A Prototype Application of StickAR to Enhance Note-Taking Activity by Using Augmented Reality Technology

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Abstract. This paper presents the work-in-progress StickAR mobile application prototype which enables the users to record real life events such as images or video recordings alongside with their physical notes. It also provides the users with the utility of information retrieval by using the AR scanning interaction to get the relevant information immediately. The StickAR application uses the Unity3D API for frontend, assets management, and server communication logic, meanwhile the Vuforia SDK is utilized for the AR scanning interaction. All the information and assets are stored in the HTTP server. This paper also focused on the reproducible methodology that consists of the use case descriptions and system architecture to build the application. The functionalities of StickAR are demonstrated in the result section which includes the key AR information retrieval feature for immediate access to the requested information based on the physical notes. Its potential and risks are also discussed in the SWOT analysis.

Keywords: Augmented reality · Graphical user interfaces · Mobile application · System development

1 Introduction

Recent research has demonstrated the effectiveness of note-taking to humans as a tool for remembering notes and comprehending details from a reading or lecture [1]. Kobayashi [2] concluded that the importance of note-taking and reviewing can bring a positive

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impact to the memory and affect the learning of a student compared to attending the class only. This method can boost the student's performance and their confidence during their studies. Stacy and Cain [3] also argued that training learners in systematic note-taking approaches can help learners encode and study large quantities of learning material. Furthermore, the research on learning performance with digital note-taking tools today is required since a potential physio-cognitive connection between writing and learning is recognised [3]. The note-taking is important as it can be a reference material to memorise or understand before the test.

In the digital age, people prefer to use the smartphone or computer to write the notes and do the revision for their studies [4]. Furthermore, the use of slide, audio, and recording can assist them in understanding the lecture after the class and are easy to bring anywhere. In line with the most recent technological developments, the fourth industrial revolution (4IR), the use of augmented reality (AR) in smartphone applications is becoming more common in order to attract users with the uniqueness and convenience of an application [5]. According to [6], AR technologies are a unique subset of mobile media that has successfully piqued the public's interest by allowing various types of visual media to be presented while simultaneously overlaid onto physical space. Besides, the use of AR interfaces in books can help users in comprehension, memory, concentration, affordance, interactivity, imagination, problem-solving, and level-differentiated learning by providing immersion, presence, and context [7]. Thus, it can provide various enhanced experiences to the user such as links to extra web contents, viewing 3D models for spatial understanding, animation, and multimedia. Furthermore, AR also can be used to integrate the physical medium, for example books, with digital contents.

Recently, digital note-taking applications have become an important application in storing important information instantly [8]. Cloud storage applications also offer users to save a variety of file types, such as images, documents, videos, and audios, in the cloud which can be accessed anywhere, anytime. These applications focus on the digital platform, from data collection to data storage processes and data retrieving. However, traditional hand-written methods are still an effective choice for note-taking and memorisation [1]. Therefore, AR technology is a potential solution for the traditional hand-written format because it can retrieve the supplementary data based on a physical medium. But the current AR-based note-taking applications have limitations include bulky installation [9] and the lack of customization function for students [10] which affect the usability and practicality of the AR-based note-taking applications.

This work-in-progress project aims to incorporate AR and mobile phone technologies into the note-taking activity to enhance the learning experience. StickAR mobile application is an AR note-taking application which provides the users with customizable contents, where they can upload their own multimedia contents, such as images and video recordings. The proposed application also offers navigation functionality to help the users to locate the relevant information instantly.

In the following sections, this paper discusses the literature review, research methodology, as well as result and discussion in Sects. 2, 3 and 4, respectively. The literature review presents the analysis and synthesis of related digital note-taking applications and AR applications for information retrieval. The methodology section includes the use case requirements of StickAR application, its framework design and system development process. In the results section, the user interfaces of the StickAR application are presented. Lastly, the paper is concluded in Sect. 5 with future works and suggestions.

2 Literature Review

2.1 Digital Note-Taking Application

The digital note-taking applications have taken a centre stage in this digitalization era, as they have become one of the staple applications provided by many big technological companies, for instance Google, Microsoft, and Apple. Popular digital note-taking applications, such as Evernote and Microsoft OneNote, have been utilized in various tasks, which ranged from management to education. A market research forecasted the increase of 5.32% in the compound annual growth rate (CAGR) of the global note-taking application market from 2019 to 2026, and the cumulative profit is estimated to reach USD 1.35 billion in 2026 from USD 897.7 million in 2018 [8].

