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Application of Augmented Reality in Statistical Process Control, to Increment the Productivity in Manufacture

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Abstract

In education from the standpoint of looking for new techniques to train staff more efficiently, especially when they have a lot of turnover of employees, the technology always helps to improve on this area. For the statistical process control, data acquisition of the manufacturing processes is very important and this can be affected if the technician who use the measure tools doesn't know how to use them correctly. On the other hand augmented reality (AR) is an alternative to the traditional training methods, where one can receive instructions on real-time on which tool use and how to use it depending of what is measuring. It's proposed on this work, if augmented reality can improve time to train a person and with this spend less money and have better prepared staff. For this experiment two groups of young engineers were given a set of instructions to do a quality process measuring. On one team a manual instructions was provided and on the other team an application of augmented reality where the subject can watch on site the instructions on real time of the process. With the analysis of the results it was determined that the group with the augmented do the process up to 30% faster and with less money than the group with the manual instructions, and also analyze the future works about this subject.

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1. Introduction and Justification

Currently, companies are seeking to lower costs in its manufacturing processes in order to deliver products with more attractive prices to the customer and obtain a competitive advantage over their competition. The problem is that the quality aspects are compromised and can get affected by third parties.

A study made by Boeing and U.S. Air Transport Association found that 15% of the maintenance errors between 1982 and 1991 were five or more people died, was because this factors [1]:

- Inspection/maintenance error by the vendor/manufacturer.
- Error due to an airline's maintenance/inspection policy.
- Poor design on the product that lead to an error in maintenance.

Another case was in 2008 with Toyota, where due to their goals of increasing the production of theirs cars and overpass the leader (General Motors) in sales, quality was affected and the problems arose, like the one where the gas pedal was stuck with floor mat of the car. So they have to recall 4.2 million cars just in United States. Then after January 2010 they have again to recall 2.3 million of cars with problems on the gas pedal and another 1.1 million again with problems on the floor mat on the driver seat. All this problems cause that Toyota lost billions of dollars and the brand was affected, giving the impression of being a brand of low-quality products. [2]

Nomenclature

AR	Augmented Reality
SPC	Statistical Process Control
QDA	Quality Data Analysis

1.1. Justification

On today companies invest on statistical process control (SPC), where they seek to measure key values in the manufacturing processes, to maintain the quality in the products. The problem is that the measurement of these values can be affected by the expertise of the staff because of poor training, a high staff turnover, or because the complexity of the process.

So the objective of this investigation is to search how the augmented reality (AR) can help to the SPC, to guarantee the quality of the products by reducing the times of training, or showing instructions on real-time of how the staff need to measure this values correctly.

2. Theoretical framework

2.1. Methodologies

- Descriptive statistical:
  Is going to be use on numerical procedures that allow to organize and summarize the data collected to facilitate: interpretation, analysis, and debugging.
- Inferential statistics:
  This looks to get general conclusions from the data, which are derived from samples for decision-making, where this is going to be used for hypothesis testing and parameter estimation.

2.2. Technologies

On this paper, is going to be used augmented reality tools and a software to analyze the information to maintain the quality of the processes of manufacture, where in this case it's called *"Quality Data Analysis (QDA)"* from ASI Datamyte. Also measurement tools as are true position TP107 from LMI [3], digital indicators 543 series standard type [4], and clamps 350 HV series [5].

The augmented reality look to put additional information over the real world, this information can be 3d models with animations, text, images and videos. Unlike the virtual reality where this completely replace the physical world for world generated by computer graphics. [6]

QDA is a software divided by several modules, where each one of this try to resolve a necessity to improve the manufacturing quality. The modules that are going to be used are [7]:

- Gage & Tool Management: This software helps to maintain the inspection and calibration plans of the measure tools that were used on the factory.
- Document Management: Organize the documents that are needed for quality audits.
- SPC & Data Collection: Collects data from manufacturing processes then this data is analyzed to generate reports to maintain the quality of the product. This last module will be used in conjunction with the AR application.

3. Methodical framework

Experiment design is deductive, because it's going to validate or invalidate the hypothesis established.

3.1. Hypothesis

Ho: The use of augmented reality facilitates the data collection in the manufacture processes.

Hi: The use of augmented reality does not facilitate the data collection in the manufacture processes.

3.2. Investigation design

The research design includes the experimental process, because they intentionally manipulate the independent variables (augmented reality) to analyze the impact on dependent variables (efficiency, quality control) within a controllable situation in the experiment.

3.3. Design methodology

The experimental design is a quantitative methodology because the following measurement variables were work:

- Time
- Costs

The scope of the methodology of the study is:

- Exploratory: Because the augmented reality is a novelty technology, and in manufacture is not very used especially for administration of quality control systems.
- Correlational: Because two methods are compare; one is traditional method in quality control, and the other one is the use of augmented reality.

On the experiment will be use two groups were each group has twenty engineers and they will have list of tasks to measure on this piece, like on Fig. 1 it's displayed.

