AR-enabled multimodal interaction mechanisms

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[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

Document history

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Abbreviations and Acronyms

Abbreviation	
3D	three-dimensional
API	Application Programming Interface
AR	Augmented Reality
AI	Artificial Intelligence
D	Deliverable
DSF	Decision Support Framework
IMU	Inertial Measurement Unit
QR	Quick Response
REST	Representational state transfer
T	Task
UI	User Interface
WP	Work Package

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Summary

This deliverable goes over the two AR applications that constitute the AR-enabled multimodal interaction mechanism of the RECLAIM project. It will be described how the application works in general, along with a comparison with the proposed architecture for the system in D2.13 to ensure all aspects of the proposed architecture are covered. Then, it will be shown in greater detail how each of these two applications functions using the two demos as examples. First, the materials provided by the pilot partners HWH and FLUCHOS will be shown, before the description of the mobile application. In the next chapter it is described how each component of the application functions using pictures from the demos to help clarify each component and how the user interacts with each one of them, before moving to the HoloLens application, where this process is repeated in a similar way. Finally, any future work that needs to be done for the two applications is discussed.

This deliverable has the following structure. Section 1 provides an introduction to the topic and explains the relation of the deliverable to other tasks and deliverables. Section 2 divided into four subsections. The first one gives a general description of the applications and how they relate with the proposed architecture for the AR mechanism. The next two subsections are centred around the two AR applications and how they work. The last one is about future work that needs to happen for the system to be fully operational. Section 3 goes over the deliverable's conclusions.

Disclaimer

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1 Introduction

The main objective of the AR mechanisms is to display the DSF recommendations for lifetime extension strategies and the particular steps to refurbish/remanufacture specific machines and/or their components to end users on top of the physical equipment through AR glasses or Android tablets / mobile phones. This deliverable describes in detail how the two AR applications that were created for this project function and how they cover each aspect of the proposed architecture. Before going over each of the applications, a general description of how the user will experience this system when trying to use one of the applications is provided. After a quick look at the materials that were provided by the pilot partners HWH and FLUCHOS for this task, the HoloLens application is discussed, going over its various components and how they interact with each other and the user. Lastly, the mobile application is reviewed in a similar way.

The remainder of this section the relation of this deliverable to other tasks and deliverables is presented, according to the 1st Amendment of the Description of Action. The related tasks and deliverables are summarized in the table below.

Related task	Deliverable(s) of the related task
T2.3: "Overall technology approach and solutions architecture"	D2.3: "The RECLAIM architecture specification" (7/2020) D2.9: "The RECLAIM architecture specification #2" (11/2021) D2.13: "The RECLAIM architecture specification #3" (9/2022)
T4.4: "Integrated Decision Support Framework (DSF) for Refurbishment & Remanufacturing Optimization"	D4.4: "Integrated DSF for Ref/Rem Optimization" (9/2022)
T6.2: "Iterative integration and testing of RECLAIM solutions"	D6.2: "Iterative integration and testing of RECLAIM solutions" (7/2023)
T6.4: "Pilot #2: Fluchos, Footwear Manufacturer"	D6.4: "Pilot #2 Fluchos, Footwear Manufacturer #1" (9/2021) D6.9: "Pilot #2 Fluchos, Footwear Manufacturer #2" (11/2022) D6.14: "Pilot #2 Fluchos, Footwear Manufacturer #3" (7/2023)
T6.6: "Pilot #4 HWH, Friction Welding Machines"	D6.6: "Pilot #4 HWH, Friction Welding Machines #1" (9/2021) D6.11: "Pilot #4 HWH, Friction Welding Machines #2" (11/2022) D6.16: "Pilot #4 HWH, Friction Welding Machines #3" (7/2023)

Table 1: Related tasks and deliverables

T5.5 is related to the other tasks as follows:

- The architecture of the AR mechanisms was defined in T2.3.
- T4.4 is the main task corresponding to the DSF Core algorithm, which may provide as input to the AR mechanisms recommendations for lifetime extension strategies along with supplementary information, e.g. ongoing failures, through the RECLAIM Repository.

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- The integration and deployment activities involving the AR mechanisms, with the relevant acceptance tests, will continue also after the end of T5.5, within the context of WP6: “Integration and Industrial Demonstrations”. Particularly, the activities will be monitored and summarized within the context of T6.2 and will be performed within the context of the pilot-specific tasks (T6.4 and T6.6, since FLUCHOS and HWH are the pilots for which the AR mechanisms will be deployed).

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2 Augmented Reality Application

2.1 General Description

When the applications become available to the pilot sites, the user will be able to open the application and scan a QR code to get directions to the room with the machinery that may need maintenance. After reaching the room, scanning a second QR will render the applications UI. The application will communicate with the DSF Core algorithm to highlight the appropriate parts of the machinery that need lifetime extension strategies (e.g. maintenance, replacement, refurbishment), while also describing to the user in the applications UI why each strategy needs to take place and which parts require their attention. From the interface the user can choose to watch 3D step-by-step instructions about how to proceed with the disassembly and reassembly of the parts that require maintenance.