However, traditional hand-written methods are still an effective and popular choice among the users to record important information [1]. The study shows that the note takers using hand-written methods tend to work more efficiently to adapt to their speed disadvantage and they also have less digital distraction [11]. Besides, lectures with image heavy contents are difficult for the digital note-taking application since they can only record text-based content but not illustration [11, 12]. In addition, past research also discovered that the users also wanted the advantages of digitalization in combination with the traditional hand-written method to make the learning process become more active and engaging [11, 13].

On the other hand, the tablet can provide a more attractive solution for the note-taking interaction, for example the stylus or pen-based input can simulate the real writing activity. Despite the usefulness of tablet and its stylus, a research done by Pew Research Center [14] found out that the percentage of tablet ownership among the United State of America (USA) adults is lower than that of smartphone ownership, which is 53% compared to 85% in 2021, as shown in Fig. 1. Therefore, there is a need for an immediate solution that is suitable for the masses. Hence, the AR tracking method for smartphones is the most reasonable and affordable solution.

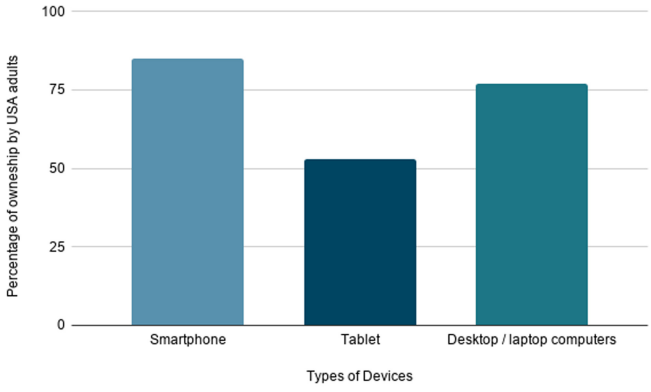


Fig. 1. The ownership percentage of digital devices by the USA adults on February 7, 2021. Adopted from [14].

Besides, users can opt for the commercialized Software as a Services (SaaS) cloud storage application, such as Google Drive, Dropbox, and Microsoft OneDrive. The benefits of these services are they can store a variety of file types and provide free storage with upgradable options to increase the storage size. Their cross-platform feature also helps users synchronize their data across their desktop computers and smartphones which allow them to access the data at anywhere, anytime.

However, studies found that it is difficult for the users to navigate to the relevant files due to the increase of the folder number and complexity of the folder structure [15]. The users also become confused and forget the contents in their cloud storage [16]. The solution to these problems is to leverage the click logs or activity logs of the users to determine the most frequently used or opened files and display them in the application's home page. But there is also a need for storing the additional multimedia information for physical note-taking activity, which can seamlessly link the real-world bookmarks to the relevant digital contents.

2.2 AR Application and Information Retrieval

AR is a display and interaction technology that superimposes virtual objects in the real-world environment. In another word, AR is also a technique which retrieves additional information based on a specific trigger point or event for display purposes. These trigger points or events can be marker-based or geoinformatics-based.

The marker-based AR uses an image that acts as a unique code, and it is recognised by the AR application to trigger the information retrieval event. The Wonderful Augmented Reality and Art (WARna) application provides an intuitive experience for the children to interact with the 3D characters they have coloured [17]. The works by [10, 18] and [19] also showed the popularity of using the AR marker in book publication to display supplementary information to enhance the reading and learning process. In addition, the marker-based AR tracking method can provide more intuitive user interaction and immersive learning environment to the applications, such as the holographic AR display of planets in the real world by using a reflective pyramid [20] and the solution of user interaction issue found in the mobile virtual reality (VR) for welding training application [21].

Meanwhile, the geoinformatics-based AR uses geographic information system (GIS) data as a trigger event where the relevant information is displayed when the users are in a certain location. It is frequently deployed in the navigation and tourism systems, such as the Google Maps AR to guide the users to the selected location [22]. Besides, Lin et al. [23] also proposed a tourism system that retrieves the name of nearby tourist attractions and displays them on the camera feed in the users' smartphone.

AR technology has the capability to integrate the physical world and virtual world to enhance and provide intuitive experiences to the users. This work also anticipated that the information retrieval is one of the features available in AR applications as it can obtain and display the relevant information immediately to the user by interacting with a physical point or event.

2.3 Related Work

Table 1 shows the comparison of features between the traditional note-taking method, existing digital note-taking applications, and online cloud storage. In this work, the digital note-taking application is the combination of Evernote and OneNote, while the online cloud storage includes Google Drive, OneDrive, and Dropbox.

Table 1. Comparison between the traditional note-taking method, related digital note-taking applications, and the online cloud storage applications.

