Evaluating the Usability of a 3D Map Visualizer Augmented Reality Application

Franklin L. N. Fracaro[1][a], Fabiana F. F. Peres[1][b], Claudio R. M. Mauricio[1][c] and João Marcelo X. N. Teixeira[2][d]

[1]*Centro de Engenharias e Ciências Exatas, Universidade Estadual do Oeste do Paraná, Foz do Iguaçu 85870-650, Brazil*
[2]*Departamento de Eletrônica e Sistemas, Universidade Federal de Pernambuco, Recife 50670-901, Brazil*

Keywords: Usability Testing, Augmented Reality, User Experience, Human-Computer Interaction.

Abstract: This study focuses on evaluating the usability of a 3D map visualizer augmented reality application through informal, remote, and synchronous usability tests, utilizing the Think Aloud process and the System Usability Scale questionnaire. The aim is to identify potential usability issues in the prototype and develop an action plan for future iterations of the application's development. The challenges of integrating end-users in the application development process is addressed and emphasizes the significance of early usability testing to uncover and address potential issues. The findings from the usability tests provide valuable insights into user experience, highlighting key usability issues and user feedback. A comprehensive action plan for addressing the identified usability issues is presented and implications for future research in the domain of augmented reality applications is discussed.

1 INTRODUCTION

Usability testing is a process that allows learning about the users of a product by observing how they interact with the product to achieve specific goals that interest them (Barnum, 2020). Usability tests can be divided into two types: formative tests, conducted while a product is still in development; and summative tests, applied when the product is finished or nearly finished. The latter needs to be applied to a large number of users to have statistical validity (Barnum, 2020).

Various testing methods can be employed separately or in combination to assess usability (Bruun et al., 2009; Ghasemifard et al., 2015; Gupta, 2015). A commonly used method is remote testing, where participants and the analyst/moderator are separated in space and/or time, making them either asynchronous or synchronous. The Think Aloud process and Performance Measurement are other methods that can be employed in usability testing.

The overall goal of this work is to identify usability problems in an AR application for displaying 3D maps through usability testing. Based on the general goal, the following specific objectives can be highlighted: I) Explore the current methods used for identifying usability problems in AR applications; II) Understand, plan, and conduct usability tests; III) Analyze the results obtained from the application of usability tests; IV) Use the knowledge gained from the analysis of usability test results to propose solutions for future development iterations.

[a] https://orcid.org/0009-0004-1274-8224
[b] https://orcid.org/0000-0002-3937-3432
[c] https://orcid.org/0000-0003-2783-3988
[d] https://orcid.org/0000-0001-7180-512X

2 USABILITY DATA COLLECTION IN AR

Developing and applying assessments that examine AR is a challenge, especially when design guidelines and how to conduct these assessments are not yet consolidated in the literature (Merino et al., 2020).

Despite the various methods that can be adopted to evaluate AR approaches, such as heuristic evaluations, usability tests, cognitive walkthroughs, among others, most of these practices end up being adapted for specific use cases, making their reuse difficult, or they are applied in a standardized format without addressing the specificities of AR. Other issues in as-

Fracaro, F., Peres, F., Mauricio, C. and Teixeira, J.
Evaluating the Usability of a 3D Map Visualizer Augmented Reality Application.
DOI: 10.5220/0012547000003660

In *Proceedings of the 19th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2024) - Volume 4: VISAPP*, pages 621-628
ISBN: 978-989-758-679-8; ISSN: 2184-4321

sessments include their execution, which is often not done with the target audience, and the failure to use established Software Engineering techniques that ensure the proper functioning and code quality of applications (Tori and Hounsell, 2020).

3 MATERIALS AND METHODS

This section presents the research methodology used for the planning and execution of this work, addressing the tools used, the study target, usability test planning, and data collection and analysis.

3.1 Development Tools

For the development of the application, Unity 3D with the AR Foundation framework, Blender, Krita, and OBS Studio were used. It should be noted that the application used for testing was developed prior to the construction of this work; thus, these tools and the development process described serve only for demonstrative purposes of its state during the testing application.

3.2 Study Methodology

This work can be characterized as a case study with the aim of exploring the issues of an AR application for mobile devices by applying informal usability tests with the collection and analysis of qualitative data.

