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Robomate: Case For Reconfigurable Collaborative Robots In Manufacturing

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Manufacturing in any major economy represents a pivotal mast for economic growth and employment, often propelled by a skilled and mature workforce. In Ireland, the manufacturing sector employs 275,000 (~11% of workforce) with an export value to the tune of €208 billion worth of goods (Ibec, 2023). Availability of continued supply of talented human resource is critical to industry growth and with near full employment levels (~4% in Ireland) and ever-growing dependence on an aging workforce, market competitiveness and industry sustainability are at question in the medium-to-long term. Conversely, supplementing low-volume complex manufacturing tasks with automation via collaborative robotics could supplement key issues, viz. skilled worker shortages, training gaps, lower (process) efficiencies/productivity and safety (Javaid, 2022; Sherwani, 2020).

This paper seeks to investigate the primary drivers influencing the adoption of easily reconfigurable collaborative robots within a manufacturing environment. Subsequently, it proposes a model prototype design for collaborative robots (cobots) aimed at replacing temporary low-cost labor in settings characterized by low-volume, high complexity tasks. In the initial phase, we sought to discern significant impediments to the implementation of Human-Robot Collaboration (HRC) within both Multi-National Corporations (MNCs) and Small and Medium Enterprises (SMEs) through an online quantitative survey comprising 32 questions. The survey focused on elucidating key attributes (mentioned below) of surveyed enterprise profiles and their corresponding HRC use-cases:

- barriers and facilitators to HRC in industry;
- User Interfaces;
- interactive learning and learning from human expert;
- flexibility of systems;
- existing safety standards and their importance;
- vision systems ;
- company's prior experience;

We assessed 226 completed questionnaire responses from diverse stakeholders across the industry sectors in Ireland. Survey results suggest that the adoption of cobots is contingent upon several factors, including the individual participant's level of experience, adherence to ISO standards, utilization of key technologies like vision systems, as well as the significance of a smaller footprint for enhanced flexibility in partial workflow automation. Additionally, ease of use and the presence of existing robot systems within the company also play pivotal roles in the furthering of the adoption process i.e., companies presently utilizing cobots exhibit eagerness towards additional adaptation. Conversely, there is no notable iqmpact observed from factors such as company sector, user usability, and robot flexibility.

Reconfigurability (programming) of manufacturing robots for task execution requires skilled human resources and any change or modification requires additional validation demonstrating the system meets predetermined specifications, ensuring its safety, efficacy, and reliability (Valori, 2021). With issues, it is imperative that a

solution to programming cobots ought to involve use of a sequence of high-level (planning) actions. While several techniques exist in SOTA such as semantic task planning (AI driven) (Cui, 2021), data driven methods (using Machine Learning) and Human-in-the-loop (HITL) (Turner, 2021), etc., HITL offers a viable scaffold and great potential to automate simple (low skill) tasks quick and efficiently. Some SOTA commercial options with relative programming versus task complexity are illustrated in fig. 1a (green star indicates our academic work).

a)

b)

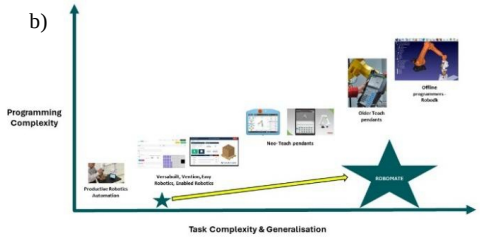

Fig. 1. a) SOTA: Commercial options and respective programming versus task complexity; b) Cobot.

Based on the findings of the survey, we are better equipped to refine our proposed cobot template tailored for application in the Low-Volume High-Mix (LVHM) industry setting. Initially, we plan to utilize the Universal Robot UR5e and Zivid 3D Camera in conjunction as a foundational configuration (refer fig. 1b) as conjured in (Bengtsson, 2017). Subsequently, we shall integrate supplementary software modules augmented with artificial intelligence (AI) for vision capabilities and robot route planning, while incorporating human-in-the-loop learning.

The insights gleaned from our study could serve to provide SMEs facing resource constraints with solutions aimed at optimizing ROI during implementation, as well as addressing safety standards for reconfigurable collaborative robotic (arm) systems (Bi, 2021). This is especially critical considering the existing challenges related to safety standards for reconfigurable collaborative robotics, notably the necessity for validation by a safety certification company for every modification to the system and its viability in LVHM scenarios.

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