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Augmented Reality for Field Maintenance of Large Telecommunication Networks

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Abstract

This paper describes the experimental activities performed to study the possibility of adopting augmented reality technology in field maintenance of large telecommunication networks. First, the presented work is framed into the larger scope of operations support and the proposed approach that combines agents, workflows and augmented reality is motivated. Then, the reference application scenario is detailed to highlight its peculiarities and intrinsic challenges. Finally, performed experiments on specific network equipments are described, and a draft assessment on the applicability of the proposed approach is outlined.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [INFORMATION INTERFACES AND PRESENTATION]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1. Introduction and Motivation

The costs of so called *operational processes*, such as the processes intended to provide new services to customers or to remove network malfunctions, represent an important part of the daily costs of telecommunication operators. The importance of solutions aimed at reducing costs of operational processes is highly relevant and unquestionable. One proven way to obtain such a reduction it is to adopt software systems that effectively support the activities of the field maintenance workforce. For example, it is well known that software systems aimed at removing malfunctions of network equipments at customers' premises have direct effect on the reduction of operational costs.

In order to support its workforce of over 2,000 technicians constantly engaged in actions related to repairing network failures and malfunctions, Telecom Italia designed and implemented a specific software system called *Wizard* [TLGS09]. Wizard has been in constant and effective use since 2007, and its value in daily operations is recognized and appreciated within the company. Wizard is considered today a cornerstone in the management of one of the most penetrating broadband networks in Europe, which counts 6.9 million retail broadband accesses and 13 million retail connections over copper and optical fibers in 2013 (data available at http://www.telecomitalia.com from the official company profile).

From the practical point of view of field technicians, Wizard guides them in a complete, integrated and exhaustive way throughout all steps of problem-solving activities. Wizard provides technicians with a direct connection with back-end systems responsible for all tasks related to network and service management. Technicians agree that Wizard is a direct responsible for significantly reducing the duration of problem-solving activities because it monitors the activities that they perform in real time, and because it can proactively trigger suitable crosschecks with relevant *OSS* (*Operations Support Systems*).

From a methodological point of view, Wizard is considered a valuable tool to support network and service management because it enforces the use of a formalized notation based on *workflows* to represent the *operative knowledge* of the company. The methodological approach that Wizard promotes enables a significant reduction of durations and costs of maintenance activities because technicians are provided with a friendly and unambiguous description of the activities that they are demanded to perform.

Wizard provides its services to field technicians via *FAS* (*Field Access Service*), a specific software system that technicians access via off-the-shelf Android smartphones and tablets. Field technicians use Wizard to have their work guided and assisted in real time with tight integration with back-end systems and related procedures.

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Today, Wizard is the primary means to support the work of field technicians, and it is in everyday use by technicians to manage an average of 5.000, and a peak of 15.000, maintenance *work requests*. Such work requests are non-trivial maintenance tasks that directly involve technicians—and sometimes customers—and that often allow direct resolution of access network malfunctions.

This paper reports on experimental activities performed to enhance Wizard with *AR* (*Augmented Reality*) technology to provide direct help to field technicians. Section 2 details the proposed approach and the application domain that was selected to study. Section 3 provides details on the performed experiments in a specific scenario that deals with the maintenance of two types of network equipments. Finally, Section 4 gives a short recap of the results of experiments and it presents some future directions of development.

2. Proposed Approach and Target Application Domain

Wizard was developed on top of *WADE* (*Workflows and Agents Development Environment*) [BCG08, CQPS08, BCG12], the *BPM* (*Business Process Management*) platform that evolves the popular agent platform *JADE* (*Java Agent and DEvelopment framework*) [BCG07,BPR01]. Both platforms are open source and they share the support mailing list and the Web site `http://jade.tilab.com`.

JADE and WADE are considered by a large community of users and developers one of the most advanced incarnations of *agent technology*, and they provide Wizard with the advanced work coordination capabilities of agents (see, e.g., [BP00, BPS02]) . Technically, JADE is a software framework that facilitates the development of interoperable *multi-agent systems*. JADE has a long and outstanding tradition of mobile developments [BP02, BPBC01] that has been recently revitalized with a specific support for Android [BCG14b]. WADE is built on top of JADE and it enriches JADE with the *workflow metaphor* to provide developers with a robust environment for embedding workflows into software agents. WADE is an industrial-strenght technology that has proven its solidity in large-scale network and service management for over 5 years [BCG14c].