The introduction of usability evaluation processes during the development cycle allowed the discovery of UX problems early on through the observation of users interacting with a functional prototype, along with the analysis of pre-test and post-test questionnaire data. This approach is indicated by various authors such as (Barnum, 2020; Rubin et al., 2008; Stull, 2018; Lewis, 2012), among others.

Usability tests were conducted online with volunteers using two UX research techniques: remote evaluation and the Think Aloud process. On the other hand, the Think Aloud process prompted volunteers to verbally describe all the actions they intended to perform in the application before executing them, allowing the moderator to understand the decision-making process of these volunteers. The planning of the format and the decision on which techniques would be used in the tests can be seen in Section 5.

Before selecting participants for the study, user profiles were created, with the aim of assisting in the selection process of users representative of the application's target audience. One critical factor allowed dividing users into two subgroups: one with prior knowledge related to Augmented Reality (AR) or Virtual Reality (VR), and another without prior knowledge of these technologies.

The first testing phase involved five volunteers from a subgroup identified by user profiles as individuals with prior knowledge related to AR or VR, with sessions lasting between 25 and 35 minutes. Comprised of 4 males and 1 female, all of them were undergrad students, with a mean age of 25.4 years. One of them worked as a professor.

Before the data from the first test was analyzed, there was an expansion of the application's target audience, which is explained in greater detail in Section 5.5 and 5.6. Thus, the study sample had to be increased to accommodate a second subgroup, representing individuals with no previous experience with AR or VR. Due to the rigid nature of usability tests, where maximum effort is made to ensure that a participant's experience in a test is the same as that of other participants (Barnum, 2020). Sessions were scheduled in advance, lasting between 35 to 55 minutes, using the same format as the previous test. Comprised of 2 males and 3 females, three of them were still undergrad students, with a mean age of 33 years (min age 24, max age 52). Their main occupations were secretary, marketing assistant and professor.

The steps followed during these usability tests were five: initial briefing, download and installation of the application, usability test, questionnaire and debriefing. Initially, the moderator contextualized the process for the volunteer, explaining what and how it would be executed, making it clear that only the application would be evaluated.

The moderator presented a pre-test questionnaire which aimed to collect specific data about the volunteer, such as their mobile device usage rate and possible prior knowledge about AR applications. When indicating that the questionnaire was filled out, the moderator provided a link to download the application to be tested, so the volunteer could install it on their mobile device. After the installation was completed, the volunteer was asked to run the application and share the mobile device screen on the online meeting software, as shown in Figure 1.

Before starting the test, an explanation of how the Think Aloud process worked was provided, including the types of descriptions expected from the volunteer when performing the various scenarios presented. The first scenario was read aloud by the moderator, with a copy of the text pasted in the chat of the online meeting software. The volunteer then navigated through the application and attempted to perform the task required by the scenario. When the volunteer in-

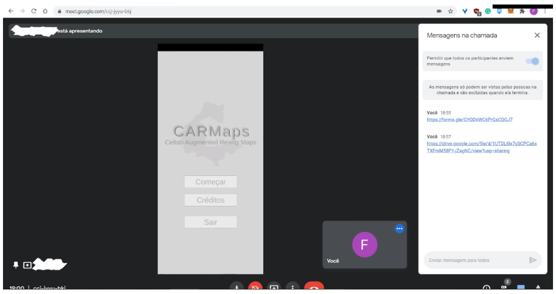

Figure 1: Screen shared by one of the participants (participant data hidden).

dicated that a scenario was completed, the moderator was alerted, allowing the next one to be presented.

While executing the scenarios, the moderator observed the volunteer's screen, making notes of possible interaction problems that may have arisen or points that should be addressed with the volunteer in the form of questions asked after completing a task. Upon completion of all scenarios, the moderator presented the post-test System Usability Scale questionnaire (SUS) to the volunteer, which helped understand how usable the volunteer considered the application used. The justification for choosing this form can be observed in Section 5.2.

As a final step, a debriefing process was initiated, with the moderator reinforcing various topics discussed before, during, and after the test, and providing an opportunity for any questions and curiosities the volunteer might have about the process.

