Towards an augmented reality approach to build use case diagrams

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Abstract

Augmented Reality (AR) and Virtual Reality (VR) environments offer users unique cognitive and behavioral benefits. AR and VR can improve the user experience by providing more immersive and engaging environments, enhancing communication, collaboration, and the visualisation of complex systems. Motivated by these opportunities, we propose an AR-based approach for constructing use case diagrams, a well-known diagram used to gather system requirements. The proposed solution employs tangible objects with AR markers to create a 3D representation of the diagram, enabling a more natural spatial organisation across space to facilitate interpretation. To evaluate this approach, we conducted a user study that demonstrated the intuitiveness and engagement of the AR application. Users also highlighted the potential of this solution in educational contexts such as classrooms or group work, as it allows for spatial organisation of the diagram, fosters more immersive meetings, and reduces communication gaps among stakeholders. Overall, this study contributes to a better understanding of the benefits of AR and VR technologies in requirements engineering, showcasing their potential to advance the field.

Keywords

Augmented reality, Virtual reality, Requirements engineering, Use case diagram

1. Introduction

Augmented Reality (AR) is a technology that overlays digital information, such as images, videos, or data, onto the real world through devices like smartphones or AR glasses. On the other hand, Virtual Reality (VR) is a more immersive technology that engrosses users in a computer-generated environment, isolating them from the physical world and providing a sensory-rich simulation of reality through VR headsets.

AR and VR applications have become increasingly sought-after systems in recent year. Different areas of the industry have sought these applications as cutting-edge solutions for developing more immersive and efficient training environments in clinical settings [1], collaborative systems between workers [2], industrial digital twins [3] or motor rehabilitation scenarios for patients [4]. Inclusively, Software Engineering has benefited from the unique qualities of AR and VR to educate students and young engineers [5, 6, 7, 8, 9], enhance the visualisation and

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understanding of software systems in three-dimensional (3D) virtual environments [10, 11, 12] and improve communication and collaboration between workers [13, 14, 15, 16].

Traditional representation of software systems has always been accomplished through 2D approaches, such as text, charts or graphs. With the expansion of AR and VR technologies, new approaches have emerged to represent systems in 3D environments. Although representing models in 2D is quite adequate, studies have highlighted emergent users' cognitive and behavioural advantages on users when using AR and VR environments. Namely, some studies suggest that representing information in 3D makes it easier to identify and recall structures compared to its 2D representation [17, 18, 12, 19, 20]; virtual experiences leverage affordances of human perception such as spatial memory, motor, and manipulation to better understand 3D visualisation [21].

Just as in other domains, employing the 3D format within the context of Requirements Engineering (RE) offers its own set of benefits. For example, it can be used for engaging in RE learning and training [22, 23], easing the task of collecting requirements from special needs populations [24], or increasing empathy during the requirement elicitation phase by immersing stakeholders into a virtual world to simulate personas and environmental conditions [25, 13, 14, 24]. The integration of AR and VR technologies hold the potential to reshape the fundamental facets of requirement elicitation, communication, and modeling. This exploration of the fundamental contributions of AR/VR applications within the RE domain underscores their potential to not only address long-standing challenges but also foster the evolution of the field.

Aiming to capitalise on these contributions and further advance the effectiveness of requirements engineering processes, we developed an AR approach for creating use case diagrams, a behavioural UML diagram commonly employed in the requirement elicitation phase of a new system. We propose a 3D environment to visualise and decompose the diagram for better interpretation and also to allow collaboration between multiple users working on the same diagram. We do not expect this approach to replace the traditional 2D format, which already allows a clear representation of actors, use cases and their relationships. With this proposal, we are particularly interested in raising the potential of 3D graph representation.

The benefits of this solution include the possibility to spatially organise and decompose more complex diagrams. We envision spatial organisation and decomposition of more intricate diagrams along three dimensions, providing a novel means to comprehend the complex relationships between actors and use cases. For instance, consider a complex software system involving numerous actors and intricate interactions. In a 3D environment, the diagram can be spatially organised, allowing stakeholders to explore these interactions from multiple angles, thereby enhancing their understanding of the system's dynamics. Furthermore, this possibility can foster discussions in a collaborative environment where each participant could drag and drop the diagram elements as if they were physical objects, rather than digital images on a 2D plane.