2.1. Agents, Workflows and AR

Together, JADE and WADE form a solid combination of the agent and workflow metaphors that the work presented in this paper complements with AR. In details, instead of providing a single powerful workflow engine, as standard practice in traditional workflow management systems, WADE gives to each JADE agent the possibility of executing workflows. In WADE, each agent embeds a *micro workflow engine* and a complex process is carried out by a set of cooperating agents, each of which executes a part of the process. It is worth noting that WADE can be used as an everyday development platform and, in principle, developers can use WADE with little or no adoption of workflows. WADE can be used as an *extended JADE* that provides transparent functionality to support fault tolerance and load balancing, as exemplified by the AMUSE platform [BCG13, BCG14a].

One of the main advantages of the workflow metaphor is the possibility of representing processes with friendly visual notations, and WADE provides both the expressiveness of the visual representation of workflows, and the power of visual programming languages. WADE comes with a development environment called *WOLF* (*WOrkow LiFe cycle management environment*) [CQPS08]. WOLF facilitates the creation of WADE workflow-based agents: it provides users with a visual notation and an advanced editor, and little or no programming skills are needed to implement workflows.

The extensive use of WADE has witnessed the notable importance of user interactions in the scope of workflows. This is not surprising and we acknowledge that the idea of workflows has its origins in the management of the work of people. Nonetheless, we believe that the common approach of treating user interactions as *yet another type of events* does not adequately capture their importance.

So called *user-centric workflows* [BCG12] were therefore introduced in WADE version 3.0 as a means to capture workflows that frequently need to interact with users, and that are mainly intended to gather information and provide feedback to users. WADE lifts user interactions to a higher level and it provides specific tools and features to manage them effectively within a generic framework.

AR fits into the generic framework that WADE provides to support user interactions because it can be seen—with no loss of generality—as a way to have a workflow prompt the user for contextual information. This can occur in two ways, that we call *blocking* and *non-blocking*. In a blocking use of AR in the context of a workflow, the workflow is suspended and the user is provided with a live view of the camera. Once a target element is found in the scene, contextual information is gathered and provided to the workflow, which is immediately resumed. The blocking use of AR is a way to let a workflow gather live information on a user's operating context, for example by means of the identification of a QR-code.

Conversely, the non-blocking use of AR in a workflow assumes that the user is interacting with the workflow via a specific application that continuously sends/received streams of events to/from the workflow. Events directed to the workflow are meant to advance its execution, while events directed to the user let the workflow monitoring or even controlling user's actions. This is the case, for example, of a workflow directing a technician in the execution of the steps of a maintenance procedure. The user transparently employs AR to feed the workflow with timely contextual information on the execution of the maintenance procedure. The workflow employs AR to direct the users through the requested steps.

2.2. Application Domain

In order to experiment with the introduction of AR in network maintenance processes, the significant and challenging application domain of service assurance in *NGAN* (*Next Generation Access Networks*) was selected.

Broadly speaking, NGAN are distribution networks that use optical fibers to increase the bitrate available to customers of, at least, one order of magnitude with respect of current service levels. NGAN normally use so called *ultra-broadband* technology, which counts on optical fibers in access network segments.

From the network architecture point of view, the distribution network in NGAN, called *ODN* (*Optical Distribution Network*), originates from cabinets where *OLT* (*Optical Line Termination*) equipments are installed. The optical fibers that connect an OLT to the network are connected to a so called *ODF* (*Optical Distribution Frame*) that work as optical permutator. ODF also hosts the fibers that reach customers' premises and that are connected to *ONU*/*ONT* (*Optical Network Units*/*Optical Network Terminations*).

Telecom Italia adopted two network architectures for NGAN that differentiates for the level of penetration of optical fibers in the access network [CGP*14]:

- *FTTC* (*Fiber to the Cabinet*). The ODN terminates in a street cabinet overlay that is added to the equipment of the traditional copper network. The installed cabinet overlay serves 48 customers by means of dedicated copper lines.
- *FTTH* (*Fiber To The Home*). The optical fiber reaches customers' premises by means of a small cabinet that is typically installed in a basement and that serves as a small optical permutator intended to distribute fibers in the building and, often, in nearby buildings.