The design of the application closely follows the system's architecture that was proposed in D2.13. In more detail, the AR mechanisms consist of the following modules:

- *Real-time 3D annotation module*: The applications render the 3D models of the various machinery over the actual machine, but make them slightly transparent to indicate that everything is functioning correctly with the machine. If the applications receive any DSF predictions about any part of the machine, the corresponding components are highlighted with a red color to draw the user's attention to them. The annotation also includes textual information about the ongoing failures and the recommended lifetime extension strategies related to these components, either on top of the components (mobile solution) or in an application menu aside (AR glasses).
- *Context-based multi-modal interaction module*: Both applications give the user the option to interact with the various UI elements. In the case of the mobile device, the user can tap the screen to select a destination or choose an animation to play, while the very same actions can be done in the HoloLens application using gestures.
- *Indoor Localization & 3D Registration module:* For the applications to know the initial position of the user they need to scan a QR code that is located in a fixed position within the indoors area. Using this QR the applications know the original location and orientation of the user and can proceed
- with guiding them using the Inertial Measurement Unit of the device.
- *Marker-based Feature Recognition module:* Using the camera of the device the applications check if any of the QR markers are present within the field of view of the user, rendering the appropriate models when necessary.
- *AR visualization module*: Combining the information from all the previous components the applications render 3D animations in the real world creating an augmented reality experience for the user.

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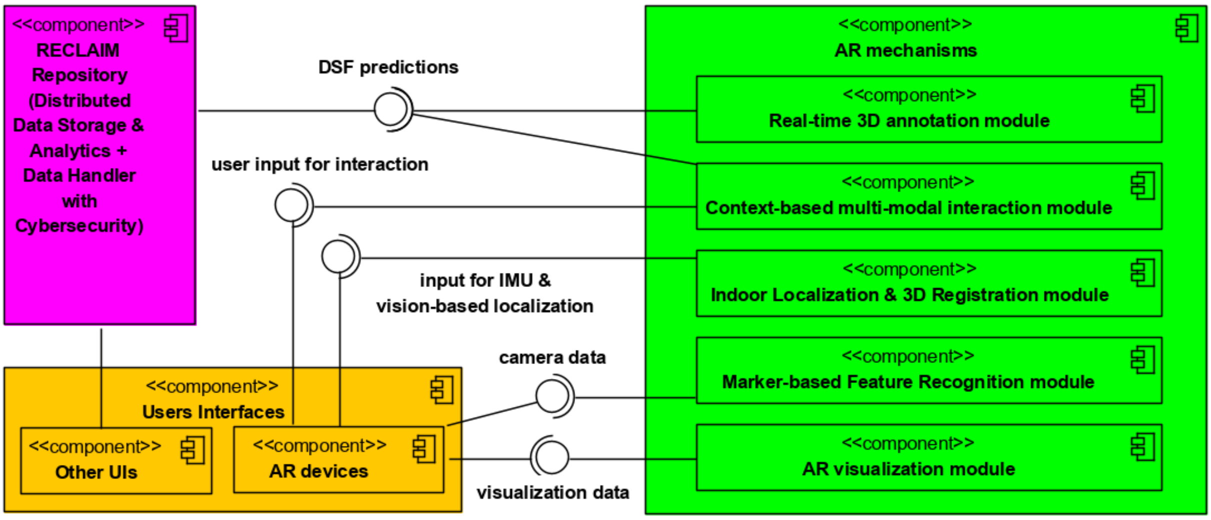

Figure 1: AR mechanisms component diagram

2.2 Provided Materials

Some of the materials used in the AR applications were provided by the pilot partners. HWH provided the 3D model of a machine that was the basis for all the animations that were created, as shown in Section 2.4. Before animating the various parts of the model, it was processed to allow for maximum detail without causing any performance issues for the application. The following top-down map of the area hosting the machinery was provided by FLUCHOS, in order to allow the user to navigate to the machinery within this area.

