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Evaluating Methods of Visual Assistance for Workers to Improve Quality and Usability in Individualized Kitchen Cabinet Assembly

Albert Eff, Michael S. J. Walter

Department of Engineering, Ansbach University of Applied Sciences, Ansbach, Germany
Email: eff19226@hs-ansbach.de, michael.walter@hs-ansbach.de

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Abstract

In times of digitalisation, visual assistance systems in assembly are increasingly important. The design of these assembly systems needs to be highly complex to meet the requirements. Due to the increasing number of variants in production processes, as well as shorter innovation and product life cycles, assistance systems should improve quality and reduce complexity of assembly processes. However, many large kitchen manufacturers still assemble kitchen cabinets manually, due to the high variety of components, such as rails and fittings. This paper focuses on the analysis and evaluation of virtual assistance systems to improve quality and usability in individualised kitchen cabinet assembly processes at a large German manufacturer. A solution is identified and detailed.

Keywords

Digitalisation, Assembly Process, Visual Assistance, Usability, Human-Centred Assembly Design

1. Introduction

Many of the production processes in the assembly of kitchen furniture are now automated. Furthermore, the operations and information are becoming more and more interlinked [1] [2]. However, due to the variety of components and the high cost of robotic techniques, there are still process steps that are easier and more effectively carried out by hand. The study in [3] showed that the use of robots decreases with increasing product complexity.

With robots, it is difficult to process a large number of different variants and require a large amount of resources, in terms of programming and development.

Hence, the current state of the art in robotics still requires analysis and evaluation as to whether a certain assembly process should be carried out manually or be automated. Despite manual assembly, the mindset of Industry 4.0 can still find its way in [4].

In order to make the manual process as effective as possible, visual assistance systems can be used. These systems enable the workers to carry out the work as quickly and efficiently as possible.

As described by Teubner *et al.* [5], following Krcmar and Zachman International [6] [7], a worker information system can be well described by a sender-receiver model (**Figure 1**). The sender creates and maintains the information first. Before transmitting this information, the questions of which application will be used, to who (consumer), which data and how (composition) this data will be transmitted, need to be clarified. Afterwards, the data is transmitted to the receiver, at the right place at the right time (receiver side). This involves the questions regarding "what kind of way, which design, how much (degree), where and when? (setting)" [5].

Errors occur during the manual mounting of fittings and rails. During this assembly process, the workers may interchange components and some components are used less often, so they need to be searched for in the storage rack. When a new employee must be trained, the process is often lengthy. Currently, many manufacturers use printed assembly instructions. However, these are likely to get dirty or damaged during the assembly process. Furthermore, language barriers can cause additional problems, since the instructions are only stated in German [8]. There is obviously a strong demand for adequate support for the workers to increase the overall performance of assembly processes leading to the following research question:

"Which methods of visual assistance for workers can significantly improve quality and usability in individualised kitchen cabinet assembly processes?".

2. State of the Art

This section illustrates the complexity of kitchen cabinet assembly processes

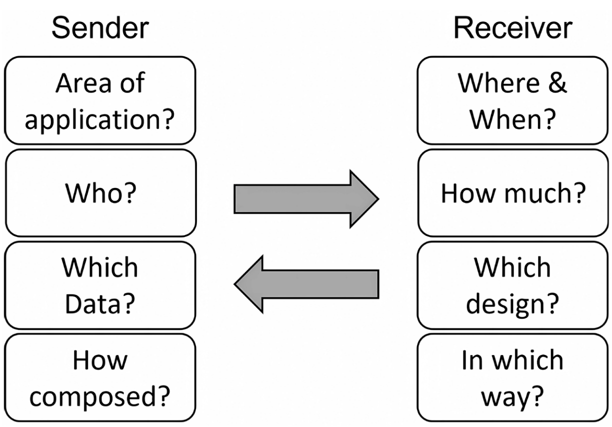

Figure 1. Structure of information systems according to [5].

(Section 2.1) and gives an overview of methods to improve the assembly process (Section 2.2). The research question is addressed in Section 2.3.

