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Use Of A Robot For Parts Provision In Manual Small Parts Assembly

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Abstract

Despite the growing popularity of automation, many companies still use manual assembly within their production. Especially when small deviations in product series are involved, automation is usually not flexible enough and does not add value.

This paper describes a new robotic assistance system with the aim to support the worker by separating him from logistics and the choice of the next component. The robot should be the interface between manual assembly and logistics, it will grip the required component and deliver it to the worker. This results in a constellation where the assembly worker can focus on value-added assembly activities and work in a more ergonomic workspace, as there are no complex and overwhelming Kanban shelfs. The consistent use of storage containers means that the robot has no workplace where it must be flexible due to varying products. Furthermore, the logistics area does not have to be adapted to the assembly worker. This enables more efficient logistics solutions that would not be used in a normal manual assembly, such as shelves filled to the ground. In this context, the main challenge is to develop an efficient relationship between the worker and the robot. Here, communication possibilities between the worker and the robot must be investigated, in particular regarding the process flow and error management. Before we focus on new logistic software tools to automate the whole logistic process and to generate the code for the robot, we first want to show the efficiency of our concept by implementing it in form of a demonstrator and testing it on a selected industrial product. Afterwards we want to compare the efficiency and ergonomics of this new approach with the usual manual assembly process.

Keywords

Assistant robotics; assembly; logistics; ergonomics

1. Introduction

Despite the distribution of automation solutions, manual assembly is still firmly anchored in industrial production. This is particularly due to the trend towards increasingly individual products, which require flexible production with small batch sizes. The skill and low training time of human assemblers is still superior to the design effort and programming of automation solutions for many frequently changing products. To deal with the high degree of flexibility required in the design of assembly processes, modular assembly workstations have already become established. These can be virtually assembled by most manufacturers and adapted to the different processes [1]. In industry, a compromise has formed between manual assembly and automation called hybrid assembly. In hybrid assembly, manual assembly is supported by the integration of smaller automations. This combines the advantages of both variants [2]. Despite automation possibilities, this leads to strong research interests in manual assembly, so that the added value can be further increased. Topics such as ergonomics and lean management often come into sharper focus, as they can reveal new potential for improvement. In addition, there are also many efforts to use new robotic technologies such as cobots to support the assembler [3].

2. State of the art

There are many industry efforts in the area of hybrid assembly. In addition to the general improvement of assembly stations through a more variable and ergonomic design, there are various technologies that are intended to increase value added [4]. A pick-by-light or pick-by-projection, for example, is intended to shorten the search time by providing visual assistance [5]. Furthermore, there are body-bound solutions such as smart glasses for augmented reality applications [6]. In the field of assistance robotics, the aim is for humans to be able to work more closely together with the robot. This results in high safety precautions with the associated costs, as well as limited speeds and payloads for the robot. Representatives of these robot systems are, for example, the YuMi from ABB [7] and the iiwa from KUKA [8]. There are also already approaches to use robots in the parts supply of the assembly. A research project of the company item deals with the integration of a collaborating robot into a manual assembly station [9]. Here, the robot works closely with the worker hands him parts and tools. This close collaboration requires high safety precautions whereby the robot may only move slowly and with little payloads. Another example are the assembly workstations from Rose+Krieger, which allow the implementation of a collaborative robot [10]. In this collaboration the robot is also severely restricted by the necessary safety precautions and cannot be utilized to its capacity. Since collaborative robotics near humans can only use its potential to a limited extent due to speed and force limitations, we would like to take a different approach in this paper to integrate robots in manual assembly.

Looking at warehouse logistics, there are already smart systems that simplify warehouse picking and reduce the associated search times. However, the approach of this paper considers the individual assembly station, which has a pre-picked logistics system (e.g. kanban shelf). Of course, this kanban shelf can also be picked in advance with a system such as the Advanced Pick Station [11].

In the following, we will first introduce our new concept and the theoretical possibilities of this approach. Subsequently, the first demonstrator is explained, with which the basics of the concept were first tested.

3. The concept

In contrast to many other new approaches in the research field of assembly, we still want to separate the robot from the worker as far as possible. This should allow each of the two partners to make the best use of their particular skills. For the worker, this means that he can focus more on the value-adding activities of assembly, while the robot performs repetitive and non-ergonomic tasks. Furthermore, this means that expensive and application-specific safety technology can be eliminated, making the systems less expensive and more flexible in their application.

One non-value-added activity is finding the components for the next assembly step. Particularly with many parts containers, which are made available to the worker on the shelf behind the table, search times can add up during assembly. Especially large shelves due to the number of components, as well as high weights, also reduce the ergonomics of assembly.

For this reason, the robot in this concept should only focus on part provision and always provide the worker with the required components. Our concept can be seen in Figure 1 and consists of the worker's assembly area, the robot area, and the logistics system. Furthermore, there is an area for part transfer, where the robot provides the component containers. The robot should only serve as an interface between assembly and logistics and be integrated as little as possible into the assembly process.