The experiments reported in this paper are all intended to target NGAN maintenance scenarios and they complement other experiments performed on NGAN-specific network equipments not presented in this paper. In details, the experiments described in next section are designed to extend Wizard with the integration of AR to assist field technicians in the identification of network equipments, and in the correct execution of error-prone activities like connection rerouting.

3. Description of Experiments

The presented experiments integrate AR via *Metaio SDK* (`http://www.metaio.com/sdk`) version 5, and the range of performed experiments is ultimately limited by the functionality that the SDK actually provides. The experiments were performed by means of a dedicated software prototype that targets *Motorola Atrix MB860* (Android 2.3.4) and *Galaxy Note 3 Neo* (Android 4.3) smartphones because field technicians are currently provided with these devices.

Figure 1: *The network equipment used for the first experimental campaign.*

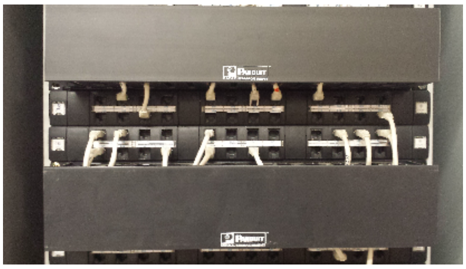

Figure 2: *A section of the equipment in Figure 1.*

Experiments were meant to simulate in a controlled environment the critical parts of so called *port change workflows*. Such workflows are normally activated to support maintenance of faulty ports in a network equipment at customers' premises. They require the technician identifying a couple of ports in the network equipment and performing a manual rerouting of connections. Such workflows are quite common in the daily operations of technicians and they are performed for more than 10% of the work requests managed by Wizard.

Figure 1 exemplifies the class of network equipments considered in the first experimental campaign. The equipment shown in the figure was used to validate the possibility of adopting AR to:

- Identify the actual equipment that the technician is facing by visually searching it into a database of installed equipments; and
- Point the technician to the two ports that would need to be rerouted by highlighting their position in the scene with appropriate markers.

The experiments on the identification of the type of equipment were performed using visual similarity with refer-

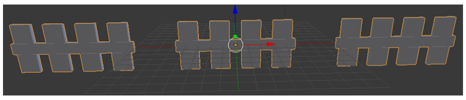

Figure 3: *The 3D model used for port identification.*

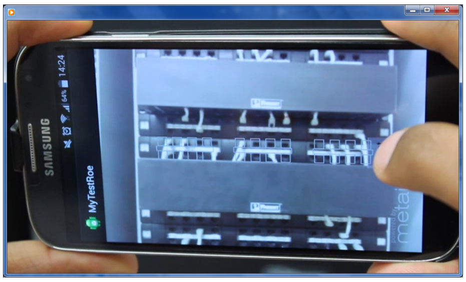

Figure 4: *Snapshot of the Android application prototype used to perform experiments on port identification.*

ence images in the database of installed equipments. The results of such experiments were not satisfactory because the equipment shown in Figure 1 was often misidentified. The main reason for the large number of misidentification is the weak visual similarity between reference images and the actual equipment. Moreover, the installed plugs on the equipment—not present in reference images—tend to complicate the identification.

The experiments intended to validate the possibility of using visual similarity to identify the two ports involved in the port change workflow resulted in a large number of both positive and negative identifications, mainly caused by the high degree of symmetry of the equipment. The overall results of such experiments is that visual similarity is by far not sufficient for port identification.

In order to help the AR engine in port identification, a second round of experiments was performed under the assumption that the technician would point the camera to the section of the equipment that hosted the target ports. Figure 2 shows how the technician was expected to point to the equipment.

The identification of ports in this second round of experiments was performed by means of a 3D model of the relevant sector of the target equipment. Figure 3 shows the adopted 3D model and Figure 4 shows a snapshot of the developed Android application prototype used to perform experiments.

