Factory Maintenance Application Using Augmented Reality

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ABSTRACT

Tissue converting lines represent one of the key plant in the paper production field: with them, paper tissue is converted into its final form for domestic and sanitary usage. One of the key points of the tissue converting lines is the productivity and the possibility to follow conversion process at relativity low cost. Despite the actual lines have yet an high productivity, the study of the state of the art has shown that choke points still exist, caused by inadequate automation. In this paper, we present the preliminary results of a project which aims at removing such obstacle towards complete automation, by introducing a set of innovations based on ICT solutions applied to advanced automation. In detail, advanced computer vision and video analytics methods will be applied to pervasively monitor converting lines and to automatically extract process information in order to self-regulate specific machine and global parameters. Big data analysis methodologies will be also integrated to obtain new knowledge and infer optimal management models which could be used for the predictive maintenance. Augmented reality interfaces are being designed and developed to support converting line monitoring and maintenance, both ordinary and extraordinary. An Artificial Intelligence module provides suggestions and instructions to the operators in order to guarantee production level even in case of unskilled staff. The automation of such processes will improve factory safety, decrease manual interventions and, thus, will increase production line up-time and efficiency.

CCS CONCEPTS

• **Human-centered computing** → *Interface design prototyping*; *Visualization design and evaluation methods*; • **Applied computing** → Command and control.

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KEYWORDS

tissue converting, augmented reality, artificial intelligence, factory of the future

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1 INTRODUCTION

Tissue converting requires complex transformation lines, consisting of a succession of machines with a total of around 10,000 components. The ordinary and extraordinary maintenance of the plant, therefore, requires a thorough knowledge of the parts and their operation, which goes beyond the skills of the maintenance teams ordinarily available at the processing centers. Furthermore, the monitoring of the production line during its operativity, the identification of anomalies and the implementation of the necessary troubleshooting procedures, require the use of technicians with considerable experience to minimize the time and downtime [Cigolini* and Rossi 2004; Noè and Rossi 2003]. While a significant issue is represented by the development of ICT solutions based on vision and video analytics to monitor the production process and allow the self-regulation of critical parameters [Caputo and Pelagagge* 2005], in this paper innovative technologies based on augmented reality are developed to support the operator and remote assistance center of the manufacturer of the line in performing efficiently and quickly those procedures that cannot be achieved except with human intervention. In particular, through the vision systems developed it is possible to implement automatic regulation and self-compensation mechanisms; however, the final wear of the components cannot be avoided, as well as the interventions of the operators necessary for their replacement [Rambach et al. 2018].

This paper describes the software prototypes created for image recognition as part of an augmented reality system for supporting the maintenance and control of a tissue transformation line. Once the requirements and specifications were analyzed and drawn up, the development of software prototypes was carried out. The paper is structured as follows: in section 2 the state-of-the-art for augmented reality solutions is presented along with the specifics on the chosen framework and devices. Subsequently, in section 3 firstly use case analysis is presented in order to derive the idea of the type of problem to face. Secondly, the prototype implementation is shown. Then, in section 4 some preliminary results, both from the lab and real factory activities are presented. Finally, some conclusions are drawn.

2 MATERIALS

There are various Software Development Kits (SDKs) for augmented reality, actually used for the development of applications for smartphones, tablets and smart glasses. The main functions offered by these platforms are, firstly the recognition of images and objects and then after the identification, its tracking through the use of SLAM technology (Simultaneous Localization And Mapping) and NFT (Natural Feature Tracking). Thanks to these, developers can produce digital content, inserted in the shooting scenes, which can interact with the surrounding environment.

Although most SDKs are designed to operate in specific contexts and on specific hardware, thanks to the spread of augmented reality technology it is possible to find more and more often SDKs supporting different systems and technologies, thus creating more flexibility.