First group will do the experiment on the traditional way, this group will have a manual with the instructions of how they need to do the measurements and also picture with the tools they will need to do the task.

The other group will use an augmented reality application where they will have the instructions with 3D models of how they need to do the measurement and the tools they need to use.

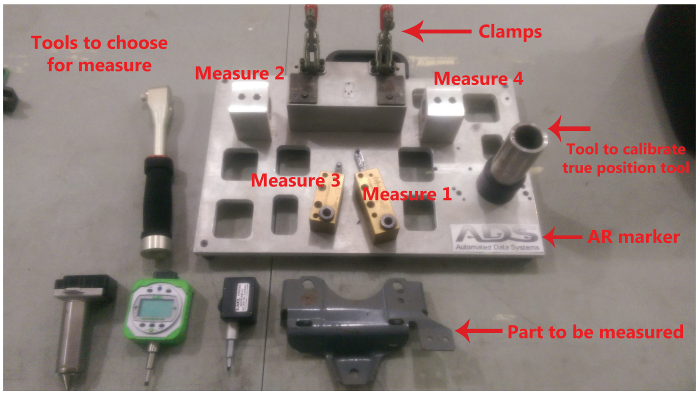

Fig. 1 Tools to do the measure, and the piece where will be performed the measures. Reference: Automated Data Systems SA. De CV. (2015)

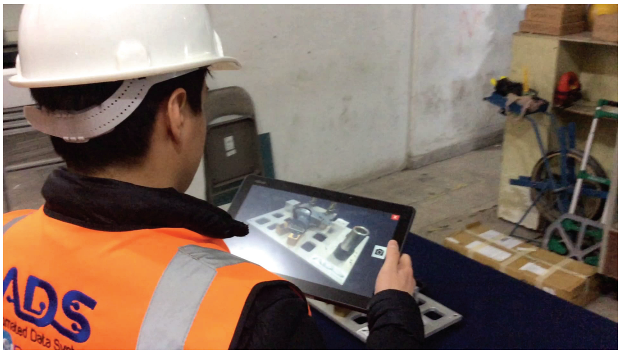

Fig. 2 Worker using the AR application. Reference: Automated Data Systems SA. De CV. (2015)

3.4. Sample calculation

The sample of the experiment will be restricted to experts that know of mechanics, and can or can't have experience with the measure tools. Also the selected personnel must be involve in the management of these sensors and will be part of these departments in the company:

- Quality
- Audit
- Operational processes
- Maintenance

The sample size was chosen from non-probabilistic way, because they had to choose staff with expertise in technologies such as checking features, with basic expertise on mobile devices (for the group of augmented reality).

The benefit of using augmented reality, is that is focused on the production of pieces of mass volume, with high grade of complexity to memorize the sequence of the operation.

3.5. Research tools

On the experiment will be use of QDA v9.0 with the module of SPC active.

The tools to measure will be:

- True position probe, with operating range of +/- 3 mm and with a resolution of +/- 0.001 mm accuracy.
- Digital calliper, with operating range of +/- 12.7 mm and with a resolution of +/- 0.01 mm accuracy.
- Digital timer, with operating range of 60 seconds.

3.6. Data collection methodology

The data collection methodology will consist of six steps where the operator will have to do in the correct order, and also choose from his set of tools the correct one to do the measure on each step. Fig. 1

The steps are the following:

1) Mount piece to measure, and close the clamps to fix the piece.
2) Select correct digital calliper, reset it to zeros, and measure on position 1.
3) Choose the probe of true position, calibrate it, and measure on position 2.
4) Again choose the digital calliper, reset it to zeros, and measure on position 3.
5) Take the true position probe, calibrate it again, and take the measure on position 4.
6) Free the clamps, and remove the piece.

3.7. Data analysis

The averages of the times collected from the two groups (without AR and with AR) and the costs (where each operator charges 500 Mexican pesos per hour) are as follows [8]:

Table 1. Average times of group without AR.

Process	Description	Times without AR	Costs without AR
Mount piece	Free Clamps	20 sec.	$2.78
	Mount piece		
	Close clamps		
Position it in the gage in the right side	Select digital indicator	35 sec.	$4.86
	Reset to zeros		
	Position it on measure 1		
Measuring height on the left side	Select true position gage	20 sec.	$2.78
	Calibrate it		
	Position it on measure 2		
Position it in the gage in the left side	Select digital indicator	35 sec.	$4.86
	Reset to zeros		
	Position it on measure 3		
Measuring height on the right side	Select true position gage	20 sec.	$2.78
	Calibrate it		
	Position it on measure 4		
Free the piece	Free clamps	10 sec.	$1.39
	Dismount piece		
	Close clamps		

Table 2. Average times of group with AR

Process	Description	Times with AR	Costs with AR
Mount piece	Free Clamps	15.3 sec.	$1.67
	Mount piece		
	Close clamps		
Position it in the gage in the right side	Select digital indicator	22.4 sec.	$2.64
	Reset to zeros		
	Position it on measure 1		
Measuring height on the left side	Select true position gage	15.9 sec.	$1.53
	Calibrate it		
	Position it on measure 2		
Position it in the gage in the left side	Select digital indicator	19.96 sec.	$2.78
	Reset to zeros		
	Position it on measure 3		
Measuring height on the right side	Select true position gage	14.1 sec.	$1.11
	Calibrate it		
	Position it on measure 4		
Free the piece	Free clamps	5 sec.	$1.67
	Dismount piece		
	Close clamps		