2.1. Complexity of Kitchen Cabinet Assembly

During the production of kitchen furniture, the cabinets are usually pre-assembled by the kitchen manufacturer. Single cabinets are delivered to customers and assembled into a complete kitchen. Many of the assembly steps are already automated and carried out by machines and robots. Due to the high level of customisation in kitchens, the resulting (very large) numbers of kitchen cabinet variants are usually manufactured in quantities of only one. This causes each cabinet to look different and be finished with different rails, fittings, or additional components. Moreover, there are different established heights and widths of cabinets and, obviously, each cabinet can have an individual interior or exterior colour, with different finishes and designs. All in all, there is a choice of over 27 different colours which can be combined with different materials and surface finishes. In addition, the layout of doors and drawers usually varies in each kitchen, to meet customer demands. Moreover, some cabinets may have special dimensions or need to be specially assembled to be a proper fit for the available space. In this case, several assembly steps still need to be carried out by hand, since automation is not justified due to expenses in time and costs.

Figure 2 shows a 3D-"exploded view" of the individual parts of a kitchen cabinet. The corpus of a base cabinet is shown, which is made up of a base panel, two side panels, a back panel, two crossbars and three drawers. The required holes in the sides (**Figure 2**, red circles) are drilled automatically on an examined machine. After drilling, the components are assembled on the corpus side panels by hand. **Figure 3** shows a front view of the manual workstation (next to the drilling machine), where the rails and fittings are attached to the

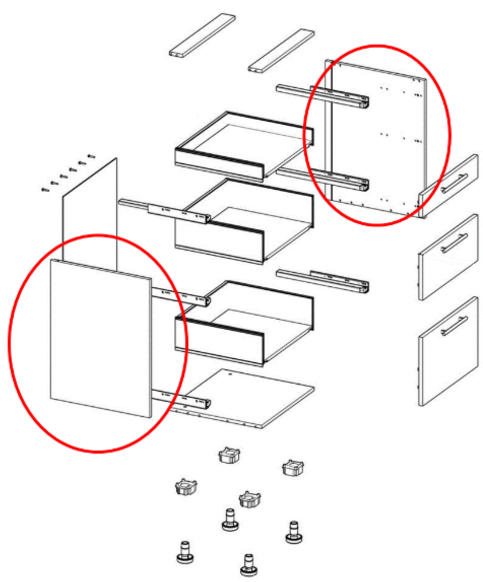

Figure 2. 3D-view of kitchen cabinet components with highlighted side panels [9].

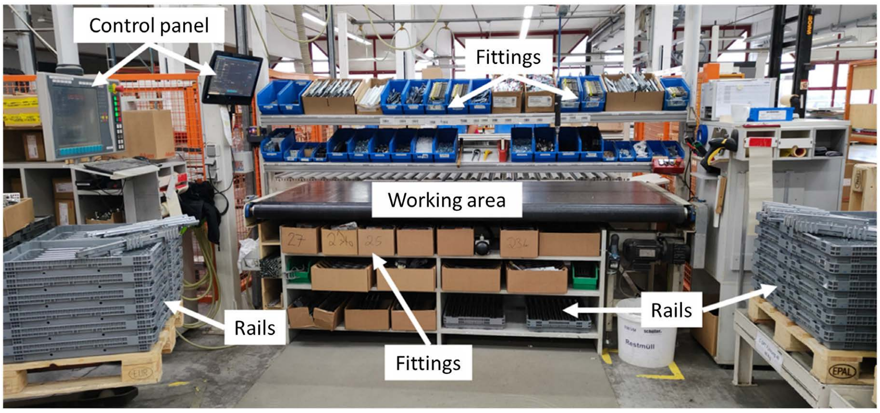

Figure 3. Current state of the art of manual workstation in the assembly process.

side panels using screws. The variation of parts includes 14 different rails and 20 different types of fittings. Up to 17 rails can be assembled on one side panel of a cabinet. Special cabinets, which are available in all sizes and variants, are produced on this machine. These highly customised cabinets cannot be produced with any other standard production lines in the factory. Currently, the worker gets the relevant information for each cabinet assembly on a screen (**Figure 3**, right control panel), mounted on the left side of the workplace. This is to support new and less experienced workers. Experienced workers, however, already recognise the required parts when looking at the hole pattern.

