Using Augmented Reality and Step by Step Verification in Industrial Quality Control

João Alves[1], Bernardo Marques[1], Paulo Dias[1], Beatriz Sousa Santos[1]

[1] IEETA- Institute of Electronics and Informatics Engineering of Aveiro,
DETI - Department of Electronics, Telecommunications and Informatics,
University of Aveiro, Aveiro, Portugal

Abstract. Quality control procedures are extremely important among industrial applications. Generally, these tasks include many repetitive tasks that require manual intervention. Given their complexity, quality control tests are often detailed in video recordings, paper instructions, photos or diagrams to guide workers throughout the process. Augmented Reality (AR) has been making significant progress in the last decades, becoming mature enough to be used in industrial scenarios. While some AR systems have been proposed to support quality control procedures, most of them only present information to workers but do not track or validate the process in real-time being used only to guide it. Another limitation of existing systems is the generation of virtual instructions used by AR systems to guide the operator. In this work, we propose an AR-based tool to guide users by overlaying information in a video stream while performing real-time validation during the execution of quality control procedures. The main objective is to provide dynamic support and decrease the mental workload needed to complete the procedure as well as the number of errors, facilitating the procedure execution by untrained workers. Besides this, the tool allows to create virtual content that can be used to generate step-by-step instructions automatically based on human demonstrations. By making the virtual instruction creation effortlessly it is possible to eliminate the user's need for memorizing new instructions with each change of the product lines. While presenting task relevant information the system uses computer vision techniques to keep track of the procedure stage, verifying its completion and switching automatically to the next step without requiring any interaction from the user. A comparison between the time taken to perform the procedure with and without validation was made. The results show that the validation process would confer the process a significant efficiency boost, while avoiding possible human errors.

Keywords: Augmented Reality, Computer Vision, Quality Control Procedure, User Guidance, Action Validation, Authoring, Industrial Efficiency

1. Introduction

Conventional assembly processes often resort to instructions available on paper or in digital format (photos, videos or diagrams) to guide users across different types of industrial procedures. Typically, users are required to map these instructions to actions to be performed on real objects, without any feedback or additional help [1]. While some processes are automated, a significant number of assembly operations still require manual intervention due to their complexity. In this context, the use of information aid systems using Augmented Reality (AR) might increase significantly task efficiency by keeping the worker focused on the task and not dividing his/her attention between the tasks and the instructions.[2]. AR makes possible to display digital contextual information [3][4] overlaid on top of the real-world, being potentially useful for quality control processes with step-by-step instructions, 3D illustrations, or other relevant data [5]. Specifically, by providing 3D relevant information AR tools can provide a guide to help users navigate through unfamiliar or complex use cases [6].

However, ready-for-market AR tools are still rarely used and as consequence its benefits are not demonstrated often [7]. One obstacle is the generation of virtual instructions that are generally a tedious and time-consuming process [8]. Another obstacle is the open-loop nature of most AR system that only present information without any awareness about the procedure current state of the assembly sequence [9].

In this paper, we address both problems in a real-world scenario, aiming to improve the efficiency of the industrial process. Our work, which is part of an ongoing project with partners from the industrial sector, aims to leverage AR methods in industrial shop floors to enrich the way instructions are presented and ease repetitive tasks associated with quality control. The paper describes the AR tool developed to guide quality control procedures, proposes the creation of virtual instructions based on human demonstration, and presents a real-time error detection algorithm to validate the assembly process.
The remaining of this paper is structured as follows: Section 2 describes the AR tool developed to guide a worker and check his/her actions in a quality control procedure. In Section 3, we discuss the impact of our method in a real industrial scenario. Finally, in Section 4 we draw some remarks and ideas for future work.

2. AR with verification in a Quality Control Procedure

This section describes a real-world problem, inspired by an industrial shop floor scenario based on a quality control procedure. First, we describe the method used to aid workers in their labour through AR. Afterwards, we present the verification method employed to determine if the worker is executing the procedure steps correctly. To close the loop, we show how the validation procedure can be used to produce virtual instructions that will be overlaid on top of the assembly video stream.

Scenario

The industrial quality control task that motivates our work requires a worker to check if the distance intervals of an automotive part at specific positions are within a pre-established interval. This procedure is needed to ensure that the assembled piece is within the final client requirements. Not fulfilling the quality check leads to the disposal of the part involved in the process.
The procedure is performed with a wireless comparator (measurement device) handled by the employee. Measurements are sent to an external computer and displayed in a monitor above the quality control cell. Figure 1 illustrates one step of the process: the measurement device is in one of the predefined positions. After each of the nine measures, the worker needs to move away from the cell to verify the measurements in the display (see Figure 2). This procedure is sequential and in each step the worker must

position the comparator in a specific location of the piece and issue an order to trigger the measurement.

