Transdisciplinary Engineering for Complex Socio-technical Systems
K. Hiekata et al. (Eds.)

doi:10.3233/ATDE190176

Proposal of a Augmented Operator for a Hydroelectric Power Plant

Felipe P. SILVA[a,1], André S. BARBOSA[b], Lucas C. dos SANTOS[a] and Rodrigo B. OTTO[a]

[a] *Itaipu Technological Park Foundation, Av. Tancredo Neves, 6731, Foz do Iguaçu, Brazil*

[b] *ITAIPU Binacional, Av. Tancredo Neves, 6731, Foz do Iguaçu, Brazil*

Abstract. There is a trend in the industry in the digitalization of assets for generating large amounts of information and greater control and supervision over the production. With this digitalization, the possibility arises to include new technologies that can facilitate the life of the maintenance team and the operator, such as the concept of augmented operator. In this concept, the operator using mobile devices can access information in real time of the desired equipment, saving time in the acquisition of this information and allowing a greater time to analyze this data. Thus, this work aims to propose an augmented operator system for an hydroelectric power generation industry, as an example there is the possibility of visualizing information of vibration, temperature and rotation of recirculating motor pumps of the cooling system from generation units. Preliminary results indicate a wide possibility of using this concept. In addition to the actual monitoring of the asset in real time, there is the possibility of obtaining the list of spare parts and materials that help in the communication to the purchasing sector and quick replacement of failed components.

Keywords: Augmented Reality, Industry 4.0, Asset Monitoring

Introduction

The digitalization of assets in industry are generating a great amount of data. That is the paradigm of the Industry 4.0. In this area, field devices, machines, production modules and products as Cyber-physical Systems (CPS) and Internet of Things (IoT) are continuously exchanging information, triggering actions and controlling each other independently [1].

Considering these available data, the presentation of the information may be used in tablets, smartphones and through wearable glasses, using augmented reality or virtual reality [2].

The concept of Augmented Reality was first introduced by [3]. The Augmented Reality (AR) is defined a variation of the wide known Virtual Environment or Virtual Reality (VR), which immerses completely the user. In AR, the user sees the real world, with virtual objects superimposed or composited with real world [3].

[1] Corresponding Author, Email felipe.silva@pti.org.br.

In Industry 4.0, the AR started to be considered one of the most interesting technologies, improving maintenance and reliability overall [4]. These technologies provide a way of replacing the traditional Human-Machine Interface (HMI), which is so common in the industry.

For this reason, it is pointless to consider the industry 4.0 a worker-less production. There is this need of a Augmented Operator [1], whose these technological advancements seek to assist and improve his work.

The Industrial Augmented Reality (IAR) is the field named for all the technologies connected to the industrial sector, being from energy sector to shipyard [5].

According to [6], the AR emerges by being a powerful technology in aiding the operators in the smart factory, and certainly a part of the factories of the future or even the present.

The objective of this work is to research the literature to gather information about the usage of AR technologies for the operation in the energy industry, thus proposing a hardware and software topology for implementing the technology in a hydroelectric power plant in Brazil.

In the first sections of the paper, a review of the technologies and concepts for industry 4.0 and augmented reality is raised. Then, based on the current work being developed, a topology is proposed for implementing an AR system for the industry 4.0 operator, with main advantage of using the current monitoring infrastructure for gathering data and showing more dynamically to the operator.

1. Digitalization of Assets, Operation and Maintenance

The digitalization equipment in the power sector is becoming a standard in the supply of new equipment and assets. As pointed by [7], the digitalization increases reliability and stability in the process of generation and transmission of electric energy.

The data generation begins in the data acquisition process. This step consists of using a transducer to convert and physical quantity into an electrical signal, after some filtering and amplification, the signal is digitalized using and Analog-to-Digital Converter (ADC) [8].

