Co-Design of Gamified Mixed Reality Applications

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ABSTRACT

Mixed reality applications currently make their way into diverse academic and industrial domains. Due to the evolving character of this new technology, early adopters face a variety of challenges for example in soft- and hardware availability. Another deficit is the lack of content. Opening up the production life cycle to involve users early on can help to improve the acceptance and target new possibilities. In this article we present a methodology and tool support for co-designing mixed reality applications by combining requirements engineering and gamification. This enables both creating a continuous innovation life cycle and achieving long-term motivation. Our prototype was evaluated in the context of technology-enhanced learning at a medical school. We are confident that our results are transferable to other application areas, as all our components are freely available as open source resources.

1 INTRODUCTION

Various academic and industrial domains currently explore mixed reality systems, driven by the availability of new hardware like the Microsoft HoloLens. The term *mixed reality* hereby describes a spectrum of systems including augmented and virtual reality. Augmented reality hardware enhances the perceived reality of users by displaying virtual information and objects. [4]. The new technology opens up new possibilities but also confronts users, employers and developers with new challenges. In the last years, faster innovation life cycles for example in mobile computing have been achieved by new software engineering methodologies like agile development; it emphasizes frequent changes and thereby acknowledges changing user requirements. As many aspects of new systems involving mixed reality and Internet of Things are yet unknown and need to be explored iteratively, the challenges are further intensified and require even greater user involvement through early feedback in the design process. However, the number of skilled developers does not keep pace with the amount of customers using these new technologies. Opening up parts of the software engineering process for end users is a possible avenue to align new software to real user needs. In particular, we refer to requirements engineering, design and provision of content.

In this article we present a methodology and tool support for co-designing mixed reality applications. The process starts by opening up the requirements collection with Requirements Bazaar, a social Web 2.0 tool. For content creation and in order to increase the motivation to use the created apps, we provide a gamification strategy that allows creating custom badges, amongst others. We evaluated our results in a medical anatomy course. The developed software is available as an open source mixed reality app on GitHub[1].

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[1] https://github.com/rwth-acis/GaMR

The structure of this article is as follows. Section 2 presents the building blocks necessary for better understanding of our methodological and technological framework. In Section 3 we further elaborate our approach by discussing the application contexts. We then show our co-design methodology in Section 4. The methodology and evaluation is discussed in Section 5. The paper is concluded in Section 6.

2 BUILDING BLOCKS

In this section we present building blocks of our approach. As details, the single sign-on solution is shown, then the gamification framework, and finally the mixed reality integration with Requirements Bazaar is presented.

2.1 Cross-Application User Identities

Managing accounts for various applications is a tedious task for users, as passwords have to be remembered. Often, the same passwords are reused which decreases security. Single sign-on systems allow the same account to be reused for multiple services, also decreasing the implementation costs as the same functionality only needs to be implemented once. Linking a user to a specific identity is particularly useful in learning applications for tracking the progress of individual learners across applications. The authorization protocol OpenID Connect provides such a single sign-on [7]. It defines a flow where the user is redirected from the application to a login page of a central login provider like Google. There, the credentials are entered and after the successful login, the user is redirected to the initial application. In the implicit authorization flow, the last redirect contains a token which can be used by the application to access secured resources. This access token is added to every request at a secured API. It is checked by the service and it only returns a result if the token could be verified. This way, resources are protected from unauthorized use. Users are distinguished by an endpoint which is offered by the login provider. Here, the application queries for the data of the signed in user. The challenge was to implement this protocol in a mixed reality application on HoloLens. To tackle it, we define a custom URI schema for the application, e.g. “gamr://”. The HoloLens app is registered as the default app to handle this custom schema. Once the system detects the schema after a successful login, it launches the app which can extract and parse the access token.

2.2 Gamification Framework

The same idea of reusing services led us to the development of the gamification framework [3]. It is a tool to administer and enact gamification data. In its internal model, the gamification consists of games which are composed of a number of quests. A quest can be fulfilled by executing a set of actions. A badge and an achievement which are associated to the quest are also awarded upon quest completion. The gamification system can be configured using a RESTful API, e.g. one can add new quests or badges and connect the different gamification elements to each other. On the base level, a PostgreSQL database keeps track of the gamification data. Additionally, the defined actions can be triggered using the API. If an action is executed, the framework automatically checks whether all actions in the corresponding quest are fulfilled. In this

case, the achievement and badge are added to the user's inventory and any subsequent quests are unlocked or revealed.