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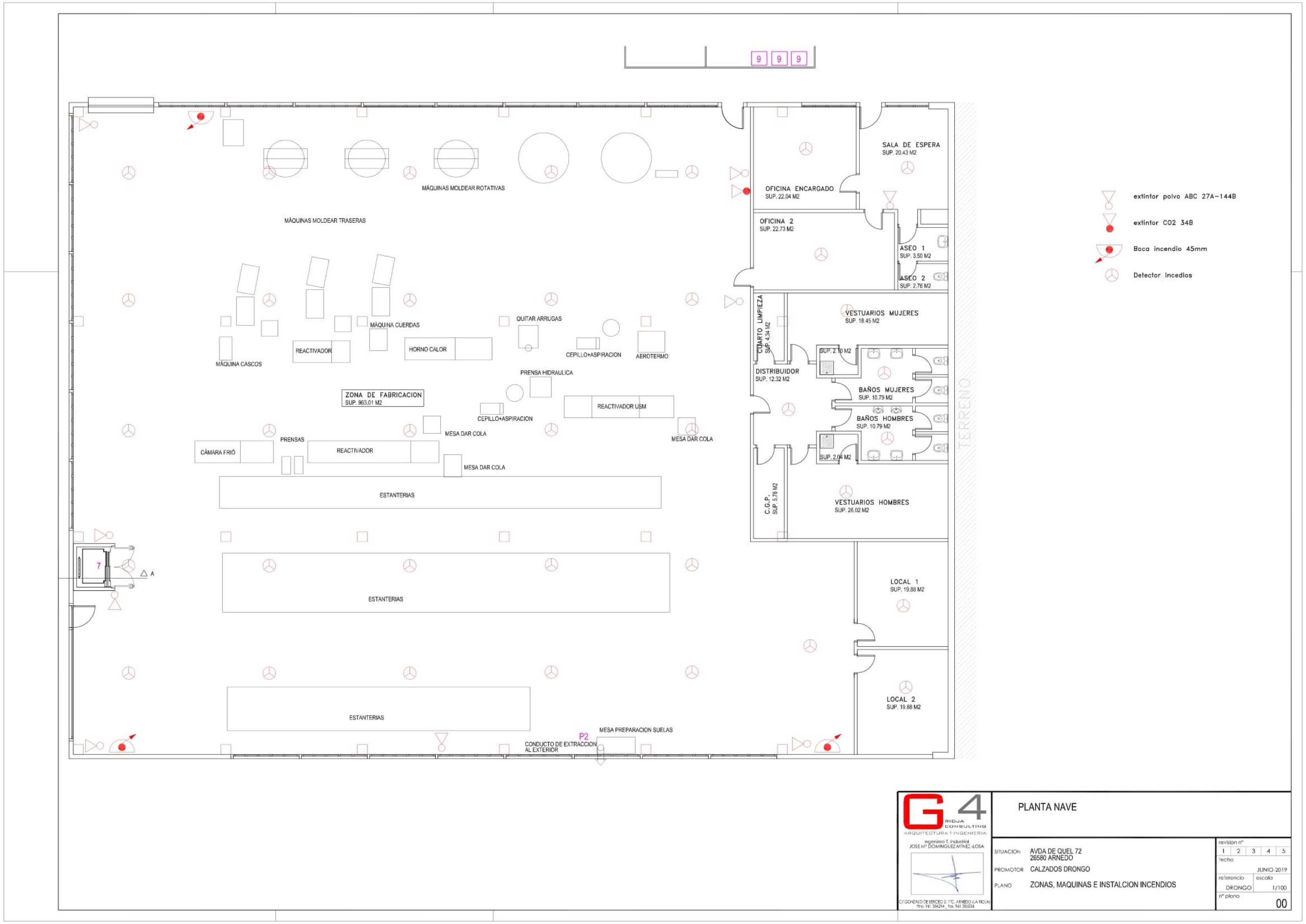

Figure 2: *FLUCHOS map*

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2.3 Tablet / Mobile Application Description

The user needs to create an account and log in before using the application. During registration the user has to specify which pilot site they are interested in. After opening the app, the user has to scan a QR code with their mobile device in order to get access to further functionality, as shown in Figure 3. After scanning, the user can see a map of the area in the bottom left area of the screen. By clicking the button to the right of the map, the map covers the whole screen.

On the top of the screen the user can choose their desired destination from a list of available destinations. After selecting a destination from the list, arrows appear in the main view that guide the user to the specified point. Along with the arrows, the calculated path is displayed on the top-down map available to the user. At the destination a new QR code will render any 3D animations or models designated for that destination along with annotated recommendations for lifetime extension strategies.

In order to calculate the path that the user must take, the application uses a navmesh. A navigation mesh, or navmesh, is an abstract data structure used in AI applications to aid agents in pathfinding through complicated spaces. For the navmesh to work properly, it is needed to annotate on the map all the obstacles and impassable areas. When the user selects a destination the navmesh is used in order to calculate the path and then display it on the top-down map available to the user. From that point navigation is done using the phone's IMU and camera.

The figure below corresponds to a demo with artificial data, created at the first stage of the task at the home of the developer. It consists of subfigures as follows. (a) The initial position of the user is identified by a marker. (b, c) Then, it is tracked by the device's Inertial Measurement Unit (accelerometer, gyroscope) and camera sensors, providing to the user directions to the equipment of interest. (d) The supposed position of the equipment is recognized based on another marker when the user arrives there, and the 3D models of the machine and its components are displayed nearby, along with annotated recommendations for lifetime extension strategies.

More realistic pilot data have been used in a more recent demo for AR glasses, shown in the next subsection.