Due to large acceptance of digital sensors in the industry, it implies in a great volume of information generated. The information technology (IT) area handles this data by storing and showing to the operator and the final user. As a result, the information received by the operator has dramatically increased as observed by [9].

The increase in storage and the modernization of the industry creates big volumes of data emerging into the big data paradigm, which according to [10] it is not a new concept, but only recently has become widely spread across the organizations.

The predictive maintenance also can take advantage of these large amount of data to create indicators, and keep the Overall Equipment Efficiency (OEE) as highly as possible and reduce downtime due to unplanned shutdowns [8].

2. Augmented Reality Technologies

According to [11], there were a lot of challenges for AR to become a viable and powerful form of media. It has taken over 20 years to move Augment Reality from being and very expensive technology restrict to few places to a head-worn system that general consumer can afford.

The technologies are becoming more popular every day from smartphones, tablets to even hand-held industrial computers. The power processing increases year by year.

The main devices used for externalizing the power of the AR are:

- Smartphones and Tablets;
- Industrial Computers;
- Head-Worn Glasses;

For software processing the AR data, there are widely known libraries such as ARToolkit. This library, developed initially in 1999, uses video tracking capabilities to track in real time the real camera position and orientation relative to physical markers. Nowadays, it has already its successor, Studierstube Tracker [12] and other libraries have taken place such as Qualcom Vuforia which also supports the Unity3D game engine [13].

As pointed by [14], the AR technologies have been used in many areas, mainly for early phases of designing in a project. In architecture and civil engineering, the usage of 3D models are more common, opposed to industry domain knowledge were apparently exists a lack of well-organized 3D database to be readly used by AR systems.

3. Use Cases of Augmented Operator in Industry 4.0

The enabling technologies for the Operator 4.0 is reviewed by [15]. In this concept, the augmented operator emerges of one of the elements from Operator 4.0. The augmented operator with usage of the AR improves information transfer from digital to the physical world, contributing to the CPS concept.

In a proposal of an architecture for implementing a CPS, [16] defines a sequential workflow manner, in order to construct such a system. This architecture is presented in Figure 1.

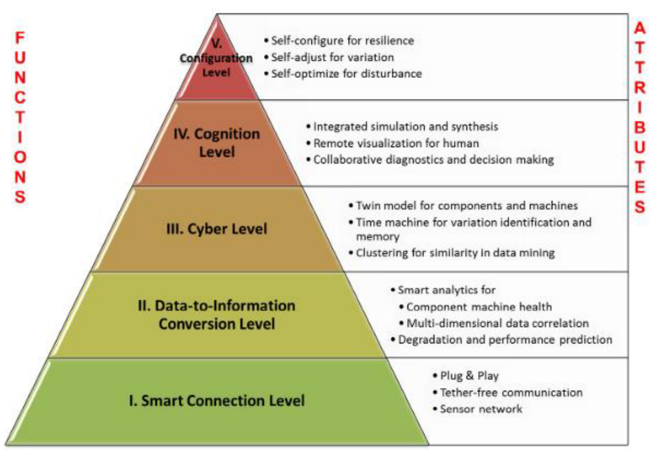

Figure 1. 5-level architecture proposed by [16].

In the framework SOPHOS-MS, proposed by [13], it is also presented a sequential workflow manner were is detailed an implementation of an AR software, following a state machine diagram and/or sequence diagram.

4. Methodology for implementing AR

The study for developing an implementing of an operator using AR is being held at the Laboratory of Automation and Power Systems Simulation (LASSE), which is an institution located within the limits of the Technological Park from ITAIPU Hydroelectric Power Plant in Brazil.

The general flow for implementing an AR in our use case is shown in Figure 2.

