PROPHESY

Platform for rapid deployment of self-configuring and optimized predictive maintenance services

DELIVERABLE

D5.4 – Training and Knowledge Sharing Platform v1

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Executive Summary

The purpose of D5.4 PROPHESY Training and Knowledge Sharing Platform v1 is to describe the implementation progress of the results of Task 5.3 (Knowledge Visualization & Sharing Platform).

D5.4 is based on the developments in the specification phase in T5.1 (Visualization and AR Specifications) and the implementation in T5.3. It builds up on the technological experiences of oculavis with the software platform SHARE and Augmented Reality applications. The result of D5.4 is called the 'PHI-AR viewer' and thus establishes the reference to the PHILIPS demonstrator in work package 7. It describes the software for the demonstration of PHILIPS in use-case 3, in which the maintenance technician can access tool data from the shop floor. In addition to the data and KPI about the 5-fold-cut-out tool, the maintenance technician also receives maintenance data and instructions via mobile devices.

Originally it was planned to use Smart Glasses, but the definition of the demonstrator with the interaction possibilities that the operator should have, as well as the requirements from an Augmented Reality perspective, led to a change in the decision to use tablets and smartphones.

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1.0	29/03/2019	OCU	Final version

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Definitions, Acronyms and Abbreviations

Acronym/ Abbreviation	Title
AR	Augmented Reality
CPS	Cyber-Physical System
ERP	Enterprise Resource Planning
FIS	Factory Information System
IoT	Internet of Things
MES	Manufacturing Execution System
MTTR	Mean Time To Repair
OEE	Overall Equipment Effectiveness
PdM	Predictive Maintenance
PROPHESY System	It is the combination of the PROPHESY-CPS and PROPHESY-PdM platform
PROPHESY-AR	PROPHESY-Augmented Reality
PROPHESY-CPS	PROPHESY-Cyber Physical System
PROPHESY-ML	PROPHESY-Machine Learning
PROPHESY-PdM	PROPHESY-Predictive Maintenance
PROPHESY-SOE	PROPHESY-Service Optimisation Engine
RUL	Remaining Useful Life
SAP	An ERP system by the company SAP
UC	Use Case
KPI	Key Performance Indicator
PHI-AR-Viewer	Philips Augmented Reality Viewer
ARCore	Abbreviation for the Google Augmented Reality Tracking SDK
SDK	Software Development Kit
ARKit	Abbreviation for the Apple Augmented Reality Tracking SDK
UML	Unified Modelling Language

1 Introduction

1.1 The PROPHESY Vision

Despite the proclaimed benefits of predictive maintenance (PdM), the majority of manufacturers are still disposing with preventive and condition-based maintenance approaches, which result in suboptimal OEE (Overall Equipment Effectiveness). This is mainly due to the challenges of predictive maintenance deployments, including the fragmentation of the various maintenance related datasets (i.e. data "silos"), the lack of solutions that combine multiple sensing modalities for maintenance based on advanced predictive analytics, the fact that early predictive maintenance solutions do not close the loop to the production as part of an integrated approach, the limited exploitation of advanced training and visualisation modalities for predictive maintenance (such as the use of Augmented Reality (AR) technologies), as well as the lack of validated business models for the deployment of predictive maintenance solutions to the benefit of all stakeholders. The main goal of PROPHESY is to lower the deployment barriers for advanced and intelligence predictive maintenance solutions, through developing and validating (in factories) novel technologies that address the above-listed challenges.

In order to alleviate the fragmentation of datasets and to close the loop to the field, PROPHESY has specified a novel CPS (Cyber Physical System) platform for predictive maintenance [See Deliverable D2.1], which shall provide the means for *diverse data collection, consolidation and interoperability*, while at the same time supporting digital automation functions that will *close the loop to the field and will enable "autonomous" maintenance functionalities*. The project's CPS platform is conveniently called PROPHESY-CPS and is developed in the scope of WP3 of the project.

In order to exploit multiple sensing modalities for timely and accurate predictions of maintenance parameters *(e.g., RUL (Remaining Useful Life))*, PROPHESY will employ advanced predictive analytics which shall operate over data collected from multiple sensors, machines, devices, enterprise systems and maintenance-related databases (e.g., asset management databases). Moreover, PROPHESY will provide tools that will facilitate the development and deployment of its library of advanced analytics algorithms. The analytics tools and techniques of the project will be bundled together in a toolbox that is coined *PROPHESY-ML* and is developed in WP4 of the project.

In order to leverage the benefits of advanced training and visualisation for maintenance, including increased efficiency and safety of human-in-the-loop processes the project will take advantage of an Augmented Reality (AR) platform. The AR platform will be customised for use in maintenance scenarios with particular emphasis on remote maintenance. It will also be combined with a number of visualisation technologies such as ergonomic dashboards, as a means of enhancing workers support and safety. The project AR platform is conveniently called PROPHESY-AR.

