https://doi.org/10.2352/ISSN.2470-1173.2018.2.VIPC-264

Improving the efficiency of on-site operators in utility management: combining HoloLens and AR for real-time check of electricity meters

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Abstract

The rapid evolution of sensors and devices capable of facilitating the adoption of augmented reality (AR) tools in the everyday work routine has motivated many actors of the public sector and private industry to explore the possibility of optimizing the workflow of their employees. Besides the entertainment and gaming fields, AR tools are currently used in a large number of professional application areas that range from maintenance of equipment to environment acquisition, modeling, and design.

The objective of this paper is to present a use case for AR in the context of utility management, where one of the major Italian operators in the electricity sector has decided to improve the efficiency of the workflow of its employees through the adoption of an AR solution. Relying on the superimposition of virtual information on the acquired visual scene, the workers can obtain a complete overview of the area to be inspected. Furthermore, the use of wearable equipment allows for a seamless integration in the maintenance procedures, also complying with the prevailing safety regulations.

Introduction

As the term suggests, Augmented Reality (AR) refers to the combination of the real and virtual worlds, considerably differing from the concept of Virtual Reality (VR) where the user is entirely immersed in a computer-generated world. As far as AR is concerned, the aim is to overlay the real scene with a set of additional information, which are computer-generated and provide a complementary description of the observed environment.

Thanks to the availability of low-cost and compact hardware capable of guaranteeing sufficient computational power, AR is becoming more and more widely adopted in many entertainment and professional fields. Since the first AR application presented in the late 1950s, when Morton Heilig introduced Sensorama [1] to extend cinema to all five senses, and the first HMD (Head Mounted Display), or the Ultimate Display patented in 1966 by Suntherland [1], the scientific community has kept investigating the topic. However, it is in the last decade that we have experienced a giant leap in this research area. Thanks to the commercialization of smartphones and smartglasses, which effectively combine computation power and wearability, various companies have decided to invest in AR applications.

Besides the choice of the hardware, the main problem that a developer has to face while making AR applications is to retrieve the information about where and how to position the computer-generated information on the screen. The most common solutions to link the real and virtual worlds rely on two different principles: location-based [2] and marker-based applications [3].

The first category exploits the capability of the device to understand its position in the world through location data as GPS sensors, and its orientation thanks to gyroscopes, accelerometers, and magnetometers. Although the precision of the GPS does not allow for a smooth integration of fine and detailed computer-generated information in overlay to the scene observed by the camera, such solutions are widely adopted especially outdoor where the accuracy of the GPS signal can guarantee a good precision in terms of spatial resolution.

The second category of methods refers to the possibility of relying on the video camera and is mostly based on the detection of features of interest as well as pre-defined patterns captured by the camera in real-time. This includes barcodes, QR codes, as well as real objects, which are of interest for the specific application scenario. The use of anchor elements gathered from the real world, allows for a higher precision when performing the overlay of the computer-generated information on the real scene. Moreover, with the advent of the new generation of devices supporting AR, as for example HoloLens[1] this operation is further simplified, thanks to the capability of the sensor of combining visual and sensorial signals, thus improving the positional tracking in the world coordinates.

In this paper we present an application scenario where HoloLens is actively used by the employees of a utility management company, for maintenance operations of electricity meters.

The paper is structured as follows: in the next section an overview will be provided about the major application domains of augmented reality. This includes both leisure, professional, and educational activities. The proposed solution is then discussed, followed by a detailed description of the implemented pipeline. Experimental results and validation details are also reported, together with a brief concluding discussion about the achieved results and the future perspectives.

Common application domains and AR solutions

It is a matter of fact that augmented reality applications will be pervasive in the coming years, helping us in obtaining directions, improving our experience in shopping and traveling. This is made possible thanks to the availability of new sensors, which, joined with the ever-increasing computational power of

[1] *By Microsoft, www.hololens.com*

mobile platforms able to support advanced artificial intelligence algorithms, is significantly helping guarantee an almost seamless integration of the real and virtual worlds. Although smartphones are the most widespread devices and the integration of AR toolkits is being offered to developers, a few companies have already paved the way for more immersive AR experiences, thanks to the commercialization of smart glasses, capable of sensing the observed world in real-time and providing immediate feedback to the users wearing them. In the next paragraph we will report how AR can be integrated in a few relevant application areas, including the domain we target in this paper, namely the supervision and maintenance of equipment.

