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Augmented Reality as a Tool for Production and Quality Monitoring

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Abstract

Augmented Reality (AR) as an info visualization tool can be used in manufacturing industries, where real time reports are essential for the decision making process. An organization must guarantee their processes are being monitored and constantly improved. That is why an AR system linked to an Computer Aided Quality (CAQ) Software is proposed as a solution to production monitoring. AR technology displays Key Performance Indicators (KPI) of each workstation inside an industrial plant, gathered from measuring devices and integrated in the CAQ Software; this information is transmitted to a mobile device via wireless and located with an Indoor Positioning System (IPS). The implementation of this system results in a dynamic tool that allows to reduce audit times.

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Keywords: Augmented Reality, Key Performance Indicator, CAQ, Q-Management Software, Mobile Device

1. Introduction

A manufacturing organization should be able to provide its customers with quality products. In order to stay active in today's market, these organizations must guarantee their processes are being monitored and constantly improved. More efficient quality systems are required when the production volumes are increased, there are a number of techniques for controlling product and process quality like Failure Mode and Effect Analysis (FMEA), Statistical Process Control (SPC), Design of Experiments (DoE) and Total Productive Maintenance (TPM) to name a few [1, 2]. The production using these quality techniques can be measured with different indexes, one of them being the process capability Cp, Cpk [3].

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Launching a defective product into the market can cause huge monetary losses to a company. The 1-10-100 rule establishes that the cost of correcting a problem in their design/creation stage is equivalent to 1 unit; this cost rises to 10 units when products are corrected after manufacture and increases up to 100 units when the defects are detected by the costumer. This rule is derived from the study *The Economic Impacts of Inadequate Infrastructure for Software Testing* published by The National Institute of Standard Technology (NIST) in 2002 and carried later on by the IBM Systems Sciences Institute reporting that the cost of fixing an error after launching the product is 100 times greater than the cost to detect during the design stage [4].

Recalling a product due to bad quality is a very expensive solution to an organization. In spite of that, there has been many cases of defective products in recent years. According to the National Highway Traffic Safety Administration (NHTSA) during 2014 almost 64 million vehicles were recalled for safety problems in the US, being this record figure [5]. The following chart shows some cases of recalls in automobile companies:

Table 1. Automobile companies recalls

Company	Failure or defect	# of recalled products	Monetary losses (US dlls)	Fatal accident
Firestone Ford	Tire tread separation Faulty suspension design (2001)	6.5 million tires	3 billion	Yes [12]
TOYOTA	Stuck gas pedals (2013) Air bag ruptures (2014)	10 million vehicles	2 billion	Yes [12]
GM	Flawed ignition switch (2014)	30.4 million vehicles	4.1 billion	Yes [8]

Taking into account the experiences of automobile companies, there is a need to reduce defects that could damage the integrity of the customer and the economy of the companies. An AR system based on the Statistical Process Control [6] and based on Six Sigma methodology [7] will significantly avoid these problems. The study presented in this paper will show the benefit of introducing Augmented Reality to assist quality data reporting by monitoring Cpk indexes for a more assertive decision making process.

2. Background

2.1. Technologies and methodologies

Augmented Reality complements the real world by superposing virtual objects in the user's environment, allowing a complete interaction with them in real time [8]. For better understanding the term, Milgram describes a continuum from completely real environment to a virtual pure environment. In the middle of this continuum are Augmented Reality (closer to the real environment ending) and Augmented Virtuality (closer to the virtual environment ending) [9]. Thus, Augmented Reality differs from Virtual Reality in the fact that VR immerses the user in a completely virtual environment [8].

