Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 44 (2016) 281 – 286

www.elsevier.com/locate/procedia

6th CIRP Conference on Assembly Technologies and Systems (CATS)

Potential advantages using large anthropomorphic robots in human-robot collaborative, hand guided assembly

Sten Grahn[a,b,*], Björn Langbeck[a], Kerstin Johansen[c], Björn Backman[a]

[a]Swerea IVF AB, Brinellvägen 68, Stockholm 10044, Sweden
[b]Mälardalen University, Drottninggatan 12, Eskilstuna 632 20, Sweden
[c]Linköping Universty, Linköping 581 83, Sweden

* Corresponding author. Tel.: +46-16-15-5125; fax: +46-16-15-3630. *E-mail address:* sten.grahn@swerea.se

Abstract

Collaborative robot installations often mean man-machine workspace sharing. This mode of operation can lead to reductions of tact time and work space requirements. We have analyzed potential further benefits of man-machine collaboration, where operators and powerful robots share workspace, cooperating when lifting and handling large objects. We found that this mode of operation has the potential to generate economic advantages by reducing the need for manual operators and lifting tools and by offering new opportunities for component logistics.

Peer-review under responsibility of the organizing committee of the 6th CIRP Conference on Assembly Technologies and Systems (CATS)

Keywords: human-robot collaboration; robot safety; human-machine interface; hand-guided collaborative robot

1. Introduction

Advancements in several fields such as programming, robot sensor and control technology, force sensing, environment recognition, human–machine-interfaces and safety system technology have made it possible for people and robots to work in absolute proximity. These installations are often called collaborative robot installations. Bley, et al. [1] have shown that this mode of robot operation promise several potential benefits as it takes full advantage of robot as well as human strengths. Collaboration can reduce costs for space and safety measures as shared space is possible. Krüger et al [2] also claim that reduced tact time is possible as operation sequences can be made more efficient. They analyzed tact time reductions using a net present value calculation and found that a hybrid collaborative robot solution had an NPV that was 25% higher than a standard robot cell and substantially higher NPV than a manual solution. However, sharing workspace is a narrow way of defining 'collaboration'. A broader definition includes a mode of operation when robots and humans cooperate to hold and move objects. This mode of operation adds more parameters to evaluate when analyzing such an installation. The aim of this work was to contribute to the development of methods to compare such installations with manual assembly or “full” automation. An initial study on what to analyze when evaluating collaborating installations [3] was complemented with recent findings on possible methods to carry out the analysis. Three large anthropomorphic collaborative robot installations were evaluated with the updated scheme and it was found that the issue of full robot speed and range utilization is more relevant to evaluate compared to evaluation of small collaborative robots. It was also found that the potential to reduce cost by eliminating lifting tools, by using the robot as a lifting tool instead, is one important added benefit that separates large collaborative robot installations with small collaborative installations. Another added benefit is that the improvement potential for component logistics is larger than for smaller robot installations, as component placements can be adjusted to utilize the robot range and lifting capacities.

Peer-review under responsibility of the organizing committee of the 6th CIRP Conference on Assembly Technologies and Systems (CATS)
doi:10.1016/j.procir.2016.02.036

2. Benefits and limits of robot installations

2.1. Benefits and limits of traditional robot installations

Traditional robot installations can offer several benefits compared to manual operation: Improved repeatability, increased precision and speed. Heavy lifting is made easy, often with a range beyond the range of a single human. Manual hours can be reduced and ergonomics improved. Traceability and general handling of information to and from the production process could also be secured easier.

However, robots still have many weaknesses compared to humans. The resources required to overcome those, limit the usability and cost efficiency of robot installations. For example, currently robots have a limited ability to perceive its surroundings, which requires costly safety arrangements in order to avoid personal injury. These safety arrangements are particularly important and costly when working with installations of large and powerful robots, as fences and light beams are required to keep humans out of the work space. However, with sufficient robot ability to perceive and adapt to a changing environment, the need for safety arrangements that keep humans out of the robot work space are no longer necessary. Robots can then be allowed to work in collaborative mode, sharing workspace with humans. In some situations, this may reduce the safety arrangement cost as fences and light beams may not be needed. This currently comes with a performance cost though, as the robot TCP speed is, by regulation, limited to 250 mm/s when humans are inside the workspace. This speed limit may, however, increase in the future.

Costs and challenges when securing handling of complex components, binge gripping, fitting and changeover between production settings may also make robot installations less cost efficient compared to manual operations as humans carry out such operations with relative ease.

2.2. General collaborative benefits and considerations

As robots and humans have different strengths, combined utilization of human and robot strengths in a collaborative robot installation, could make such an installation competitive. This is especially the case when the ability to cost efficiently carry out the challenging robot operations mentioned in 2.1 is important. Comparing manual operations, traditional robot cells and collaborative installations, though, is not a straightforward affair. The different setups require different considerations and impact many production parameters in different ways. In order to secure a ‘fair’ and relevant comparison and identify which solution is the most cost efficient, Grahn and Langbeck [3] developed an indicative evaluation scheme for collaborative robots. Some of the main points found relevant to evaluate in that study are briefly mentioned below:

- *Role assignment* between robot and human, see e.g. Jarasse, et al. [4] and Li et al. where they mention game theory [5] and optimization [6] as methods to approach the problem.
- *Acceptability* of these types of installations. Weistoffer, et al. [7] found for example that it is robot appearance dependent.
- *Context*. Hedelind and Jackson [8] studied benefit from a lean perspective. They found that lack of information from what caused production standstills hampered possibilities. They found that it is not necessarily a conflict between lean and automation, but that providers want closer contacts with applications to ensure maximum benefit from robots in a lean environment.
- It is important to find both the *level and type of automation* [9] that best suits the needs and requirements of the environment in which the automated equipment should be used. Säfsten et al. [10] address the concept of *rightomation*. An evaluation scheme should hence produce results that can be viewed in the light of environment requirements.
- Krüger, et al. [2] emphasize that collaboration offers several alternative *assembly sequences* that need to be evaluated in order to minimize tact time.
- *Set-up time.* Kus, et al. [11] have analyzed the requirements of small and medium size enterprises (SME). They found that one of the most important disadvantages of using robots compared to manual assembly was that reprogramming requires expert knowledge. Programming improvement has, however, led to robots that can be programmed by taking the arm of the robot and showing the robot what it should do (hand guiding). This can reduce the time it takes to integrate robots into factory operation from typically 18 months, down to 1 hour [12]. A robot equipped for collaborative hand guiding work can be programmed by hand guiding as well.

3. General large collaborative robot considerations

The evaluation scheme [3] suggesting an initial guidance on what parameters to analyze when implementing and evaluating collaboration cells, was combined with recent findings on how to carry out an analysis, mainly collected from the IROS 2015 conference in Hamburg and was applied on three theoretical large anthropomorphic robot installation cases with a payload up to 500 kg (further described below). This was in part done to identify the initial scheme limits and in part to get an initial indication on expected benefits for large collaborative robot installations.

Context and automation level considerations indicate that large robots potentially adds further benefits compared to small robots as they can also offer a solution for *heavy object lifting* and *human range limitations*. Full exploitation of these further potential benefits requires evaluation of more design alternatives compared to collaboration with small robots. These considerations led to three initial designs for a collaborative assembly cell using a large robot. The alternatives exploit large anthropomorphic robot benefits using alternative combinations of robot operation modes and manual assembly with lifting tools (MA). Current robot operation mode (CRM) with standard safety arrangements using for example fences, makes it possible to utilize max speed and range of the robot. Collaborative robot in active