Design and Implementation of the Reconfigurable Cobot Workstation into the Learning Factory Environment

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Abstract. One of the key features of Industry 4.0 automation is the development of collaborative robots (cobots) designed to work alongside humans. Their importance is further highlighted in Industry 5.0, which, in addition to promoting resilience and sustainability, places people at the center of industrial processes. Cobots are generally easy to operate. However, most cobots lack a machine vision system, which makes reconfiguration of the cobot workstation more challenging. With the growing trend toward product personalization, it is essential to reduce product changeover time to lower the costs. In the learning factory environment, the reduction of the product changeover enables using the same cobot in many different projects and applications. It enhances flexibility and increases the usage of the cobot that usually has low OEE (Overall Equipment Effectiveness) in the learning factory environment. A concept of reconfigurable cobot workstation has been developed in the Learning Factory at FESB, University of Split. This research presents its successful implementation for Franka cobot. The proof of concept is presented through different application examples that are used for education of students and life-long learning activities.

Keywords: Cobot, Reconfigurable Workstation, Learning Factory.

1 Introduction

The evolution of manufacturing under Industry 4.0 is characterized by the integration of digital technologies – such as the Internet of Things, artificial intelligence, and real-time data exchange – to create connected, smart factories [1]. With Industry 5.0 as its update [2], a shift in this transformation is its human-centric focus, moving beyond the automation-for-replacement paradigm of Industry 3.0. The goal is to synergize human creativity with machine precision, creating systems that are both automated and flexible enough to collaborate with human operators [3]. This approach has positioned collaborative robots (cobots) as one of the key enabling technologies in Industry 4.0/5.0.

Modern cobots are defined by their ability to operate safely alongside humans in shared workspaces, utilizing environmental sensing, compliant mechanics, and autonomous decision-making to perform joint tasks [4]. To function within a collaborative

environment, cobots incorporate advanced safety features like force limiters and velocity/acceleration monitoring. They are commonly deployed for repetitive, physically demanding tasks such as part handling and positioning, screwing bolts, and similar. This deployment reduces worker injury risk, improves workflow efficiency, and allows human operators to focus on higher-value activities, thereby contributing directly to the core Industry 4.0/5.0 objectives of productivity, adaptability, and optimized human skills. However, to fully unlock this collaborative potential, careful attention must be paid to the design of the cobot workstation.

The ongoing evolution of cobots necessitates parallel progress in workstation design. A well-designed workstation is essential for safe, efficient, and uninterrupted human-robot collaboration. Furthermore, it represents a necessary step toward the human-centricity – a goal of Industry 5.0. Unfortunately, many existing collaborative workstations rely on simple, improvised surfaces like flat tables or T-slot plates, which lack the precision required for tasks setup (Fig. 1).

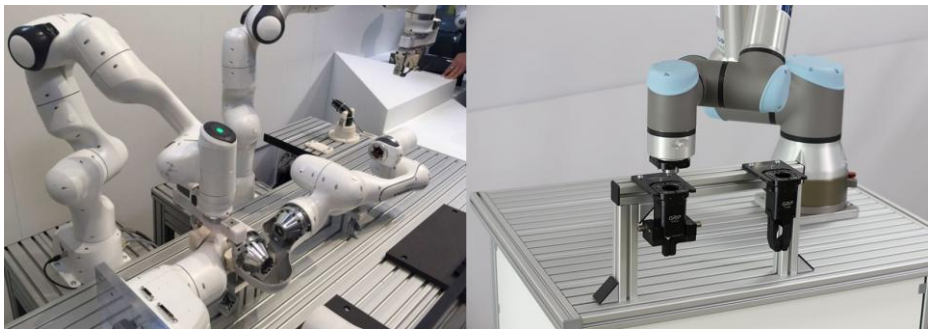


Fig. 1. Common cobot workstations with T-slot plates [5, 6].

If the cobot is not guided by vision system, it needs to be spatially adjustment for the task that has been set up. This can lead to misalignment errors, failed operations, and production inefficiencies. To address this gap, this research proposes the construction of a reconfigurable workstation based on a tooling plate instead of T-slot plate. The tooling plate design, similar to the conventional welding workstations, enables precise, repeatable component placement, thereby enhancing workflow reliability for both the cobot and the human operator, or in to put it short: it enables reconfigurability.

Reconfigurability is especially important in the learning factory environment, where reduction of the product changeover and setup times enables using the same cobot in many different projects and applications. It is a common thing in LF that the cobot is used as an industrial demonstrator in LF's assembly line, then students use it for their different projects, and it becomes time consuming moving the cobot around LF and setting up its worktable for different projects or demonstrations. Of course, the solution can be to purchase more cobots. However, this paper presents different solution: cobot's worktable design that enables easy reconfiguration of the workplace thus allowing usage of the cobot in many different projects in a single day.