3.3 Data Analysis

The recorded interviews were watched, allowing for the supplementation of notes made during the online synchronous process. These data were organized in the format of a report, taking into account two main factors: the severity of the problem and the number of volunteers who encountered the same difficulties during the use of the application.

The obtained results were transformed into adjective ratings and acceptance categories. This transformation aided in the interpretation of the results presented in Section 6.3.2.

4 DEVELOPMENT

A functional prototype of an application for displaying 3D maps generated by drones using AR was requested by the Latin American Center for Open Technologies (b), one of the research centers at the Itaipu Technological Park (PTI). The initial goal was to use this application in meetings related to smart city projects, where participants could freely navigate the map and add markers to points of interest. Based on these requirements, it was possible to develop a functional prototype with the following features: I) Selection of a map for display; II) Addition of the selected map to the real environment; III) Adding, editing, removing, and moving points of interest on the map; IV) Functionality on mobile devices, preferably Android; V) Use of 3D maps generated by drones.

Since it was requested that the application be developed for mobile devices, using Unity's AR Foundation was a natural choice, as it functions as middleware between Google's AR Core and Apple's ARKit (Oufqir et al., 2020).

The first map provided by Celtab was created using the senseFly eBee Plus drone (SenseFly, 2021), flying over the Vila A region in Foz do Iguaçu. This region serves as the pilot neighborhood for the implementation of the Smart Cities project. It was necessary to open and edit some basic settings of this map, such as the textures that came separated from the mesh and to centralize the map at the origin.

After the adjustments to the map, small tests were possible using AR Foundation, including the prototyping of some buttons. Among these tests was the addition of markers on the map, as shown in Figure 2.

Figure 2: Test of markers on the map.

Having obtained positive results with the tests, the last stage involved building a basic screen flow, wich was used as a guide for implementation in the Unity 3D game engine using the C# programming language. The result of the implementation can be seen in Figure 3.

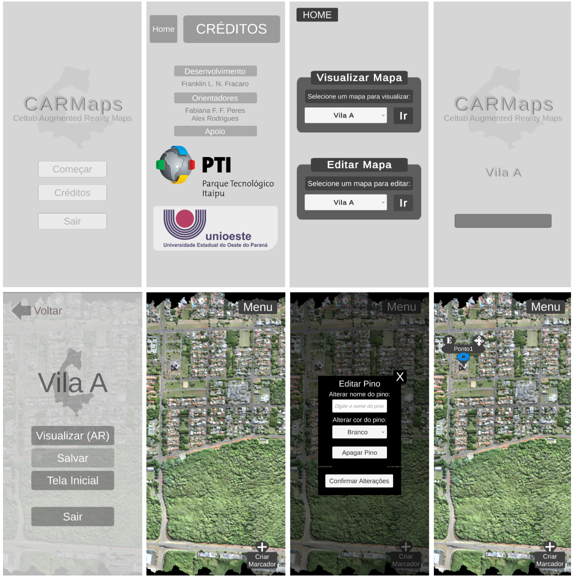

Figure 3: Implemented screens.

4.1 Issues Encountered

The implemented prototype worked as expected for Celtab stakeholders. However, several new features were requested. This presented some problems. The first problem arose because the inicial intention was only to create a functional prototype and, based on it, conduct a feasibility analysis and a more in-depth requirements gathering to eventually initiate the project. Therefore, continuing development without a defined plan could result in an application that does not meet the needs of its users. A second problem was related to the usability of the application. Despite approval from the stakeholders, no end users participated in the design decisions, which were made unilaterally. Continuing the development of the prototype without feedback from these users could result in an application with all implemented features but none of them being actually usable.

To address these problems, firstly, a development plan based on some parts of the unified process was adopted (Pressman and Maxim, 2020) . This allowed organizing the project requirements, prioritizing the next features to be implemented and placing the application development in an iterative and incremental cycle. With a defined development methodology, a solution was found for the usability issue. As mentioned by (Barnum, 2020; Nielsen, 1993; Rubin et al., 2008), one of the best approaches to quickly discover usability issues from user feedback is the application of informal iterative usability tests.