Due to the large variety of components, the currently established assembly process reveals common sources for problems, variations and slow-downs. The rails and fittings can be interchanged by the workers. Some kitchen cabinets require several rails to be mounted on the side panels. Therefore, the worker has to pay attention, to ensure that the right rail is mounted at the right position, to avoid interchanged parts. For inexperienced workers, it takes time to find and pick the correct components in the storage rack. The rack usually carries many boxes and trays, in which the components are stored. Currently, a Poka-Yoke-system is established using plug-in tabs and holes to ensure that the correct rails are mounted. As already mentioned, experienced workers can visually identify the type of rail required. The rails are manufactured by an external supplier. Furthermore, the huge variety of rails leads to higher manufacturing costs since the total production numbers of each type are comparably low. A standardisation of the rails and the interface design of the holes would lead to a significant reduction in manufacturing expenses.

These issues result in the rising demand for an assistance system to support the workers in identifying, picking and assembling individualized kitchen cabinets.

This assistance system must clearly visualise the required components, show the tray on the storage rack and identify the correct position on the conveyor belt. In the following step, the correct positioning of the components must be checked automatically and communicated to the worker.

Furthermore, the six fundamental recommendations on the design of information technology assistance systems, according to Bornewasser *et al.* [10], should be taken into account [11]:

- The assistance system must provide relief.
- The assistance system must be adapted to the internal information structures of the individual workers or worker types.
- The assistance system must meet the requirements.
- Basic principles of dialogue design must be considered (enabling feedback and correction, etc.).
- Assistance systems must be integrated into the existing IT-infrastructure (no stand-alone-solutions).
- An analysis of the initial situation and the determination of requirements must be made. A test and evaluation phase should be carried out beforehand.

2.2. Methods for Digitalising Assembly Processes

The current state of the art details many different methods of displaying information supporting workers.

The most common approach to sharing information is to 'just' show information on a screen. On the screen, the information about the cabinet and its components can be presented in text form or in pictures. Moreover, video detailing certain steps in the assembly process (or 3D-animations) are shown on the screen. Currently, a computer monitor is already used to support the assembly process. On this display, the worker sees a visualisation of the cabinet he is currently assembling.

Another approach to worker assistance is a pick-by-light system. These assembly-support-systems have a light display on each storage bin at the assembly working place. This display can indicate the quantity to be picked. In most cases the worker has the option to confirm the pick [12] [13]. Pick-by-light systems are currently used in various picking applications, such as the picking of additional components that need to be added to the kitchen cabinets during delivery. This involves sorting cutlery trays or bins. These systems are also found among other German kitchen manufacturers [14].

The use of pick-by-vision systems can be advantageous. These use head-mounted displays (so-called smart glasses) and transmit information to the worker by augmented reality technologies [15]. The user's real environment is enriched by virtual content, such as images, videos or virtual objects in real-time [16]. These pick-by-vision systems are already used for picking applications in industry [17].

In addition to the mentioned solutions, it would be conceivable to display information via a projector, which is also considered a type of augmented reality—called spatial augmented reality [18] [19]. In this case, images, text, and information are displayed directly on the work surface by means of a powerful light projector [8]. The information could be projected onto the workstation via a laser projector. Similar to the light projection, this technique works with laser projectors that cast the information onto the projection surface through mirrors and prisms [20] [21] [22].

2.3. Resulting Research Questions

The overall research question for this work is: "Which visual assistance method is best for supporting workers and improving quality and usability in individualised kitchen cabinet assembly processes?". This question goes hand in hand with several sub-questions. There is a need to clarify how performant or error-prone the considered methods are. Furthermore, the costs, the effort for implementation and the user-friendliness are unknown and must be examined. Finally, acceptance by the workers must also be considered. This paper will consider all these questions.

The paper's structure is as follows: Section 3 gives an overview of the functionality of the methods and discusses their advantages and disadvantages. This section also goes into detail regarding performance and susceptibility to errors. In Section 4, an assessment of usability and acceptability is carried out. The effort estimation and a representative cost calculation are detailed in Section 5. In Section 6, the methods are compared, leading to a conclusion and recommendations in Section 7.

