USABILITY TESTING OF AN AUGMENTED REALITY APP FOR LEARNING 3D STATICS IN ENGINEERING

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ABSTRACT

This work was developed with the purpose of evaluating the usability of an augmented reality (AR) application, designed to visualize three-dimensional structures through physical markers. This, with the intention of strengthening the design of the app based on the usability results, thus achieving improvements in the user experience and in the problem-solving practices of three-dimensional statics and the analysis of forces in equilibrium. The evaluation instruments were applied to a sample of 90 students of the School of Mechanical and Electrical Engineering of the Universidad Autónoma de Nuevo León. These instruments consist of 15 items, 6 of which register measurable parameters under the 5-point Likert scale, while the rest are control items.

The usability tests yielded information that allowed implementing improvements in a new version of the AR app, which was tested again, obtaining positive results in all measured parameters, averaging an overall score with an increase of 7.9% with respect to the beta version of the app and savings in waiting times of approximately 10 seconds.

KEYWORDS: Usability testing, augmented reality, engineering students, statics.

RESUMEN

El presente trabajo se desarrolló con la finalidad de evaluar la usabilidad de una aplicación en realidad aumentada (RA), diseñada para visualizar estructuras tridimensionales a través de marcadores físicos. Esto, con la intención de fortalecer el diseño de la app partiendo de los resultados de usabilidad, logrando así, mejoras en la experiencia del usuario y en las prácticas de resolución de problemas de la estática en tres dimensiones y el análisis de fuerzas en equilibrio. Los instrumentos de evaluación se aplicaron a una muestra de 90 estudiantes de la Facultad de Ingeniería Mecánica y Eléctrica de la Universidad Autónoma de Nuevo León. Estos instrumentos constan de 15 reactivos, de los cuales 6 registran parámetros medibles bajo la escala de Likert de 5 puntos, mientras que el resto son reactivos de control.

Las pruebas de usabilidad arrojaron información que permitió implementar mejoras en una nueva versión de la app en RA, misma que se puso a prueba nuevamente, obteniendo resultados positivos en todos los parámetros medidos, promediando un puntaje global con incremento de 7.9% respecto a la versión beta de la app y ahorros en tiempos de espera de aproximadamente 10 segundos.

PALABRAS CLAVE: Pruebas de usabilidad, realidad aumentada, estudiantes de ingeniería, estática.

INTRODUCTION

Usability perspectives of a product are relevant for the success of interactive software systems, such as augmented reality systems, as they provide a clear visibility of the quality aspects for both users and developers, [1]. One of the biggest challenges that arise when designing and developing an augmented reality app is the interaction required with the user, in addition to this, this type of technology is not comparable to the interaction between computers and humans, but it is something more complex than that [2]. This unfolds the task of implementing tools that can measure aspects to improve to achieve optimal results, so through usability testing can be obtained very valuable information to achieve it. To test the AR application used in this research work, a software usability test was used in order to evaluate the user experience of the simulation. According to [3], an augmented reality application can be evaluated in the context of usability objectively and subjectively, the first being an observational measure by an expert using cognitive techniques and the second measurement, using human perception or an objective measure of observation. In this case, a usability test based on measurement using human perception as an objective measure of information was used, since users evaluated the application according to their experience. The use of evaluation tools such as usability tests can allow us to establish parameters with a view to improving augmented reality products, making them more effective, developing a more enjoyable experience for users [4]. In addition, these tests would allow the

development of an improved version of the app in augmented reality, which presents three-dimensional models that represent engineering problems, in order to visualize elements in three dimensions to perform vector analysis based on the equations of translational equilibrium from Newton's laws, serving as support for a better performance of students in the academic context of mechanical physics for engineering.

METHODOLOGY

To measure the usability of the augmented reality software that aims to offer an alternative with good results in the learning of three-dimensional statics in engineering, and to carry out this work, several tasks were performed, such as the selection of the evaluation instruments (usability test), the selection of the sample, implementation, analysis of preliminary results, then modifications were made in the app following the results of the first usability test, and then re-test the usability of the app and finally compare the results to identify the improvements that this new version presented with respect to the beta version of the app.