In order *to develop and validate viable business models for predictive maintenance deployments,* the project will explore optimal deployment of configurations of turnkey solutions, notably solutions that comprise multiple components and technologies of the PROPHESY project (e.g., data collection, data analytics, data visualisation and AR components in an integrated solution). The project will *provide the means for evaluating such configurations against various businesses and maintenance criteria,* based on corresponding, relevant KPIs (Key Performance Indicators). PROPHESY's tools for developing and evaluating alternative deployment configurations form the project service optimisation engine, which we call *PROPHESY-SOE.*

1.2 PROPHESY WP5 Overview

WP5 (PdM visualization and Augmented Reality Services for Remote Expert Support) is devoted to providing visualization and augmented reality (AR) services for remotely-supported predictive maintenance processes, as a means of improving the efficiency of maintenance services and increasing maintenance employees' productivity. Visualization will be provided at a machine, component and production system level, the AR solution will be part of OCULAVIS support and knowledge sharing platform. The main objectives of WP5 include:

- To specify and implement user-centric visualizations of the condition of machines, tools, components and production systems, including relevant predictions derived from PROPHESY-ML.
- To provide a platform for training remotely employees and sharing knowledge across maintenance stakeholders based on the visualization and AR technologies of the project.
- To specify and implement the PROPHESY-AR technology of the project, which will leverage AR in order to support remote maintenance services.

1.3 PROPHESY Task 5.3 Overview

As part of this task the project implements a knowledge sharing and visualization system for the maintenance technician, which is enhanced with remote and advanced visualization capabilities including AR. In particular, the so called 'PHI-AR-Viewer' is developed and presented here. The technological basis of the PHI-AR-Viewer is based on Augmented Reality technologies as well as experiences and technologies from oculavis SHARE platform. oculavis SHARE is a cloud-based platform for manufacturers that already provides a cyber-representation of training content on the field, which is accessible through smart glasses. The further development and usage of oculavis SHARE is described in D5.6 and part of T5.4 for remote maintenance procedures, whilst in this T5.3 the focus lies on the AR-based support of the maintenance engineer in the tool shop. As a first step, and based on the demonstrators defined at the beginning of PROPHESY project, a concept for the data providence and guidance of employees in the scope of maintenance processes was defined, which aimed at making available the right information, at the right time and based on the most appropriate device. This requests a suitable didactic design aiming at the intuitive collaboration between shop floor and maintenance department. Afterward the implementation of the PHI-AR-Viewer took and still takes place.

Together, the deliverables of T5.2, T5.3 and T5.4 form the PROPHESY-AR results.

1.4 Document scope and structure

The current document is structured as follows:

Section 1. **Introduction**: details the document context and purpose.

Section 2. **Methodology and Implementation:** describes the methodology for designing and implementing the AR-viewer for the Use Case

Section 3. **PHI-AR-Viewer:** gives an overview of the PHI-AR-Viewer, user stories and first sketches.

Section 4. **Conclusions**: provides the conclusion of this document and point out the next steps.

2 Methodology and implementation

2.1 Reminder from D5.1

In terms of PROPHESY architecture, the PROPHESY-AR is a crosscutting layer which crosses PROPHESY-CPS and PROPHESY PdM. Figure 1 reminds the PROPHESY-AR components.