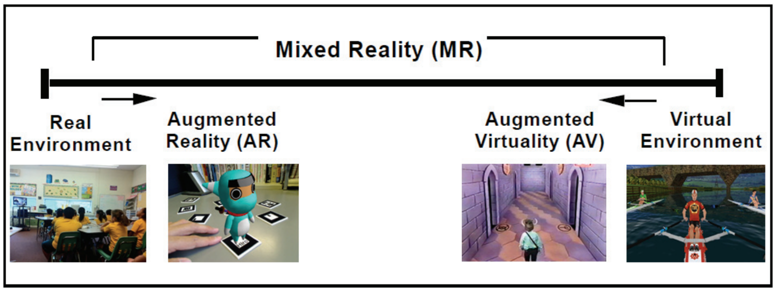

Fig. 1. Paul Milgram's Reality-Virtuality (RV) Continuum

Geo Location AR: this type of system superimposes virtual information without the use of physical markers. AR based on Geo Location, uses positioning sensors such as GPS, accelerometers and gyroscopes to determine the location of the user and provide information on the surroundings [10].

Fig. 2 shows that AR applications may be created with the purpose to be used as Technical support in manufacturing industries to facilitate maintenance processes or assembly procedures, aiming to reduce the operating time and training costs. Simple and complex animations can be generated from 3D CAD models to be displayed through an application run by a mobile device, either a tablet PC or a smartphone.

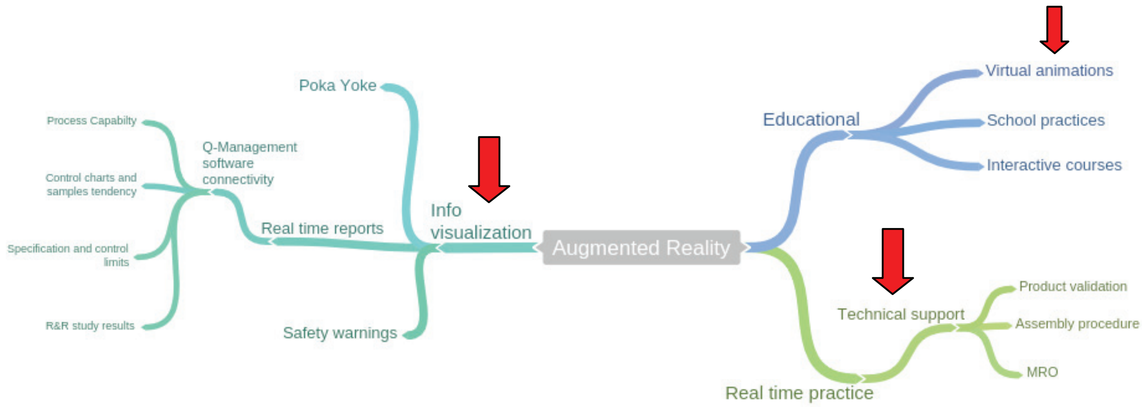

Fig. 2. Augmented Reality mind map of its principal functionalities

Fig. 2 also illustrates AR applications as an Info visualization technology, this concept may be vague but in this paper it is referred as data displayed on the user's sight. This information is not necessarily using 3D models but instead graphical data that shows the process capability and/or control charts that help tracking the origin of a problem in a productive line. Traceability is a desired characteristic in the visualized information.

The CAQ software to be used is Quality Data Analysis (QDA Q-Management). The versatility of the QDA software allows the user to verify quality goals such as process control, cost reduction, process optimization and standard compliance documentation. The key indicators, such as Cpk, are calculated in QDA and later used for early identification and location of process faults. By locating these faults, the user can make decisions faster and more efficiently, reducing and preventing product defects instead of correcting them after fabrication [11].

Statistical Process Control (SPC) charts offer users the chance to monitor their processes. SPC uses statistical method for quality control, by collecting data it can predict the process performance. The control charts have been tried and proven, and accepted as a highly effective tool in improving processes [12]. From the SPC method, the process capability index Cp, Cpk is obtained. Cpk is a statistical measure which gives insight of the process proficiency to produce inside the specification limits [3].

The proposed system in this paper is delimited to be used in general industry. Any manufacturing process that is able to collect random variable data and use it in a normal probability distribution.