Evaluation instrument

The usability test was established taking as a reference the research of [5], [6] who implemented it in their research work, one in the medical context and the other in the educational context. This usability test is composed of 15 items, of which 6 are measurable using a 5-point Likert scale, with the score of 1 point being a bad score and 5 an excellent score, covering the needs of the system, the user's experience, the ease of interaction and the time it takes to interact [7], adding 2 items, one referring to the visual presentation and the other to the clarity of the instructions. Another 5 items are control items, in which the age, gender, the group to which the students correspond, and the start and end time are requested. Two more items correspond to difficulties that may have arisen when using the application, leaving these questions open-ended, another to the visualization of the models and a final multiple-choice item, referring to the time it took to understand the information presented by the application.

Sample size

In research works, an important issue to address is the determination of the sample sizes to be analyzed in the intervention, with a desired degree of confidence, allowing a reliable analysis to be made with a finite and manageable number of data [8]. Several aspects were considered to determinate sample size, including population size, confidence level and evaluation instrument characteristics. To determine the sample size according to [9], as shown in equation 1, where n is the sample size, N is the population, s is the variance in normal distribution for a 4-point Likert scale ($s = 0.7$), d is the error margin ($d = \pm 5\%$) and z is the confidence level. A population of 160 students was considered, the same as those who registered according to the groups in the subject of mechanics, with a confidence level of 95%.

$$n = \frac{Ns^2}{(N-1)\left(\frac{d}{z}\right)^2 + s^2} \qquad (1)$$

The sample size obtained after tabulating the data in equation 1 was 84.3, so a sample $n > 84.3$, was selected, for this case the sample selected was 90 engineering students from FIME-UANL.

Figure 1. Usability test of an augmented reality app for engineering.

Implementation

As mentioned above, the app being tested in terms of usability is designed to promote improvements to statics problems in engineering, so the implementation of this evaluation tool was carried out by engineering students who are part of the enrollment within the faculty of mechanical and electrical engineering of the Universidad Autónoma de Nuevo León.

The tests were implemented using the Microsoft Forms platform, in two groups in the subject of mechanics, for this, students were previously asked to download the app through a link, which they should access and install it on those smartphones that run under the Android operating system since this app is compatible with this platform. They were then allowed to navigate the app intuitively and without prior instructions for a few minutes, then asked for more specific tasks, such as determining the position vectors of the forces that appear in the structural elements.

**Figure 2. Students using the augmented reality app.**

Feedback

The first usability test allowed us to identify weaknesses in the app and its handling according to users, some to mention were the interface and user interaction with the app, which affects their experience, this is based on the assumption that it did not have a home screen, or access/exit and instructions buttons, and it could affect the time it took the user to detect the information directly from the software. Therefore, in the improved version of the app, a home screen was added, where access and exit buttons were placed, and when running the app, back and instruction buttons were added for each model. It should be noted that text islands were also added to break down the instructions for each model, which can be activated and deactivated by pressing a button.

RESULTS

The usability tests applied for the beta version of the app, showed that 100% of the users found it appropriate the colors used in the design of the models to represent the scenarios and no one experienced difficulties when using the app. However, with respect to the instructions provided in the app in this version, an average of 4.3 points was obtained out of 5. When evaluating the item for interaction with the interface, users scored an average score of 4.1 points, while in the app's standby time assessment they obtained 4.2 points. For users, the satisfaction according to the visual representation of the app deserves an average of 4.1 points, but with regard to the graphics and images that represent the three-dimensional models, 4.2 points. Finally, the item that evaluates the user's handling with the app, was the one that obtained a lower rating, with 3.9 points.