The applications that can be developed in this area can be divided, mainly, into two groups: those based on the use of markers and those based on location. Marker-based applications work mostly with image recognition, using the device's camera to recognize predetermined markers or patterns, and, once the pattern is recognized, the application overlaps its digital content. This type of application also supports the recognition of three-dimensional markers, such as small objects. On the other hand, location-based applications do not require markers but use localization technologies, such as the GPS signal, associated with accelerometers to establish the position of the device and create digital content[Lima et al. 2017].

Most software for the development of augmented reality applications are released under license, free or commercial (and therefore for a fee); however, there is also open-source software [Billinghurst et al. 2015; Syberfeldt et al. 2017]. However, due to the features and support offered, we are oriented towards using a licensed framework.

In addition to the functionalities offered, it is possible to distinguish the various SDKs taking into account the mobile platforms and, above all, the supported smart glasses. All the frameworks support the development of applications for Android and iOS (but exceptions can be found), while support for smart glasses (among the ones available on the market), is not guaranteed by all the frameworks.

An analysis of the limits and potential of augmented reality systems for the management and use of contents was carried out, also based on existing works in the literature. In particular, the analysis was divided by distinguishing those that are usable devices, typically smart-glasses and smartphones, and the development frameworks for the integration and use of contents [Fraga-Lamas et al. 2018].

2.1 Wikitude

The final choice on the framework to be used for the project fell on Wikitude SDK [GmbH 2019], a software developed since 2012 by the company of the same name, active since 2008. This SDK includes, among other things: image recognition and tracking, rendering of 3D models, the possibility of video overlays and the creation of location-based augmented reality content. Besides, in 2017, Wikitude launched its SLAM technology that allows the recognition and tracking of objects, as well as instant tracking without the use of markers. The platform is available for Android, iOS and Windows systems, and is optimized for use with different smart glasses models.

Furthermore, Wikitude was the first publicly available application to use a location-based approach to augmented reality. It is a commercial solution, but a full trial version is available, albeit with some minimal limitations. Wikitude also provides a web service, called Wikitude Studio, which simplifies development procedures.

2.2 Devices

Currently, there are many devices useful for the use of augmented reality content. The first devices worth mentioning are common smartphones. Their widespread diffusion has meant that around 90% of the European population owns at least one, and the current models have increasingly powerful and performing hardware features.

Tablets, on the other hand, do not have such a widespread diffusion, also given their size. The main functionality of these devices concerns the productive sphere, exploiting applications aimed at the drafting of documents, as well as web browsing or e-mail consultation. They also find use in the use of multimedia content, such as photos and - above all - videos due to the large size of the displays. The last category of devices indicated for the use of augmented reality content is represented by the see-through smart glasses; this type of device allows the user to see content (text information, images and even more or less interactive objects) positioned directly on the scene observed with his own eyes, thus increasing the amount of information available in real-time. Among the models of smart-glasses analyzed, three were the most significant and efficient ones: *Microsoft Hololens*, *Meta 2* and *Epson Moverio*.

3 METHODS

3.1 Use cases

Once both the current state of maintenance and technical assistance was established, and the various possible intervention situations relating to the production line identified, it was decided to determine the circumstances that could be set as use cases of the technologies and applications implemented. Later on, more precise specifications of these use cases were established, to be able to verify and validate what was planned and implemented in the real environment. We have mainly identified three macro-categories of intervention, which could be linked to the use cases of the realized technologies, which are:

- Monitoring of the recipes (i.e. parameters) of the line and live view of the cameras
- Ordinary maintenance with documentation and video access
- Troubleshooting

As for the first category, using the device as a control tool gives real-time access to all the parameters of the machine and their modifications, and to the monitored performance of the production line (e.g. line speed). This type of display shows a series of data available on the operator panel and obtained from the various machine PLCs. This situation can be critical also in light of the possible variations that the technicians have made (based on experience, or for other reasons) to the recipe, so the actual real-time parameters can only be obtained by accessing the values of the machine through the PLC. Also for this category of intervention, preventive identification of the area to be accessed will be provided by limiting and isolating the parameters to that specific area.