3. Methods of Visual Assistance

The five methods described in Section 2.2 are further taken into account for the following evaluation. In this chapter, the different methods are presented in detail.

3.1. Display-via-Screen

The position and type of the component can be displayed on a screen which is mounted in the assembly area. A 3D-view of the component and/or the assembly can show where the components need to be mounted. This system is currently in use in the assembly line considered. However, it only shows a 3D-view of the cabinet type that is processed. Further information on the exact position of the railings and fittings are not given, since only basic information on the type and quantity of railings and fittings are provided. Experienced workers already recognise the right rails via the drilling patterns on the side components. In this case, the application has to show the components which are currently processed. The main advantage of this approach is the low effort required to implement it. However, the display size is limited due to a relatively small screen. Hence, not all information would properly fit onto the currently installed screens, so that the workers can easily identify and read the relevant information. A disadvantage arises from the need for the worker to actively look at the screen. In order to get the information, they have to move their head to the screen and search for the information needed. Furthermore, the workers do not have a direct view of the storage rack where the components are taken from. It could be possible to assemble a second screen on the workstation, which displays an image of the storage rack. This must show the position depending on the required component via marking or highlighting. Another possible solution is to display each tray's individual number on the screen. However, the worker still has to search the tray at the storage rack.

3.2. Pick-by-Light

Pick-by-light systems could support the task definition for the worker. Therefore, a display-unit with lights (see **Figure 4**) is attached to each compartment of the storage rack. Available industrial solutions already indicate the number of components to be removed from the tray [14]. In addition, light indicators could be placed right where above the position on the workplace where the individual component is assembled. Hence, also the position of the components on the workplace can be indicated via the lights.

The main advantage of pick-by-light systems is their fast and simple integration into existing assembly processes. However, there are also disadvantages. The program for displaying the position must be developed and tested first. Assigning the colours to the correct components can also be a time-consuming challenge.

Furthermore, the worker would have to compare the colours of the compartment displays and those on the position display. Colour blindness (or any other visual handicaps) can also be a problem, as some workers may not see the differences.

3.3. Pick-by-Vision

For a pick-by-vision system, augmented reality glasses would be used. According to [23], these head-mounted assistance systems are equipped with a small display in the user's field of view and are functionally comparable to a smartphone. **Figure 5** shows that these systems' main field of application is in logistics.

The currently used pick-by-vision system is used to display the components on the storage rack. A symbol or QR-code would be attached to each compartment as a marker. Markers are visual shapes that are recognised by the camera of the augmented reality system. Via tracking, the camera of the head-mounted display captures the markers. Then, an indicator is presented on the different markers in the worker's field of view. The biggest advantage of such a system is

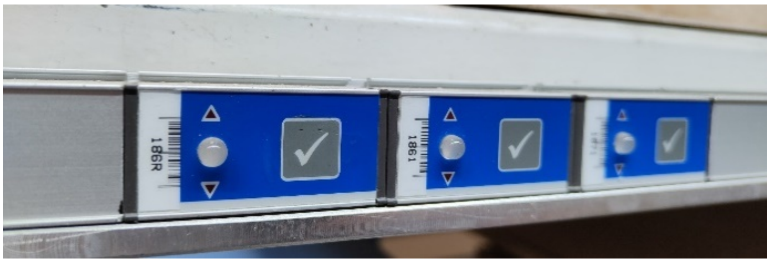

Figure 4. Display unit of a pick-by-light system.

