An Augmented Reality Framework for Supporting Technicians during Maintenance Procedures

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***Abstract*—The rise of Industry 4.0 and Smart Environments is contributing to a growing interest towards the use of Augmented Reality (AR) for supporting technical procedures, due to its ability to add layers of information on top of the physical world. This paper presents an AR framework to support technicians during maintenance procedures and monitoring operations in smart environments. This work is the result of a human centered design, based on an iterative approach with the collaboration of partners from the industry. The main features of the framework are described, focusing on: manual calibration of AR content, visualization of components and digital documentation including illustrative videos, step-by-step instructions, monitoring and data visualization associated with smart appliances and a multi-device approach to improve visibility and understanding of information.**

***Index Terms*—augmented reality, industry 4.0, smart homes, technical support, maintenance, information-display, human-machine interaction.**

I. INTRODUCTION

As Industry 4.0 becomes a reality, technicians experience increased complexity on their daily tasks, requiring flexible mechanisms with adaptive capabilities to interact with smart environments [1]. Augmented Reality (AR) offers the possibility to overlay information directly aligned with real content such as instructions, guidance tools, step-by-step instructions and interactive content [2]. Nowadays, AR is considered an interdisciplinary area, transcending boundaries between concepts, such as Optics, Computer Graphics, Computer Vision, Human-Computer Interaction, among others [3].

Since the origins of AR, Industry has been one of its most prominent application domains. The contributes of AR in this sector are undeniable [4]. Studies show that AR can contribute to reduce cognitive load, increase workers motivation and interest, resulting in less error rate and faster time completion [5]. These advantages, combined with the emergence of cheaper, more powerful devices like mobile devices is encouraging the development of AR-based solutions [2].

Therefore, AR-based solutions present significant potential to empower workers with real-time information, better decision-making and work procedures, and increase engineering and manufacturing quality in several industrial sectors ranging from maintenance and training, management and control to quality assurance and safety, among others [2].

In training, users are able to use AR to improve their skills before moving to real-life scenarios [6]. In product inspection and monitor operations, technicians can use AR to notice discrepancies of items and highlight any errors [7]. In maintenance and assembly tasks, AR can be used to assist technicians with specific problems, while reducing errors and time duration [8].

These technologies are not limited to industrial scenarios: smart environments are appearing in several areas of application. For example in Smart Homes, AR interfaces can be beneficial to monitor and interact with physical appliances, allowing a better control, understanding and monitoring by residents and technicians (energy consumption, fault monitoring, appliances control, etc.) [9] [10].

In this paper, we describe the BARTT (Bosch Augmented Reality Technical SupporT) framework, an AR system to help and assist Technicians during maintenance and monitoring operations in smart environments. The framework is the result of a human centered design, based on an iterative approach with industrial partners. The paper present and describe the main features of the framework through a maintenance and monitoring scenario. Finally some conclusions and ideas for future work are drawn.

II. BARTT - AUGMENTED REALITY FRAMEWORK

This section describes the BARTT framework, an effort towards the creation of an AR support system to support technicians during maintenance procedures. In the context of this work, a demonstrator has been developed including a living room and a kitchen with various smart household appliances such as plugs, lights, sensors, cameras, and heating devices. All appliances are network capable and managed by a central controller, which can respond to commands from residents or technicians. In this context, technicians can point a mobile device to an on-site boiler and perform maintenance tasks while supported by 3D interactive virtual instructions (text, images, videos, 3D models and audio support) and other relevant contextual information.

The human centered design methodology used required several iterations with industrial partners to fulfil a list of requirements regarding how to assist technicians. Preliminary tests of the AR system were performed with different focus groups and presented (namely in several public events) to collect feedback for improvements [11] [12] [13] [14] [15].

The major contributions of the framework are:

- Guidance/assistance while performing maintenance tasks;
- Presentation of information in digital format (standard 2D interfaces or through AR);
- Manual calibration of AR content to ensure correct alignment with real world environment;
- Possibility of freezing information while performing tasks, which enables hands-free intervention;
- Annotation in freezing content, which can be used for creating information for training;
- Monitoring of appliances, allowing to evaluate different parameters of smart environments;
- Use of a Multi-Device approach, allowing presentation of additional information (digital manual).

The framework was developed using the Unity 3D game engine, based on C# scripts. To place the virtual content in the real-world environment, Vuforia library was used together with predefined markers. All deployment was performed in handheld devices (smartphone and tablet) and a touch-enabled projector. Communications with the different appliances was over Wi-Fi through specific calls to a central controller API.

A. Manual Calibration of AR content

Technicians can perform a manual calibration of the augmented content using an interactive re-sizable image representation of the boiler: the image is displayed over the real boiler and can be moved and scale until the image representation and real equipment are aligned (Figure 1).