3.2 The prototype

The developed prototype aims to generate a tool for recognizing features of **target objects** (targets from now on) and provide the user with a set of Augmented Reality information (AR content) once the recognition took place. In particular, each target is used to localize predefined areas of interest and enrich them with a series of multimedia files (i.e. videos, images and PDF) or real-time data (e.g. updated labels or through a hyperlink for visualizing complex content or charts) that will be available for reference.

The methodology included the development of a tool for the recognition of targets firstly in a controlled laboratory environment (see example in Figure 1), and subsequently within a real factory environment, which was constituted of more targets (i.e. separate rooms of the tissue converting machine), as shown in Figures 2 and 3.

In the factory environment, to optimize the targets recognition, two separate acquisitions bringing to different *.wto* collections were created, one for each room involved, and containing only the AR content related to the specific target.

The developed prototype is composed of two main components that are in charge, respectively, to recognize the targets in order to place the AR content and to recover remote data. Target recognition and AR content displacement are entrusted to Wikitude framework through the development of the relative AR scene. The AR scene is built starting from the pictures of the targets, acquired through a simple smartphone, exploiting Wikitude Studio, which is a dedicated program in the Wikitude framework. From the acquired images, a feature point cloud is generated; despite the initial limit of 50 pictures, the point cloud can be extended and refined by uploading further images. Once the point cloud is generated AR objects can be placed directly in a 3D environment relative to the point cloud itself, an example of the laboratory environment reconstruction is shown in Figure 5. Wikitude allows five types of AR content: *(i)* Images, *(ii)* Videos, *(iii)* 3D objects, *(iv)* Labels and *(v)* Buttons. The AR scene is then downloaded as an offline application and integrated with the prototype component committed to the remote data recovery; indeed, the downloaded application can be easily modified through a common editor or an IDE such as Android Studio (concerning AR Android application). Aiming at further enriching the AR experience and providing interactive functionalities, AR content is addressed, exploiting its unique ID given by the framework, and edited adequately on the basis of real-time data of monitored parameters recovered from a remote database; for instance:

- specific AR content is colored differently depending on the actual parameters (e.g. defective parts colored in red, as shown in Figure 1 (top));
- labels are modified in order to report meaningful information (e.g. live values such as the *rpm* values of a working engine, as shown in Figure 4);
- interactive buttons are activated depending on the retrieved parameters (e.g. allowing to show specific maintenance assistance video, as shown in Figure 1 (bottom)).

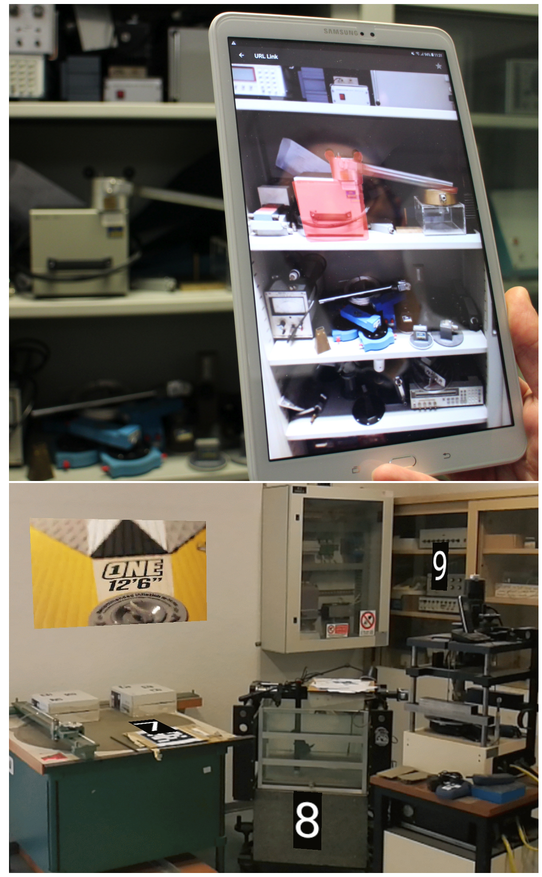

Figure 1: Laboratory environment: (top) an example with a super-imposed interactive object highlighted in red; (bottom) screenshot from the application of another laboratory scenario, with super-imposed interactive objects, a playable video on the top left and numerical tags.