Student t test was calculated using the average of the times of the two groups, where each group has twenty members and using confidence level of 95%. With this we have the next table:

Table 3. Values of t student

Student t test	$\lvert t_0 \rvert$	T(38,0.05)	$H_0: \bar{X}_1 = \bar{X}_2$	$H_1: \bar{X}_1 \neq \bar{X}_2$
Average time with AR vs without AR	297.74	1.68	Rejected	Approved

The alternative hypothesis is approved, where the inspected processes are different so this leads that exist a difference in times and costs where augmented reality was used; and we can conclude that this technology improves the times and reduce the costs where one needs to audit some pieces while maintaining the quality of the measures.

4. Conclusion

With the results of this experiment, it conclude that exist a variation in times, where these benefits on using augmented reality technology, for very complex measurement procedures and we can also see some savings on training of new personnel where normally each receives a week of training where each day they just learn the procedure during 4 hours and each hour they cost $500 Mexican pesos, so for that week the company will have to pay $10,000 Mexican pesos per person. But on the other hand if the company use augmented reality for their training, instead of a week the can have the same training on half a week, with a cost of $5,857 Mexican pesos, and this like 41% of savings on the training for each new operator.

5. Limitations

On this paper two training methods were compared, one assisted by augmented reality where this one permits to know the same information of the traditional method but with more speed to memorize the instructions. Also we have to mention that the developing of the content and the code of the augmented reality application can increase the cost for more complex operations in comparison of the traditional method. So it's important to have this in consideration where one wants to implement this technology.

6. New lines of research

Following the result of this research, you can discuss new ways to create augmented reality content faster and more cheap that it is used on this paper, also one can explore new forms of recognition because some of the used on this paper (markers) they no meet the requirements of some policies in the company.

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Appendix A. Table of times of each group

A.1. Table for the group of without AR

Steps/Workers	1	2	3	4	5	6	7	8	9	10
1	19.59	19.73	20.46	19.06	20.88	19.44	19.42	19.71	20.27	20.03
2	35.58	35.28	34.88	35.2	34.21	34.06	34.18	35.59	35.98	35.28
3	20.43	19.61	20.41	19.63	20	20.91	20.21	19.13	19.11	19.78
4	35.4	35.35	34.64	35.81	35.43	35.77	34.84	35.45	35.26	35.6
5	19.93	20.65	20.81	20.13	19.05	19.25	19.76	19.76	20.02	19.88
6	10.51	9.2	9.67	9.99	10.34	9.19	9.17	9.25	9.14	9

Steps/Workers	11	12	13	14	15	16	17	18	19	20
1	20.8 9	19.35	19.42	20.53	19.63	19.56	19.76	19.37	21	19.91
2	35.5	35.62	34.24	35.92	34.71	34.03	34.91	34.1	35.03	34.48
3	20.4 8	19.51	20.13	19.26	20.48	20.35	19.79	20.87	20.98	19.61
4	35.5 1	35.97	34.63	35.67	35.18	34.47	34.58	34	35.09	34.51
5	19.6 1	19.31	20.7	19.21	19.43	20.83	19.97	20.69	20.81	20.28
6	9.4	10.98	10.85	9.18	9.92	10.78	10.69	10.71	9.55	9.58

A.2. Table for the group with AR

Steps/Workers	1	2	3	4	5	6	7	8	9	10
1	11.95	12.07	11.22	11.37	11.75	12	11.95	12.33	11.27	12.65
2	18.27	19.34	19	18.38	18.72	18.19	19.52	18.75	19.71	18.93
3	11.22	11.87	10.48	10.57	11	10.04	10.67	10.63	10.77	10.9
4	20.85	19.04	20.65	19.31	20.08	20.82	20.34	19.55	20.89	20.13
5	8.93	7.42	8.3	8.07	7.45	7.36	8.25	8.05	7.67	7.26
6	11.2	11.66	11.9	11.84	13	11.98	11.76	12.97	12.67	11.08

Steps/Workers	11	12	13	14	15	16	17	18	19	20
1	11.37	12.4	12	11.31	11.39	11.81	12.29	12.83	11.53	11.74
2	19.78	19.76	19.47	18.89	19.29	18.37	18.75	19.83	19.94	18.79
3	10.13	11.34	10.84	10.06	11.81	11.15	11.76	11.84	10.55	10.65
4	20.63	19.13	19.86	20.8	20.19	20.05	20	21	19.74	20.16
5	7.46	8.4	8.95	8.82	8.85	8.17	8.82	7.77	8.68	8.34
6	12.57	11.4	11.29	12.25	11.46	12.18	12.48	12.3	12.38	12.31

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