5 USABILITY TESTS

The process moved directly to the creation of user profiles and the definition of which techniques would be used to conduct informal usability tests to discover problems.

It is common to conduct tests in person. However, due to the continued social isolation during the Covid pandemic, any type of in-person testing would put participants at risk. Synchronous remote tests were favored over asynchronous due to the possible need to ask additional questions to a participant after the execution of a scenario.

As recommended by various authors (Barnum, 2020; Lewis, 2012; Rubin et al., 2008), it was decided that the Think-Aloud process would be used during remote tests because it allows the moderator to understand the participants' decision-making process, which aids in the discovery of potential errors.

5.1 User Profiles

The following characteristics formed the profile of the application user that was tested: I) Previous knowledge related to AR or VR; II) Own mobile device compatible with Google Play Services for AR; III) Mobile device used for tasks related to their work/activity; IV) Stable internet connection; V) Users over the age of 18.

5.2 Questionnaires

The next step in usability test planning was to define which questionnaires would be applied at which stages. First, a pre-test questionnaire was necessary to collect participant information relevant to the study. Following the question standards present in a pre-test questionnaire proposed by (Barnum, 2020), it was possible to develop a questionnaire that would collect specific participant data.

A post-task questionnaire was not used due to the test configuration allowing questions to be posed to participants after the completion of each task.

For the post-test questionnaire, it was decided to apply the SUS questionnaire (Brooke, 1995), as it allows the collection of qualitative data related to the user's opinion (Lewis, 2018). It is also a powerful tool for understanding the evolution of user opinions regarding apparent usability between iterations. As a technology-agnostic questionnaire, there was no need to adapt its questions, applying a translated version provided by (Geraldes et al., 2019; da Costa et al., 2021).

5.3 Scenarios and Tasks

Based on the prototype used in the tests and the implemented features, a list of various scenarios that participants executed during the tests was created. This list includes a description of tasks and the objective of each scenario, totaling eight scenarios. Examples of these scenarios can be observed in Figure 4. Despite the numbering, the first scenario was not number one but a scenario consisting of the following question: ”What do you think you can do here?” This allowed capturing participants’ initial impressions of the application.

Scenario	Task	Objetive
1. In a meeting about points of interest in the 'Vila A' neighborhood of Foz do Iguaçu, you were requested to present the digital map of this neighborhood. How would you do this using the provided application?	- Press the 'Maps' button on the main screen; - On the new screen, within the 'View Map' option, select 'Vila A' and click the '>>' button; - A new screen will appear with the camera on; - Follow the instructions provided by the application to anchor the virtual map to the real world."	Add the virtual map to the real world following the instructions provided by the application.
2. The location where you anchored the virtual map in the real world isn't in a favorable spot for your observation. Therefore, would you like to place it in another location. How would you do this?	- Press the 'Menu' button; - Select the 'Remove Map' option; - Follow the instructions provided by the application to anchor the virtual map in a new location.	Change the position where the virtual map appears in the real world.

Figure 4: Example of scenarios, tasks, and objectives.

5.4 Tests in Development Cycle I

All previous steps helped plan the insertion of three usability tests, after each of the three development cycles. Iteration I corresponded to the functional prototype already developed with the prototype being used in Usability Tests I, and the feedback from this test stage was used to correct application problems in Iteration II, leading to Usability Tests II, and so on until the three test stages were completed.

5.5 Recruitment of Participants

The final step before executing any test consisted of recruiting participants. At this stage, it should be considered that the target audience of the application was still people with experience in AR/VR applications. Therefore, only five participants were chosen.

There was a change in the target audience of the application shortly after the execution of the first iteration of usability tests, resulting in the modification of the original test plan (Section 5.6). This change was prompted by the presentation of the functional prototype to one managers. Thus, it was considered ideal for the application not to be restricted only to people with experience in AR/VR applications but to be usable by anyone participating in meetings requiring the sharing of information on a map. To meet this demand, a new recruitment process had to be executed. This way, five more participants were selected.

5.6 Modified Test Plan

The decision to conduct the first usability test with two user subgroups resulted in changes in the insertion of usability tests into the development cycle.

