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Preserving hands-on learning experience with physical equipment in distance learning—findings of a course pilot

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Abstract

Since 2016, SZTAKI and Fraunhofer Austria/TU Wien have been exploring possibilities of adding a cross-site dimension to learning factory courses. The pandemic situation has highlighted the relevance of certain collaboration practices, suggesting that real-time remote connection to processes and use of virtual models can recover a significant part of the hands-on experience students normally gain with physical equipment. This working assumption was successfully tested in a summer school course for layout and process planning in humanrobot collaborative assembly, jointly organized by SZTAKI and Fraunhofer Austria in 2021. The paper recapitulates findings tat could be gained with the first limited run involving 8 students, highlights recognized issues, and presents opportunities for extending the course or adopting the practices in other learning factory scenarios.

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1. Introduction

Leaving behind the second year of the COVID-19 pandemic, the education sector has gathered considerable experience in coping with attendance and travel restrictions [1, 2]. Distance learning [3] was found to bear the potential of new evolution paths for certain learning factory types, yet, reconciliation with hands-on experience using physical equipment remains a core problem and limitation factor, especially for facilities that have previously evolved around on-site presence and co-located teamwork [4]. The history of suitable mitigation measures reaches back to years before the pandemic—earlier alternatives include tangible equipment scaled to portable dimensions [5], or made suitable for reproduction using local/home resources. Interactive virtual environments [6] present another alternative, potentially serving as platforms for remote teamwork. Remote connection is also fundamental in the *Teaching Factory* paradigm,

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connecting real-life processes with students [7]. In practice, a combination of several measures is needed to make a learning factory work with remote attendance [8], its feasibility depending on the proper interplay of components, and quality of services provided by teaching and operating staff [9]. In 2021, SZTAKI and Fraunhofer Austria made an initial roll-out of a learning factory course on process and layout planning of collaborative assembly stations, adapted to hybrid participation options. While an earlier publication presented the didactic program and infrastructure in detail [10], this paper gives a first assessment of the initial run as far as the limitations of only 8 participants allow.

2. Course implementation

Despite an increasing number of cobot manufacturers, industrial implementation of collaborative systems is rare, partly due to not fully tackling the complexity of aspects interlinked in collaborative systems. This has not been typical for conventional automation, and the coming generation of engineers has to respond to these challenges with more emphasis on independent, critical thinking. This shift of emphasis is also reflected by the composition of the course reported in this paper. Students receive a comprehensive theoretical background addressing complexity-related aspects in a holistic way [11], in preparation for the practical design and testing tasks centered around a collaborative assembly station. In the practical track of the course, independently working student teams elaborate parallel solution alternatives of the same assembly problem relying on different appliance alternatives, which are then built up, tested, and compared across all teams. Originally planned for on-site attendance, the course has undergone key modifications for hybrid roll-out in summer 2021 [10]: (1) problem complexity has been tailored to work without immediate live assistance, mainly by discretization of design decisions; (2) support for remote attendance has been created by means of a model-based virtual design and testing environment, provision of physical replicas to participants in remote locations, and remote connection to staff and the physical facility; (3) course structure and staff availability have been reorganized for remote participation involving real-time attendance and independent work.

3. Findings of the initial roll-out

An initial roll-out of the modified course took place in July–August 2021 in the form of a six-day summer school. 8 students from 4 countries participated in the program, with one group attending on site for experiments, one group meeting up at their own location, one group combining periods of meeting locally and working individually at separate locations, and one team with members remaining at separate locations. Lecturers joined in via video connection from Vienna, Budapest and Győr, and physical equipment with on-site staff was located at SZTAKI's facility in Győr. Despite the small number of participants, the diversity of their backgrounds and available resources did allow a relatively broad first qualitative view at course outcomes and needs of continued improvement.

Assessment of technical feasibility and transferability—The successful completion of the course by all teams, as well as positive feedback, supports the initial working assumption of the feasibility of hybrid courses built on physical equipment. In this particular case, further improvement is advised regarding (1) handling of deviations between virtual model states and physical system states (e.g., coverage of robot inverse solution pairs, orientation ambiguity of workstation components, or effect of geometrical features omitted due to poor predictability), and (2) more systematic coverage of backup measures for live connections and remote resources. While the approach has not been applied to other scenarios to date, the key transferability requirements recognized so far for this particular approach are (1) feasibility of creating a virtual model and corresponding design/test environment that represents system characteristics and states to the level required by the course context; (2) practicable means of transferring designs onto the physical system and relaying system responses back to the participants to a depth sufficient for evaluation within the course context; (3) availability of staff to carry out local operations on the physical equipment and to provide expert assistance with related problems; (4) sufficient infrastructure for remote communication and data exchange.

Assessment of the didactic approach—Since all participants have met the learning targets of the course and impressions were generally favorable, the didactic approach—combining online lectures, consultation and remotely assisted exercises partly in flipped-classroom arrangement—can be considered adequate. Nevertheless, further improvement must address challenges mostly stemming from the reduced face-to-face nature of the course, hindering much of informal communication which keeps students on track but is often omitted in formal content: (1) Background material has to give a more structured view of the "big picture," the reasons behind actions, and their context. (2) Even after reshaping complexity and decision diversity, a complete estimation of difficulty levels of all solution alternatives is not realistic—this has to be mitigated by more flexible and responsive assistance by expert staff. (3) Remote participation precludes student teams from observing each other while elaborating their solutions, potentially increasing the impact of local working culture on choices in design and self-evaluation. This diversity can be a source of new insight but also a comparability/interoperability challenge which has to be taken into account accordingly in future improvements. (4) The observation of students asking for additional material to be used in their own experiments weeks after completing the 6-day course indicates that ripening of new inspiration does take time, and follow-up by learning factory staff must be conducted accordingly. Further insight in this aspect is expected upon repeated runs of the summer school, and extension into a full-fledged course spanning an entire semester.

4. Conclusion and outlook

In recent years, a learning factory course in human–robot collaborative assembly has been jointly prepared by SZTAKI and Fraunhofer Austria/TU Wien, rolled out in 2021 with adaptations to hybrid participation. The pilot has generally confirmed the assumption that it is possible to reconcile hands-on work involving physical equipment with remote attendance. The limited number of participants has, so far, allowed qualitative assessment only, pinpointing aspects of further improvement and conditions of transferability to other scenarios. Repeated runs of the shortened program, as well as extension into a full-fledged course are planned, which are expected to deliver more informaton for a comprehensive and systematic evaluation and a roadmap for adoption in other course scenarios.

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