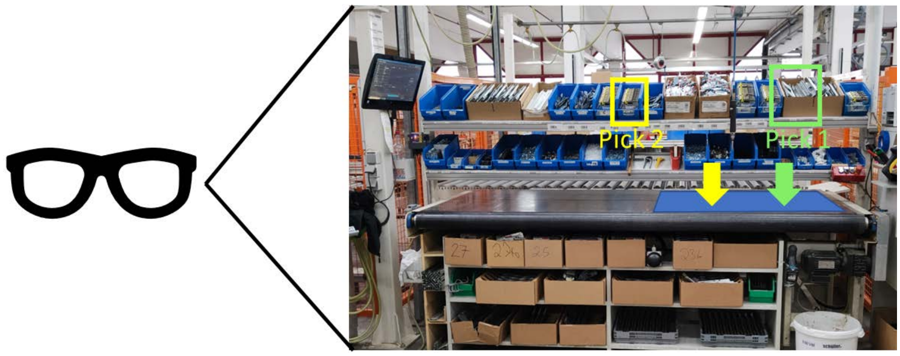

Figure 5. Illustration of pick-by-vision, following [24].

that it is not fixed to one static place. The markers that trigger advertisements can be QR-codes printed on paper and placed at any position. For instance, if all the components of a compartment are required at the workstation, a QR-code can show the worker the compartment with the material for refilling. In contrast to a static solution, the head-mounted system allows it to detect markers that would otherwise be hidden to static cameras.

The dynamic pick-by-vision applications are gaining more and more attention in research and industry. The works of [18] and [25] showed how mobile augmented reality applications can help the routing of electrical harnesses on the frame of an Airbus aircraft. The authors found that the achieved user satisfaction was very promising, and that virtual assistance could improve performance.

While the Airbus system uses tablets for visualisation, the system in the kitchen cabinet assembly would be realised using head-mounted displays. As a consequence, the two hands of the worker remain free. The displays are controlled via voice commands. However, disadvantages arise, since it is mandatory that they have to be worn on the body. Each worker must wear their own glasses to work, which may cause discomfort and varying levels of acceptance. At workstations where a lot of physical work is done, the glasses can be annoying, since wearing comfort is not sufficient.

In addition, the currently available battery power is low. Models such as the Vuzix M400 have a battery life of 2.5 to 3.0 hours, causing the need for replaceable batteries. Google Glass, on the other hand, has a battery life of up to 8 hours [26]. However, the optical tracker used causes a delay in the tracking phase and the dynamic head movements could not be compensated sufficiently and reliably [18].

Moreover, a distinction must be made between two types of glasses. On the one hand, there are optical see-through displays (OST displays) and, on the other hand, there are video see-through displays (VST displays) [27]. OST displays use a transparent screen, while VST displays use a camera to capture the environment and display it on the small screen in front of the eye. Google Glass uses OST and the Vuzix M400 uses VST. Glasses like the Vuzix M400 have a bigger lag than the glasses which use OST-technology.

3.4. Display-via-Projector

Display-via-projector is another kind of augmented reality system, called spatial augmented reality (SAR). Therefore, computer-generated clues are projected directly on surfaces. The users do not have to wear any additional equipment that could interfere with their work [18]. As shown in **Figure 6**, the workers can see the information (images, videos, texts, shapes, animations, presentations, etc.) directly on the work surface. During automotive assembly, the in-line use of a projector-based spatially augmented reality system was tested by [18]. This system highlights spot-weld locations on vehicle panels for manual welders. With this system, the process could be improved considerably, reducing the standard deviation of manual spot-weld placements by 52%.

The worker gets information regarding which components are needed and the projection can be exactly positioned at the parts which have to be processed. This reduces working time, shortens the learning curve for new employees and fulfils ergonomic standards. Furthermore, a step-by-step presentation can simplify complex tasks. Such a system can contribute to increasing efficiency and quality, reduce stress and strain and improve flexibility [8] [18]. This can be even more positive since handicapped workers are also enabled to do more complex assembly works.

A major issue of projection-based assistance systems is shadow-casting by physical objects and interacting users. Multi-projector configurations can solve this problem; however, when storage racks are located above workspaces (how workplaces are usually designed), the projection may not reach its position. The display area is also limited by the projection angle and the dimensions of the available projection surface. Moreover, video projection is sensitive to ambient brightness and the colour, material, and roughness of the projection surface. Light coloured materials would be ideal, while dark and highly reflective surfaces