Graph 1 shows the cumulative results for beta version of user scores for items measured through the Likert scale of 5 points, 40% corresponds to the highest rating or excellent score, and less than 1% belong to the lowest rate or bad score. The average score is 4.1 points out of 5.
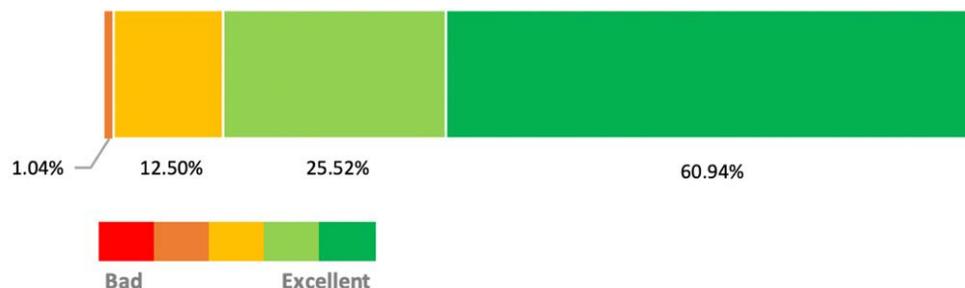
Facultad de Ingeniería Mecánica y Eléctrica
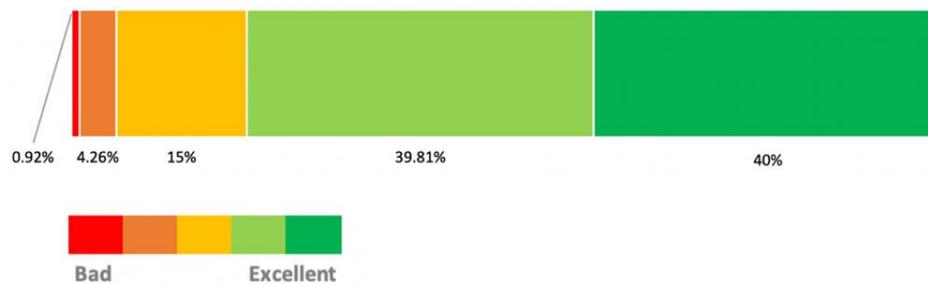
Graph 1. Usability testing results for beta version.

Also, for the beta version of the app it was obtained that the time it takes users to collect information through the presented models is approximately 4.0 minutes.

The usability testing for the enhanced version of the app show that in addition to the fact that the totality of users considered the design and colors of the 3D models appropriate and did not experience difficulties when using the app. The instructions provided in the app in this version obtained 4.5 out of 5 points on the Likert scale, and evaluating the item for interaction with the interface, users gave the same score as before. About the app's standby time assessment, they gave a score of 4.5 points too, and the satisfaction according to the visual representation of the app obtained an average of 4.5 points. In addition, with regard to the graphics and images that represent the three-dimensional models, users score with 4.4 points, the same rating for user handling of the application.

Graph 2 shows the cumulative results for new version of user scores, 60.9% corresponds to the highest rating or excellent score, and less than 0% corresponds to the lowest rate or bad score and the average score is 4.5 points.

Graph 2. Usability testing results for enhanced version.

For enhanced version of the app, it was obtained that the time it takes users to collect information through the presented models is 3.9 minutes.

CONCLUSIONS

The average of the usability parameters obtained in the test of the enhanced version of the application was 4.5 points versus an average of 4.1 points for the usability test in the beta version, representing an average increase from the beta version to the enhanced version of 7.9%.

On the other hand, according to the information presented, the average corresponding to the time intervals was obtained and it was found that it takes users approximately 3.9 minutes to grasp the information provided by the app, compared to the time it took them in the beta version, which was 4.0 minutes, which means a gain of almost 10 seconds in the time required to understand the information.

In general, the usability tests used, allowed to detect the weaknesses of the app in its beta version, which brought with it the need to develop an improved version of the application that covered these details, leading the user to live a more enjoyable and rich learning experience. Significant improvements were obtained in all the items covered by the usability tests according to the improved version of the app compared to the usability parameters obtained in the beta version tests, so the changes that the app underwent in the improved version will provide a better user experience, improve the time it takes to develop the learning process, present a more attractive interface and is expected to provide a better learning process in the field of three-dimensional statics for engineering.

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