2 Methodology

The selection of a collaborative robot (cobot) workstation constitutes a multi-criteria problem. This is due to the wide range of possible designs, which are contingent upon the final application. Key requirement for the workstation in this case is reconfigurability, which includes: adaptability, easy configuration, a plug-and-play capability that minimizes setup time used for cobot's spatial adjustment, as well as low cost and assembly complexity. Such a problem necessitates a structured evaluation using multi-criteria decision-making methods [7].

A benchmarking process identified three fundamental design variants [8] and multi-criteria decision-making was applied to evaluate cobot workstation designs. The analysis resulted in the selection of a workstation with the cobot installed onto it, which was consequently chosen for detailed design [9], manufacturing and assembly as a reconfigurable workstation for a Franka collaborative robot (Fig. 2a).

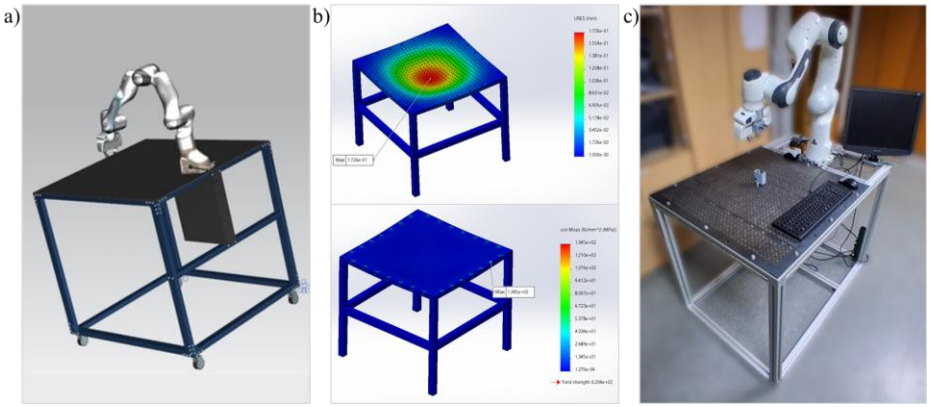


Fig. 2. Reconfigurable cobot workstation design process: a) Selected design of the cobot workstation; b) Cobot workstation FEM analysis (stress and displacement analysis); c) Final product with cobot Franka Panda.

The detailed design process included a stress and displacement analysis of the workstation's tooling plate which was selected to be 5 mm thick steel plate (DIN EN 10111). This part is critical part of workstation, since the tooling plate consists of more than 1200 holes and the goal was that it can sustain a product weight up to 50 kg. CAD and FEM models of the tooling plate were created for the FEM analysis of stress and displacement (Fig. 2b). The results of the FEM analysis confirmed the design's structural integrity with a maximum stress of 134.5 MPa and a maximum displacement of 0.172 mm under the 50 kg load. It is a low stress comparing it to the steel's yield strength of 620.4 MPa. Franka cobot has 3 kg payload and it weighs approx. 20 kg, so it could be mounted on the tooling plate without issues. Nevertheless, cobot wasn't mounted on the tooling plate in a final design, which allows using cobots weighing 30+ kg with 10+ kg payloads, and the design remains over-dimensioned.

Following the approval of the workstation design through FEM analysis, physical construction, i.e. manufacturing and assembly commenced. The primary components included the steel tooling plate, responsible for product placement, and a structural frame made from aluminum profiles with a rectangular T-slot cross-section. A slight modification was made to the original design variant: the tooling plate is used only for upholding the parts and product, and the collaborative robot (Franka Panda weighting approx. 20 kg) was mounted separately onto the frame (Fig. 2c).

3 Results

Reconfigurable cobot workstation allowed easy workplace configuration with minimal setup times (several minutes), and, more important, it allowed easy reconfiguration from one cobot task to another cobot task, i.e. from one workplace configuration to another. At first, it seems that reconfigurable cobot workstation enabled SMED (Single-Minute Exchange of Die) approach, which minimizes setup times in manufacturing processes, especially in cases of product changeover.

However, in the learning factories the OEE of cobot is low, therefore a need for SMED is usually not needed. But, reconfigurable cobot workstation actually enabled the reconfigurability itself. As mentioned before, switching from one cobot task to another can be quite demanding and time consuming, because a cobot needs to be positioned in a precises position that task demands. It usually requires cobot's spatial adjustment, or trial and error method until the task is working.

For learning factory implementation purposes, a documentation template was made for presenting the workplace configuration that can be easily transferred into reality. A simple task of RAM assembly and disassembly is made together with its workplace configuration documentation. With a workplace configuration scheme (Fig. 3a), a cobot task can be set up within several minutes (Fig. 3b).
Nevertheless, removing products and parts belonging to RAM assembly/disassembly task takes several minutes, as well. After that, cobot workplace can be configured for another task.

