10th Conference on Learning Factories, CLF2020

Concept for distributed robotics learning environment - Increasing the access to the robotics via modularisation of systems and mobility

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Abstract

The ongoing digital transition affects manufacturing industry at all levels, from workers at a shop floor to machine systems, and from business models to future markets. Emerging technologies such as robotics, Internet of Things (IoT), Artificial intelligence (AI), and cyber-physical production systems (CPPS) capable of facilitating real-time processes, visibility and transparency of factory operations will speed up the change of manufacturing paradigms. The mass customization and personification is expected to increase further. The capability to address the requirements and needs of each individual customer will be a key differentiation and competitive factor. At the same time the workforce in Europe is diminishing, causing a miss-match between skills and needs from the industry. In manufacturing industry any skills are developed by experience, reflecting time on the labour market and age and skills taught in qualifications change. Qualifications which are prone to technological change are likely to reflect quite different embodied skills according to age cohort. In order to answer these challenges we have established a robotics fablab concept to support both formal and non-formal education offered to the younger students and industrial workforce alike. The concept utilises digital learning contents, a fablab operating philosophy and mobile factory concept, meaning that parts (e.g. robot cells) of the laboratory can be shipped to another location for a while to be used by learners. This paper will described the concept and preliminary findings from the applicability of the concept.

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Peer-review under responsibility of the scientific committee of the 10th Conference on Learning Factories 2020.

Keywords: Robotics; Automation; Learning; Modular; Education

1. Introduction

Manufacturing and technology industries have constantly looked for new business models and opportunities. The change in the field has been a constant movement, pushed forward by changes in customer preferences and/or emerging technologies. There is a trend of ”involvement” and ”co-creation” among industry that encourages to try out and embrace new business logic and models in and among the supply chains [3]. In new business logic, competitiveness of industrial actors is highly based on digital knowledge-intensive solutions. It can even be stated...

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Peer-review under responsibility of the scientific committee of the 10th Conference on Learning Factories 2020.
10.1016/j.promfg.2020.04.087
that in the novel data-driven business models it is a question of race between industrial and digital companies (IoT, platform or other software companies): which ones will be the first credible actors in the markets with appropriate market value. This is also a paradigm change: whether smartness is added to physical products or physical products are part of digital solutions [11]. In many cases, the emergence of new technologies such as IoT, AI, advanced robotics and CPPS is faster that the workforces capability to adopt them. This will require new education models for the existing workforce to keep up with the technology.

The number of jobs in manufacturing in Europe as a whole requiring high-level qualifications is projected to rise by 1.6 million (21%) by 2025 [8], whereas the growing automation of production processes will see the number of low and medium-skilled jobs decrease. A similar pattern is expected in the high- and high-medium technology industries within manufacturing, although the shifts are less pronounced at the high-technology end of the scale [13]. While the discussion is indeed about the skills gap and how to improve existing skills, there is little attention paid to demographics. The population of the European Union (EU) was estimated at almost 513.5 million, compared with 512.4 million on January 2018. During 2018, more deaths than births were recorded in the EU (5.3 million deaths and 5.0 million births), meaning that the natural change of the EU population was negative for a second consecutive year[7]. Eurostat’s baseline projections suggest that the EU-28 population will grow more slowly than in the past, peaking in 2050, and then declining. The EU-28 working population (defined as those aged 15 to 64) shrank for the first time in 2010 and is expected to decline every year to 2060 [6]. This means that the availability of skilled workforce is diminishing from the industry.

On of the challenges is also a lack of interest towards engineering subjects in general. Employment of science, technology, engineering and mathematics (STEM) skilled labour in the European Union is increasing in spite of the economic crisis and demand is expected to grow. In parallel, high numbers of STEM workers are approaching retirement age. Around 7 million job openings are forecast until 2025 - two-thirds for replacing retiring workers. Concerns about the supply of STEM skills rely on two basic facts: the proportion of students going into STEM is not increasing at the European level and the under-representation of women persists [5]. The key challenge in addressing the evolution of future education in the manufacturing sector involves developing skills and expertise as well as pedagogical and technological approaches that match the changing needs of today’s and future workplaces, taking into account how to widen the heterogeneity of the workforce[11].