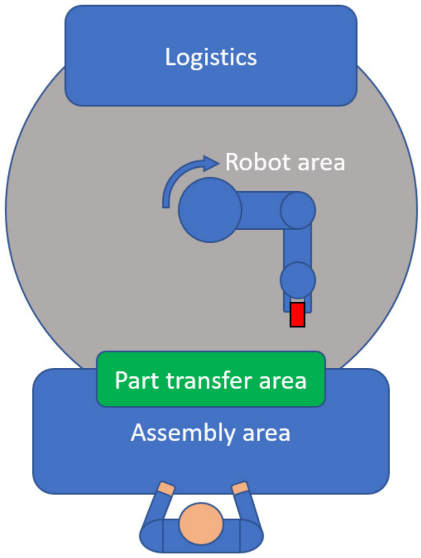

Figure 1: The basic concept

To simplify the gripping process and to be able to use the concept for as many applications as possible, no individual components but always component containers are gripped. This makes it easier to use the system for different assembly processes. The gripped containers are deposited by the robot in the part transfer area. There is enough space for several containers at the same time, so that work steps requiring several components can also be carried out without waiting times. Furthermore, to avoid waiting times, components can already be placed ready for the following work steps. The aim is to reduce the worker's search times by requiring him to select from only five or six ergonomically optimally positioned containers instead of 20 to 60 as we have seen it before in some companies.

To implement this, the robot must know which container is required for which work step. It is also possible for a container to remain with the operator for several steps in succession or for a step to be performed later. This information must already be available before assembly and, in the best case, is already created during product development or production planning.

Communication between the operator and the robot can be implemented most easily by means of a confirmation button, which is pressed after a successful assembly step. For error management, it must also be possible to quickly retrieve boxes that have already been used if the worker has removed too many or too few components.

This concept also opens new possibilities for the logistics system. Since it no further needs to be adapted to the worker, an ergonomic shelving system is no longer required. For example, the effective radius of the robot can be further exploited by filling the rack more to the top or to the bottom. The whole concept can be scaled up as required by using additional linear axes for the robot. If the individual assembly steps take more time, it is also possible for one robot to supply several workers with component containers, as can be seen in Figure 2. The increase in this workspace illustrates the benefit of using faster non-collaborative robots for this task.

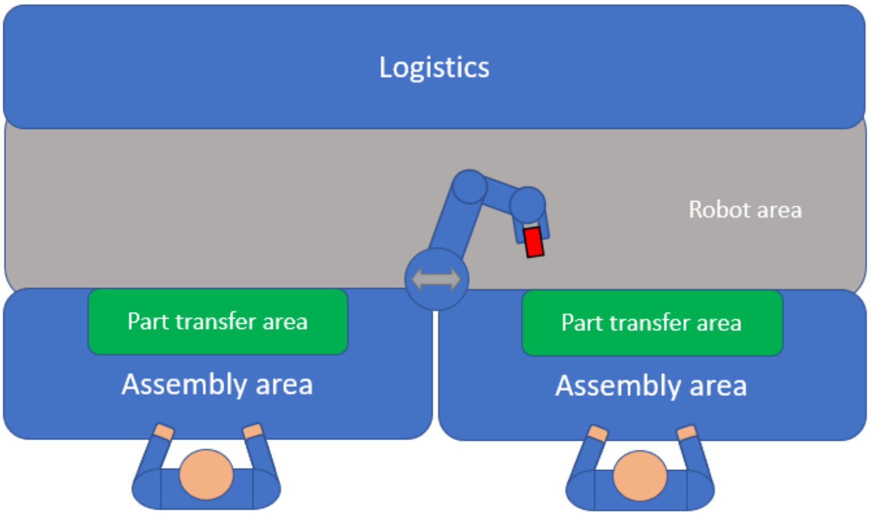

Figure 2: Concept with several stations

In summary, the concept offers the opportunity to reduce the worker's search times while improving the ergonomics of assembly. In the following, a first demonstrator was implemented based on this concept to investigate some initial fundamental questions. How does it affect the assembly process? Can the robot transport the parts to and from the workstation so quickly that the worker does not have to wait? What problems can arise in the area of part transfer?

4. The first demonstrator

In order to be able to test the concept and answer the first questions, a demonstrator was created which contains the basic functions of the concept. In the following, the construction of the demonstrator is explained first. Then the test execution and the results are presented and finally a conclusion is drawn.

The robot-assisted assembly station consists of an usual table as assembly surface, a robot standing behind it as well as an ordinary kanban shelf (Figure 3). A KUKA iiwa was chosen as the robot. Other robots offer higher payloads and speeds, but it turned out that this makes no difference in our first exemplary process. Due to the weights of our components and the times of the individual assembly steps, the KUKA iiwa was used to almost 100% capacity. Our components had a low weight, the component bins were almost empty and the work steps partly time-consuming. This shows the potential benefit of a non-collaborative robot for this application, as it would not yet have reached its limits in this use case. An additive manufactured gripper was used, which was customized to the containers and enabled the robot to remove the boxes from the shelf and store them again. The part transfer area was covered with an anti-slip mat to prevent the crates from being displaced when the parts were removed. This enabled the robot to find the containers even without a vision system.