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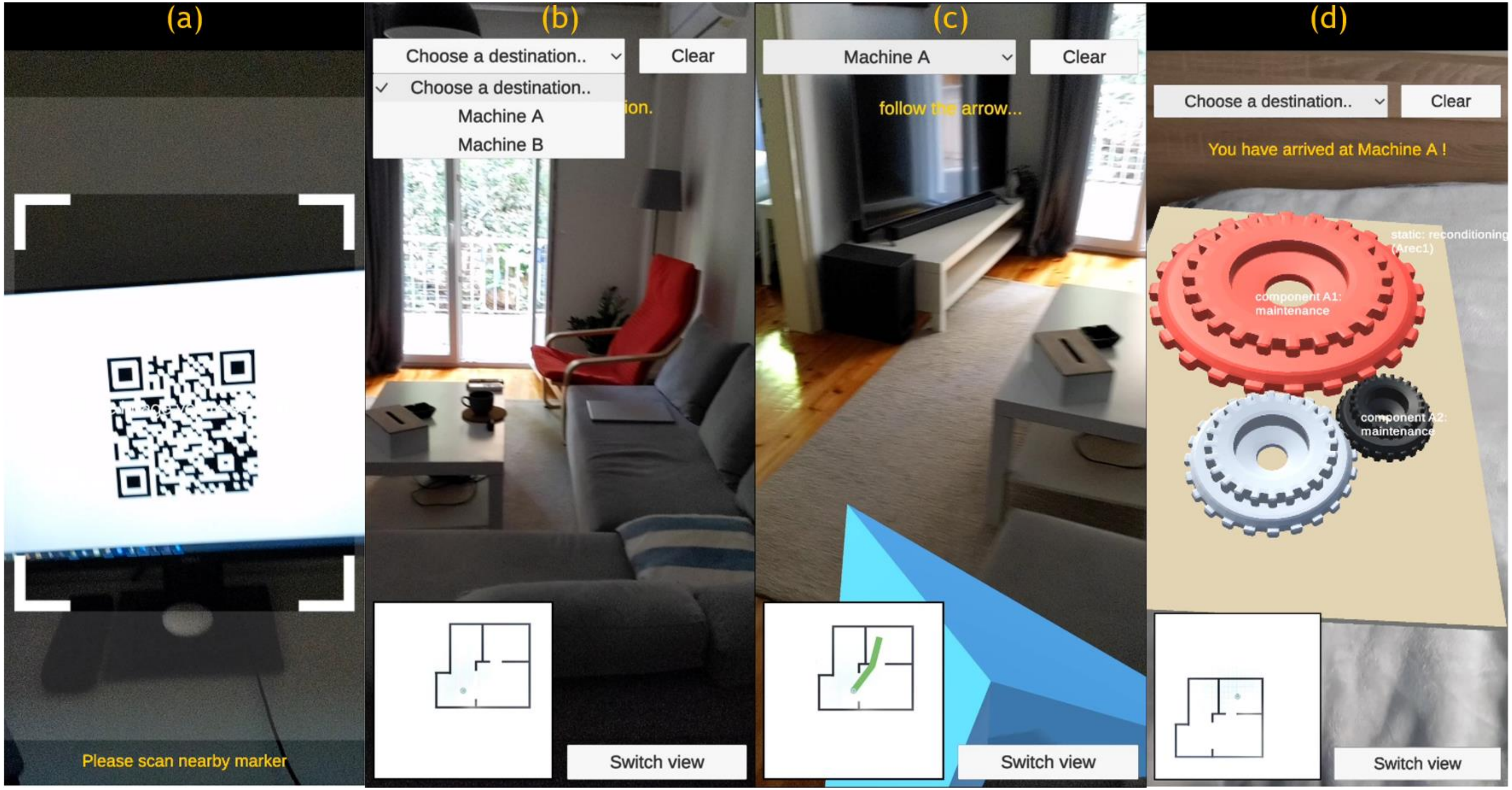

Figure 3: Demo on mobile phone using artificial data

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2.4 Glasses (HoloLens) Application Description

A unity app was created for HoloLens AR glasses to assist the personnel with all the necessary actions for the requested lifetime extension strategy scenarios. In the following, a demo with realistic data related to the friction welding machine RSM401 of HWH will be discussed.

In this pilot case, it is not needed to direct the user to the machine, because it is located in a known small room.

On their left side the user can see the application's menu where they can check for notifications that will be sent from the DSF Core informing them about present failures and required lifetime extension strategies, as shown in the figure below. For the moment, the information about failures and strategy recommendations is artificial. In the future, it will be received from the RECLAIM Repository as an output of the Adaptive Sensorial Network (or some DSF algorithm if not directly registered) and the DSF Core respectively.