In order to address these challenges in manufacturing industry, new types of education tools and methods are needed to be taken into use. The universities will need to push the focus more on the life-long education as the life-expectancy grows and the length of working-life will increase and while the fresh students number is decreasing. Based on Abele et al. [1] modern concepts of training, industrial learning and knowledge transfer schemes are required that can contribute to improving the performance of manufacturing. These new concepts need to take into account that: (a) manufacturing as a subject cannot be treated efficiently in a classroom alone, and (b) industry can only evolve through the adoption and implementation of new research results in industrial operation.

2. Theoretical Background

Learning Factories (LF) have shown to be effective for developing theoretical and practical knowledge in a real production environment [2]. According to PWC’s report [14] there is a need for tools to make education efficient in embracing change, to bring practice into schools, to bring knowledge directly to the workplace. This may require the use of new media. The notion of a Learning Factory represents a promising approach in this respect. A ‘Learning Factory’ is a realistic, but for didactic reasons simplified model of real working environments, which allows problem-based, project-based and action-oriented training. Learning Factories are located in the heart of the factory and implies; Learning on demand; Short training units (30 min); Managers as trainers; Train the trainer concept; Administration by apprentices; and Covering: basics (Soldering, screwing etc.); product training; automation; organisation (5S, One-piece flow), etc. Meyer et al. [12] introduced a concept for a modular learning laboratory based on the Festo Didactic learning environment. The concept, namely modular smart production lab (MSPL) was based on a learn repository enabling lecturers to individually design courses using centrally managed, well-structured
learning objects e.g. nuggets. ‘Teaching factory’ developed by University of Patras [4] aims at a two-way knowledge communication between academia and industry. In this case the industry proposes engineering challenges for students to be solved in university facilities. The approach relies on two-way communication throughout the process.

While there are multiple good learning and teaching concepts available, there is a lack of a modular approach that supports learning outside of the existing dedicated physical site. The concept for a modular and transportable learning factory, introduced in this paper, aims to provide a solution for supporting both centralised learning in dedicated laboratory, be it in the university or industrial site.

3. Research Background and Design Setting

Finland is sparsely populated country. In order to provide education for smaller student groups mobility and digitalisation of the education has to be improved. The education strategy of Tampere University aims to provide student-centred and dynamic education that serves as a means for renewing society and working life. The strategy envisions a global digital campus that offers a broad range of opportunities to join or pursue studies within our university community regardless of geographical boundaries [15]. Figure 1 summarises the needs represented from the university side to the learning environments.

In order to match the education environment with the new education strategy, industrial needs, interest in FabLabs and general rise of robotics trends, the RoboLab Tampere was formed. Robolab Tampere is a fablab for robotics located in Tampere University. The main principle of this learning environment is to increase the amount of both supervised and un-supervised active learning. E.g. exercises that aim to strengthen the problem-solving, learning from errors and reflection skills of the students, which were found highly relevant from industrial perspective. While the traditional lectures are given in lecture rooms, practical work and demonstrations make use of a laboratory environment specifically designed for education. The number of lectures is decreasing and learning events are developed further to be more interactive and independent. RoboLab Tampere offers a place for students to work with robotic equipment and experiment without major restrictions. The environment includes for example industrial manipulators (KUKA LBR iiwa with FlexFellow, Universal Robots UR5s, Fanuc Educell, EPSON T3, F&P Robotics PRob2, Franka Pandas), mobile robots (Turtlebot, MiR100, in-house developed robot), a multitude of sensors such as 2D/3D Time of Flight (ToF) cameras, lidar, etc.) and different processing platforms (PCs, embedded PCs, Raspberry Pi). While giving preference to course students, the lab is available 24/7 to all students interested in robotics and aims to create a casual learning environment. Access to the lab is granted after participation in a safety training [10].