B. Visualization of Components

After the calibration, a schematic representation of the main components of the boiler is presented through a virtual representation of their area of interest (Figure 2). This provides a quick understanding of the boiler internal mechanism. By interacting with these representation, the technician can access additional information, like specifications and step-by-step instructions, among others.

C. Digital Documentation and Illustrative Videos

In addition, the framework is also able to provide relevant contextual and interactive information through digital documentation (Figure 3) or illustrative videos. The system

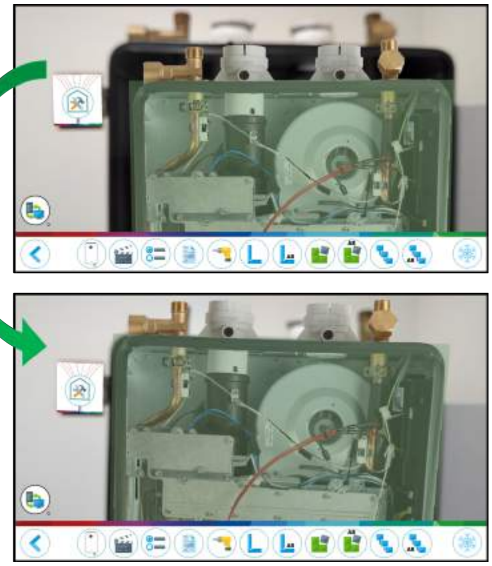

Fig. 1. Manual calibration of the augmented content through a re-sizable frame of a boiler, showing before (top) and after (bottom).

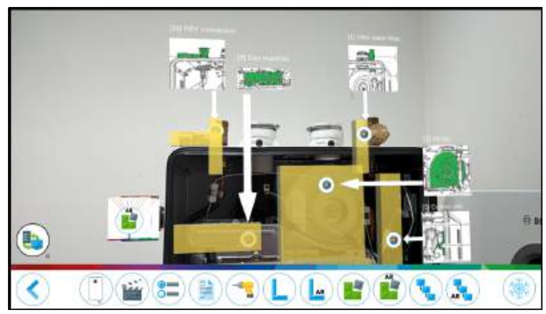

Fig. 2. Highlighting of specific components (areas of interest) on a boiler with AR content.

supports at this time: manuals, schematics, specifications, step-by-step instructions for specific tasks, information about the tools required to perform a specific task and safety measures needed to be taken into account.

Fig. 3. Example of digital documentation - Technical specifications of the boiler.

D. Step-by-Step Instructions

Figure 4 shows the illustration of two instructions presented to the Technician during a step-by-step procedure, aiming at replacing a specific component of the boiler. The AR interface uses text for the task description, images regarding what tools to use or security warnings to take into consideration and augmented content aligned with the heating appliance.

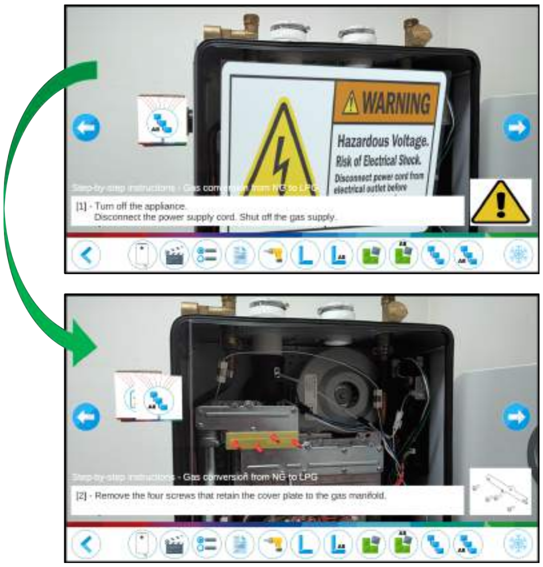

Fig. 4. Presentation of step-by-step instructions to guide a Technician during the performance of a specific maintenance task - replacement of a component.

E. Annotation Tool

Despite the powerful characteristics of handheld devices, one major limitation of this approach is the constant need to hold and face the device to the desired location where the procedures must be performed at all time. Furthermore, current AR-enabled HMD still present several limitations for real use: they are expensive and lack proper field of view, tracking capabilities and precise interaction mechanism [5]. As such, we explored the possibility to freeze the screen of handheld devices, similar to capturing a screenshot that combines the real world environment and the augmented content. With this tool, Technicians can freeze the device image, place it nearby and perform the procedures hands-free, while having the framework providing static assistance. Technicians can combine the freeze option with annotation mechanisms (drawing, addition of spatial text to enhance the screenshots) (Figure 5). At any time, the user can pick the device and re-align the annotations with the real world based on a semi-automatic mechanism similar to the calibration process described in subsection II-A. Through this, Technicians can create personalized reminders based on visual cues to remember specific tasks for later reuse or even training. This capability can also be used easily to generate content captured during real maintenance procedures to produce more detailed and complete step-by-step instructions, or documentation. In the future this capture mechanism might be the basis of an AR collaborative platform, allowing on-site technicians to interact with remote experts anywhere on the world while sharing images and annotations of the current maintenance being performed.