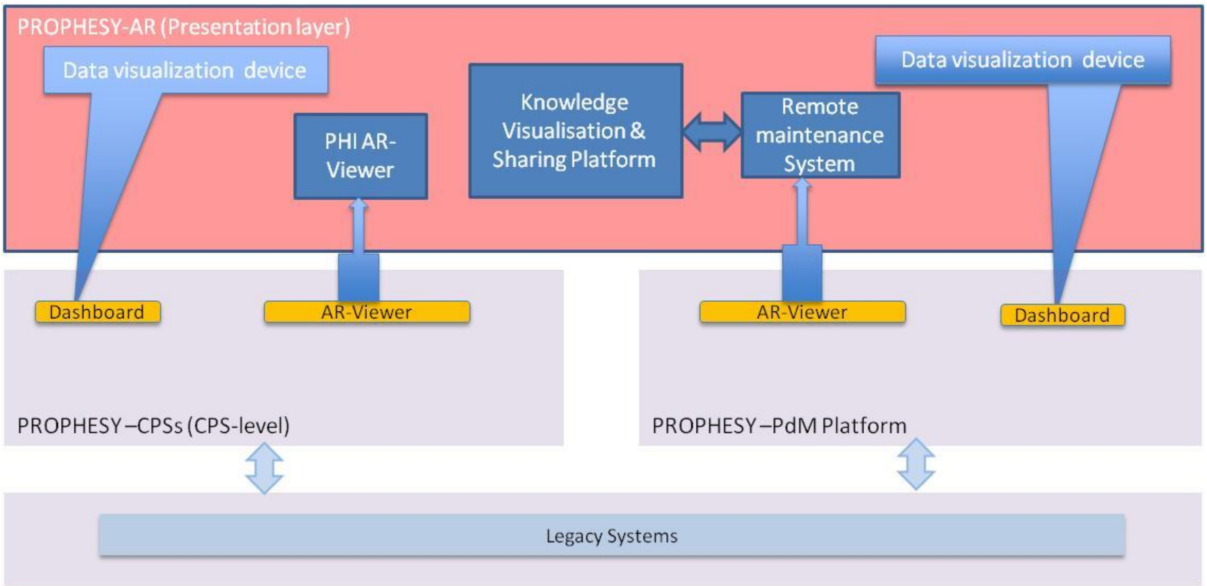

Figure 1 PROPHESY – AR components

Table 1 provides a brief summary of the components in the architecture.

Table 1 PROPHESY-AR Components & Description

Component	Description
Data visualization*	This component is responsible for visualizing information to users involved in the maintenance process. It displays information for tools, indicators useful for the maintenance team in the workshop and for the maintenance management
CPS Message Bus	retrieves data coming from CPS assets (such as sensors, machinery) and local machine learning algorithms (PROPHESY-ML -HF/ML). Data is presented as topics in the CPS message bus
PdM Message Bus	retrieves data coming from connected CPS to PdM platform central machine learning algorithms (PROPHESY-ML -LF/ML). Data is presented as topics in the PdM message bus
PHI-AR – Viewer	Philips Augmented Reality Viewer provides relevant maintenance knowledge to technicians using augmented reality and acts as a maintenance assistant
Remote – AR service (and client)	allows remote training and maintenance support. A machine manufacturer can help the customer operator or maintenance engineer

Platform repository	retrieves data come from legacy systems (PDFs, csv, files etc.).

*It is important to note that D5.3 deals with the PHI-AR-Viewer component, but not the other listed components of Table 1.

2.2 Tools and methodology

The PHI-AR-Viewer is one of the outputs of the PROPHESY project and is implemented in task "T5.3". External PROPHESY stakeholders will be delivered with key components that will enable them to make decisions based on a mix of information from various databases (e.g. MES, Windchill, SAP) and learning algorithms, that are represented in Augmented Reality. The PHI-AR-Viewer will be adaptable to other situations and data sources in the future with additional manual effort.

Two-step implementation approach

The PHI-AR-Viewer implementation is a two steps process that leads to two versions (D5.4 and D5.5). The first version aims at achieving a demonstrator, identified constraints, data sources to be visualized and end devices, describing the expected features with a clear objective to begin version two with an implementation such that it can be further deployed and connected to the enterprise information system via the PROPHESY data bus and databases. The initial demonstrator of the PHI-AR-Viewer is hard-coded not connected to the data sources, yet. The final result (D5.5) will describe a fully-integrated PHI-AR-Viewer. As an outlook for future developments, the AR-Viewer can be enhanced by an AR-editor functionality. Such an editor will reduce manual effort to describe the AR-scene, upload 3D models, connect marker as tracking systems and add/link the relevant data sources of the enterprise to be displayed in Augmented Reality.

2.3 Implementation

The PHI-AR-Viewer is implemented based on Unity3D as programming environment and open source tracking libraries (ARCore, ARKit) for smartphones and tablets. The data connectors will be established through the PROPHESY PDM platform via a standardized Kafka-Connector (D5.5). The flexible connection to the databases is part of the 2nd version of the PHI-AR-Viewer, whilst the first implementation aimed at a working and presentable prototype of the system.

End-user devices

In D5.1 it was described that the implementation would take place on the Microsoft Hololens. Since this device is not available on the market anymore and the maintenance engineer has several requirements to view wear part information, 2D73D CAD designs as well as to input data and control the system, it was decided to change the implementation to a tablet and smartphone application instead. Since Unity 3D as an operating system-agnostic development environment is used, the code and the system can be deployed to iOS and Android devices.

Tracking services

For tracking functionalities Vuforia SDK has been initially used due to good performance results. This SDK provides the highest precision at the beginning of the project in the market for device-agnostic tracking technologies, however it is not free of charge. Future development (D5.5) will take a change to ARKit and ARCore into mind since these tracking libraries are offered on a free basis and can make use of all device-specific tracking functionalities. Also, the performance and precision of these SDKs will obviously overcome PTC Vuforias performance in the closer future because it can use device specific tracking capabilities.

System structure

The following UML-diagram gives an overview about the stand-alone version of the PHI-AR-Viewer (see Figure 2).