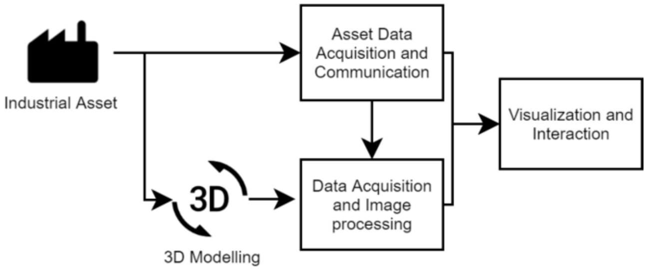

Figure 2. Flow for implementing AR for an Operator

These steps are described in the following sections, detailing some of the technologies and options for implementing this concept.

4.1. 3D Modelling

During one of phases in the development of the projects in LASSE, already described by [17], there are the 3D modelling of parts for use in the technical documentation, such as diagrams, cabinet layouts (Figure 3), among others.

For this type of modelling, the software used is the 3D CAD (Computer-Aided Design) *SolidWorks* from *Dassault Systemes*.

The development may include some of the assets, which these projects are monitoring, such as a pump coupled with an electric motor, as show in Figure 4.

Figure 3. 3D model of an electrical cabinet used in motor pump monitoring.

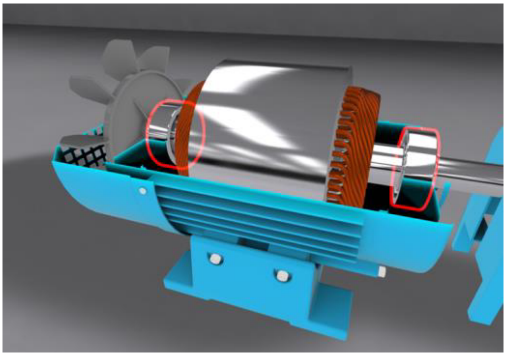

Figure 4. 3D Model of inner parts of a Motor Pump [18].

In the shown drawing, it is observed a major difference between those models. The first one is a raw 3D modelling using only a CAD software. The second one is a 3D model rendered with realistic features from an open-source software named *Blender*.

4.2. Asset Data Acquisition and Communication

The monitoring system provides continuous data to the web server where data is processed and published. After this step some alternatives may be used for capturing the data by the HHD.

One of the common technologies is the Web Services using RESTful calls over the network, as better described by [19].

Simultaneously other protocols such as streaming message have been developed to adjust the increasing need for scalability and data throughput.

Many of them work with the concept of publish/subscribe mechanism (Figure 5). In this area, a very light binary protocol is being used, it is called MQTT (Message Queue Telemetry Transport) [20].

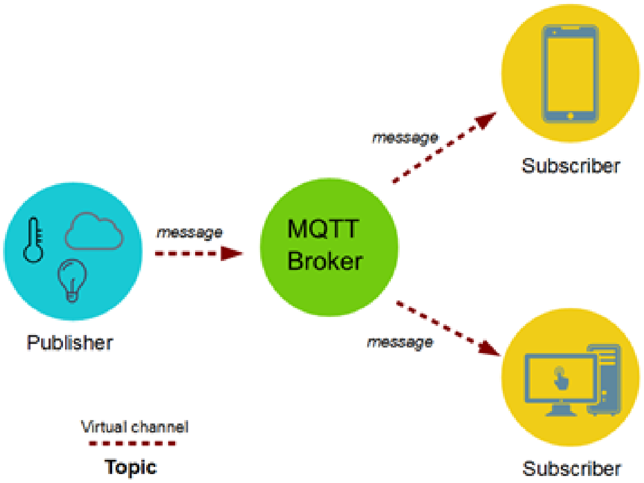

Figure 5. Typical Topology of MQTT Driven Messaging [21].

Although, there are other protocols such as AMQP (Advanced Message Queueing Protocol) and Apache Kafka® which would perform in a very similar manner. Some studies implementing communication with AR were developed also using substation automation standards, such as ICE 61850, as better described by [22].