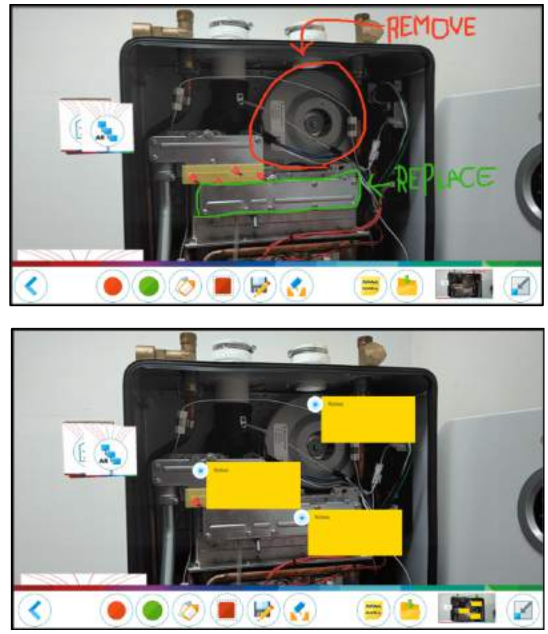

Fig. 5. Annotation tool to enhance a freeze capture of the interface, through drawings (top) and/or textual notes (bottom).

F. Monitoring and Data visualization

Besides providing guidance to technicians during technical procedures, the framework can support monitoring operations in smart environments using standard 2D or AR interfaces (Figure 6). This allows Technicians to check appliances state after a maintenance task and perform additional tunning. Technicians can also use diagnostic appliances based on an array of sensors to verify multiple parameters. Figure 6 shows the access to a device monitoring the level of CO2 in the environment after conclusion of a maintenance task.

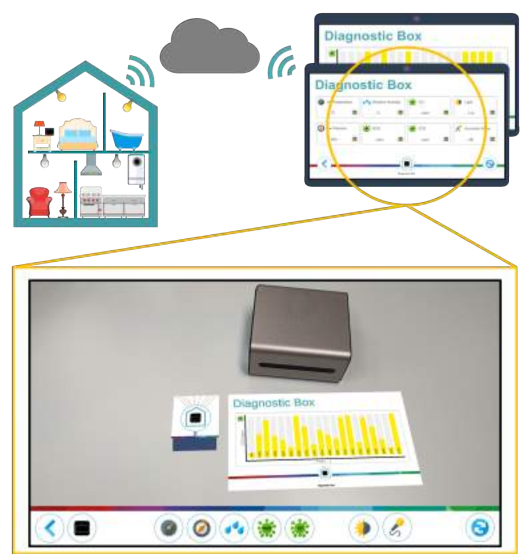

Fig. 6. Monitoring of environment parameters (e.g. temperature, humidity, air pressure, noise, NO2, CO2, among others) using standard 2D (above) or AR interfaces (below).

G. Multi-Device Approach

During the work, it becomes clear that the use of a single mobile device is a limitation due to its limited screen space that becomes easily overloaded with information. To avoid cluttered AR visualizations and improve visibility and understanding of AR content while providing specific documentation access we allow the use of an additional device [11] [12]. In a typical setting, the main device is used to highlight areas of interest and aligned content, while the second device automatically complements the current operation with detailed documentation without occluding the area where tasks need to be conducted (Figure 7).

Fig. 7. Multi-Device approach. The mobile presents the aligned content, while the tablet displays complementary information.

III. Concluding Remarks and Future Work

In this paper, we presented BARTT, an AR framework to provide support to technicians during technical procedures and monitoring operations in smart environments. The different features of the framework were presented and illustrated. We addressed the challenges of performing technical procedures using AR with the collaboration of industrial partners through an iterative process. All features were designed based on a human centered design approach with different focus groups and were presented and discussed in several public events.

Future development will focus on conducting formal user studies to validate the annotation tool and collect feedback regarding the usability and user acceptance. The framework development will continue to support remote interaction, first based on 2D annotations and later using shared 3D content, allowing remote experts to provide guidance during maintenance operations. A challenge will be to address how information can be exchanged and presented between multiple remote and co-located users, without interfering with the task being undertaken.

Acknowledgments

This work was developed in the scope of the Smart Green Homes Project [POCI-01-0247-FEDER-007678], a co-promotion between Bosch Termotecnologia S.A. and the University of Aveiro. It is financed by Portugal 2020 under the Competitiveness and Internationalization Operational Program, and by the European Regional Development Fund. 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.

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