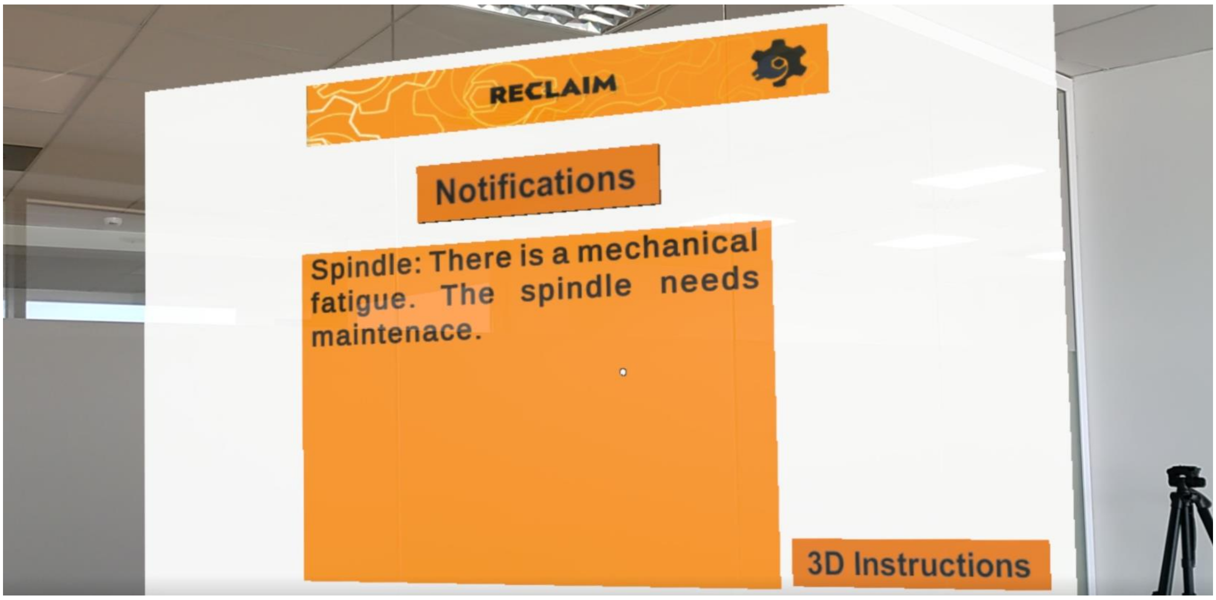

Figure 4: Application UI with notifications about present failures and recommended strategies in the demo on AR glasses for the friction welding machine RSM401 of HWH

The application may render the machine's 3D model on top of the real machine, but it makes it transparent to allow to later highlight the areas that need attention with a red colour. The position of the machine is calculated based on a QR code located in a fixed location that the user has to scan before being able to see the 3D models. The DSF Core algorithm will send a signal to the application, in order to dynamically highlight the areas (components) on the machine that require the user's attention red. Since no marker has been placed on the machine yet (it will be done within the context of WP6), for the moment the position of the 3D models and the menu depend on the orientation of the user when launching the application. The 3D model of the machine is shown in the following figure.

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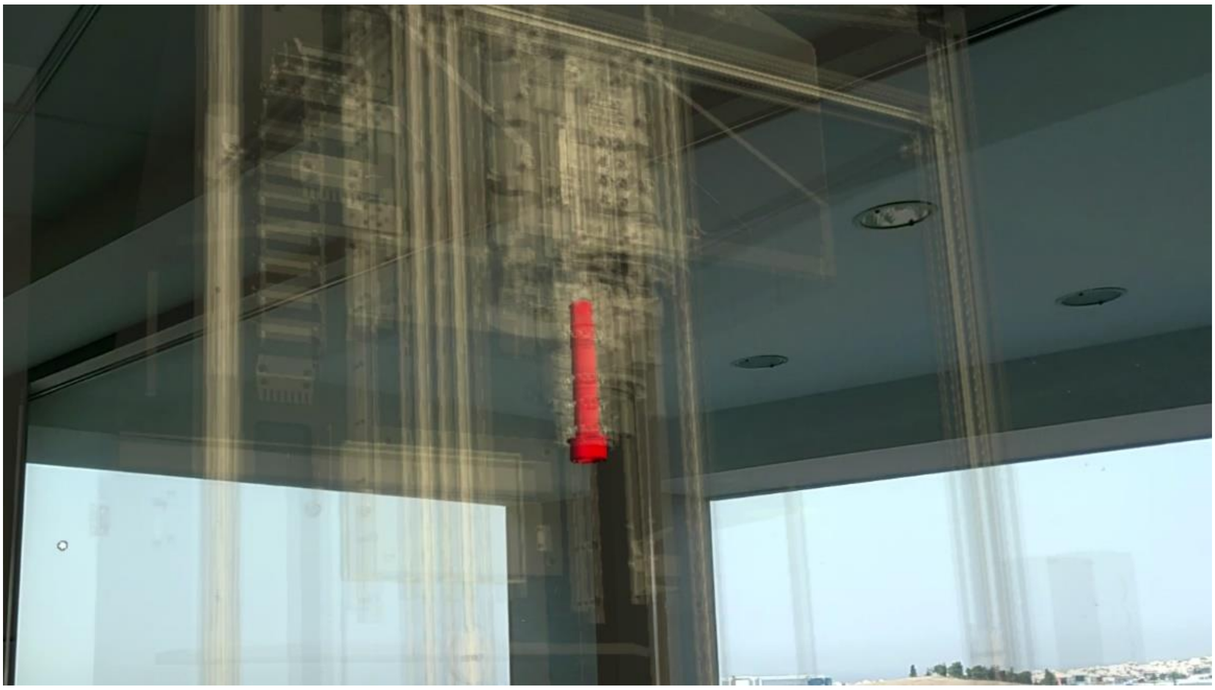

