Hybrid Work for Industrial Workers: Challenges and Opportunities in using Collaborative Robots

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The COVID-19 pandemic has drastically impacted how work is conducted, shifting many jobs to a hybrid nature with an emphasis on work-from-home. This shift has, however, not affected all job types equally. In this position paper, we argue that the advancement of collaborative robots in the industrial setting presents a unique and underexplored opportunity for robot-supported hybrid work in the industrial setting. We present five challenges that act as contributing factors that stifle access to hybrid work opportunities in the industrial context. These point to (i) the need for spacial awareness of both the robot and its surroundings, (ii) the, at times, need for physical presence for breakdown intervention and recovery, (iii) the need for contextual awareness, (iv) the need for additional employee training, and (v) a clear interface to map the varying degrees of freedom to a remote interface. We present future research opportunities with the potential to address some of the presented challenges.

CCS Concepts: • **Human-centered computing → Computer supported cooperative work**; • **Computer systems organization → Robotics**.

Additional Key Words and Phrases: Industrial hybrid work, robot teleoperation, remote work

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1 REALISING HYBRID WORK IN THE INDUSTRIAL CONTEXT

Following the COVID-19 pandemic, a multitude of workplaces has shifted from a classic office-based working context towards a more hybrid-oriented approach involving remote work. While existing research has focused on the impact of this shift towards hybrid work on, e.g., productivity and wellbeing [12, 14], happiness [8], and job satisfaction [15], most research has focused on desk-based workers such as academics or software developers. Consequently, the industrial sector remains an often overlooked context. Similar to the office environment, reducing human-to-human contact in the industrial sector can lower the risk of infection.

Over the last decade, industrial manufacturing has seen an increased focus on automation utilising collaborative robots (cobots). The switch from caged industrial robots to more mobile and collaborative robots allows for closer collaboration—due to, e.g., the removal of cages and a reduction of robot speed and force—between humans and cobots. Furthermore, with this new generation of industrial robots comes the opportunity to reduce the need for physical collocation due to their potential for teleoperation (i.e., remote interaction) during task completion [13]. However, a minimal number of industrial work processes are supported by hybrid work for industrial employees.

With this position paper, we call for a greater emphasis on hybrid work for industrial workers by utilising teleoperated collaborative robots. As the industrial workers' primary task typically changes to a supervisory role following the introduction of cobots [3], employees could monitor multiple robots simultaneously, thereby allowing for efficient task completion through remote interaction [5, 16]. This position paper outlines five open challenges which currently constrain efficient robot-supported hybrid work in the industrial context.

The following five challenges highlight the need to:

(i) **Provide spatial awareness of the robot site.** A digital representation of both the robot and the robot's environment is critical. As incoming errors require a high degree of contextual awareness of the robot's surroundings, merely seeing the work environment from the robot's point of view is insufficient. This requires an extensive extension of the spatial setup within the production cell/pipeline with additional cameras and sensors to provide in-depth information to the remote operator.

(ii) **Address the absence of physical breakdown intervention and recovery.** The industrial manufacturing context is typically characterised by streamlined processes designed to improve performance. Nevertheless, unexpected errors and breakdowns—of the robot and other devices and processes—might occur that require physical intervention and error recovery. As hybrid workers are unable to physically intervene while working from home, this absence might act as a barrier for hybrid employment in these contexts.

(iii) **Increase the operators contextual awareness of and around the work process.** Industrial work relies extensively on knowledge of contextual information such as auditory cues—produced by the robot, other machinery, and colleagues, shortage of new material, or knowledge of the physical presence of other workers. This information is difficult to convey through an online-based digital representation.

(iv) **Provide additional training to operators to acquire remote controlling competencies.** As collaboration with cobots requires training [2, 7]. The additional support for hybrid operation requires additional training as well as potential new hardware, such as is the case in remote-based operations, the learning curve constitutes an additional obstacle to the adoption of more hybrid possibilities for industrial work [7].

(v) **Improve the representation of multiple DOF in a intuitive interface.** As collaborative robots (e.g., the UR10e [11] or Sawyer [10]) have a high number of degrees of freedom (DOF), converting these into an easily understandable interface for remote interaction remains a challenge. Contrasting the teleoperation of, e.g., an RC car, collaborative robots—especially with multiple limbs—have a high number of DOFs, and the manipulation of one DOF might affect the entire robot's positioning in space. Therefore, an intuitive interface which maps user input to robot manipulation is critical [1].

While the possibility of hybrid work benefits worker flexibility and reduces infection risk, just as in desk-based occupations, it does add potential downsides. The five above-listed challenges all add an, initial, expense to the employer. The following section will present potential future aspects to investigate.

2 ONGOING AND FUTURE ACTIVITIES

This section outlines ongoing and future research opportunities to address the challenges listed in Section 1.

In prior work, we have studied industrial operators and their working practices [2, 3]. This has revealed valuable insights that ought to be considered for a transition to hybrid work for industrial work. For example, we found that the introduction of cobots can lead to increased social interaction amongst workers [2]. Shifting physical, collocated collaboration to remote-based collaboration using cobots might negatively impact this development as the number of concurrently collocated workers decreases. Further, we found that the cobot's introduction in the workplace leads to a fragmentation of work tasks, resulting in humans shifting job identity to, e.g., 'robot supporter' or 'robot operator' with responsibilities such as monitoring and restocking of needed materials. Future work would need to investigate how these new responsibilities—which at times require

locomotion—can be performed while working remotely. These examples highlight the operators' importance of spatial closeness to colleagues and the contextual awareness of the surroundings. Furthermore, we found a close degree of cooperation between the operators, which is essential to consider when supporting a hybrid industrial work environment.

To address challenges regarding spatial and contextual awareness, as well as to provide a digital representation of multiple DOF, future work might explore the use of virtual reality (VR) combined with wearable devices mapping human movement to the robot [6, 9]. While VR can provide spatial and contextual awareness—and addresses shortcomings of 2D-based interfaces—it does not suffice for the intervention into breakdowns that require a physical presence on site. Recent advancements in robotics with locomotion support, such as Boston Dynamics Spot robot [4], allow for teleoperated physical intervention. This would enable the worker in charge of supporting the robot to perform tasks requiring physical manipulation. Furthermore, supporting hybrid work, including a mix of remote and on-site collaborators, requires an in-depth exploration of safety precautions and how spatial and contextual information is communicated amongst these two groups of collaborators.

3 AUTHORS

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