Figure 3: The hybrid assembly station

In the manual workstation without the robot, the shelf was placed at the rear edge of the table, as it is widely used in the field of assembly (Figure 4). In both cases, the worker was provided with assembly instructions and the necessary tools on the table.

Figure 4: The manual assembly station

Our example process involves the assembly of a small control cabinet. This consists of 22 different components and requires various assembly steps. This includes screwing with and without tools, inserting cables and installing switching terminals. Some steps are fast while others take much more time or require several components at once.

5. Test execution

The study began by recording the assembly times for manual ($t_{m,raw}$) and hybrid ($t_{h,raw}$) assembly. Measurements were made with four test persons, two of whom performed the assembly in one variant first. Table 1 shows the results of the measurements, which variant the subjects performed first and the difference of both recorded times

Table 1: Assembly times

Test person	Started with:	Manual: $t_{m,raw}$	Hybrid: $t_{h,raw}$	Difference
1	manual	15:15	12:00	3:15
2	manual	20:00	15:05	4:55
3	hybrid	19:50	20:00	0:10
4	hybrid	14:10	13:25	0:45

In addition, the search times were recorded. It was particularly difficult to measure the very short search times with hybrid assembly, since the test person only had to choose from a maximum of five boxes in the direct field of view. The following Table Y shows the individual search times. The table already shows that the new concept can reduce search times in the assembly process.

Table 2: Search times

Test person	Started with:	Manual: $t_{m,search}$	Hybrid: $t_{h,search}$
1	manual	1:59	0:31
2	manual	1:20	0:20
3	hybrid	2:39	0:39
4	hybrid	1:30	0:28

When evaluating the recorded times, it is noticeable that the hybrid process reduces the search times, and the process times are also shorter except for person 3. Despite a significantly reduced search time, person 3 is faster in the manual process. This may be due to a learning effect of the test persons, whereby they are faster the second time they perform the assembly, regardless of the variant. This learning effect can be calculated by the following formula.

$$t_{learning} = |(t_{m,raw} - t_{m,search}) - (t_{h,raw} - t_{h,search})| \quad (1)$$

Using this formula, the following learning effects, shown in Table 3, can now be determined for the four test persons.

Table 3: Learning effects

Test person	Started with:	Learning effect: $t_{learning}$
1	manual	1:47
2	manual	3:55
3	hybrid	2:10
4	hybrid	0:17

If these times are now subtracted from the times of the first performed variant of each test person, these new times can be compared without the influence of a learning effect. In addition to the learning effect, other external influences can of course also play a role which could lead to the difference in times. However, according to the test subjects, this learning effect should have the greatest influence. The now processed times are shown in Table 4.

Table 4: Assembly times without the learning effect

Test person	Started with:	Manual: $t_{m,l}$	Hybrid: $t_{h,l}$	Difference
1	manual	13:28	12:00	01:28
2	manual	16:05	15:05	01:00
3	hybrid	19:50	17:50	02:00
4	hybrid	14:10	13:08	01:02

As expected, the differences between the two methods also reflect the differences in search times described above. These results will now be interpreted in the following.

6. Conclusion

Since the search times of the worker could be minimized with the help of the robot, the total assembly time was also reduced by just this amount. In relation to our application example, this proportion is only very small. The special opportunity of this approach is in its scalability. Even if the assembly process becomes more complex and requires more part containers, nothing changes for the worker. He still only has to choose between the few containers provided by the robot. This can pay off especially in a production with many variants, when the search times due to the changing containers cannot be reduced by a learning routine in the assembly process.

Furthermore, this makes it easier to have all the parts containers for a variety of different assembly processes at one station and thus to be able to switch more flexibly between the variants. It makes no difference to the worker's workload whether he assembles something consisting of 20 or 200 different components. The ergonomics of the workstation, consisting of the gripping ranges and the search times, are always the same, and the worker can focus more on the assembly process itself.

The previous investigation was carried out with a KUKA iiwa, and the robot's speeds and payloads had no negative effects in the selected application. The worker did not have to wait for the robot at any time, despite an assembly with very different work steps. As a result, it can be expected that a more powerful robot will also be able to supply the assembly with components quickly enough with even shorter process steps. Furthermore, an ordinary industrial robot is also significantly less expensive, which means that the changeover to the new workplace pays off financially at an earlier stage. The possibility of supplying several workers with components is also still an option if the process permits this. The next problem arises from the part transfer between the robot and the worker. The problem of locating the boxes for the return to the rack was solved in the demonstrator by simple anti-slip mats. For the industrial application, another possibility must be found here. A vision system would be possible, which could also be used for safety. When a powerful industrial robot is used, a solution must be found for the safety of the worker. The interface between man and robot is the transfer of parts through the containers. The area is therefore very small and direct contact could be avoided. A vision system could be used to track the worker so that the robot knows at what speed it is allowed to approach the area or if it should even stop briefly. A container with high weight or sharp objects, which is moved at high speed, represents the biggest safety risk, for which a solution must be found in following studies.

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Biography

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