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Augmented visualization using homomorphic filtering and Haar-based natural markers for power systems substations

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ABSTRACT

This paper presents an approach for annotating real data of power system equipment and has a main goal of improving visualization in outdoor scenarios where lighting presents itself as a problem for the detection of objects. It proposes the creation of object detectors as natural markers using Haar-like features and homomorphic filtering to include real information in an augmented visualization of a substation. The proposed system provides a real-time solution for displaying the data that are acquired from the SCADA/EMS automation system over the real scenario of the substation by providing an augmented visualization. The proposed system achieves an acceptable response time and the object detection step receives updates on each frame from the camera. Thus, it allows the use of augmented reality within operation and maintenance activities in the substation equipment, thereby providing data visualizations at the location where the demand exists instead requiring one to move to the control room to visualize the actual systems status. Equipment detection is performed on the video camera of a mobile device, frame by frame, by using a cascade classifier that is based on Haar-like features for the training and detection processes and by applying homomorphic filtering to reduce illumination problems. The proposed system can be used for training several detectors for substation equipment with the same technique. As a proof of concept, this work presents the results that are obtained using the power transformer. Thus, an augmented reality system prototype was developed that achieved good detection rates, thereby showing that the use of theses features is promising for augmented reality implementation in the daily routines of an electrical company.

1. Introduction

System status visualization plays an important role in the process of electrical power system operation and maintenance. The operators/maintainers monitor the variables that describe the operating state, the operating conditions set-up, and the devices that constitute these systems. However, when the operator/maintainer is in the operating area to accomplish procedures such as inspection or equipment maintenance, he or she does not have this information at his or her disposal.

According to [6], the operators of power systems must monitor a large and complex set of operational data while maintaining system reliability and stability. The authors highlight that visualization tools in power systems are a critical part of the modern Supervisory Control and Data Acquisition Systems/Energy Management System (SCADA/EMS). An important goal of this technology is to convey a relevant abstract view of information to operators.

A common application area for visualization of power systems is simulation for training, in which a virtual reality (VR) computer-generated system can be used as an efficient training medium for both novice and expert engineers [12]. This is because, in the field of electrical systems, there is a wide gap between theoretical studies of the equipment functions and the operations of the equipment in practice. Despite this gap, [2] addresses the

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simulation area and the use of VR as the best way to improve trainee learning through equipment visualization using real images of the operating environment. The approach of using real images and real data to facilitate greater understanding of the operating situation is one of the goals of our paper. However, instead of using VR, we propose the use of augmented reality (AR) as an industrial on-site viewing solution.

VR systems attempt to stimulate human senses to include the user in the computer-generated synthetic environment [9]. VR systems can solve many aspects of training, visualization and even operation or maintenance by providing dynamic visualization. However, the AR systems can create a natural visualization of the environment because the user is watching the real operation area where the tasks are performed.

Although control centers receive real-time information from the SCADA/EMS, the operation architecture is isolated, and the information is only available in the control rooms, not in the courtyard of the facility.

1.1. Related work

According to [10], the integration of the SCADA/EMS design enables the global unification of the system and supports the goal of increased productivity. The growth of the communications infrastructure, which enables greater speed and exchange of large volumes of information, makes this possible through the use of technologies such as virtual and augmented reality.

There is an area of study in electrical engineering that is dedicated to the equipment that makes up an electrical power system, such as transformers and circuit breakers [2]. VR has been used in learning systems in the last decades and has achieved large improvements in many areas. However, despite the investments and the learning advances in VR systems, there are new technologies such as AR that can be used in real scenarios to better facilitate the activities of operators and improve their training.

In [11], a type of AR is presented that uses a markerless framework, which means that the AR system does not require fiducial markers or even natural markers in the environment. The authors solved this problem using calibrated cameras that are fixed inside the exam room. This solution differs from our proposed solution because it does not allow camera movements in the environment.

In [7], it is stated that there are no effective lightweight AR handheld solutions for supporting maintenance tasks. The authors presented a method for content presentation and emphasized that 2D annotations are frequently used in manuals of equipment maintenance in different areas. However, a difficulty regarding annotated 2D overview is that the information does not reflect the user's viewpoint, which is one of the benefits of our proposed solution.

This work intends to introduce a new solution for the annotation of real data of power system equipment in real outdoor scenarios, in which the main challenge is the lighting. This may allow the visualization of real situations inside electrical power systems based on the use of natural markers for augmented visualization of real-time information of substation equipment. Our system detects the equipment in the industrial environment using mobile devices, thereby allowing the exhibition of information from the SCADA/EMS over the acquired image of the equipment in real time. The detection method, along with the manual identification and monitoring of equipment in real time, makes possible the visualization in the field (industrial plants) of power system information that is traditionally available only in the control and operation rooms.

To develop this work and test the Haar-like AR marker and the developed power system visualization system, the industrial environment was simulated through a set of images that were obtained from a real substation that simulates the view of a human operator. The processing of these images allowed both the training of the algorithm and the simulation of the view in the physical environment, with the inclusion of information about the equipment operational status.

In this work, real-time detection and connection are performed with the SCADA/EMS to provide an integrated view that may give operators/maintainers a new tool through an innovative display format, which is the main motivation of this proposed method. In addition, this system can still be used for simulation/training purposes for operation and maintenance tasks.

2. Material and methods

This proposed method used the Unity Game Engine [17] which enables the creation of applications for mobile devices. The detection algorithms were written in C# language and the application was generated initially for the Android operating system. Our implementation of the detection module is based on the OpenCV Libray [15].

The hardware that was used for the classifier training step and detection was a computer with an Intel Core i5-2.5 GHz, 8 GB of RAM and 500 GB of storage. The cameras that were used for image acquisition were a SonyR Cyber-shot 8.1-megapixel camera and an iPad with 16 GB and 8 megapixels. To perform the detection tests with Haar-based natural markers, we used a Positivo tablet with a 7-inch display, Android 4.0, a 1-GHz processor, a camera, and 16 GB of memory storage.

2.1. Augmented reality and markers

An important concern in the operation of a power system is real-time information visualization. There are many examples of successful uses of new visualizations tools in the control center room [6], including pie charts, power flow animations and text messaging, which were each innovative solutions when they were proposed and are still in use currently. All of these visualization tools rely on delivering a visual information of variables of the system. This is the motivation for using AR technology. Although it is not a recent technology, only in recent years has it become possible to use it effectively, thereby allowing the development of practical solutions for real-time visualization of industrial fields.

Another benefit of AR is that its use reduces the completion times of operation tasks and reduce errors. This statement is based on [8], which presents an empirical study that evaluates the effectiveness of technical maintenance with the assistance of interactive AR instructions using commercially available solutions.

According to [5], AR solutions create new forms of interaction and new user interfaces. The use of AR technology has grown in several application fields and allows the amount of information that is available in a real environment to be increased. The easiest way to create AR systems is by using fiducial markers, which are 2D registered patterns that are used to facilitate detection by image processing, mostly using corner detection algorithms. Even recent works such as [8] use fiducial markers in the detection problem. Moreover, these markers are used to include additional information at a specific location in a viewed scene. Markers of this type are widely used in AR projects.

Although the use of fiducial markers increases the robustness and reduces the computational cost, it is necessary to include these markers in the observed environment. This restriction makes impracticable the use of such AR solutions in industrial environments, especially in scenarios of power system substations.

Another type of marker is called a natural marker, which is used in our proposed method. Natural markers are objects or elements