3.1. Technical aspects

The concept for a modularised learning factory includes the modularisation of the physical systems e.g robot cells and accessories, and also includes the modularised learning content that can be used online. The main idea is to
host different robot and automation platforms in the central site. Whenever the need arises for external education
to focus more on field of PLC or robotics. A few selected exercise modules work as threshold for higher grades of

In the past, our main course utilising these resources was graded as pass-fail, and students had one common set

3.2. Exercises

The modular and transportable learning factory was tested in one of the Master level courses with 20 students, who were doing their M.Sc. level education outside of Tampere. The students were working during the week, and they had specific lecture times in Friday evenings and Saturdays. The learning goals in this course were described as “The student can program and use the basic equipment of the discrete manufacturing automation in practice (e.g. sensors, actuators, PLC logics, robotics). In the end of the course students have a good practical understanding of the field of discrete manufacturing automation and (s)he can also use the virtual design tools in practice.”
working order. There were minor problems with the collisions with the robot, which caused need for both off-line and on-line principle the robot cell modularisation was in such robust level that the single cells could be shipped and they were in working order for only 2-4 weeks at a time. In this way the learning factory modules can be utilised in several locations even during the same semester. The locations of the cells have been 2-3 hours away by driving from central site, thus the need for module robustness, and clarity of the exercises and online material has been in the center of the development.

3.3. Student Feedback and Analysis of Outcomes

The feedback from the students was in general positive. They do like learning-by-doing activities, and when they finally can apply the knowledge gained in the preceding courses. They gain practical skills and experience in problem solving, which they will need in their upcoming professional work. We have realised that it is important to provide experiences of success during the exercises, especially when the exercise is done un-supervised in remote location. These motivate student forward and increase their self-efficacy beliefs. On the contrary, if they stuck at whatever reason, frustration increases very quickly. According to our analysis, there are two main points supporting the student’s success. Clear and well-prepared instructions and frequent (even ad hoc) support sessions. This is an important aspect to take into account when (re-)designing and instructing the exercises. I.e. to plan how a student advances through the exercise and what kind of problems (s)he will come across. However, this is not very easy to implement in practice, because our students are coming from very different backgrounds and initial knowledge levels, as we are serving both life-long education and graduate students.

The students reported that specifically one of the exercises (PLC.1) is too large and gigantic to handle. This has been reacted now by splitting it into two separate modules. The instructions were enhanced to clarify even more the implementation in practice, because our students are coming from very different backgrounds and initial knowledge levels, and online self-learning materials and increasing the amount of variety in exercises, and later consider other learning methods as well.

The modularisation and development of exercises has received funding from FiTech programme funded by the Ministry of Education of Finland.
online help. Based on the immediate problems, the technical weaknesses will be eliminated with the second round of development and enhancement of the cells. There were no safety-related problems or accidents during the independent and un-supervised work, which indicates that the cells were both safetified up to needed level, and safety guidelines were understood and respected by the students.

4. Conclusions

The main contribution of the paper was to introduce the second development phase of the RoboLab Tampere robotics learning environment, which was the modularisation of the robot cells and development of suitable exercises for un-supervised learning for different students. The modularisation of the robot cells from both technical, safety and exercise perspective were considered rather successful. The paper considers mainly the technical development of modules and associated exercises. We foresee two main development directions in future. From technical perspective, we will continue the modularisation the rests of the robot cells and automation systems belonging to the RoboLab concept in Tampere, and possibly developing the physical cells to be suitable for integration and reconfiguration. The future work also consist of improving the educational perspective. At first we will proceed to improve the instructions and online self-learning materials and increasing the amount of variety in exercises, and later consider other learning methods as well.

Acknowledgements

The modularisation and development of exercises has received funding from FiTech programme funded by the Ministry of Education of Finland.

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