Advertising and marketing

One of the most promising areas in which AR can have a groundbreaking impact, is the retail sector, mostly thought as a mean to improve the customer's experience [4]. Companies are seeking new ways to engage new potential customers, and a variety of AR applications has been proposed and implemented, in order to present to the user virtual objects and advertisements that can be explored and virtually manipulated using natural movements and hand-gestures. For example, cutting-edge automotive campaigns are displaying full-size AR virtual cars in shopping centers and public areas. A marker-less interface allows people to toggle virtual buttons, open doors, fold seats, and rotate virtual model vehicles. In the case of smaller products, such as toys, potential customers can now check them out virtually in stores and kiosks world-wide, sometimes with integrated 3D animations. Somewhat more sophisticated campaigns allow to view, rotate and resize virtual models of products, such as furniture, anywhere in their environment, so that they can gain a more accurate impression of how the item would complement their current furniture. The virtualization of contents is also an important milestone in fashion and apparel, where the current trend is to wear clothes virtually through smart mirrors, able to capture the person's appearance and dress him/her up with items available in the shop database [5]. Such solutions allow customers accessing a convenient way to try on new clothes, moving freely, and without the hassle of waiting for a physical fitting room.

Travel and leisure

One of the first applications made available to the consumer market is the integration of AR information exploiting the GPS data for tourism applications [6]. The availability of a large collection of GPS coordinates from relevant Points of Interest on the planet (e.g. monuments and buildings), can be used to create AR contents and enhance the visitors' experience providing, e.g., additional historical and artistic information. In fact, most smartphone users are already accustomed to using the onboard GPS while driving, when looking for locations and services. Beyond the simple sensory expansion of these existing services, AR can lead to newer and more comprehensive interfaces showing tourists relevant data related to the visited area and its surroundings, by simply checking their screens. In the automotive sector car manufacturers have plans to complement vehicles with built-in monitors, and AR windows providing information with virtual-holographic markup of the surrounding real world.

Architecture and Construction

Augmented reality applications can be used to allow designers, workers, customers and potential employers to actually explore the real-world site or building under construction. AR allows visualizing not only how the final output could look like, but can also retrieve important data about the underground layout of the power lines and pipes. Especially this last element can facilitate the workflow of electricians and other professional figures who can now have the complete picture of the ongoing and planned activities, and it can help dealing with potential changes that might occur in the project. An oft-cited use case of augmented reality is related to the 2011 earthquake in New Zealand. The University of Canterbury released CityViewAR [8], which enabled city planners and engineers to visualize buildings that were destroyed in the earthquake.

Augmented reality and utility operators

All the items mentioned in the previous paragraphs represent in fact useful elements that can be considered in any AR applications. In this paper we refer to a specific category, the utlity management companies.

Utility companies are among those subjects, who are always looking for new ways to increase the efficiency of their operators. In fact, as they are dealing with the coverage of wide and heterogeneous territories, the availability of advanced visualization tools can be helpful in many different ways. It would on the one hand speed up the intervention on the field, but it could also guarantee an improved level of safety. Nowadays the most common and widespread solutions in this area are location-based services, which let the operator see the electric lines, pipes and others objects around his position; these objects are displayed virtually and superimposed in the field of view of the device (see an example in Figure 1). The possibility of *seeing through dirt* is actually a giant leap in terms effectiveness and promptness of the intervention. The early results are sparking widespread interest, driven in part by the growing excitement and investment in AR applications. As more companies and organizations see the potential of these applications in terms of savings and increase in productivity as well as job safety, especially the adoption of hands-free devices may set the new standard for avoiding utility breaks while digging, and preventing errors when marking line locations on asphalt, concrete, or lawns [9]. Another important AR application for utilities is the remote assistant or, more realistically the possibility to contact a remote expert directly from the position where the fault has been identified. The real change is here the fact that the operator can share with the remote expert what he is actually seeing, while the latter can share information in the form of holograms, images or 3D models. A beta application has also been released as a plugin for the Skype service, and integrated with HoloLens, although many others companies are actively working on their own applications.