2.1.1. Equipment and devices

The Augmented Reality applications are processed in mobile devices or Head Mounted Display (HMD) units. In the past decade, the mobile devices, including smartphones and tablets, have increased their number of users. The mobile technology has become more available to the general public. On the other side, the HMD units have been present for a long time but they have not been received as well. HMD have been used mainly for Virtual Reality (VR) purposes but has found a new market opportunity with Augmented Reality apps. The HMD units for AR applications have grown its popularity only in the recent couple of years. The GPS functionality is integrated in practically all mobile devices and HMD units, accelerometers and gyroscopes are incorporated to be compatible with popular apps like Google Maps or Waze.

Data collection in each workstation is made using different measuring devices depending on the characteristic that needs to be analyzed. The information can be obtained from torque wrenches, digital indicators, true position gages, seal gap systems, among others; these devices can transmit data to the CAQ software via wireless for a more practical approach. After this, the software (QDA) will utilize the collected data in order to create real time reports which will be exported to the AR system. Fig. 3 shows examples of measuring devices used in automobile industry and their connection to QDA.

2.1.2. Hypothesis

The hypothesis arises from the necessity of having easier access to the information gathered from the productive line. This hypothesis establishes that Augmented Reality technology facilitates the decision making process in quality matters by monitoring the Cpk index.

Fig. 3. Measuring devices: Digital indicator, Torque wrench, Seal gap systems. Wireless connectivity with QDA software

2.2. Methodological frame

2.2.1. Methodology

The methodology used in this project is similar to the one proposed in a previously published paper [13], this methodology is a more synthesized version of the work presented in [8]. The characteristics of this project are different due to the lack of 3D models and animations. This AR system does not teach the user any procedures nor shows virtual models, instead it connects and displays information from a Computer Aided Quality (CAQ) software. As shown in Fig. 2 the system can focus only on Info visualization rather than superimposed virtual models. The new methodology replaces the *3D modelling* and *Textures & animations* stages for *Sample collection* and *CAQ connectivity* respectively as shown in Fig. 4.

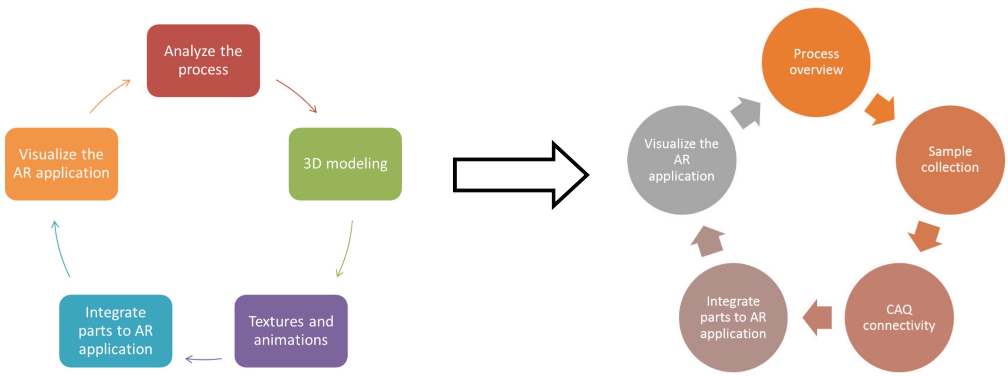

Fig. 4. Methodology changes for the development of an AR / CAQ application

The experiment design is deductive and descriptive. A sampling was made in five milling machine stations, measuring critical dimensions from every manufactured piece. A Vernier caliper with wireless connectivity with QDA is used to measure the diameter from the machined hole. This methodology is quantitative, using descriptive statistic (generating graphical tools) and inferential statistic (calculating indices).

2.2.1.1. Process overview

The main objective in this stage is to identify which Key Performance Indicator (KPI) should be displayed onto the user's field of view. Statistical measures such as Process Capability (Cp, Cpk) and Process Performance (Pp, Ppk) could be obtained from the CAQ software as well as histograms, charts or any graphical tool generated by the software itself. In a consensual decision, it was determined that the Cpk index is the most useful indicator to represent the production behavior, this index provides a general overview of the process capacity and how it is centered relative to control limits.