The Login service allows the user to authenticate in the system and will prevent un-authorized access in the future. The HTTP-service initiates the system and creates the empty tool, that is filled with data by the help of the JSON Manager. The ToolManager finally creates the AR-object that is shown in the 3D scene of the app. The tool data is so far hard-coded in the system, but will be replaced for D5.5 by a flexible and configured interface to the PROPHESY data bus. For this, the Tool Manager will be able to constantly update the AR Object with relevant data. The AR Object is shown in the AR Window, a 3D scene that is initiated by markers (AR labels that define the 3D scene, position and size of the object). The AR Object is subdivided into several components, since the Philips tool consists out of ten functional parts (5-fold cut-out: 5 cutting punches on the lower side and 5 die-plates on the top side). On the right side of Figure 2, the data structures of the AR object (the tool) are described in more detail.

The overall structure of the PHI-AR-Viewer will be enhanced and further developed within the next D5.5.

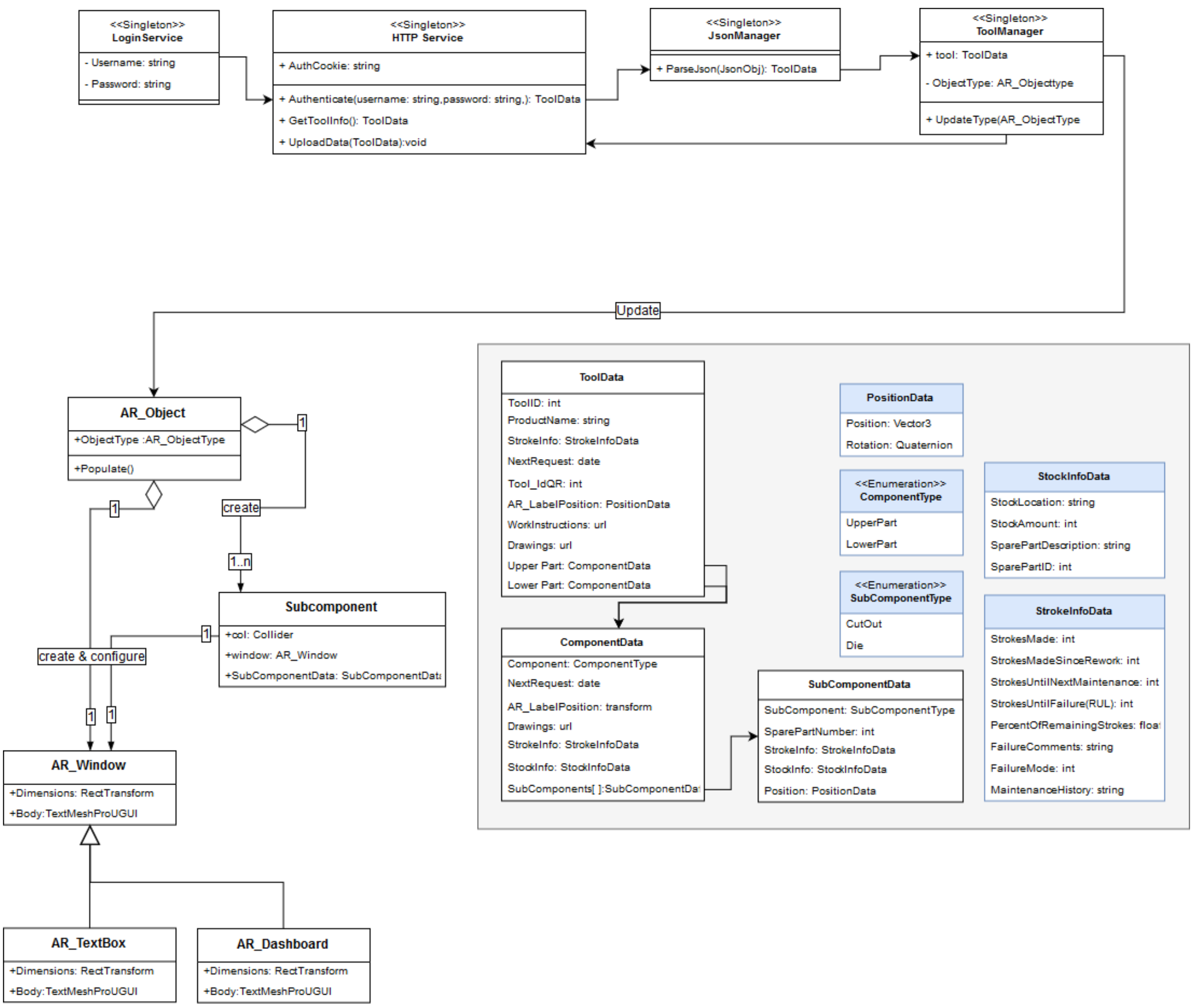

Figure 2: UML Diagram of PHI-AR Viewer

3 PHI-AR-Viewer for training and knowledge sharing

3.1 PHI-AR-Viewer (use case 3) overview

Within Task T5.3 oculavis provides the training and knowledge sharing platform oculavis SHARE for the project. The platform is already existing and is refined within the project by the end – users' feedback with remote capabilities. In addition, the solution is enhanced with advanced visualization capabilities including Augmented Reality. For this purpose, oculavis discussed the requirements for an AR-based solution in detail with the end-user Philips to share and present relevant maintenance knowledge to tooling workshop mechanics.