2.3 Requirements Bazaar

Requirements Bazaar is a social Web-based tool for continuous innovation[2]. Its software architecture is based on components. On the backend, data storage is handled by multiple microservices connecting to a MySQL server. They are accessible via a REST-based interface. In the Web browser, we employ HTML5 Web Components. This way it is possible to externalize certain parts into third-party websites. Also, the service-based approach enables a mixed reality version of the feedback entering form. As shown in Figure 1, it is possible to enter feedback directly within an app. If the comment is submitted by the user, the form's content is transferred to Requirements Bazaar. There it is posted as a new entry which can be evaluated by developers and other users. The feedback form can be placed at any location within the mixed reality application.

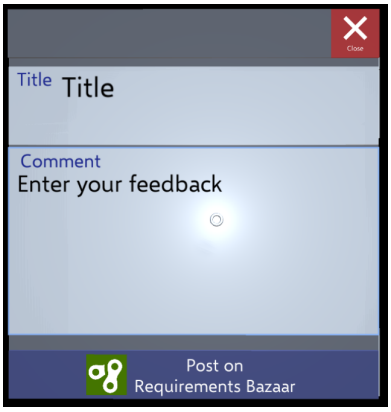

Figure 1: Feedback Form in GaMR

3 Application Contexts

In this section we show the application areas of our ongoing mixed reality projects. Both are driven by collaborations on the European level; one involves high-tech industries, the other is located at a higher education setting at a medical school.

WEKIT is a three-year project funded by the European Commission targeting high-tech industries involving manual work. The goal is to create a hard- and software platform to record and replay training situations. The three target areas are aircraft maintenance, bioimaging and astronaut training. For example, a use case is to record a foreman mounting a wing flap, and later showing the recorded actions to trainees. A vest records the activities with the help of several body sensors. When a trainee wants to re-perform these actions, a virtual mannequin demonstrates the previously recorded movements within an augmented reality view. The initial idea collection for the implemented features was carried out in the *WEKIT Community*[3], an online social platform where stakeholders can meet and discuss. It is connected to the Requirements Bazaar. User ideas can be posted, rated, commented and taken on by developers while keeping a feedback loop to users.

GaMR is a mixed reality application which is taking place in a higher education setting. In the medical course of anatomy, it is required that students get familiar with models of certain body parts; the learning process involves visualizing and memorizing many spatial structures. As physical objects are expensive and working with them is hard to scale, we first scanned the objects with a professional 3D scanner and made them available in the browser [5]. One drawback of the desktop-based application is that the 3D models are only displayed on a flat screen. The evaluation also showed that students usually lose their long-term motivation when working with learning applications.

Using the Microsoft HoloLens we offer them a new learning scenario where the objects can be freely placed in the environment. In order to assure long-term motivation, the application is gamified. The augmented reality version features a quiz mode where lecturers can setup their own quizzes and quiz questions. In the quiz mode, students associate a text with a region or point on the uploaded 3D model or vice versa. Lecturers can design their own badges and add them to a quiz. If a student successfully answers all quiz questions, the badge is added to the student's inventory where it can be exhibited. For further motivation to complete a quiz, a progress bar is displayed. With each correctly answered question it fills up more and it releases the badge once all questions have been answered. The gamification elements also give an overview of the learning progress as the achieved badges show which 3D models have already been memorized.

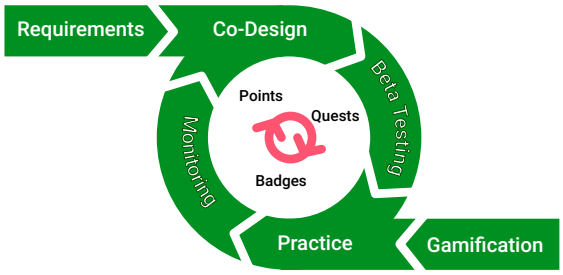

Figure 2: Intertwined Requirements and Gamification Life Cycle

4 Design Methodology

In this section, we show the comprehensive methodologies that emerged and were followed in the projects described above. Figure 2 shows the intertwined life cycle of requirements engineering and gamification. Both enable users of applications to actively participate in the design process and improvement of the application. Because of the high innovation factor of the largely unknown territory of mixed reality applications we see a special applicability and need for involving end users. The swirl starts with the initial requirements in top left of the figure. Through co-design sessions (both co-located and remote), first versions are beta tested and evaluated. The working contexts and practices of user communities are highly influential on the development of the application. Monitoring ensures both a formative and a summative evaluation of the (learning) content. The other source for user involvement is through the use of gamification, introduced on the bottom right of the picture. Its exemplary artifacts are found in the center of the figure. In the following, the two influencing elements of the life cycle are explained in more detail.