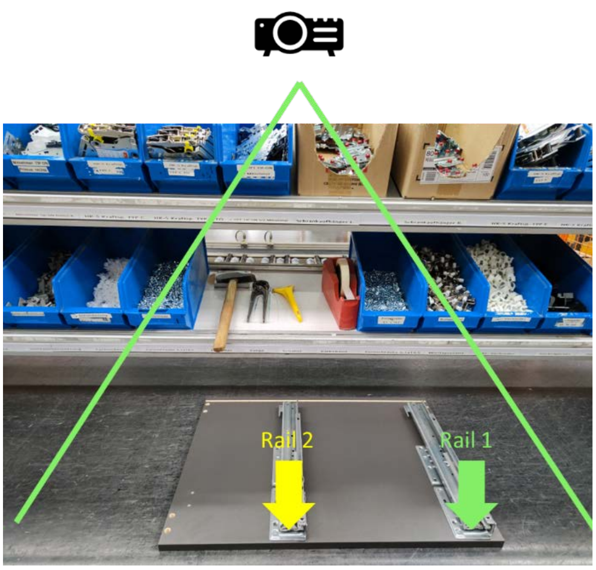

Figure 6. Projection-based assistance system.

lead to lower visualisation quality. Finally, the use of projectors requires focusing. Regular projectors only focus on one focal plane at a certain distance and, as a consequence, uneven projection surfaces (such as free form surfaces) and blurring-effects are likely [28].

3.5. Display-via-Laser Projection

Display-via-laser projection is very similar to display via a light projector; the main difference is the projection technique. In laser projectors, the laser beams are directed onto the projection surface by means of mirrors and prisms [20].

Existing systems mainly have green laser diodes. However, there are also systems with several diodes that can apply different colours on the projection-surface [22]. This technique can project shapes onto surfaces. As seen in **Figure 7**, these shapes can be used for worker guidance, put-to-light or pick-and-place applications. Quality control and logistics applications can also be carried out.

Depending on the distance to the projection surface, areas up to 14 × 14 m can be covered by the laser-projection of certain laser models, as detailed in [22]. The focus of a laser projection always remains good, independent from the distance between the projector and the surface. According to [22], the relevant advantages are:

- Minimization of errors during storage and order picking;
- Process acceleration;
- Reduced training times for employees;
- High flexibility in warehouse design.

A disadvantage is that the laser can only show a limited number of texts or drawings without flickering, due to the limited processing speed of the mechanism. When many details need to be shown, flickering occurs. A highly reflective projection surface can lead to safety risks for workers. As in the study of laser projectors for use in spot weld locations, safety issues occurred due to their use on aluminium sheets as a projection surface [18] [29].

4. Assessment of Usability and Acceptability

In our work, we refer to the definition of usability according to Nielsen [30] [31], which states: "ease with which people can employ a tool or other human-made object in order to achieve a particular goal". Furthermore, the term "acceptance" follows the definition in Niklas [32]: "Acceptance describes a subjective, positive attitude of an individual towards an innovation as well as its (potential) use and

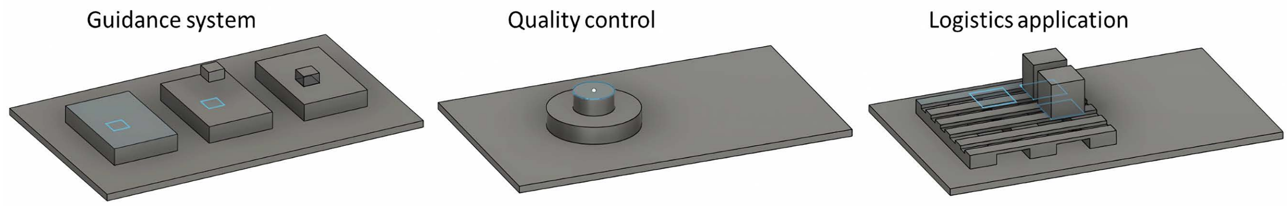

Figure 7. Different applications for laser-protection in production processes.

reflects the mental processes related to innovation adoption and use, which include both cognitive beliefs and emotional feeling impressions and end in action-oriented motivation". This means that the individual has a positive attitude towards an innovation and approves of its use.

A complete assessment of usability and acceptability is difficult to carry out in advance because the real usability can only be determined by testing the systems. User acceptance can be ascertained through trial runs. However, increasing usability and acceptability in the development of a product is an iterative process in which the developer must always confer with the users [33].