With the increase in the sample from five to ten participants, it was necessary to recruit five more volunteers. The application has been updated to cater to these two subgroups, which would require more time than was available for this study. Thus, the study was concluded with only one iteration of tests in the development cycle, where the results of the first and second usability tests conducted were combined, allowing coverage of the two subgroups present in the study.

6 TESTS AND ANALYSIS

6.1 Application of the First Test

The first test took place with five volunteers representing the subgroup with experience in AR or VR. It is worth noting that of the five participants in this stage, only one identified as female.

Four of the tests occurred without major issues; however, one participant’s device proved to be incompatible with the application. Fortunately, they could borrow a compatible mobile device from a family member.

Regarding the first conducted test, the following issues were identified:

- **Moderate Problems Found:** I) Zoom speed in the point of interest editing module is too fast for three out of the five participants; II) Movement speed in the X and Y axes in the point of interest editing module is considered too fast for three out of the five participants; III) First interaction with the add markers button in the point of interest editing module is not intuitive. IV) Font used on the marker editing button is not intuitive enough; some participants took too long to find the option to edit a marker. Two participants had difficulty finding the marker editing button, and one participant could not complete the scenario that included the task of editing a marker without the help of the moderator; V) Difficulty displaying the name of the marker in the AR module of the application; two participants had to click two or three times on a marker for their touch to be registered.

- **Minor Problems Found:** I) In the prototype, animations that guide the user on what to do to add a map to the real world contain English words, making it difficult for one participant to understand. This error was considered minor because these animations are temporary and would not be used in the final version of the application in any way. However, it is worth noting that the use of English terms can complicate the use of the application; II) Some windows use a black color, which contrasts with the gray used in other screens. This problem is quite noticeable in the marker editing window. One participant pointed out this issue; III) The animation indicating that the mobile device has started the process of tracking the participant's environment tends to disappear quickly on some devices, a problem related to processing speed. Two participants drew attention to this rapid disappearance.

No severe errors were reported by the participants during the test execution.

6.2 Application of the Second Test

The second part of the tests took place with five volunteers representing the subgroup with low or no familiarity with AR or VR.

An initial problem before the start of the test, as reported by three participants, was the initial difficulty in installing the application, running it, and simultaneously starting the screen sharing. After a few minutes of assistance with these configurations, it was possible to proceed with the test plan.

Regarding the second conducted test, the following problems were identified:

- **Serious Problems Found:** I)Lack of an integrated tutorial in the application's features, meaning, the first time a user uses any part of the application, it should be possible to provide a tutorial that guides and teaches them practically how to add a map to the real world and how to add markers in the map editing module. All participants in this test had difficulties following the provided scenarios because they lacked knowledge of how certain AR concepts and the application itself worked; II)Lack of an FAQ that allows the user to better understand how relevant AR concepts work and addresses frequently asked questions that were not resolved during the guided tutorial. Four participants mentioned that some applications have a section of questions and answers where various doubts can be clarified, and having a similar functionality might help them solve their doubts with greater autonomy; III) Similar to participants in the first usability test, participants in this subgroup also had difficulty adding a marker to the map in the map editing module. Two participants managed to understand the button's operation after a few attempts, one participant couldn't complete this task and had to ask the moderator for help, and two participants ended up repeatedly clicking the add marker button until a considerable number of buttons appeared around it, requiring the application to be restarted. IV) Unlike participants in the first group, this group had greater difficulty performing actions that allowed them to manipulate the map in the marker editing module. One participant even accidentally discovered that trying to force movement on the x-axis beyond the maximum allowed made the map jump for a brief moment.
- **Moderate Problems Found:** i) Similar to participants in the first group, three participants had difficulty understanding the instructions given by the animations indicating to the user what needs to be done to add a map to the real world in English. This time, this error was considered moderate because the number of affected users increased; therefore, this error should be prioritized for fixing right after addressing the serious errors; II) There was difficulty displaying the name of the marker in the AR module of the application, similarly to what happened in the initial tests. However, this time, three participants had to click two or three times on a marker for their touch to be registered on the 3D object anchored in the real world.
- **Minor Problems Found:** I) Two participants raised the issue that the amount of zoom available in the marker editing module should be greater, or a magnifying glass functionality should be offered; II) The chosen location for one of the participants to perform the test did not have sufficient size to display the 3D map that is anchored. III) Two participants experienced some performance issues on their mobile devices. Due to the AR Foundation's plane tracking never being able to be fully deactivated, even with the object anchored, the framework continued to update and expand the detected planes.