4.3. Data acquisition and Image Processing

The data already processed in the monitoring system is published through one the services mentioned above. The data acquisition field will take place and the data will be processed by the device or a server using AI (Artificial Intelligence). The steps for the AR reality are better described in the Figure 6.

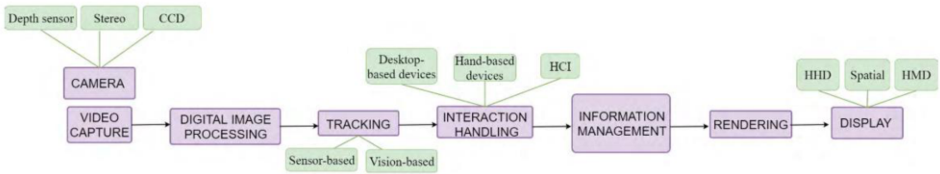

Figure 6. AR Processing Pipeline [5].

Software such as *PTC Vuforia Augmented Reality* are used to track the real scene and allow to superimpose digital information in the real environment. These software have the ability of recognizing images that will be used as a marker for augmented reality applications [4].

In industry, generally, it is very common to exist similar cabinets and assets in the same area. Therefore, image recognition may fail to identify the correct object properly. Other technologies used for position location (GPS) could be unavailable, for instance, inside a hydroelectric power plant.

In these cases, it is possible to use technologies such as NFC (Near Field Communication) or optical identification (marker) methods (QR Code), as shown in Figure 7.

Figure 7. NFC or Optical recognition [23].

The QR (Quick Response) code has the advantage of handling many data types, such as numeric and/or alphabetic characters. It can store large chunks of data, and on the other hand it can be decoded by very lightweight smartphone or PC applications [22].

4.4. Visualization and Interaction

4.4.1. Hardware

In AR there are a couple of technologies that can be used to replicate the real environment. Usually mobile devices are used for capturing the data. They are considered Hand-Held Displays (HHD). They embed a screen that fits in a user's hand [5].

In our proposal, we intend to use a 10" Screen Tablet from a traditional manufacturer. This Tablet has octa-core processor, 2 GB of RAM Memory and 16 GB of flash storage.

4.4.2. Interaction

After finalizing all the steps previously described, it comes to the visualization where user can provide feedback to the application.

In this step, the interaction to the final user requires the use of the hardware described previously (HHD) or some other AR technology.

It is of great importance keeping the compatibility between the Communication and Data Acquisition/Image Processing layers.

5. Early Results

5.1. Topology

As result of the research in the literature and the technologies involved in the AR field, it was proposed the following topology (Figure 8) for implementing our AR system for the operator and maintenance staff.

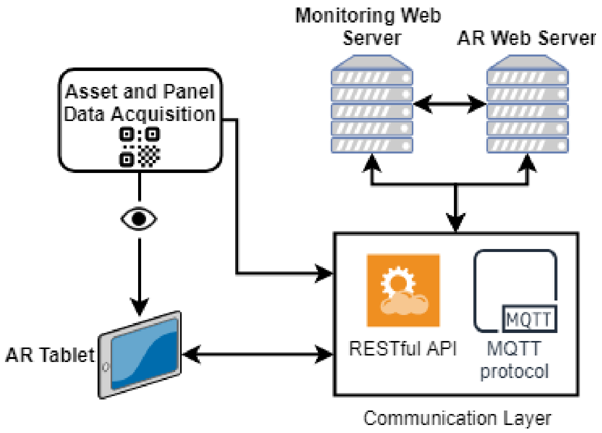

Figure 8. Chosen Topology for the AR Application.

In this topology, the monitoring system send continuously data to de web server responsible for storing and displaying these data through a Web Page or other super visioning software.

These data are processed and published back through one of the protocols located in the communication layer. On the other hand, the panel keeps publishing raw and local calculated data to a MQTT server.

Most of this topology is already implemented in the field, and few modifications to the communication layer will be needed to include the AR resource. It is also a very flexible and scalable architecture, allowing including more data producers and consequently increasing the range of the system.