Figure 5: The 3D model of the friction welding machine RSM401 of HWH with the supposedly[1] failed component (spindle) needing maintenance highlighted in the demo on AR glasses

For more detailed instructions on lifetime extension strategies, four animations were created, two covering the drive unit exchange and two the exchange of the quill unit of the friction welding machine RSM401, based on 2D manuals and components' 3D models the pilot provided. Each pair of animations consists of one for disassembling and one for reassembling the corresponding unit. The application's menu is also used to display the various available scenarios for the user to choose. If the user chooses a specific scenario, the right area provides written step-by-step instructions about the actions the user must take. The menu with detailed written instructions is shown in Figure 6, whereas Figure 7 and Figure 8 relate to 3D animations of the involved components corresponding to these instructions.

[1] "Supposedly" implies that the failure information is artificial in this demo.

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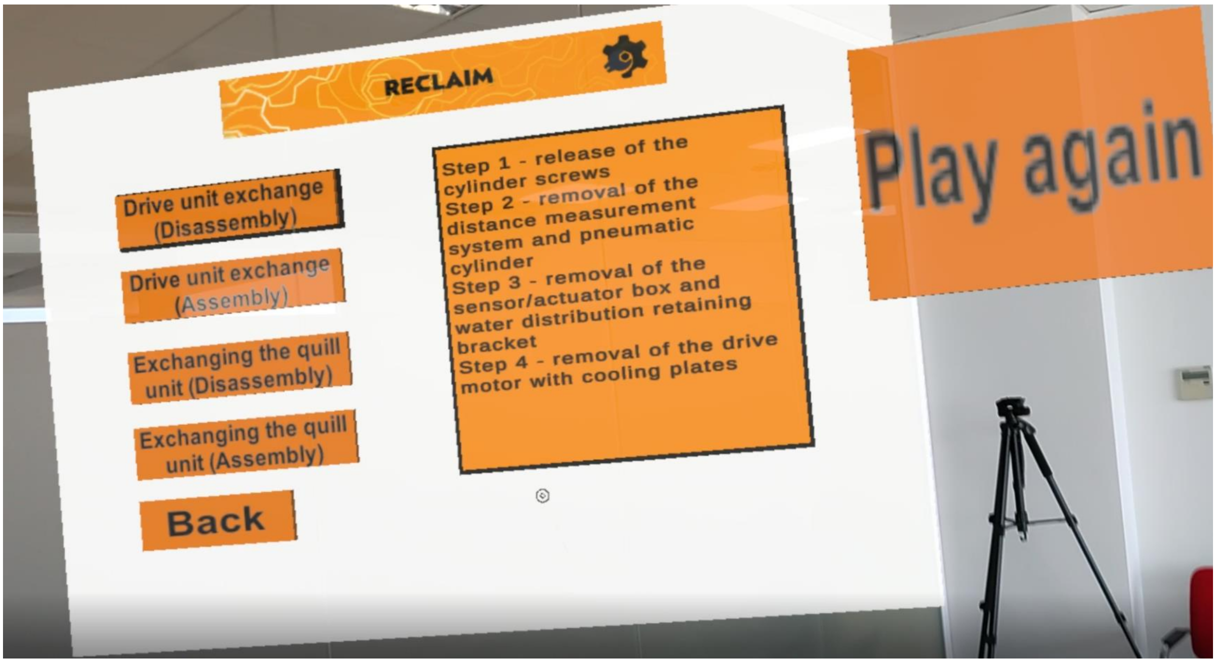

Figure 6: Application UI with menu of 3D instructions in the demo on AR glasses for the friction welding machine RSM401 of HWH. Textual instructions for disassembly during drive unit exchange appear to the right of the menu.