Possible indications of a low usability are a high learning time and a significant number of employees who do not want to use the system. To be able to quantify the usability and acceptance of systems, two personas are defined which cover most users. Then, these personas' daily interactions with the system are observed and difficulties are identified. The following two personas are considered:

- Persona #1: A 48-year-old male worker who has worked for the company for 20 years. He is familiar with the processes and has been working on the special drilling machine in shifts for the last four years. He knows the different rails and fittings and their locations in the storage rack by heart. However, due to recent design modifications in drilling positions, he does not know which rail has to be screwed onto the corpus side.
- Persona #2: A 24-year-old female worker, who started working for the company three months ago. Since then, she has been trained but does not yet know all the processes and components.

For persona #1, the information given via the screen would be a minor disadvantage, as this person knows his way around the system and does not have to search for a long time for information on the components' locations in the storage rack and their assembly positions. On the other hand, this is a greater disadvantage for persona # 2 since persona #2 still has to search for the compartment in the storage rack and the position on the cabinet sides.

The pick-by-light system could help persona #2 to find compartments faster. The colour of the light could also be used to find the screw-on position more quickly. However, both personas need to be briefed, so that they understand the meaning of the lights. The pick-by-vision system could show the screw-on position, as well as further information on the component, even more precisely than the pick-by-light system. However, every user would have to wear augmented reality glasses, which may lead to a reduction in acceptance. Furthermore, the battery life of the glasses repeatedly disrupts the workflow. The systems with the projector and the laser-projection are similar in operation. However, the projector (like the glasses) can display more detailed information than the laser-projection. In addition, the use of laser-based technology leads to significant safety issues with reflective components. To be able to compare the methods, a point-based evaluation was established and carried out, with 5 being the best score and 0 the worst. **Table 1** shows the points awarded to each method on the usability and

Table 1. Evaluation results (min: 0; max: 5).

Method	Criteria		
	Usability	Acceptability	Costs
Display-via-screen	2	5	100%
Pick-by-light	3	4	300%
Pick-by-vision	4	3	3500%
Display-via-projector	4	5	3000%
Display-via-laser projection	4	4	3000%

acceptability requirements considered. Furthermore, the estimated costs are stated, normalised to the costs of the "display-by-screen". The results clearly show that "Display-via-projector" is the most promising method, in terms of usability and acceptability. This system can provide the most accurate information and is as unrestrictive as possible for the user.

5. Effort Estimation and Cost Calculation

In this section, the required effort, further relevant aspects on the implementation, and the associated costs of each method, are estimated.

5.1. Effort Estimation

The effort required for display-via-screen would be the least. Only the existing software for displaying the current cabinets would need to be modified and expanded. The software code for the display of the storage racks would have to be modified to detail the visualisation of which position the components need to be assembled. The information on the screwing position is already available in the existing software. The information regarding where the components are stored still needs to be maintained. In addition, a second screen has to be installed, to display the storage rack.

For the pick-by-light system, the effort would be slightly higher. First, a manufacturer for pick-by-light systems would have to be selected. Then, the system would have to be installed at the assembly line and integrated into the existing systems, both mechanically and in the existing software environment.

The pick-by-vision system is easier to integrate than the pick-by-light system since augmented reality glasses can operate as stand-alone systems. However, the software of the glasses requires an interface to the existing software environment to display correct items. Depending on the item, the software of the glasses can autonomously request the information for each component. Additional visual markers (such as simple images or QR-codes) must be attached to the storage rack.

The effort for display-via-projection (both light-based and laser-based) is mainly similar. Both systems are very complex, and the entire workplace must be reconfigured. A storage rack must be built to carry the projectors and cameras.

Furthermore, the storage shelf (right above the workplace) must be redesigned. In addition, the projectors require a control system, and the projection needs to be programmed.