As a proof of concept prototype, we are primarily interested in whether users adapt and can easily create the diagram in the suggested 3D environment. To this end, we conducted a user study with 10 computer engineering students familiar with use case diagrams so that they could compare the traditional 2D format and our 3D proposal. The results showed that the participants could interact intuitively with the application and found value in using it. They specifically mentioned its potential usefulness in classroom and group work settings.

Within this paper, we commence by introducing, in Section 2, related work concerning the advantages associated with the utilisation of AR/VR technology in RE tasks. Next, Section 3 presents the proposed AR approach and Section 3.0.2 shows details about the system design and implementation. Section 4 describes the user study conducted and the results obtained. In Section 5, we discuss the results, followed by the conclusions and future work in Section 6.

2. Related work

Within the RE life-cycle, the elicitation process stands out as a pivotal step. Any errors or incompleteness in requirements can significantly impact project success and cost [26]. Eliciting requirements is particularly challenging, requiring collaboration among individuals from diverse backgrounds towards a common goal. Here, the integration of cutting-edge technologies like AR and VR holds substantial promise in revolutionising how requirements are gathered, understood, and refined. These immersive technologies provide a dynamic environment that can potentially address the longstanding challenges of requirement elicitation, communication, and modeling. This section explores the fundamental contributions that AR/VR applications offer to the realm of RE and examines the pertinent literature that has explored these contributions.

One of the foremost advantages of incorporating AR/VR in RE is the automation of processes. Stakeholders can immerse themselves in a virtual environment, replicating real-world scenarios and role-playing actions just as they would in reality [14, 16]. Consequently, business process models can be generated automatically based on these actions, eliminating the need for stakeholders to familiarise themselves with modeling grammar. This approach not only reduces errors during requirements elicitation and specification but also accelerates the modeling process, minimising the time stakeholders need to invest in constructing a process view.

Still related to the possibility of immersing in a virtual world, AR/VR applications enable the embodiment of stakeholder perspectives through 3D avatars based on user persona documents. This strategy immerses stakeholders in a first-person view, facilitating comprehensive understanding and validation of requirements within a simulated real-world environment [25, 13, 14, 24]. Moreover, simulating various environmental factors and user conditions, such as accessibility requirements, proves invaluable in the holistic gathering, analysis, and validation of requirements.

Furthermore, AR and VR provide an interactive platform for enhancing communication during RE meetings, mitigating challenges often linked with stakeholder collaboration [13, 14, 15, 16]. Integrating AR/VR technologies with Machine Learning (ML) and Deep Learning (DL) mechanisms further enables the automated classification of requirements, assisting in categorising requirements discussed in meetings and interviews with stakeholders and users.

Additionally, the integration of VR offers a distinct advantage in creating, manipulating, and visualising models and diagrams within a native 3D space [23]. This spatial experience allows requirements engineers to engage with models at a deeper level, facilitating better abstractions and accommodating layered complexity that is challenging to achieve in conventional 2D spaces.

The educational potential of AR and VR applications extends to providing immersive platforms for students and software engineers to learn and practice building models and diagrams within a

3D environment. These applications enhance content engagement and foster retention through hands-on learning experiences [22, 23].

3. Create use case diagrams in Augmented Reality

Building upon the insights garnered from the literature review, we propose an AR-based approach for developing use case diagrams. This solution has significant potential for enhancing the creation of models and diagrams, facilitating communication, and supporting training and learning in RE activities. AR allows for the creation and manipulation of 3D models, simplifying the interpretation of intricate diagrams that pose challenges when reproduced on a 2D surface. Additionally, the use of AR/VR applications provides a comprehensive learning experience, improving content engagement and retention.

We chose the use case diagram as a case study because it is a well-known diagram for requirements gathering. We chose AR instead of VR to create a collaborative environment that is easily accessible in classrooms or remotely; participants can join using just their smartphones. Figure 1 shows an overview of a use case diagram created with our application.