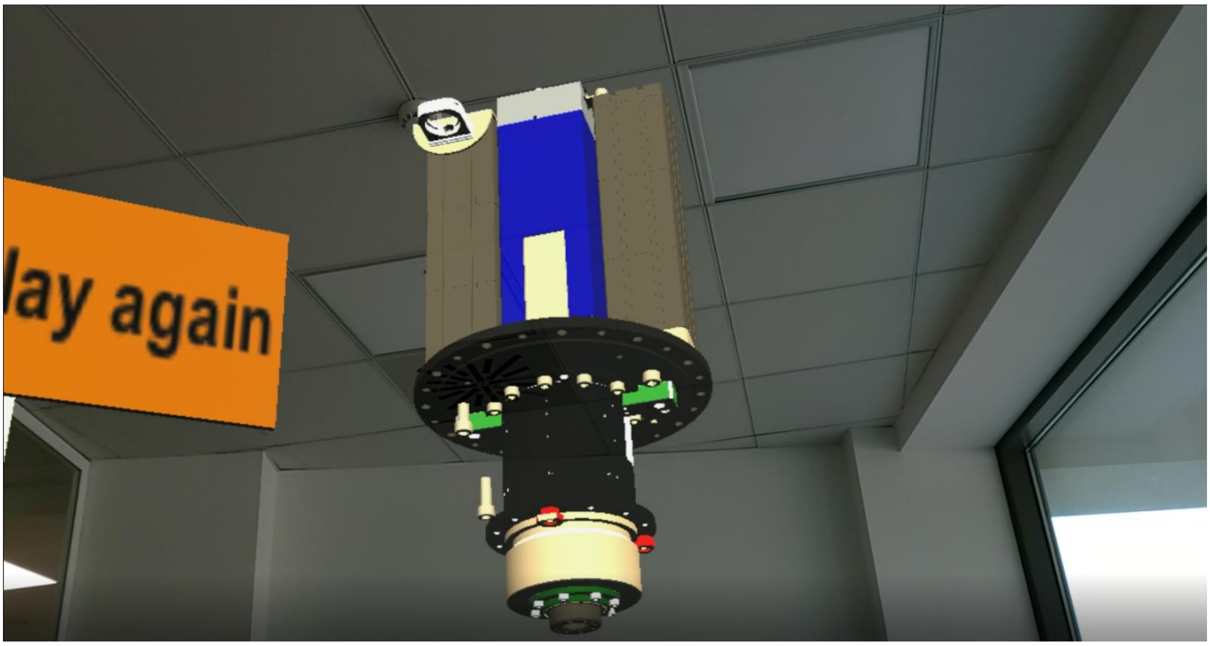

Figure 7: Snapshot of 3D model render for disassembly during drive unit exchange in the demo on AR glasses for the friction welding machine RSM401 of HWH

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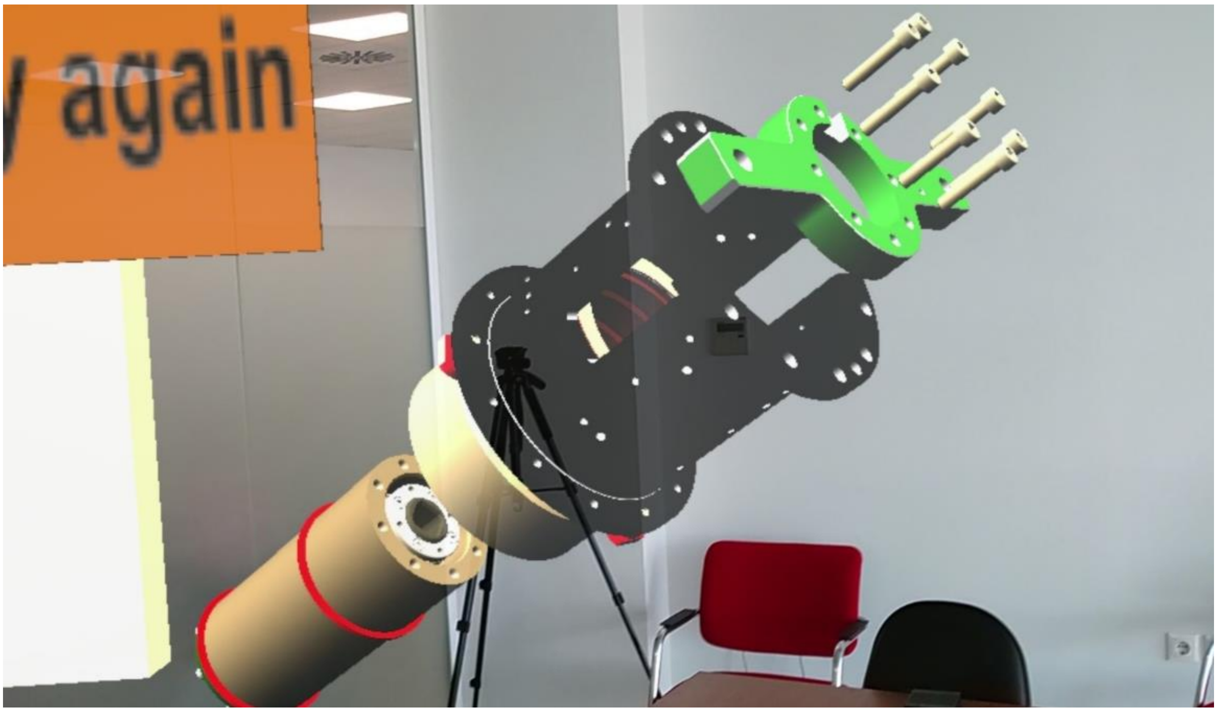

Figure 8: Snapshot of 3D model render for disassembly during quill unit exchange in the demo on AR glasses for the friction welding machine RSM401 of HWH

The user navigates the application's UI using hand gestures, as shown in the next two figures. When the app detects the user's hands, a faint dotted line connects their hand with the cursor. Bringing the index finger and the thumb together makes the line appear bolder and releasing the fingers emulates clicking on the element behind the cursor. The user can use this functionality to choose between the available 3D instructions or return to the starting screen to check the information provided by the DSF Core again. They can also navigate multi-step scenarios by using the "next" button or simply replay the current step by clicking the "Play Again" button. The detailed 3D instructions may be displayed regardless of the DSF-Core-based need for lifetime extension strategies, which should be rare.