The result is the initial demonstrator, the 'PHILIPS AR-VIEWER' as described with its requirements in Figure 3 with goals, roles, the process, benefits, and sketch of UI as well as technologies for the development.

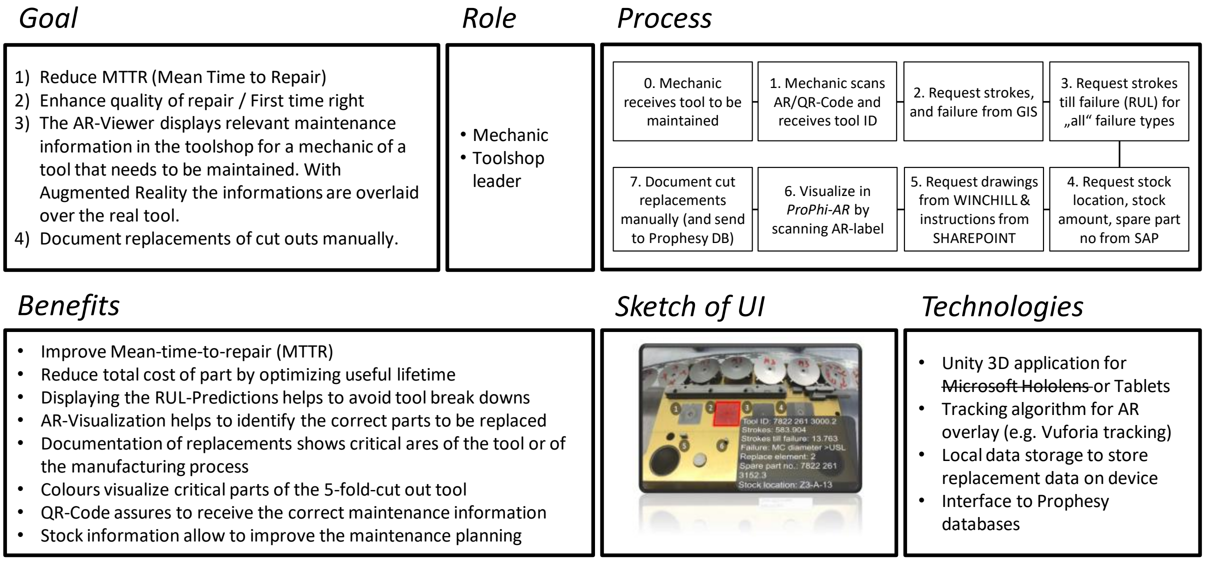

Figure 3: Goal and components in the PHI-AR-Viewer

The use-case of the PHI-AR-Viewer is described in the process of Figure 2Figure 3. The maintenance mechanic can use a tablet to analyse the tool that has been sent to the tool shop. He scans the AR/QR code to receive the tool ID can request various data including KPIs e. g. RUL and technical drawings, manuals and documents. Finally, he can document replacements and add comments to the scene. The system helps to reduce MTTR (mean time to repair), enhances the quality of the repair and delivers the right maintenance information right to the point of the tool.

3.1.1 Description of the PHI-AR-Viewer (closed tool)

The following screenshots show the status of the PHI-AR-Viewer in the current development phase (M18). The system was developed for the 5-fold-cut-out tool of Philips. The login page and the scanning page are shown in Figure 5 and Figure 6, respectively. After login, by scanning the relevant QR-code and marker, the workshop employee can retrieve the relevant maintenance information about the overall tool, which is:

- Tool name and ID
- Strokes remaining
- Strokes made since last maintenance
- Percentage of remaining strokes (see Figure 4)

This initial information gives a very good overview about the tool condition as-is. The percentage of the remaining strokes allows an initial estimation for the maintenance employee to decide how to proceed with the tool after the scheduled maintenance or repair. Is it an older tool that should get more attention in the next runs or is it a new one, that just gets regular maintenance? The overall tool information is retrieved by scanning the marker on the top-side of the 5-fold-cut-out (see Figure 7). The marker overlays the information badge at a readable and well-defined position over the tool. A good user-experience and precise overlay of virtual information is dependent on precise markers.