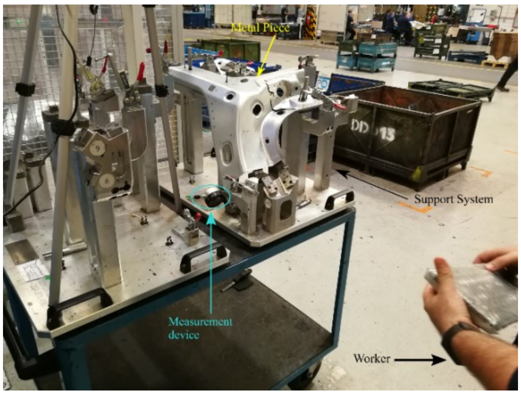

Figure 1 - Quality control process. A gauge ensures the correct placement of the automotive piece under evaluation. The measurement device determines the distance intervals of an automotive part at specific positions during the nine steps measurement process.

User Action Verification During procedure

One problem identified in the procedure depicted above was the time required to trigger the measurement since the worker had to move away from the support system to look at the monitor to validate the measurement on the display before moving to the next action. This also requires the interaction with a wireless keyboard during the process (see Figure 1).

With this in mind, we developed a computer vision process to verify the correct localization of the comparator. The system can trigger automatically the measurement when the device is correctly positioned advancing to the next stage showing the collaborator the next location to be measured.

The correct information about the measurement device placement is critical to trigger the measurement and enable a correct control of transitions between assembly stages. To obtain it, an algorithm based on a template matching approach to compare two 3D point clouds produced by the same perspective is used validating if the measurement device is correctly positioned. The point cloud is processed to extract only the objects that are not present in the initial template acquired before the start of the procedure.

With this in mind, we developed a computer vision process to verify the correct placement of the comparator. The system can trigger automatically the measurement when the device is correctly positioned advancing to the next stage showing the worker what is the next location to be measured.

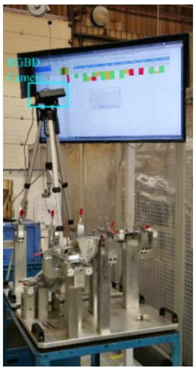

Figure 2 - Verification setup with a fixed depth camera held by a tripod, looking down to the support platform where the quality control procedure is executed

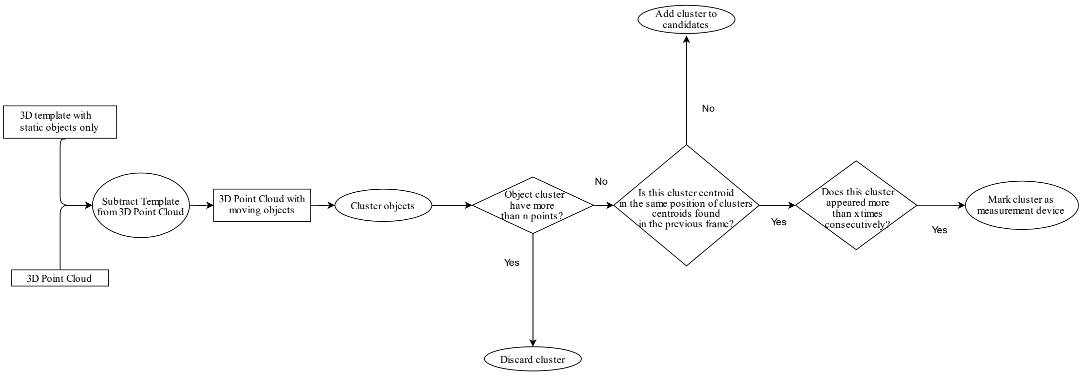

Figure 3 – Algorithm workflow aimed to perform the verification process

Figure 3 presents the workflow of the verification process, which starts by capturing a point cloud using the camera (mounted in such a way as to detect the support system 2) and send it to a computer for processing. Subsequently, dedicated software running on the computer filters the objects outside a pre-established working area and segments the pieces which were not present in the initial point cloud template, to extract the associated clusters of points. After this step, the number of points of each cluster is checked and the ones below a certain threshold are discarded. The algorithm considers that the measurement device is in a specific position if a cluster is in the same position for more than 2 seconds. To perform this verification procedure, we set up a RGBD camera (ORBBEC ASTRA) held by a tripod, looking down to the support platform (Figure 2).

The validation mechanism presented above can be also used to leverage the creation of virtual content based on a demonstration. For example, in Figure 4, a worker placed the comparator in a certain location and the system creates automatically the green arrow indicating the device position. This process can be used to easily create step-by-step instructions for this specific use case or a similar one.