FIGURE 1. SUPERIMPOSITION OF VIRTUAL INFORMATION FOR REAL-TIME INSPECTION OF UTILITY INFRASTRUCTURES.

Proposed solution

In this section we present how one of the major Italian operators in the electricity sector has decided to improve the efficiency of its in-the-field operators through the adoption of AR and HoloLens.

The sensing equipment

HoloLens is a standalone device able to deliver processing capabilities compatible with many notebooks and tablets. It embeds an Intel Atom processor and features 3D spatialized sound, Wi-Fi connectivity, a depth and colour camera in line with the specifications of its predecessor Kinect, and offers a 120 degree spatial sensing system, a fleet of gyroscopes and accelerometers, as well as a see-through screen for each eye, all assembled in a lightweight portable wearable system. Along with its CPU and GPU, the unit features a Holographic Processing Unit (HPU), which is responsible for the processing that integrates real-world and holographic data. The device is able to track its movement, capture the 3D surrounding environment, and is also able to understand hand gestures performed by the user wearing it.

Compared to other devices with similar functionality, HoloLens has shown better integration capabilities for the specific application, especially thanks to the gesture recognition features, and the wider field of view, that, for example, are not available in other smartglasses commercialized by the competitors. Both the scientific community and the industry have however big expectations for the immediate future, as other sensors are being developed and made available on the market with promising performances and improved functionalities.

Matching AR and on-site operators' duties

One of the most critical tasks that workers operating in the electricity sector face, is the prompt search and fix of faulty electricity meters, usually located in ad-hoc areas of condos, offices, and commercial centers. The presence of dozens of meters often limits the rapid intervention due to the difficulty in associating the meter with the corresponding owner (client). The identification of the right meter requires thus a slow and repetitive job where the worker has to scan every meter barcode and verify the association of the customer, querying the company database.

However, another requirement has to be met, namely the compliance of the intervention with respect to the prevailing safety regulations that require the use of gloves and helmets in the first place. In the past years, this particular problem of meters checking has been in fact addressed using smartphones and other types of handheld devices. However, the approach turned out to be impracticable as the use of a handheld device severely limits the mobility of the worker, as one hand (often both) is required to operate the smartphone, making the intervention rather cumbersome, due to the need of wearing and removing the gloves multiple times. This, together with the limited performance of the detection and tracking, due to the instability of the phone, as well as to the limits imposed by the 2D vision of the camera, resulted in a poor quality of experience for the worker, who could not perceive a significant improvement in the trade-off between benefits and usability.

To improve the efficiency of the procedure, leveraging on AR would be the most desirable option, letting the worker go inside an electricity meter room and after a fast scan of the objects, the useful information is visualized in the form of a hologram in a single step.

To achieve this, in our implementation we rely on the information provided HoloLens to detect and track the meters positions in real time. After detection and thanks to the tracking capabilities, it is possible to compute the 3D coordinates where the hologram will be positioned in the virtual environment.

Furthermore, the head-mounted display provided by HoloLens smoothens the drawbacks of other implementations that rely on handheld devices, including safety, for a more comfortable experience both in terms of freedom, and stability of tracking. In fact, thanks to the 3D tracking, the main problem left is the detection of the electricity meter to obtain the 3D points in the HoloLens space, where the hologram with the relevant information will be positioned. All collected data is stored and reused, including the 3D model of the electricity meter room as well as the 3D position of each and every meter, to be used in further sessions and for workers' training.

Implementation

As far as the detection algorithm is concerned, and considering that the computational power of the device is anyway limited, after looking into the available literature and calibrating on the problem at hand, SURF features [10] and the Viola-Jones cascade detector [11] turned out to be the most suitable options to be investigated.