5.2. Application Recognition

The Operator uses the tablet with visual recognition of the QR code located either in the panel or in the monitored asset, as shown in Figure 9 and Figure 10.

Figure 9. Using the Tablet to identify the panel and acess the AR mode.

Figure 10. QR Code identification by the tablet.

In Figure 11 is shown an example of the QR code that can be used for the AR recognition system. It gives information of a unique identifier, the system, the location and the monitored assets.

Figure 11. Example QR Code used for the cabinet recognition.

5.2.1. Possible Usages

As the application recognize the shape of panel, asset or the QR code located in the panel, the user may access some information about the panel, indicating some failure or warning about the monitored device.

In Figure 12 is shown an example of information when the operator virtually accesses the inner part of the panel. The “balloon” was indicating a warning about a low voltage in the DC source.

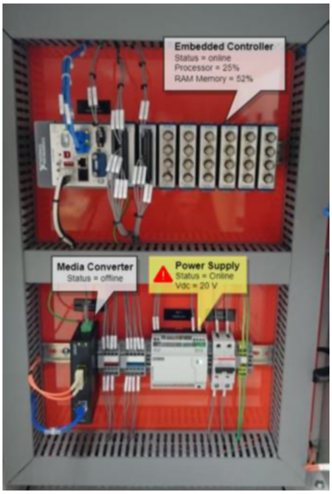

Figure 12. Indicators about panel state.

Beyond this routine usage, there are many other information that can be accessed when locally using AR, such as:

- Access documentation (drawings and schematics);
- Consult warehouse for spare parts and place order if necessary;
- Follow maintenance procedures indicated in the AR (previously uploaded by the specialist);

The usage of the AR in this field is very wide and can reach even the training field where supervisors can simulate field failures for the operators. Other usage are briefly discussed by [5].

6. Conclusions

Augmented reality expands the possibilities of the industry sectors that daily handle the equipment. During this study, it was possible to detect many uses for a system that is already digitalized. In addition to the equipment information, the operator can extend the use to other areas of the plant, as the request of spare parts.

From this initial study, the laboratory intends to start the implementation of this AR system with the use of existing data by the other monitoring systems already developed, which are currently generating information, but being accessed in a traditional way, such as web browsers. This is a big step towards industry 4.0, and in this matter the operator's training will become of great relevance.

Acknowledgement

Acknowledgements for the support and promotion of this work are to Itaipu Technological Park Foundation (FPTI) and ITAIPU Binacional.

References

[1] S. Weyer, M. Schmitt, M. Ohmer and D. Gorecky, Towards Industry 4.0 - Standardization as the crucial challenge for highly modular, multi-vendor production systems, *IFAC-PapersOnLine*, vol. 48, no. 3, pp. 579–584, 2015.

[2] I. Maly, D. Sedlacek, and P. Leitao, Augmented reality experiments with industrial robot in industry 4.0 environment, *2016 IEEE 14th International Conference on Industrial Informatics (INDIN)*, 2016, pp. 176–181.

[3] R. T. Azuma, A survey of Augmented Reality, *Presence Teleoperators Virtual Environ.*, vol. 6, no. 4, pp. 355–385, 1997.

[4] R. Masoni *et al.*, Supporting Remote Maintenance in Industry 4.0 through Augmented Reality, *Procedia Manuf.*, vol. 11, no. June, pp. 1296–1302, 2017.

[5] P. Fraga-Lamas, T. M. Fernández-Caramés, Ó. Blanco-Novoa, and M. A. Vilar-Montesinos, A Review on Industrial Augmented Reality Systems for the Industry 4.0 Shipyard, *IEEE Access*, vol. 6, pp. 13358–13375, 2018.

