: Proc. SIMPAR 2010. LNCS, vol. 6472, pp. 300–311. Springer (2010)
9. Quigley, M., Conley, K., Gerkey, B.P., Faust, J., Foote, T., Leibs, J., Wheeler, R., Ng, A.Y.: ROS: an open-source Robot Operating System. In: ICRA Workshop on Open Source Software (2009)