6.3 Analysis of Questionnaires

With the conclusion of the tests, it was possible to begin the data analysis phase, including, in some cases, the need to watch the test recordings to complement the notes taken during the tests and ensure that no problems went unnoticed.

Part of the analysis of the questionnaires was carried out considering the tests with the two subgroups as just one group representing the target audience of the application. However, in some instances, it was considered relevant to point out the differences in the results found between the two subgroups.

6.3.1 Pre-Test Questionnaire

The first data collected with the pre-test questionnaire was the age of the participants. Despite some outliers, most participants have a very similar age. Future studies could attempt to recruit participants of older age, allowing for greater diversity of opinions.

The second piece of data obtained from the pre-test questionnaire is the gender of the participants. Although the study did not achieve an equal number of male and female participants, it came close, with 40% female and 60% Male.

The educational level reported by the participants also shows a concerning result in the overrepresentation of students with incomplete higher education (70% had incomplete higher education, 20% had completed higher education and 10% completed high school). This occurred because of the ease of recruiting users with this characteristic, although they are part of the target audience of the application, a more diverse group could have resulted in different issues being discovered.

All study participants used their mobile device for communication (32%) and social media (32%), with the third most frequently reported usage being for leisure (26%). All participants indicated that they use or have used their mobile device for work.

6.3.2 Post-Test Questionnaire - SUS

Calculating the results of the SUS questionnaire, it was evident that Subgroup I (SD 8.4039 and Mean 89) obtained higher results compared to Subgroup II (SD 5.7009 and Mean 69.5).

Using different ways to present the SUS results, the results were transformed into adjectives and opinions of acceptance. The two most prevalent opinions indicate that the apparent usability of the application is excellent (four participants from the first subgroup) and reasonable (four participants from the second subgroup), with a minority (one participant from each subgroup) indicating it is good.

Regarding acceptance, the system's apparent usability was deemed acceptable by 60% of the participants, while 40% considered it marginally acceptable, meaning it was deemed acceptable but with reservations or areas identified for correction. These outcomes underscore the severity of the issues encountered during the tests involving Subgroup II.

By employing the SUS assessment for adjectives and acceptance across the average outcomes of each subgroup and their combined data, a perception emerges that the apparent usability is deemed good and acceptable when both subgroups are treated as a single entity. However, this overall impression overlooks the challenges encountered specifically by Subgroup II during the testing phase. Consequently, it is advised that the forthcoming iterations of the product prioritize the resolution or reduction of these issues. This strategic focus is likely to lead to an improved perception of the product's usability.

6.3.3 Action Plan

Based on the results obtained, it was possible to develop an action plan that should be executed in the next development iteration of the application. Considering the problems affecting Subgroup II, there should be a focus on resolving two of the severe issues affecting them: the lack of a guided tutorial and a FAQ section. The following steps are recommended:

- **Guided Tutorial:** I) Analyze the need for creating a specific module for the guided tutorial or if it can be integrated into the already implemented modules. This analysis will help understand the time and effort required to complete the integration of this functionality. II) Low-fidelity screen prototypes based on the analysis results should be constructed, i.e., prototype modifications to existing modules or the entire new module. III)
- **FAQ:** I) Integrating an FAQ will require modifying the existing menus by adding a button that opens a window with available questions and answers. II) A low-fidelity screen prototype should be built for the FAQ screen. In it, the need for a search field and its placement should be analyzed. III) Develop possible questions and answers for issues that users may encounter during the application's use. Avoid delving into extremely technical details, striving to present answers simply and concisely. If it is genuinely necessary to provide more details, indicate links to websites/articles.

This action plan does not consider possible new functionalities that may be integrated simultaneously with the corrections. However, by focusing on the problems presented by Subgroup II, it is expected to equalize the perceived usability between the two subgroups in future usability tests. This equalization can be observed by comparing the SUS results from the tests conducted in this iteration with those conducted after the implementation of the modifications.