Our user study aims to investigate the usability and effectiveness of creating use case diagrams with AR, a relatively new approach. We will gather participant feedback on satisfaction, ease of use, engagement, and perceived usefulness of the AR technology. By examining these factors, the study can provide valuable insights to improve the development outcomes of RE.

3.1. Feature selection

We conducted a brainstorming session with two Software Engineering experts to determine the functionalities for the first p rototype. The session focused on identifying limitations of current 2D editors and finding ways to address them in our solution. The following features were selected:

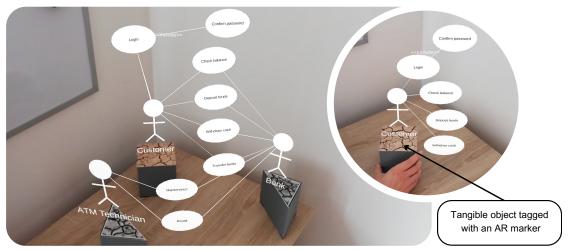


Figure 1: An AR mobile app to draw use case diagrams. The integration of tangible objects allows users to decompose and arrange the diagram in the 3D space.

- Create use case diagrams in 3D space: The user interface allows users to add actors, use cases, and relationships, and arrange them in a 3D space in a way that is considered most appropriate to facilitate diagram interpretation.
- **Highlight requirements:** Highlight elements of the diagram that satisfy a particular requirement of the system (e.g. usability, security).
- **Decompose the diagram by actors:** AR markers are used to represent each actor in the diagram, making it possible to decompose the diagram to analyse each actor or only a subset of actors.
- **Collaboration:** Support multiple users' collaboration in the same diagram (in-person or remotely) using their mobile devices. Face-to-face collaboration, in particular, fosters interactive communication as all participants can be around the diagram and manipulate it more naturally than on a computer screen.
- Export the 2D diagram: Export the diagram into a traditional format so it can be archived along with the rest of the system documentation.

The system workflow is shown in Figure 2. In-person users can manipulate AR markers to arrange diagram elements. While remote users cannot interact with physical markers, they can interact with virtual elements by adding, moving, or editing them. While creating the diagram, the system simultaneously updates an XML file, which can be later exported in a 2D format. For the proof of concept, we utilised three markers attached to objects with simple geometric shapes, allowing one-handed manipulation. The user study focused on a bank ATM system with three actors, as shown in Figure 1.

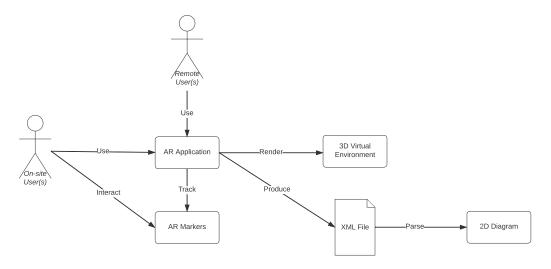


Figure 2: System workflow.

3.2. Implementation details

The application was developed using Unity¹, a cross-platform game engine that supports intuitive tools for interactive 3D content and a straightforward integration with the Android SDK. The AR tracking relies on the Vuforia SDK, which uses computer vision technology to track markers. Briefly, the Vuforia library² uses Natural Feature Tracking (NFT) algorithms to detect feature key points and determine the scale of the marker in real-time.

To enable collaboration between multiple devices, we used the Mirror Networking API³ that allows all changes made to the diagram to be automatically updated on the server side and reflected on the client side (i.e. on users' devices).

3.3. User interface

Figure 3 shows some screenshots of the developed prototype. The option to export the diagram to 2D format appears in the top right corner, generating a PDF document that will be saved on the device. The button below allows the users to choose the category of requirements they want to highlight in the diagram. Figures 3c and 3d illustrate the example of highlighting diagram elements related to authentication requirements. The buttons in the bottom left corner allow the user to add actors and use cases to the diagram. If any element is selected, the options to edit, delete or add a relationship appear in the bottom right corner. To add a relationship between two elements, the users must select the elements they want to link. It is also possible to choose the type of relationship, as shown in Figure 3a, each marker belongs to an actor. In this way, it is possible to decompose the diagram, working separately with each actor. Furthermore, in a collaborative scenario, each user can work on a single mark and join all the parts afterwards.