2.2.1.2. Sample collection

A Vernier caliper is the conventional gage to measure the diameter of holes. 20 pieces were machined in each of the five working stations and their dimensions were registered using the caliper and Wireless connectivity into the Quality Data Analysis software. Besides these 100 samples, the user can access the historical data for a better understanding of the process.

2.2.1.3. CAQ connectivity

The reports generated in QDA software will be exported automatically to a comma separated value (.csv) or a .pdf file. This file will be the input in the next stage of the process. The selected data from the PDF report will be parsed and transferred to Unity. Once inside Unity, we will be able to integrate this data inside an Android or iOS application so the user can visualize it.

2.2.1.4. Integrate parts to AR application

Wagner enlists the main tasks for making a functional AR application as follows [14]:

- Initialization of Graphical User Interface (GUI)
- Tracking of the marker
- Estimation of scale and position
- *Renders* creation

The *Initialization of Graphical User Interface* is also to be completed within Unity. The application is programmed using a videogame engine, Unity, creating as many scenes as necessary to show all the information previously collected. Each scene includes scripts with the codes that allow the user to import the collected data from the QDA software. Usually these codes are written in Java, C# or C++ language.

The *Estimation of Scale and Position* task will be carry out by a positioning system. It is important to know that a Global Positioning System or GPS does not work inside a building or warehouse. Considering that this AR system is intended to be implemented inside a facility, an Indoor Positioning System (IPS) is a more viable option. In this work, the tasks *"Tracking of the marker"* and *"Renders creation"* does not apply for the AR-Quality Monitoring application due to the lack of 3D models as it was previously mentioned.

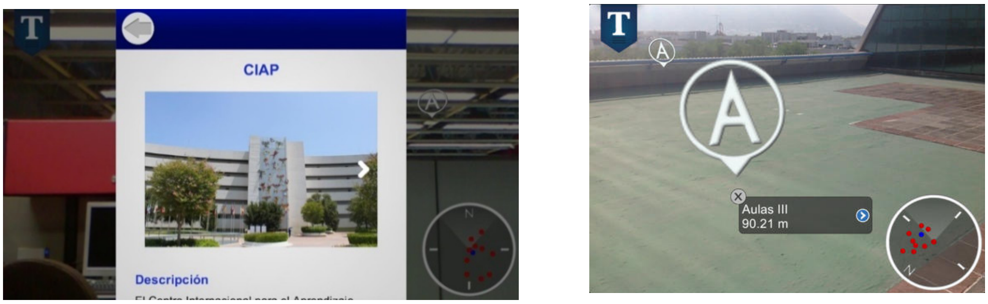

Fig. 5. Sample App running inside and outside environments

2.2.1.5. *Visualize the AR application*

This stage consists in testing the AR application to identify any flaws in the programming or connectivity with QDA. It is important to verify that the data displayed on the user's field of view is not misplaced in different workstations because relevant and timely information is the main purpose of this Augmented Reality system.

Fig. 6. Conceptualization of using the AR-QDA application on a full productive line

2.2.2. *Experiment tools*

- Asus Google Nexus 7 tablet is the mobile device where the AR application will run. It uses Android Operating System, with a Quad-core 1.2 GHz Central Processing Unit. Nexus 7 has an internal memory of 16GB and 1GB RAM [15].
- Nexus 7 features Assisted GPS (A-GPS), this includes sensors such as accelerometer, gyroscope, proximity sensor and compass.

- QDA software is capable of having Wireless connectivity with measuring gages. QDA communicates via e-mail, SMS and internet. It also generates .DOC, .PDF or HTML reports [11].
- ADS industrial unit specifications: Windows® 7 Professional Sp1 Operating System, Memory DRAM 4GB. Solid State Drive 120 GB SATA.
- Mitutoyo digital indicator 543-692 model. Stem diameter of 3/8". Measuring force of 2.0N. Operating temperature of 0 F to 140 F (0°C to 40°C) [15].