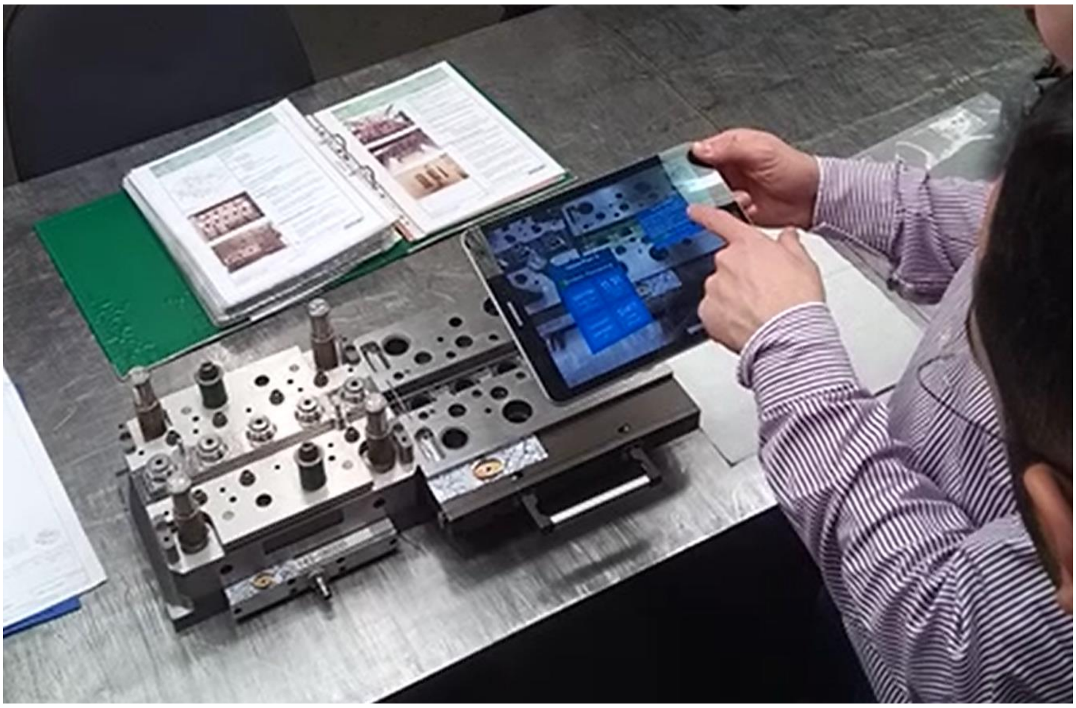

Figure 4: Usage of the PHI-AR-Viewer prototype on the shop floor with real tool

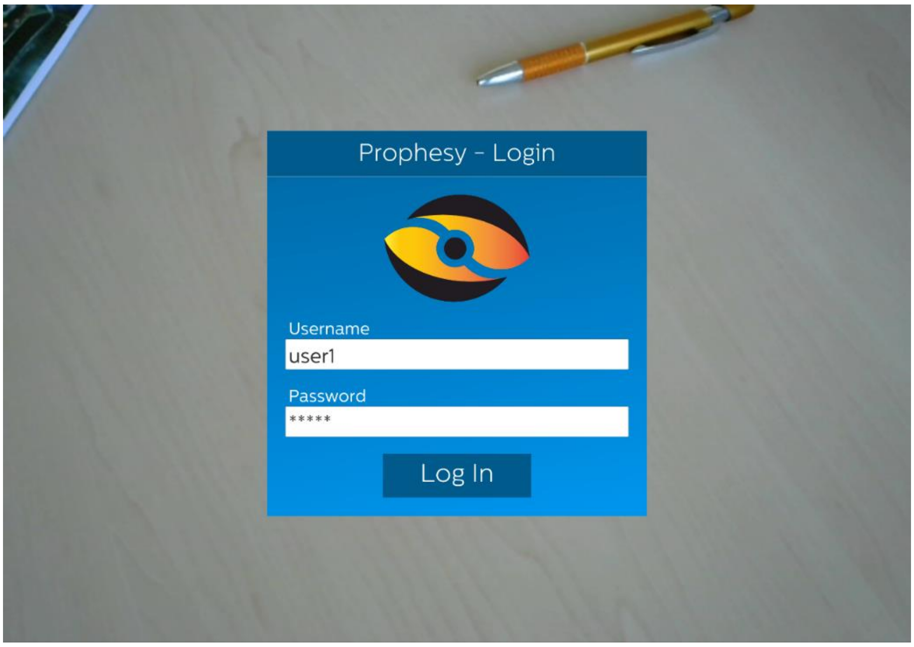

Figure 5: PHI-AR Viewer Login page for access and authentication

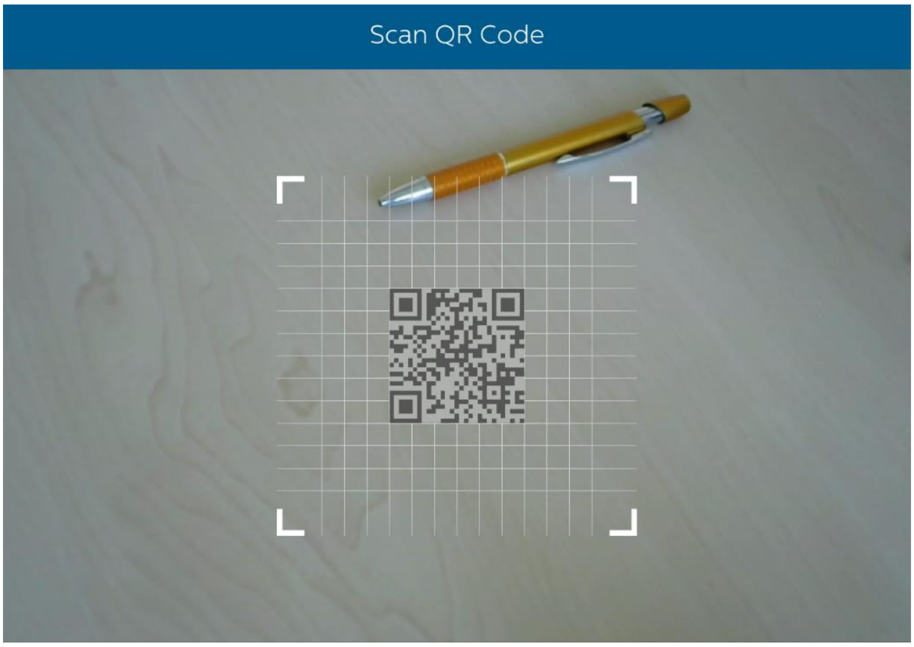

Figure 6: QR-Code scan to identify the tool and request tool data

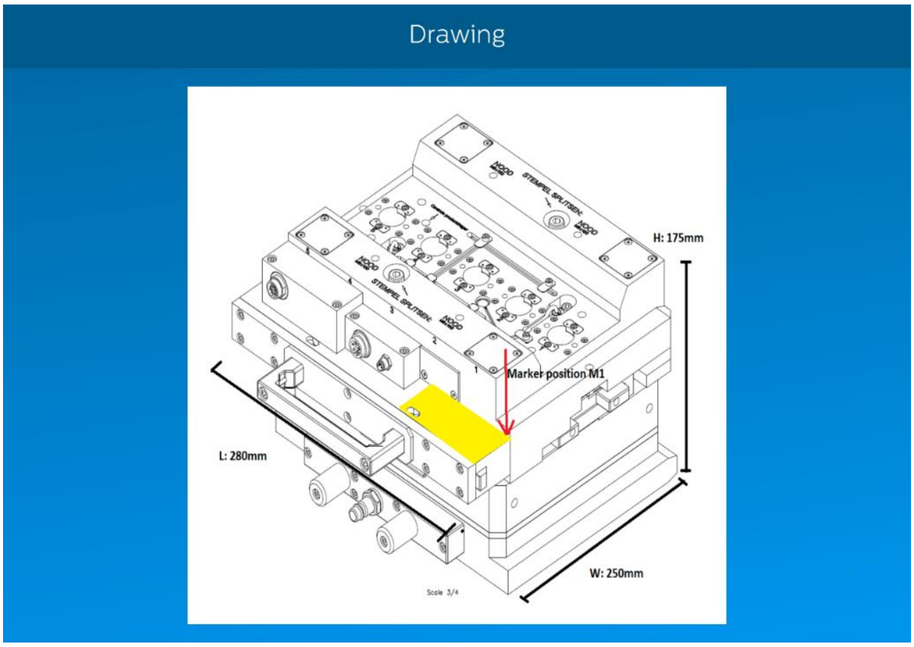

Figure 7: The previously defined marker position references the tool in the 3D scene

Figure 8: Example overview of an 3D printed tool dummy

3.1.2 Description of the PHI-AR-Viewer (lower tool part)

When the tool shop engineer disassembles the tool and scans the marker inside the tool of the lower part, he receives information about its main and critical parts: The punches of the 5-fold-cut-out tools.

An overview table gives the maintenance technician quick information about the overall status of the lower tool part:

- Strokes made since last maintenance
- Percentage of remaining strokes (of the worst wear part)
- Amount in stock inventory
- Spare part ID

The tool shop engineers receive the following information per punch (so the worst health status per punch defines the overall tool status, because the tool breaks, when one of the punches is not working anymore):

- Wear part name
- Number of strokes since maintenance: Information about the last run length of the punch
- Percentage of remaining strokes: Indication of the health status
- RUL-prediction: The main PROPHESY result, that gives an indication about remaining useful life of this specific punch
- Spare part ID: to identify the right spare part
- Stock location: To find the location of the right spare part
- Stock inventory: the amount of spare parts
- Comments
- A signal lights visualization in green, yellow and red to identify very critical wear parts quickly

With the information given per wear part, the tool shop technician can easily identify critical parts of the tool and can assess the remaining useful life. Also parts that need to be replaced soon can be identified without much effort. Since with Augmented Reality tracking a direct connection among data, status and real part position is given, failures in replacing the parts will be reduced to the minimum.