4. User study

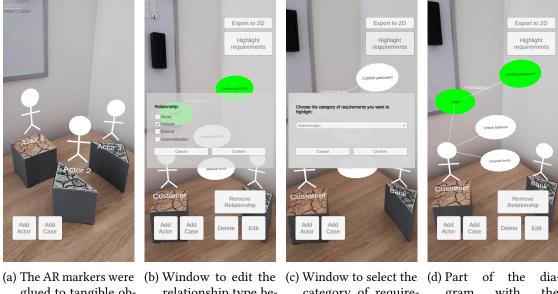
We conducted a user study with two main objectives: evaluating usability and gathering participant feedback. We aimed to understand participants' perspectives on our AR approach, the most valuable features, potential enhancements, advantageous scenarios, and benefits compared to traditional 2D versions. Students and professors with computer science backgrounds were recruited for this study. All the participants were volunteers and had the minimum knowledge on use case diagrams, so they could compare our innovative approach and the conventional one. This section presents the design and results of our user study.

4.1. Experimental design

The study was conducted in a controlled laboratory environment under the same conditions for all participants. Each participant began the session by reading an informed consent form explaining the experiment's context, data anonymity, and the right to withdraw at any time.

¹Unity: https://unity.com/ - Last accessed 15/10/2023

 ²Vuforia: https://library.vuforia.com/articles/Training/vuforia-fusion-article.html - Last accessed 15/10/2023
³Mirror Networking: https://mirror-networking.com/ - Last accessed 15/10/2023



(a) The AR markers were glued to tangible objects and each marker represents an actor.

b) Window to edit the relationship type between two diagram elements.

e) Window to select the category of requirements the user wants to highlight in the diagram.

(d) Part of the diagram with the authenticationrelated elements highlighted.

Figure 3: Four screenshots of the AR mobile application.

Participants were then asked to perform the following tasks to build part of the case study scenario in Figure 1. The order of the tasks was the same for all participants, following the logical order of drawing a use case diagram: 1) Add the "Customer" actor; 2) Add the use case "Login"; 3) Add the relationship between "Customer" and "Login"; 4) Add the use case "Confirm password"; 5) Add the "include" relationship between "Login" and "Confirm password"; 6) Add the use case "Check balance"; 7) Edit the use case "Check balance" to "Deposit funds"; 8) Delete the use case "Deposit funds"; 9) Highlight the diagram elements related to authentication requirements.

After completing each task, participants were asked to rate their level of agreement with the statement "I found this task easy/intuitive to accomplish" on a scale of 1 (strongly disagree) to 7 (strongly agree). After completing the nine tasks, participants were allowed to freely explore the app and interact with the markers. Once completed this phase, participants filled in the System Usability Scale (SUS)⁴ questionnaire and answered the following open-ended questions: 1) What was the feature you appreciated most about this product? 2) What was the feature you liked least about this product? 3) What features would you add/change to improve this app and add benefits that the traditional 2D version does not have? 4) What benefits/potential do you see this AR approach having compared to the traditional desktop (2D) approach?.

Finally, participants completed a characterisation questionnaire providing demographic

⁴System Usability Scale (SUS): https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html -Last accessed 15/10/2023

information including age, education level, experience with AR applications, and use case diagrams.

4.2. Results and analysis

The results of the data analysis are comprised in this section. Firstly, we show the demographic information of the participants. Next, we present the quantitative results concerning the 7-point Likert question and the SUS questionnaire. Finally, qualitative results are described, including the answers to the open-ended questions and comments made during the experiment. Descriptive statistics were used to analyse the task ratings and the SUS questionnaire, while qualitative content analysis was used to analyse the open-ended questions.

Demographics A total of 10 participants (9 male, 1 female) aged 22-40 (M = 26.20, SD = 6.41) participated in the experiment. All participants had a computer science background: 5 bachelor's, 4 master's, 1 PhD. Regarding their experience with using case diagrams, 1 participant was familiar with this diagram and used it from time to time in work; the remaining 9 participants indicated that although they do not often use this type of diagram, they were familiar enough to successfully perform the proposed tasks. Regarding the experience with AR applications, 1 participant claimed to have never tried AR before, 4 participants have tried it a few times, 3 participants use it once in a while, and 2 use it regularly (monthly, weekly or daily).