Similar experiments were performed in a second experimental campaign using the network equipment shown in Figure 5. Such a network equipment—which is very often found in real access networks—is characterized by a grid of 48 ports and most of maintenance activities require adding/removing cables or changing the allocation of cables to ports. Before working on the grid of ports, the technician was expected to match the unique identifier of the equipment against the information contained in the current work request. A QR-code was used to confirm that the equipment was the correct one. This step allowed providing the technician with contextualized documentation about the equipment and installed cables. Then, AR was used to guide the technician in connecting or disconnecting cables.

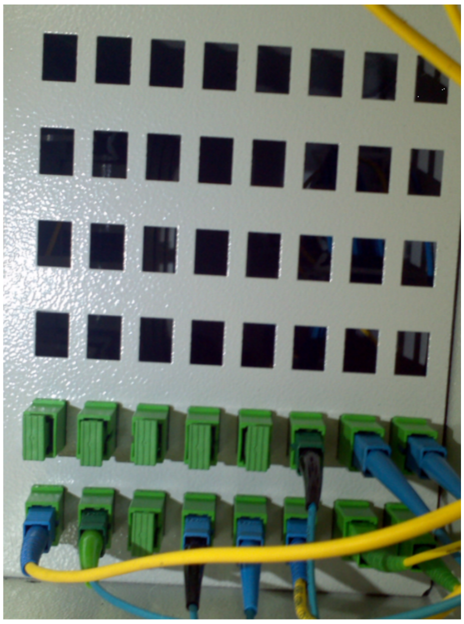

Figure 5: *The network equipment used for the second experimental campaign.*

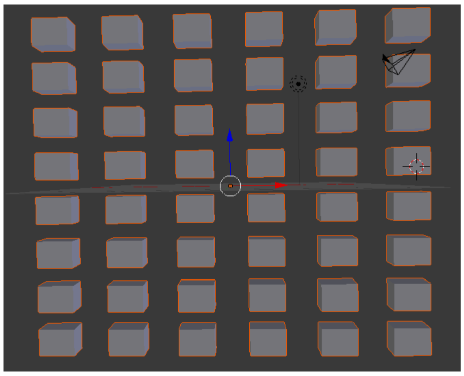

Figure 6: *The 3D model used to support port identification in the second experimental campaign.*

The very first implementation of the application prototype used in this experiment employed the *image tracking 2D* mode that Metaio SDK offers to match a reference image of the grid of ports against the actual scene. The inherent symmetry of the reference image made the use of such a tracking technique very fragile. Moreover, such a tracking technique fails for large perspective distortions, which is often the case in practice because the considered equipments are often located in sites that the technician cannot fully access. Finally, the mismatching between the reference image and the actual scene that the presence of cables caused made the experimented tracking technique very faulty.

The second implementation of the application prototype experimented with much better results the 3D model shown in Figure 6. Such results are still preliminary, but we have already witnessed the improved stability of the tracking based on the 3D model, even if the high degree of symmetry of the scene severely limits the robustness of the identification.

4. Conclusions

The adoption of AR technology to support technicians in service and maintenance activities is quite common and it is surely one of the application scenarios that is often cited as a success of AR (see, e.g., [AVDN14, OFSG13]). What makes the application domain discussed in this paper particularly significant is the large number of technicians involved—potentially more than 10.000—and the large number of concrete conditions that needs to be addressed. In particular, the significant number of types of the equipments in the network and the—sometimes extreme—installation conditions contribute to exacerbate the operative conditions. Moreover, the integration of AR into Wizard has to be very robust and responsive in virtually any environmental condition in order to gain significant acceptance from field technicians.

Unfortunately, the experiments performed so far are not satisfactory mainly because the concrete installation conditions make the adopted tracking techniques too fragile. Equipments are rarely visually similar, even if they are of the same type, and the use of reference images is often not sufficient. For the case of FTTC networks, cabinets are often installed outdoor and illumination conditions tend to create serious problems. On the contrary, for the case of FTTH networks, equipments are often installed in the basement of customers' premises in dark and dusty sites.

Finally, network equipments often exhibit a high degree of symmetry because they are characterized by arrays of ports. The network equipment shown in Figure 5 is an extreme case where the grid of port fully cover the only interesting side of the equipment. Such a high degree of symmetry is obviously problematic for AR because tracking techniques cannot identify stable references. The effect of such a symmetry for end users is a serious lack of usability caused by the instable identification of interesting points in the scene.

