Proceedings of the 2019 Winter Simulation Conference
N. Mustafee, K.-H.G. Bae, S. Lazarova-Molnar, M. Rabe, C. Szabo, P. Haas, and Y.-J. Son, eds.

PROCESS BALANCING OF HUMAN-ROBOT COLLABORATIVE ASSEMBLY STATION USING SIMULATION

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ABSTRACT

Collaborative robots (or cobots) are getting attention in manufacturing for high-mix low-volume production by human-robot collaboration (HRC). When used in assembly, the HRC process needs to be balanced to avoid idle times and bottlenecks. It is different from conventional balancing problems given the fact that robots have varying speeds depending upon the distance from the operator and skillset, while the flexibility of cobots requires that balancing is done more frequently. In this article, the balancing of an HRC assembly-cell is studied using an industrial case study. First, continuous simulation is used to model the human and the robot to estimate the cycle times. Secondly, an event-based simulation is used to introduce variables such as varying robot speeds and variability due to human factors.

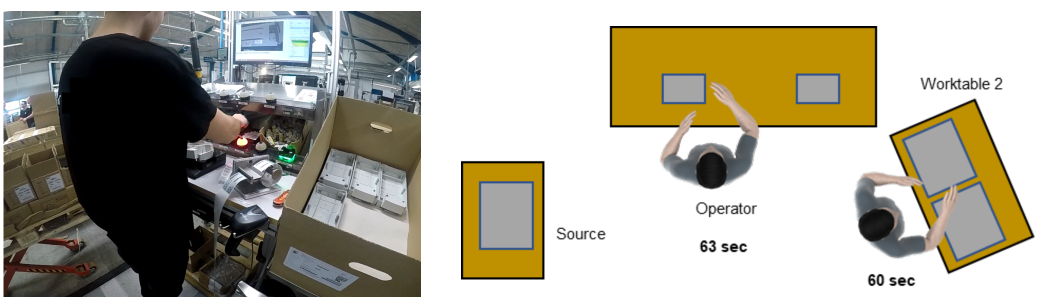


Figure 1: Manual assembly station.

The process starts by evaluating the assembly process for the ease of automation. For this purpose, different studies are available in the literature. A set of tasks are identified that can be automated given the shape of the components being assembled and ergonomic complexity involved. Though many tasks are potentially identified for automation the speed to perform the task is a determining factor. Due to safety constraints, cobots are operated at lower speed resulting in higher cycle time for the same task if performed by humans. Secondly, since a cobot and operator are coexisting and assembling the product, given the assembly precedence constraint, the product will be switched between the operator and the robot multiple times. Therefore, it is possible that one task can become a bottleneck for the other at the same workstation.

Accurate cycle-times for cobot are estimated in a continuous simulation. Later a design of experiment model is used that estimates the utilization of resources and cycle time with each task. By comparing the robot cycle times and tasks precedence constraints a final assembly balancing is performed. If the operation time of the machine (being used for automation) and the operator are different, it is referred to as a two-resource model and is often a case in hybrid assembly stations. But as already said, cobots are different than conventional automation of hybrid cells and human variability will also play its role. The problem is solved using two types of simulations i.e., continuous and stochastic.

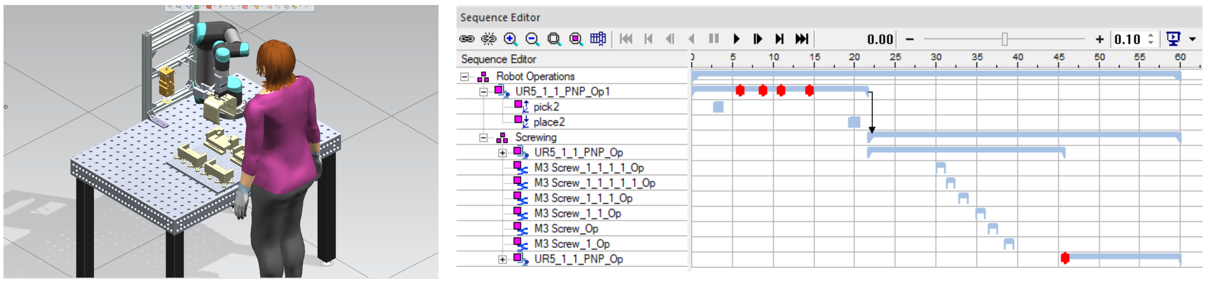
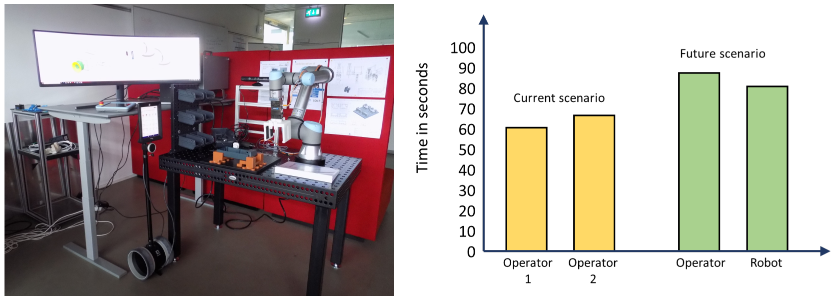


Figure 2: The simulation model developed for human and robotic tasks, & estimation of robot cycle-times considering robot joint-constraints, speed and torque.

It is proposed that more sophisticated ways of process balancing, and task assignment are needed in case of human-robot assembly cells considering the dynamic nature. This requires that dynamic process balancing is made possible with a degree of artificial-intelligence so that the robot and the operator can dynamically switch the tasks during operation. In this context, the approach of simulation based digital-twins is highly relevant.

Table 1: Assembly tasks, their precedent and final tasks for cobot automation after process balancing.

Sr No.	Part name	Manual task time	Precedent	Suggested Resource	Robot working time	Task assignment
1	Gear wheel	6 s	0	Robot	12 s	Robot
2	Bush	5 s	1	Robot	12 s	Human
3	Ball bearing	5 s	2	Robot	14 s	Robot
4	M9 nut	17,6 s	3	Robot	-	Human
5	Back fixture	5 s	4	Robot	15 s	Robot
6	Back fixture shell	4 s	5	Human	-	Human
7	Gasket	5 s	0	Human	-	Human
8	Lid	7 s	7	Human	-	Human
9	M27 nut	8 s	8	Robot	10 s	Human
10	Lid screws	22 s	9	Robot	26 s	Robot



(a) (b)

Figure 3: (a) The developed human-robot cell, (b) Cycle times after balancing the HRC scenario.