Likert ranking Table 1 presents the users' ratings on the statement "I found this task intuitive" on a 7-point Likert scale (1="Strongly Disagree" and 7="Strongly Agree"). The median value of the rating and the respective quartiles are presented for each task. In general, we can observe that users found the tasks intuitive since the ratings given were all higher than 4.

Task	Median	Q1	Q3
1. Add the "Customer" actor.	7.00	7.00	7.00
2. Add the use case "Login".	7.00	6.25	7.00
3. Add the relationship between "Customer" and "Login".	7.00	6.00	7.00
4. Add the use case "Confirm password".	7.00	7.00	7.00
5. Add the "include" relationship between "Customer" and "Confirm password".	6.00	6.00	7.00
6. Add the use case "Check balance".	7.00	7.00	7.00
7. Edit the use case "Check balance" to "Deposit funds".	7.00	7.00	7.00
8. Delete the use case "Deposit funds".	7.00	7.00	7.00
9. Highlight the diagram elements related to authentication requirements.	6.50	6.00	7.00

Table 1

Results on the ratings obtained to the statement "I found this task easy", on a 7-point Likert scale.

SUS Table 2 presents the results obtained with the SUS questionnaire, filled out by the participants at the end of the experiment. Each statement was rated on a scale from 1 to 7 (1="Strongly Disagree" and 7="Strongly Agree"). The final score was calculated following the guidelines of the questionnaire author [27]. SUS scores range from 0 to 100 and provides insights about usability performance in effectiveness, efficiency, and overall ease of use. The result of 86.33 gives the system category A ("Excellent") in usability. Looking at each question individually, we can see that participants found the system intuitive and easy to use.

4.3. Qualitative results

According to the open-ended responses to the first question, the participants appreciated several features of the AR application. The ability to physically manipulate the diagram was highlighted as a positive feature, providing a more engaging and dynamic workspace. Many participants also mentioned the ease and simplicity of creating new elements and features, as well as the ability to quickly move actors on and off screen to concentrate on one area of interest at a time. The collaborative feature was also often mentioned as positive, with participants noting the ability to work with multiple users using tactile pieces. The use of AR for spatial organisation was also seen as beneficial to make the experience more dynamic than the traditional 2D version. Overall, the participants appreciated the creativity and interactivity of the AR-based environment.

Regarding the second question, one of the main concerns expressed by participants was the interface design, which some found to be rudimentary and static. Some suggested that labelling relationships could be more intuitive by, for example, allowing users to click directly on the line

Table 2 SUS results.

System Usability Scale (SUS)	Median	Q1	Q3
1. I think that I would like to use this system frequently.	5.00	4.00	5.75
2. I found the system unnecessarily complex.	1.00	1.00	2.00
3. I thought the system was easy to use.	6.00	6.00	7.00
4. I think that I would need the support of a technical person to be able to use this system.	1.00	1.00	1.00
5. I found the various functions in this system were well integrated.	6.50	5.25	7.00
6. I thought there was too much inconsistency in this system.	1.00	1.00	1.75
7. I would imagine that most people would learn to use this system very quickly.	6.00	6.00	7.00
8. I found the system very cumbersome to use.	1.00	1.00	2.75
9. I felt very confident using the system.	6.00	5.25	6.00
10. I needed to learn a lot of things before I could get going with this system.	1.00	1.00	2.00
SUS Score	86.33		

connecting two elements to change the label automatically. Other minor issues mentioned were overlapping elements. Some participants did not immediately realise how to move the objects after inserting them. Although they were able to figure out how to do it within a few seconds, they suggested adding a restriction that new elements should appear only in free spaces not already occupied by other elements.