2.2.3. Data collection

As it was mention before, the Vernier caliper is the chosen gage to measure the diameter of holes in this experiment. The data was collected inside the machine shop department in the milling stations. In order to have more relevant data, a sample of 20 pieces were machined and their hole dimensions were registered into the QDA software. For the analysis of the milling station process, besides the recently taken samples, the historical data was also available for deployment.

2.2.4. Data Analysis

The information gathered will be used in three different scenarios:

- Hand written dimensions and manual calculations of the Cpk index
- Using only QDA interface, reviewing reports directly on the ADS industrial unit
- Using AR-QDA application, displaying reports and Cpk indexes on the user's field of view

2.2.5. Results

Hand written scenario: as expected this was the slowest and more error prone option. The hand calculations of the Cpk index takes too long when the means and σ' are obtained manually. Without graphical help, the user may not be able to reach an objective conclusion.

QDA only scenario: this is a very powerful tool that saves a lot of time by generating graphics and automatic calculations. The main disadvantage turn out to be the access to the information inside the software, new users are unaware of its functions and interface. During an audit to the machine shop department, printing the reports from the industrial units (where QDA is installed) may take more time than expected.

AR-QDA scenario: this option proved to be the fastest tool taking advantage of QDA calculations and reports to identify the tendency of the process. The AR functionality creates an easier interaction, reducing time in accessing the information from an industrial unit. Users tend to have a more critical analysis of the process by focusing only in the information forgetting about using QDA interface.

3. New research lines

In order to make the system 100% functional in manufacturing environments and productive lines, an ergonomic and safety study will be conducted. When used carelessly, this application could compromise the integrity of the person holding the mobile device especially when his attention is focus on the screen instead of the warning signs. This system needs to be compatible with every personal protective equipment security norm such as NOM-017-STPS-2008 and ANSI/ISEA Z87.1-2010 [16].

The next stage of the Project consists in designing and building a Head Mounted Display (HMD) prototype in collaboration with the local university: Tecnológico de Monterrey. A development group is currently working to create a wearable device based on Google Cardboard, SEER helmet and Archos VR Glasses. These wearable devices or HMD are similar because they all use a mobile device, cellphone or Tablet, to run the Augmented or Virtual Reality application. This way, the AR-Quality Monitoring application described in this paper becomes more immersive without ignoring safety rules.

4. Conclusions

Augmented Reality has demonstrated that it can be a guidance tool for technicians during maintenance and training courses [17, 13]. It reduces working time and significantly decreases the probability of making mistakes by clearly displaying the knowledge needed to complete a task (information and animations). Also, the advantages of Augmented Reality technology can be exploited in different applications for other areas apart from the manufacturing industry. It is worth noting the potential capacity of this technology to serve as a key tool in education and other areas where knowledge transfer is necessary to successfully complete critical tasks.

In manufacturing and quality control operations, the proposed system in this paper allows the information to be available in any required frequency. The visible historical record of samples dates back from a few hours or days to several weeks or months before. This allows us to observe tendencies inside the production line, not only in one machine but in several work stations. The access of timely and accurate collected data helps the decision making process to be correct and easier.

The Q-Management software (QDA) becomes a more dynamic authoring tool when is supported with Augmented Reality technology. AR turns QDA into a simplified way to access the process performance information of several work stations in a general view of the productive line, i.e., it is no longer necessary to visit each station one by one to consult their status.

The AR system also acts as an educational tool, during the trials, the user seem to have a better understanding of the quality terms when using Augmented Reality. Written data collection and manual calculations seem to overwhelm the users without any graphical help especially if they were not previously related to the topic. Guidance and visual aid through the AR application shows clearly the Cpk index along the Xbar and Rbar Graphics with their respective specification limits and place it directly on the user's field of view without having the necessity to access databases or reports stored in the PC. The quick access to visual information facilitates the user comprehension of the process.

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