4 RESULTS

At this preliminary stage of the project and research, the devices that has been chosen were a Xiaomi Mi 5S Plus smart-phone and a Samsung Galaxy Tab S5e tablet. The camera characteristics of the two devices are shown in Table 1. At the same time the portability over a smart-glass model is under achievement, the selected one has been the Epson Moverio BT-350.

Figure 2: Running prototype application showing an example of augmented reality implemented on a real operating tissue line (cutting blade section). Highlighted in the yellow circle is the interactive label tagged in the real environment (top); a contemporaneous screenshot from the running application (bottom).

Table 1: Camera characteristics of the two devices.

Device	Xiaomi Mi5s Plus	Samsung Galaxy Tab 5Se
Resolution (MP)	13	13
Aperture	f/2.2	f/2.0
Focal Length (mm)	34.88	26
Sensor format	1/4.3"	1/3.4"

In Table 2 and 3 the performances of the application are listed, depending on the number of images used for the point clouds generation, for two different scenes. For each scene, the performances were measured using two different configuration: initially without obstacles, then in presence of an occluder between the user and

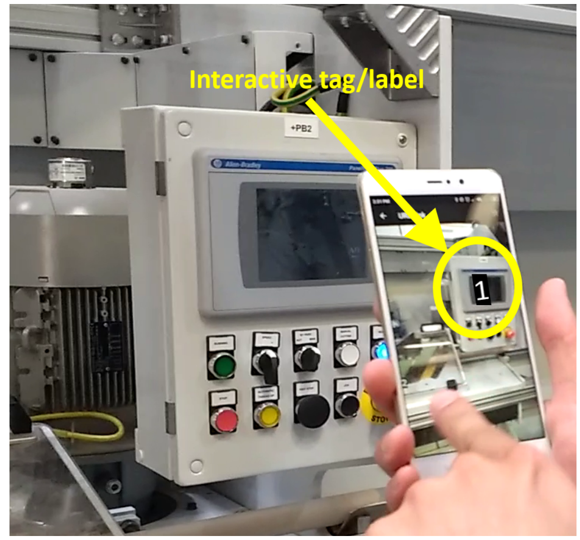

Figure 3: Second room of the real tissue converting machine used for the deployment of the prototype. Highlighted in the yellow circle is the interactive label tagged.

Figure 4: Sample of the application while showing real-time dynamic values (e.g. *rpm* values of the working engine) as AR objects.

the target. In addition, the size of the point cloud file generated by Wikitude is listed. The efficiency measures how many times the target is recognized by the application (i.e. $recognizedTargets$). The recognition has to occur within a predefined slot of time, which for the experimentation is fixed as $1sec$. The number of recognition attempts (i.e. $totalAttempts$) is the same for all the experiments. Efficiency is computed as: $Ef = recognizedTargets/totalAttempts$.

In Table 4 the application stability is described, for the scene no. 2. This stability has been measured in the following way: at first, the targets in a scene are recognized by the application with the user standing in front of it, subsequently the user moves with a