The experience acquired during the presented experimental campaigns suggested the possibility of integrating QR-code identification into the base services that WADE offers. QR-code identification is mature enough to be applied in the practice of field maintenance, and it smoothly fits the interaction model that WADE implements [BCG12].

References

[AVDN14] ALEKSY M., VARTIAINEN E., DOMOVA V., NAEDELE M.: Augmented reality for improved service delivery. In *AINA* (2014), pp. 382–389. 5

[BCG07] BELLIFEMINE F., CAIRE G., GREENWOOD D.: *Developing multi-agent systems with JADE*. Wiley Series in Agent Technology, 2007. 2

[BCG08] BANZI M., CAIRE G., GOTTA D.: WADE: A software platform to develop mission critical, applications exploiting agents and workflows. In *Procs. Int'l Joint Conf. Autonomous Agents and Multi-Agent Systems* (2008), pp. 29–36. 2

[BCG12] BERGENTI F., CAIRE G., GOTTA D.: Interactive workflows with WADE. In *Procs. IEEE Int'l Conf. Enabling Technologies: Infrastructures for Collaborative Enterprises* (2012), pp. 10–15. 2, 5

[BCG13] BERGENTI F., CAIRE G., GOTTA D.: An overview of the AMUSE social gaming platform. In *Procs. Workshop From Objects to Agents* (2013), pp. 85–90. 2

[BCG14a] BERGENTI F., CAIRE G., GOTTA D.: Agent-based social gaming with AMUSE. In *Procs. 5^{th} Int'l Conf. Ambient Systems, Networks and Technologies (ANT 2014) and 4^{th} Int'l Conf. Sustainable Energy Information Technology (SEIT 2014)* (2014), vol. 32 of *Procedia Computer Science*, pp. 914–919. 2

[BCG14b] BERGENTI F., CAIRE G., GOTTA D.: Agents on the move: JADE for Android devices. In *Procs. Workshop From Objects to Agents* (2014). 2

[BCG14c] BERGENTI F., CAIRE G., GOTTA D.: *Large-Scale Network and Service Management with WANTS*. In press, 2014. 2

[BP00] BERGENTI F., POGGI A.: Agent-based approach to manage negotiation protocols in flexible CSCW systems. In *Procs. 4^{th} Int'l Conf. Autonomous Agents* (2000), pp. 267–268. 2

[BP02] BERGENTI F., POGGI A.: Ubiquitous information agents. *Int'l J. Cooperative Information Systems 11*, 34 (2002), 231–244. 2

[BPBC01] BERGENTI F., POGGI A., BURG B., CAIRE G.: Deploying FIPA-compliant systems on handheld devices. *IEEE Internet Computing 5*, 4 (2001), 20–25. 2

[BPR01] BELLIFEMINE F., POGGI A., RIMASSA G.: Developing multi-agent systems with a FIPA-compliant agent framework. *Software: Practice & Experience 31* (2001), 103–128. 2

[BPS02] BERGENTI F., POGGI A., SOMACHER M.: A collaborative platform for fixed and mobile networks. *Communications of the ACM 45*, 11 (2002), 39–44. 2

[CGP*14] CHIAPPONE M., GOTTA D., PASCHETTA E., PELLEGRINO P., TRUCCO T.: Augmented reality for TLC network operation and maintenance support. In *Procs. 2014 Int'l Working Conf. Advanced Visual Interfaces (AVI '14)* (2014), ACM Press, New York, NY, USA, pp. 349–350. 3

[CQPS08] CAIRE G., QUARANTOTTO E., PORTA M., SACCHI G.: WOLF: An Eclipse plug-in for WADE. In *Procs. IEEE Int'l Workshops Enabling Technologies: Infrastructures for Collaborative Enterprises* (2008). 2

[OFSG13] OLIVEIRA R., FARINHA T., SINGH S., GALAR D.: *An augmented reality application to support maintenance – Is it possible?* Lappeenranta University of Technology, 2013, pp. 260–271. 5

[TLGS09] TRIONE L., LONG D., GOTTA D., SACCHI G.: Wizard, WeMash, WADE: Unleash the power of collective intelligence. In *Procs. Int'l Joint Conf. Autonomous Agents and Multiagent Systems* (2009), pp. 1342–1349. 1