The advantages of SURF are the precision of the detection and the robustness to rotation. The algorithm, however, requires to be sufficiently close to the electricity meter in order to detect its salient features, thus losing the overall view of the whole scene. Furthermore, although faster than other local feature extraction algorithms, the computational load is not compatible with the overall real-time requirements of the application. In fact, the extraction of the feature points, the matching phase, and the homography computation, significantly increase the processing burden. Furthermore, scale issues may arise in case the distance of the meters varies, making it difficult to map the environment correctly. We have realized this is an issue due in particular to the nature of the object to be detected, which does not exhibit neither strong textures nor characteristic color patterns.

Eventually, the choice favored the Viola-Jones cascade detector. The algorithm, once properly trained, is capable of detecting multiple objects simultaneously, and the Haar-like features guarantee a good matching also at a longer distance, allowing for rapid scanning of the environment to be inspected. The main drawback is the limited robustness to rotation; this aspect, however, does not influence the performance significantly in our application domain, as the worker has to inspect the entire space moving inside it, therefore the meters are seen from a frontal perspective at least once.

Although performances are good, misdetections can occur; in such cases, the issue can be easily addressed by human intervention during the acquisition phase, as the system allows positioning the hologram in the corresponding location manually, thanks to the capability of HoloLens to understand gestures, and letting the cascade detector serve mostly as a first screening procedure.

Using the cascade detector, the center point of the meter is identified and the point can be located in the sensor 3D space, where the hologram with the utility information will be positioned. For this task, the capability of HoloLens to map the environment helps in associating also the depth information to the meter location. We can then trace a ray that intersects the center of the camera view and the central point of the meter to finally determine the coordinates where the hologram will be positioned, superimposing the relevant information. At this stage, we need to compute the orientation and scale of the hologram, starting from the distance of the electricity meter from the camera to determine the scale (meters have known size).

Two options are in this case possible. In the first case, assuming that the view is mostly frontal, the hologram would be oriented facing the camera. If on the one hand this could significantly simplify the overall system and reduce the computational burden, at the same time it makes it less appealing from the perceptual viewpoint. This is why it becomes necessary to make sure the holograms are properly positioned in the 3D world coordinates. Achieving this goal implies relying on the information provided by HoloLens and the capability to track the meters positions in real time, right after the detection. An example of the final output of the system is shown in Figure 2.

FIGURE 2. SAMPLE VIEW FROM THE APPLICATION USER INTERFACE.

Experimental Setup and validation

For the implementation, the cascade detector has been trained using the standard set of Haar-like features. The samples selection includes 500 positive images and 1000 negatives. In order to test the robustness of the detector, two different training procedures have been conducted. In the first one, the entire meter was used, while in the second one only the upper part of the meter was selected, as the bottom area is mostly flat. This second version achieves better detection performances, but only if the acquisition is close enough, in the range of 1.5m, while for the first implementation the scanning could be conducted at 2m and above depending on the illumination conditions.

FIGURE 3. RUNNING THE CASCADE CLASSIFIER ON AN UNKNOWN SCENE.

For the validation, the obtained results mostly depend on the capability of the classifier in detecting the highest number of meters possible. This is very scene-dependent and may severely alter the subjective perception of the end-user. In fact, a correct detection allows for a seamless interaction of the operator with the environment, with limited or no manual correction of the acquired data. An example of the classifier run on an unknown scene in shown Figure 3, where it can be seen that, despite the overall performances are quite good, the detection of some electricity meters is inaccurate, and manual adjustments are necessary to guarantee the correct positioning of the hologram.

Concluding remarks and future perspectives

In this paper we have proposed a novel solution commissioned by a major utility operator in Italy aimed at facilitating the on-site maintenance operations of electricity meters. The prototype, based on the use of HoloLens, is a first milestone in the definition of new standards for human machine interaction and seamless integration of real and virtual information for maintenance purposes. In fact, although the current implementation stage is complete and a fully functional demonstrator has been finalized and validated, the next objectives include, besides detection and information visualization on-site, the capability of acquiring and mapping the observed environment, so as to train the personnel offline for an even prompter and efficient intervention.

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