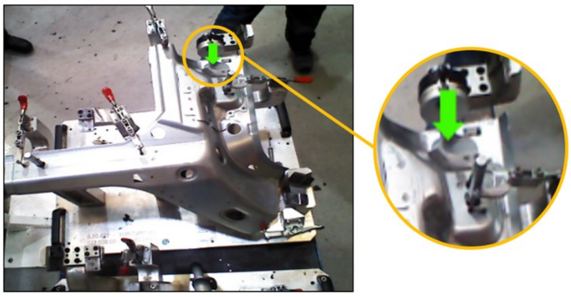

Figure 4 - Virtual content creation through comparator position detection

3. Discussion

At this stage the prototype was tested using recorded data obtained from a traditional human demonstration of the quality control procedure.
On this data, the estimated time needed to perform the complete quality control procedure was 82 seconds. Using the same sequence and considering only the time required to move the comparator between locations, we estimated the process would require only 36 seconds while using the AR with validation system triggering the measurements representing a time reduction of 56% per operation. This presents the possibility to process more two pieces in the same amount of time required now for a single one (not considering the time for removing and placing a new part in the gauge). We also argue that the system is flexible and simple enough to be easily transposed to the shop floor, namely because only 3D data is used providing some robustness to lightning conditions changes.

4. Final Remarks and Future Work

Augmented Reality (AR) has great potential for assisting in many industrial tasks (assembly, quality control, maintenance). In this study, we presented a system that shows potential use of this technology in a real quality control procedure. We explored how an action validation mechanism and virtual content authoring in our scenario can speed up the procedure and facilitate the creation of new guides using step-by-step instructions. In the specific case study considered, our tests suggest that is possible to reduce to less than half the task time while guiding the operator through the several repetitive steps, avoiding errors, additional movements and keyboard interactions.
As future work, we plan to perform a more extensive test in real conditions to further evaluate the qualities and limitations of the system and fine tune the system for real use. We also plan to further increase the AR capabilities showing not only information concerning the comparator locations, but also additional information about error location, that might help operators to correct previous mounting steps to reduce the number of

faulty parts, resulting in a significant reduction of the discarded pieces along the whole manufacturing process, and thus contributing to a leaner approach in several ways, by reducing time, waist, motion and extra-work [10].

Acknowledgments

The present study was developed in the scope of Produtech – SIF – Solutions for the Industry of the Future [POCI-01- 0247-FEDER-024541]. This study was possible because one of the industry partners presented us the procedure performed in its shop floor allowing us to record one of the procedures performed. This study was also supported by IEETA - Institute of Electronics and Informatics Engineering of Aveiro, funded by National Funds through the FCT - Foundation for Science and Technology, in the context of the project UID/CEC/00127/2019.

References

[1] L.C. Wu, I.C. Lin, and M.H. Tsai, “Augmented Reality Instruction for Object Assembly Based on Markerless Tracking,” in *Proceedings of the 20th ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games*, 2016, pp. 95–102

[2] M. Funk, T. Kosch, S. W. Greenwald, and A. Schmidt, “A Benchmark for Interactive Augmented Reality Instructions for Assembly Tasks,” in *Proceedings of the 14th International Conference on Mobile and Ubiquitous Multimedia*, 2015, pp. 253–257,

[3] G. Michalos, P. Karagiannis, S. Makris, Ö. Tokçalar, and G. Chryssolouris, “Augmented Reality (AR) Applications for Supporting Human-robot Interactive Cooperation,” *Procedia CIRP*, vol. 41, pp. 370–375, 2016

[4] R. T. Azuma, “A Survey of Augmented Reality,” *Presence: Teleoper Virtual Environ*, vol. 6, no. 4, pp. 355–385, Aug. 1997

[5] B. M. Khuong, K. Kiyokawa, A. Miller, J. J. La Viola, T. Mashita, and H. Takemura, “The effectiveness of an AR-based context-aware assembly support system in object assembly,” in *2014 IEEE Virtual Reality (VR)*, 2014, pp. 57–62

[6] S. Borsci, G. Lawson, and S. Broome, “Empirical evidence, evaluation criteria and challenges for the effectiveness of virtual and mixed reality tools for training operators of car service maintenance,” *Computers in Industry*, vol. 67, pp. 17–26, 2015

[7] J. Jetter, J. Eimecke, and A. Rese, “Augmented reality tools for industrial applications: What are potential key performance indicators and who benefits?,” *Computers in Human Behavior*, vol. 87, pp. 18–33, 2018

[8] A. Plopski, V. Fuvattanasilp, J. Poldi, T. Taketomi, C. Sandor, and H. Kato, “Efficient In-Situ Creation of Augmented Reality Tutorials,” in *2018 Workshop on Metrology for Industry 4.0 and IoT*, 2018, pp. 7–11

[9] J. Alves, B. Marques, M. Oliveira, T. Araújo, P. Dias, and B. Sousa Santos, “Comparing Spatial and Mobile Augmented Reality for Guiding Assembling Procedures with Task Validation,” in *19th IEEE International Conference on Autonomous Robot Systems and Competitions (ICARSC)*, 2019.

[10] R. Lopes, L. Teixeira and C. Ferreira,” Lean Thinking Across the Company: Successful Cases in the Manufacturing Industry”, in *Lean Manufacturing, Implementation, Opportunities and Challenges*, Nova Science Publishers, 2019