About the third question, participants provided valuable insights and suggestions on how to improve the app and make it stand out from the traditional 2D version. The most common suggestions were to add more feedback, such as using vibration or sound, and add more dynamic features like automatically assigning relationships or having use cases attract each other based on proximity. Additionally, some suggested adding a menu of possible items to add or prompting to name an element as it's created to streamline the process. Almost all the participants highlighted this approach's potential in real-time collaboration and the ability to edit collaboratively with the team anywhere, anytime.

In response to the last question about the benefits and potential of the AR approach compared to the traditional 2D approach, participants highlighted several advantages. One of the main benefits is the ability to quickly isolate parts of the diagram being worked on, such as quickly focusing on one actor's relationships. Additionally, the AR approach allows for collaborative work with multiple people in real-time, making communication, planning and brainstorming easier and more engaging. Participants also mentioned that AR could be used to teach concepts in classrooms or create more intuitive interactions in real-world settings. The AR approach has the potential to make pre-planning with diagrams less tedious, especially in small teams working in the same room. Finally, participants noted that AR has the potential for more engaging experiences; when the diagram is grounded by a marker, AR can allow for intuitive collaborative interactions, such as handing someone a diagram just by giving them the marker.

5. Discussion

The user study contributed to evaluating the usability of our AR-based method and gathering insights from participants regarding the effectiveness, user perceptions, and inherent advantages of our AR-driven approach in the realm of use case diagram creation.

The user study results showed that participants received the AR approach for creating use case diagrams well. The Likert ranking consistently rated tasks above 4 on a 7-point scale, indicating that the AR approach is easy to use and understand, even for those unfamiliar with AR applications and/or use case diagram design. The SUS questionnaire results further supported the positive feedback from the Likert ranking, with a score of 86.33 out of 100, indicating that the AR approach is an effective method for creating use case diagrams.

The qualitative results of the study provided valuable insights into the participants' opinions on the AR approach. The participants appreciated the physical manipulation of the diagram, the simplicity of creating new elements, the collaborative aspect of the application, and the use of AR for spatial organisation. Participants also provided suggestions for improving the app, such as adding more feedback and dynamic features and enhancing the interface design, which shows a genuine interest in making this model design process more interactive.

Regarding the benefits and potential of the AR approach compared to the traditional 2D

approach, participants noted several advantages, such as the ability to quickly isolate parts of the diagram being worked on, collaborative work with multiple people in real-time, and more engaging experiences. These advantages could make pre-planning with charts more attractive and less tedious, especially in small teams working in the same physical space.

Overall, the user study results demonstrate that the AR approach is an effective and intuitive method for creating use case diagrams. The positive feedback from the participants highlights the potential of AR technology in enhancing the usability and engagement of diagramming tools, and the study's findings can inform future research on the use of AR in software engineering.

6. Conclusions and future work

In this paper, we begin by reviewing the present contributions that AR/VR technologies can provide to the RE activities. Building upon the benefits identified during the literature review, we introduce an AR-driven approach for creating use case diagrams. We validate our approach through a user study, and our findings affirm the positive reception and effectiveness of our method. As we conclude this investigation, our focus shifts towards the future, where we identify potential avenues for additional research and development in the ever-evolving realm of AR-enhanced software engineering.

Inspired by the contribution of creating 3D models, we proposed our 3D approach for creating use case diagrams to provide a more immersive and layered experience challenging to replicate in the traditional 2D space. The user study results suggested that the AR approach can be an effective method for creating use case diagrams. The participants appreciated the physical manipulation of the diagram, the simplicity of creating new elements and features, the collaborative aspect of the application, and the use of AR for spatial organisation. The findings of this review and our proposed 3D approach demonstrate the potential of AR/VR in enhancing the usability of RE processes and also the high receptivity of this type of solution by people with a background in computer engineering.

Future research should focus on applying these techniques to assess their effectiveness in practical settings, explore the challenges associated with their adoption, and evaluate their impact on software development outcomes. Building on the results of this work, it would be interesting to compare the completion time of software engineers using a traditional 2D interface versus our AR approach for modeling the same diagram. Since the participants highly praised the collaborative component of the application, it would also be interesting to further study the usability of this solution in a collaborative environment.

Overall, we believe that our study's findings can contribute valuable insights to future research on the use of AR in software engineering and can guide the development of more interactive and engaging diagramming tools.

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