In this case, second cobot task is 3D scanning by using Photoneo Phoxi 3D scanner [10]. Using a similar workplace configuration document, the workplace has been set up in no time (Fig. 4).

These two simple examples clearly demonstrated that using a reconfigurable cobot workstation in learning factory environment enabled that cobot can be easily used for different tasks, different students' projects, different demonstrations, etc. Every other approach will usually end up with purchasing more cobots. Because, it is hard to avoid complex workplace reconfigurations, if single cobot is used.

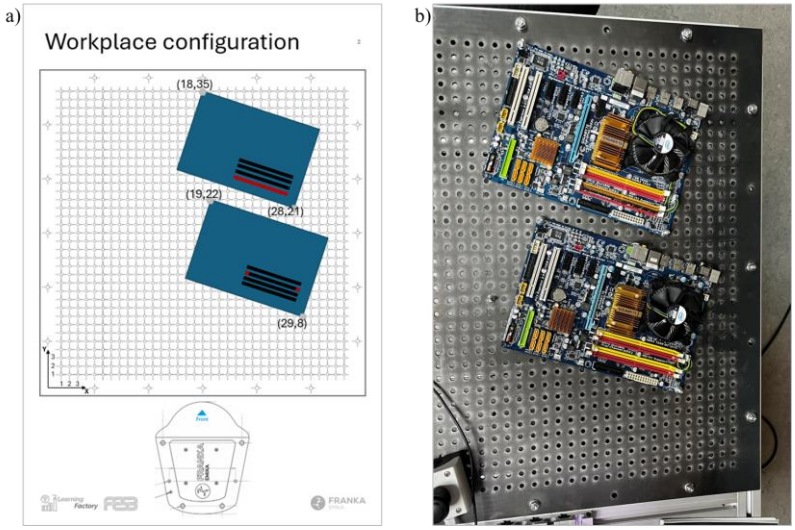


Fig. 3. Workplace configuration for computer RAM assembly/disassembly: a) Workplace configuration template; b) Workplace setup.

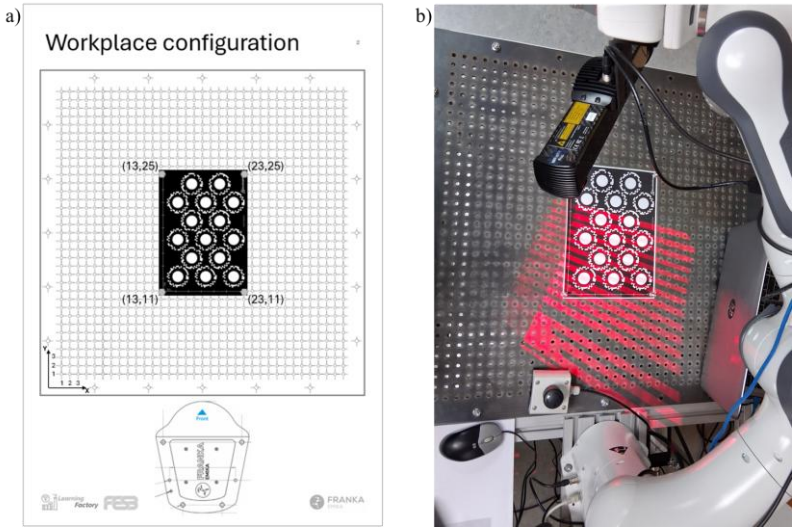


Fig. 4. Workplace configuration for Photoneo Phoxi 3D scanner: a) Workplace configuration template; b) Workplace setup.

4 Conclusions

This research presented an approach in which reconfigurable cobot workstation is made for application of cobot in the learning factory environment. As already mentioned,

using a cobot in learning factory usually ends up with low OEE of cobot, but enormous setup (changeover) times when moving a cobot from one task to another.

The presented reconfigurable cobot workstation successfully addresses this issue by enabling the reconfigurability with low setup (changeover) times: from few minutes to dozen of minutes, depending of the setup complexity. The workplace configuration documentation has been developed to further enhance the process. In this paper two significantly different workplace configurations are presented: RAM assembly/disassembly example and Photoneo Phoxi 3D scanner example. It takes only several minutes to reconfigure the workplace from one task to another.

The future research will consist of testing the reconfigurability of the workstation on more complex workplace setups for more precise cobot tasks. The limitation of the designed workplace is that specialized jigs should be made to position some products or parts on the tooling plate, and it is something that also requires future research.

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Disclosure of Interests. The authors have no competing interests.

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