7 CONCLUSION

Throughout this study, numerous adaptations were made to overcome challenges, ultimately highlighting the profound impact of user feedback on project success. While some identified issues were already known, confirming their significance to users underscored the need for consideration and prioritization.

With the completion of the initial usability test, the development process advanced addressing the problems identified. Subsequent tests, involving participants from the two main subgroups, enabled a comparative analysis of SUS questionnaire results. This approach provided valuable insights into the evolving perception of application usability and revealed latent issues overshadowed by severe problems.

The positive response from usability test participants towards AR highlight its value, demonstrating its potential to generate interest and engagement. This aligns with the broader importance of immersive technologies in capturing user attention. The effectiveness of usability evaluation tools like the SUS was evident in uncovering valuable insights, emphasizing the pivotal role of systematic testing methodologies in refining applications.

Considering questions about the necessity of AR in this context, a future study could explore an application with similar objectives but without the AR component. A comparative analysis between the original app and the AR-free version could elucidate user preferences, guiding decisions on the inclusion of AR modules.

ACKNOWLEDGEMENTS

We express our gratitude to PTI for their contribution in providing the drone-generated 3D map data. We appreciate their commitment to fostering research and innovation in technology.

REFERENCES

Barnum, C. (2020). *Usability Testing Essentials: Ready, Set… Test!*

Brooke, J. (1995). Sus: A quick and dirty usability scale. *Usability Eval. Ind.*, 189.

Bruun, A., Gull, P., Hofmeister, L., and Stage, J. (2009). Let your users do the testing: A comparison of three remote asynchronous usability testing methods. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '09, page 1619–1628, New York, NY, USA. Association for Computing Machinery.

da Costa, R. P., dos Santos, A. F. S., and Santiago, C. P. (2021). Análise de usabilidade do sistema q-acadêmico utilizando o método system usability scale (sus): Um estudo de caso. In *Anais do XIV Encontro Unificado de Computação do Piauí e XI Simpósio de Sistemas de Informação*, pages 231–238. SBC.

Geraldes, W. B., Martins, E. R., and Afonseca, U. R. (2019). Avaliação da usabilidade do scratch utilizando o método system usability scale (sus). In *Anais da X Escola Regional de Informática de Mato Grosso*, pages 25–30. SBC.

Ghasemifard, N., Shamsi, M., Kenar, A., and Ahmadi, V. (2015). A new view at usability test methods of interfaces for human computer interaction. *Global Journal of Computer Science and Technology*, 15(1).

Gupta, S. (2015). A comparative study of usability evaluation methods. *International Journal of Computer Trends and Technology*, 22(3).

Lewis, J. (2012). *Usability Testing*.

Lewis, J. R. (2018). The system usability scale: Past, present, and future. *International Journal of Human–Computer Interaction*, 34(7):577–590.

Merino, L., Schwarzl, M., Kraus, M., Sedlmair, M., Schmalstieg, D., and Weiskopf, D. (2020). Evaluating mixed and augmented reality: A systematic literature review (2009-2019). In *2020 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pages 438–451.

Nielsen, J. (1993). *Usability Engineering*.

Oufqir, Z., El Abderrahmani, A., and Satori, K. (2020). Arkit and arcore in serve to augmented reality. In *2020 International Conference on Intelligent Systems and Computer Vision (ISCV)*, pages 1–7.

Pressman, R. S. and Maxim, B. (2020). *Software engineering: a practitioner's approach*. McGraw-Hill Education.

Rubin, J., Chisnell, D., and Spool, J. (2008). *Handbook of Usability Testing - How to Plan, Design, and Conduct Effective Tests*.

SenseFly (2021). senseFly – The Professional's Mapping Drone. Dísponível em: https://www.sensefly.com/. Acesso em: 05 de mar. de 2021.

Stull, E. (2018). *UX Fundamentals for Non-UX Professionals: User Experience Principles for Managers, Writers, Designers, and Developers*.

Tori, R. and Hounsell, M. d. S. (2020). Introduçao a realidade virtual e aumentada. *Porto Alegre: Editora SBC*.