4.1 DevOpsUse

The term *DevOpsUse* is an extension of *DevOps* which itself is a clipped compound of "development" and "operations". DevOps has been popularized lately as an extension of agile development life cycles, where the developers, who create applications, and operators, who put them into practice on servers, work more closely together. Although agile development methodologies have been introduced to accelerate the identification and realization of user requirements, they do not directly include the user apart from the start and end of

[2]https://requirements-bazaar.org
[3]https://wekit-community.org

the process. Especially the expectations of users with diverse demands are not adequately met. Therefore we proposed DevOpsUse. It includes the notion of users who deliver initial ideas, perform beta tests, monitor and who give feedback [6]. Our main instrument to collect comments from users is Requirements Bazaar.

In our mixed reality tools, we employ Requirements Bazaar at different stages. Before the development is started, requirements are collected. An example is the idea collection within the WEKIT Community. The tool is embedded on the third-party website of the community[4]. Users can search for requirements or sort them according to different criteria. During runtime, users continue writing feedback and add new ideas. One example is the feedback form in a mixed reality environment presented in Figure 1.

4.2 Gamification

The second major concept which was used in the GaMR mixed reality app is gamification. It allows the use of game elements in non-game contexts [1]. By means of points, achievements and badges, users can progress in a gamified application in order to achieve given goals. This motivates users to resume the application. It also triggers a feeling of reward if a goal is reached because a badge is awarded [2]. In the context of learning applications, badges may give feedback about the personal learning progress and it can also serve as an indicator about a skill level to others. Gamification can also be used to increase user participation in the design process of an application by rewarding users who give helpful feedback to developers. One important requirement is that users, e.g. lecturers, are able to customize the gamification to their needs. In the GaMR framework developed within the medical context described above, users can create their own quizzes and questions. For each quiz they can define a badge which is issued if the quiz is correctly answered. The badge can also be customized by lecturers as they can assign their own imported images to the badges. As opposed to ready-made gamified learning solutions in mixed reality with predefined game elements and fixed paths, customization is a key element in our methodology and heavily involves users.

5 Discussion

In this section we discuss the general applicability of our methodology and suggest further real-world use cases driven by the application areas presented in Section 3.

The GaMR framework was evaluated at Maastricht University by four lecturers and 14 students of a medical study program. In the evaluation, anatomical quizzes were created and solved. After this, the participants answered a questionnaire which contained quantitative and qualitative questions regarding the framework's usability and applicability. Many students commented on GaMR's abilities to visualize complex structures which are ideal for anatomy learning. The gamification was also well perceived since a majority of the participants awarded good scores to the employed motivational elements. One remark mentioned that the necessary AR hardware is still expensive and heavy. The evaluation also underlined the flexibility of the framework since it works with custom 3D models, quizzes and badges. Therefore, it can be employed in various use cases and is also suitable for different fields of studies. For instance, the framework can be employed in academic education, medical training, bedside teaching, museums or apprentice training.

5.1 Open Source Artifacts

The GaMR framework is designed to be customizable in order to open up a wide variety of use cases. The existing prototype uses the open source anatomy models of the Anatomy 2.0 application but users can import any 3D model in the X3D format at runtime. This means that the framework cannot only be adapted to any learning context but it can also be used as a mixed reality 3D viewer, e.g. when designing a 3D model. This is particularly helpful if the proportions of the object need to be modeled according to a real scene. Additionally, the developed solutions for mixed reality like the user interface's buttons, menu or the login redirection procedure for apps in mixed reality have been extracted and are provided as separate elements. Developers of mixed reality applications can import them into their own apps and use them as a starting point.

Requirements Bazaar components are also available as an open source solution. A ready-made library allows embedding feedback forms or complete requirement overview tables in arbitrary webpages. Ideas entered anywhere are available within the main installation of Requirements Bazaar, where they can be further processed by developers or other users.

[4]https://wekit-community.org/ideas/

6 Conclusion and Future Work

In this paper we presented a methodology and tool support for involving users in the development and design of mixed reality applications. The two key instruments are social requirements engineering and gamification. Social requirements engineering allows to contribute and discuss ideas early and directly in the mixed reality application. Gamification is a means to enhance long-term motivation by introducing game elements in non-game contexts. In this regard, our framework enables users to create custom badges and leaderboards.

The evaluation of the GaMR framework shows promising results. We are still improving the developed solutions. For example, monitoring of mixed reality interactions for reaching community self-regulation is not yet implemented. We are currently evaluating the usage of a learning record store to collect activities. Our results show that in particular the open source artifacts are helpful to work with user participation in arbitrary mixed reality contexts.

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