5.2. Cost Calculation

The costs can only be estimated based on the details provided by the companies that develop and implement these systems. To provide accurate cost estimation, the costs are considered as percentages in relation to each other, instead of absolute amounts. In the comparison, display-by-screen is considered the reference, corresponding to costs of 100%. The introduction of a pick-by-light system would cause costs of 300%, while a pick-by-vision system with augmented reality glasses is comparably expensive, with resulting costs of 3500%. Both projector-based methods (light and laser), are in the same price category. Here, more than 30 times the costs can arise, since the required technology on projectors is very expensive. The normalised costs (in %) of all five methods are given in Table 1.

6. Comparison of the Methods

The presented results clearly show that display-via-screen is the simplest and least expensive method (see Table 2).

However, this method provides the least increase in information for the worker. On the other hand, the projections via light and laser offer very detailed information at the position where the information is needed. In addition, they affect the worker the least of all methods. Moreover, it can be argued that a great amount of experience is already available for pick-by-light systems. However, it is difficult to implement a system that shows where fittings or rails must be

Table 2. Evaluation results: pros and cons of the five methods considered.

Method	Pro	Con
Display-via-screen	- Less effort - Low cost	- Not all information on needed position - No display directly on the workpiece
Pick-by-light	- Little experience required - Visual information directly on storage shelf - Simple presentation of information	- No precise information for the worker - Position on workpiece only in x-direction
Pick-by-vision	- Independent of location - 3D and 2D information - Directly in the worker's field of view	- Limitation due to glasses - Limited battery life of the glasses - Limited acceptance by users
Display-via-projector	- Information in the most detailed way - Directly in the worker's field of view - The worker does not have to wear any equipment	- Shadow casting impairs presentation of information - High costs - Much effort for reconstruction and maintenance
Display-via-laser projection	- Directly in the worker's field of view - The worker does not have to wear any equipment	- Shadow casting impairs presentation of information - High costs - Much effort for reconstruction and maintenance - Not much detailed information can be transferred

mounted on the corpus sides. The pick-by-vision solution has the disadvantage that the workers must wear glasses that have a limited battery capacity. This could impair the workers during heavier work. However, the system works independently, for example, the markers could be attached to different racks and the glasses would be still able to display components in all storage racks. It is also possible to change components on the rack simply by remounting the markers for the augmented reality system. Another advantage is the detailed display of the information, which is always in the worker's field of view and, thus, difficult to oversee.

7. Conclusions and Recommendations

Comparison of the methods has shown that each method has its advantages, but also, disadvantages. The use of worker assistance systems is becoming increasingly important in times of customisation in production. More and more variants will be produced and each variant will bring new requirements.

In this individual case of the kitchen manufacturer, a solution using pick-by-vision or projection is probably the most suitable. The detailed information provided by the systems is essential here. For the worker on the spot, information directly on the work surface or in the field of view would be a great advantage.

When choosing between pick-by-vision via augmented reality glasses and the solution via a projection, the modification of the storage rack for components must be considered. If the rack, which is currently above the work area, is moved to the back, then relatively short workers will no longer be able to reach all of the components. For space reasons, the shelf cannot be mounted in any other position; therefore, a pick-by-vision system would be decided upon. With this in mind, the following difficulties must be eliminated. The battery capacity must be high, or at least increased, so that the system can last (at least) one shift without a battery change, or with only one battery change. Some manufacturers already have additional batteries available, which are attached to clothing and are connected to the goggles via a cable. However, this could lead to impairments for the workers. Furthermore, there are systems that can replace batteries during use, without having to switch off the glasses, which would cause down-time in production [26].

In addition, the glasses must be individually adjustable for each worker to provide comfort since the glasses are to be worn for several hours. However, there are already solutions to this problem, such as frames or headbands, which can be fitted to the system as required. There are also systems that can be mounted on helmets or caps. Every worker can adapt the system to fit their own personal requirements.

In addition to technical challenges, the system must provide enough benefits for the workers to increase its acceptance. It must be designed to be more user-friendly. This requires constant communication with the workers. The importance of this cooperation with the users was also described by Lörer *et al.* [34]

in a test of augmented reality systems in the textile industry. As Kleine [35] describes, wearable technologies can bring many benefits. Nevertheless, humans must remain autonomous in their decisions and the use of the technology must not be prescribed. If the technology is forced on the user, the user's options and acceptance may be limited.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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