3.1.3 Description of the PHI-AR-Viewer (upper tool part)

The upper tool part holds the die-plates. For the die plates, the same information exists for the maintenance technician as for the cutters':

- Wear part name
- Number of strokes since maintenance: Information about the last run length
- Percentage of remaining strokes: Indication of the health status
- RUL-prediction: The main PROPHESY result, that gives an indication about remaining useful life of this specific die-plate
- Spare part ID: to identify the right spare part
- Stock location: To find the location of the right spare part
- Amounts in stock: the amount of spare parts
- Comments
- A signal light visualization in green, yellow and red to identify very critical wear parts quickly

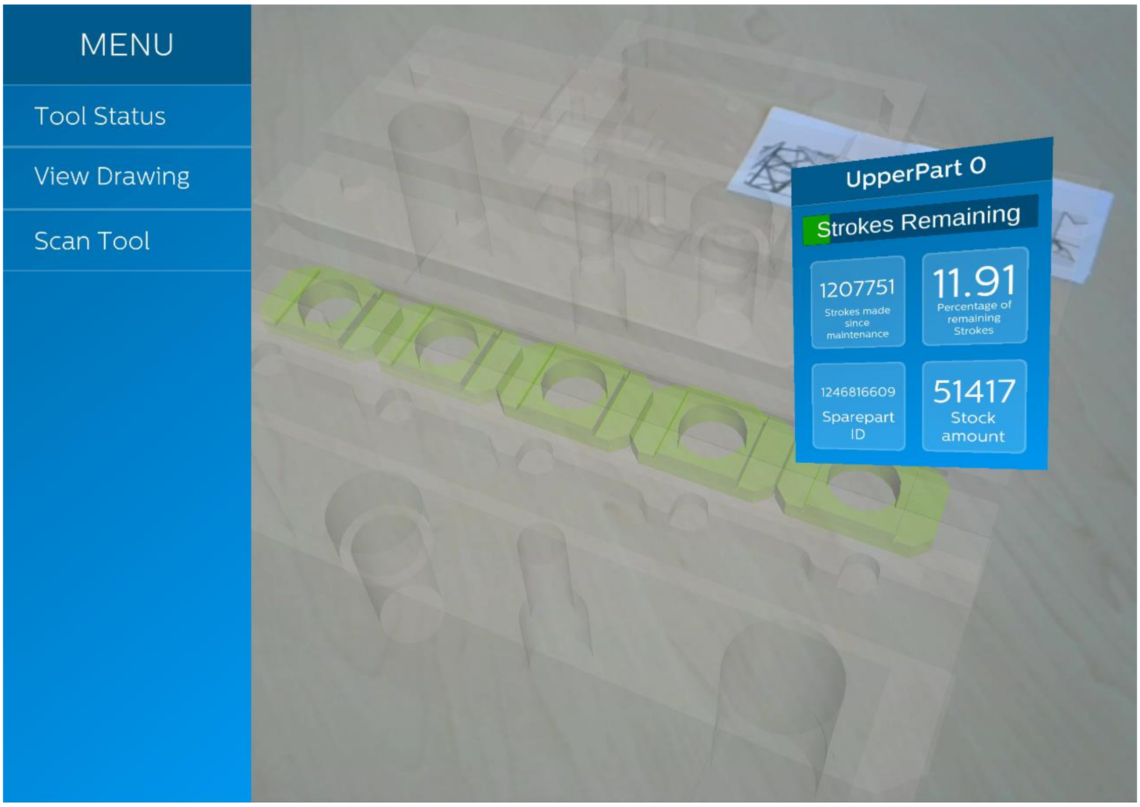

Figure 9: Example for the information retrieved from the upper tool part and main menu (dummy data)

Figure 10: Detailed information about the die-plate (dummy data inserted, no real tool shown)

4 Conclusion and Future Outlook

WP5 is devoted to providing visualization and augmented reality services for remotely-supported predictive maintenance processes, built into the PROPHESY-AR architecture. D5.4 describes the PHI-AR-Viewer as a software tool for training and knowledge sharing with Augmented Reality features. The requirements for the PHI-AR-Viewer have been derived from the Philips use-case 3 and its demonstrator described in D5.1 in more detail.

For the up-coming version (D5.5, M30), several optimizations and integration steps are to be done:

- Connection of the PHI-AR-Viewer to the PROPHESY-PDM data sources for live and real-time data;
- UI design improvements;
- Definition of steps for re-configuration to other tools and data sources than the 5-fold-cut-out.

The initial version of the PHI-AR-Viewer was successfully tested and demonstrated at the PROPHESY integration meeting in Drachten, Netherlands in January 2019.