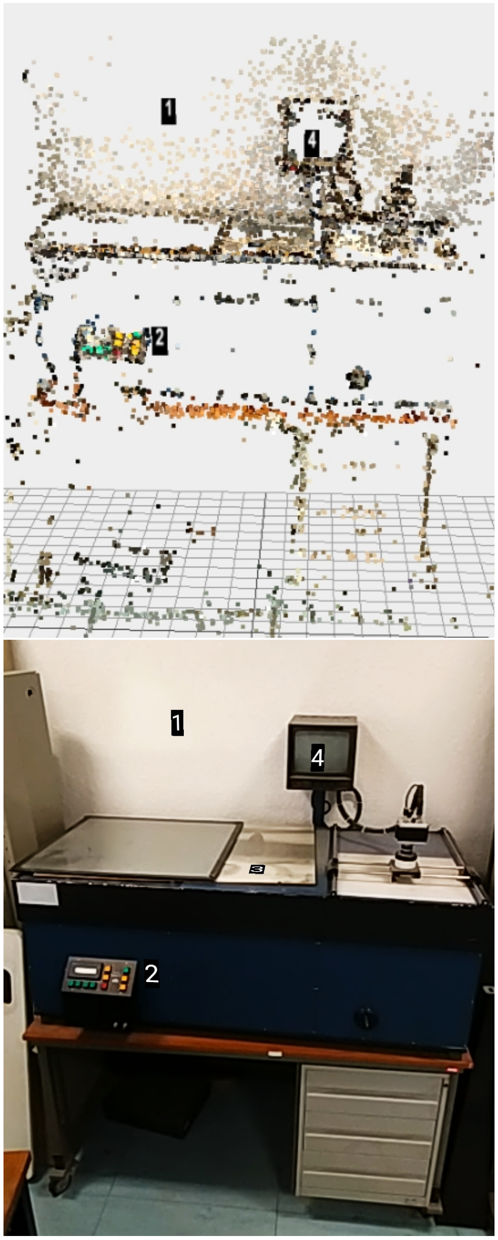

Figure 5: Reconstructed point cloud of the laboratory experiment with AR content inserted as labels from Wikitude Studio (top). Actual visualization from the interface of the same scene with AR content shown after the target recognition (bottom).

steady speed along a predefined path in the scene, and we count how many times the targets are lost. Thus stability is computed as: $St = 1 - (lostTargets/totalRecognitions)$.

These results show a better behavior for models built with more images, where the application performs better even in the presence of obstacles. It should be noted that adding more images produces a progressive slow-down of the application, so a compromise must be reached between usability, efficiency and robustness.

Table 2: Scene no. 1: point cloud file dimension and application performance (with and without occlusion) vs. the number of used images. (S is for smartphone, T is for tablet)

Number of images	Point cloud dim. (kB)	Eff. (%)		Eff. w/ occl. (%)	
		S	T	S	T
20	831	80	40	40	50
30	1414	90	50	95	55
40	2206	90	55	100	65
50	2875	100	70	100	75

Table 3: Scene no. 2: point cloud file dimension and application performance (with and without occlusion) vs. the number of used images. (S is for smartphone, T is for tablet)

Number of images	Point cloud dim. (kB)	Eff. (%)		Eff. w/ occl. (%)	
		S	T	S	T
20	339	50	20	70	30
30	825	55	25	75	30
40	1548	75	50	80	50
50	2207	85	60	85	60
60	2280	90	80	95	80
70	2795	100	90	100	90

Table 4: Scene no. 2: application stability. (S is for smartphone, T is for tablet)

Number of images	Stability (%)	
	S	T
20	0	20
30	20	35
40	75	80
50	85	90
60	90	95
70	90	95

5 CONCLUSIONS

In this paper, we described the software prototypes realized to perform image recognition for the visualization of scenes in an augmented reality system used to support the maintenance and control of the transformation line of a tissue converting factory.

Initially, we described the software framework chosen for augmented reality. Subsequently, its operating principles and possible uses of the acquired images for the recognition of objects or scenes were described.

Following this, the actual functioning of the software prototype was described. In particular the initial one implemented and used to perform laboratory tests, first by recognition of single targets and then on complete scenes; finally the extended implementation for the recognition in the real factory environment.

As a numerical result, the performance and robustness of the developed prototype has been analysed and reported. At this preliminary stage of the prototype the results show a very promising trend in terms of usability and robustness. The extension of the acquisitions and reconstructions will follow as well as the refinement and the increase of AR content available.

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