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Figure 9: User making a gesture while wearing the AR glasses as viewed from the side

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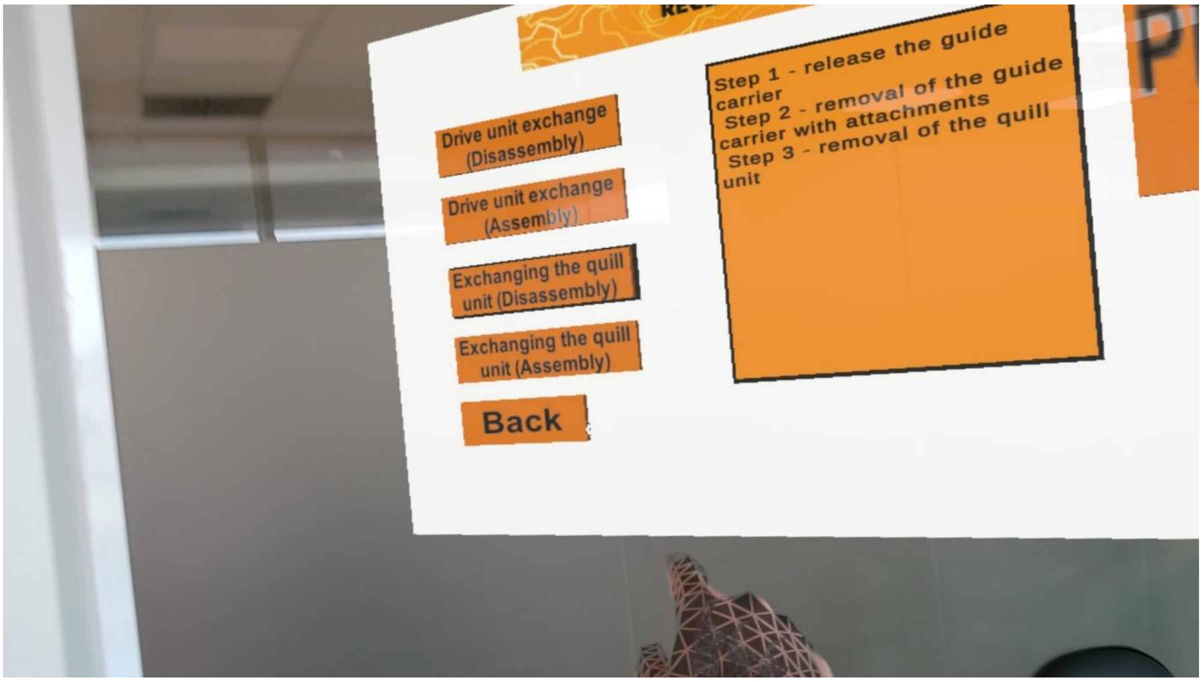

Figure 10: User making a gesture while wearing the AR glasses from their point of view

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3 Conclusion

This deliverable described how the AR application works. A general description to highlight the flow of use of the application was given, and it was showcased how it reflects the proposed architecture of the AR interaction mechanism. A more thorough description of the various components of the two applications followed with examples from two AR demos, one for tablets and mobile phones and another one for AR glasses. The latter also showcased some of the 3D animations that were created from the materials that were provided by HWH. In the near future HWH will select the preferable AR device type between glasses and mobile phone. During the following months in the context of WP6 the pilot sites will have a chance to use the applications and evaluate the impact they have on the tasks they relate to.

The two applications work in similar way, aiming to guide the user to the location that requires their attention, show them in a concise way where the problem resides by highlighting the appropriate area, and provide support to the maintenance personnel by showing them a variety of instructive animations that will allow them to carry on lifetime extension strategies with greater speed and efficiency.

Finally, although all the components are functional between the two applications, the two applications will need some work in the following months within the context of WP6 to fully implement the desired functionality and be deployed on the two pilot sites. The connection between the AR application and the DSF Core is not yet supported and will be implemented in the following months through the RECLAIM Repository, after both services are able to communicate with one another. The application will be getting the data through REST API and will be filtering them based on the related pilot and the related machine that the user is interested in. The map provided by FLUCHOS will replace the dummy one that was used in the mobile application. It will be used to guide the maintenance personnel from a designated point to the machinery room in order for them to take any required actions.

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