[6] A. Syberfeldt, M. Holm, O. Danielsson, L. Wang and R. L. Brewster, Support Systems on the Industrial Shop-floors of the Future - Operators' Perspective on

Augmented Reality, *Procedia CIRP*, vol. 44, pp. 108–113, 2016.
[7] A. A. Gibadullin, V. N. Pulyaeva and Y. V. Yerygin, The Need for a Digital Substation during the Digitalization of Energy, *2018 Int. Youth Sci. Tech. Conf. Relay Prot. Autom. RPA 2018*, pp. 1–12, 2018.
[8] E. Jantunen, J. Campos, P. Sharma and D. Baglee, Digitalisation of maintenance, *2017 2nd Int. Conf. Syst. Reliab. Safety, ICSRS 2017*, vol. 2018-Jan, pp. 343–347, 2018.
[9] S. Nazir, R. Totaro, S. Brambilla, S. Colombo, and D. Manca, Virtual Reality and Augmented-Virtual Reality as Tools to Train Industrial Operators, 2012, pp. 1397–1401.
[10] A. Zaslavsky, C. Perera, and D. Georgakopoulos, Sensing as a service and big data, *arXiv Prepr. arXiv …*, 2013.
[11] R. T. Azuma, The Most Important Challenge Facing Augmented Reality, *Presence Teleoperators Virtual Environ.*, vol. 25, no. 3, pp. 234–238, Dec. 2016.
[12] J. Carmigniani, B. Furht, M. Anisetti, P. Ceravolo, E. Damiani, and M. Ivkovic, Augmented reality technologies, systems and applications, *Multimed. Tools Appl.*, vol. 51, no. 1, pp. 341–377, Jan. 2011.
[13] F. Longo, L. Nicoletti, and A. Padovano, Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context, *Comput. Ind. Eng.*, vol. 113, pp. 144–159, Nov. 2017.
[14] X. Wang, Augmented Reality in Architecture and Design: Potentials and Challenges for Application, *Int. J. Archit. Comput.*, vol. 7, no. 2, pp. 309–326, 2009.
[15] T. Ruppert, S. Jaskó, T. Holczinger, and J. Abonyi, Enabling Technologies for Operator 4.0: A Survey, *Appl. Sci.*, vol. 8, no. 9, p. 1650, 2018.
[16] J. Lee, B. Bagheri, and H.-A. Kao, A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems, *Manuf. Lett.*, vol. 3, pp. 18–23, Jan. 2015.
[17] C.H. Szollosi, R.B. Otto, and G.G. Terada, Estudo sobre o desenvolvimento de produtos em Ambinetes P&D, *VII SINGEP - Simpósio Internacional de Gestão de Projetos, Inovação e Sustentabilidade*, 2018.
[18] A. da S. Barbosa, F.P. Silva, L.R.D.S. Crestani, and R.B. Otto, Virtual assistant to real time training on industrial environment, *Advances in Transdisciplinary Engineering*, vol. 7, pp. 33–42, 2018.
[19] C. Pautasso, O. Zimmermann and F. Leymann, Restful web services vs. 'big'' web services, *Proceeding of the 17th international conference on World Wide Web - WWW '08*, 2008, p. 805.
[20] J. Mesnil, *Mobile and Web Messaging*. O'Reilly, Sebastopol, 2014.
[21] F. Azzola, "MQTT Protocol Tutorial: Step by step guide," 2016. [Online]. Available: https://www.survivingwithandroid.com/2016/10/mqtt-protocol-tutorial.html. [Accessed: 01-Aug-2017].
[22] M. Antonijevic, S. Sucic, and H. Keserica, Augmented reality for substation automation by utilizing IEC 61850 communication, *2016 39th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, 2016, pp. 316–320.
[23] M. Schmitt, G. Meixner, D. Gorecky, M. Seissler and M. Loskyll, Mobile interaction technologies in the factory of the future, *IFAC Proceedings Volumes*, vol. 46, Issue 15, 2013, pp. 536-542.