	Traditional note-taking	Digital note-taking application	Online cloud storage
Description	Hand-written note	Writing notes digitally	Cloud storage
Platform	–	Web browser and mobile application	Web browser and mobile application
Medium	Physical	Digital	Digital
Display on	Paper	Screen	Screen
Accepted file format	Text-based, images	Text-based, images, video recordings, audio, documents, and PDFs	Accept all file types, such as images, video recordings, audio, documents, PDFs, zip files, and more
Interaction methods for data input	Writing and drawing by using pen or pencil	Keyboard (key in the data), pen (write or draw), browse and upload files	Browse and upload files
Navigation task	Searching manually through the notebook	Searching, navigate manually	Searching, most frequent files section, navigate manually
Storage size (free version)	–	**Evernote:** 25 MB maximum note size **OneNote:** depends on the size of OneDrive	**Google Drive:** 15 GB **OneDrive:** 5 GB **Dropbox:** 2 GB

As for the related AR-based note-taking application, Mitsuhara et al. [9] was the first project to use marker-based AR and projection-based display technologies to display additional notes alongside the textbook. They set up a specialized frame to hold a video camera to detect the marker in the textbook and a projector to display the additional contents on the page. In 2004, Yang et al. [24] used a head-mounted device (HMD) for AR-based note-taking applications to display 3D curricular contents. The users can use hand gestures to write the note and annotate the 3D models in a virtual 3D space. Suzuki et al. [10] introduced an active textbook (A-txt) for iOS mobile applications. Teachers can upload the customized information and assets, such as diagrams, videos,

3D models, and audios, into the server, and the student can use the application to scan the marker to obtain this information. Yang et al. [24] focused on the interaction with the 3D contents and storytelling, but less concentrated on notes storage and information retrieval. Meanwhile, the customization capabilities in [9] and [10] are only limited to the teachers, and the students can only retrieve the information but cannot edit them. Thus, this project proposed to enhance the AR-based note-taking application in mobile phone and to improve the interaction for information retrieval. In addition, supporting the traditional hand-written method and customizable contents were also the main focus in this research. Table 2 shows the comparison of features between the related AR-based note-taking applications and the proposed StickAR application. Figure 2 shows the chronological order of AR-based note-taking applications.

Table 2. Comparison of related AR-based note-taking applications and the proposed StickAR application.

	Mitsuhara et al. [9]	Yang et al. [24]	Suzuki et al. [10]	StickAR
Description	Note-taking with AR	Note-taking with AR and HMD	Textbook notes with AR	Note-taking with AR
Platform	Mobile application	Mobile, HMD application	Mobile application	Mobile application
Medium	Digital and physical			
Display on	Virtual materials are projected on paper	HMD	Screen	Screen
Accepted file format	Images and text	3D models	Images, video recordings, audio, documents, and PDFs	Images and video recordings
Interaction methods for data input	Browse and upload files (by teachers only)	Select the 3D models from library, hand gesture for writing	Browse and upload files (by teachers only)	Browse and upload files
Navigation task	AR marker navigation	Not stated for information retrieving	AR marker navigation	Navigate manually, AR marker navigation
Storage size (free version)	Not stated	Not stated	Not stated	1 GB maximum note size for free account

Fig. 2. The chronological order of AR-based note-taking applications.

3 Methodology

In this section, the methodology to develop the StickAR mobile application is described succinctly. This work implemented the prototyping software development model to guide the design and system development stages, as shown in Fig. 3. This method is useful to build the prototype incrementally and evaluate the prototype at each iteration for improvement [25].

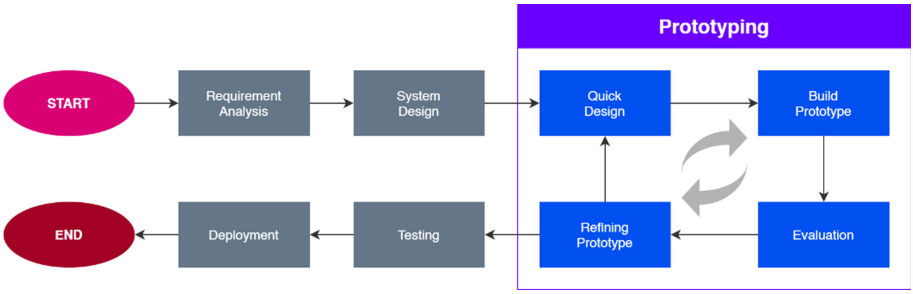


Fig. 3. The software prototype model of StickAR application.

3.1 Requirement Analysis for the StickAR Mobile Application

This section describes the functional requirements in the StickAR System. Figure 4 shows the use case diagram of the StickAR System.

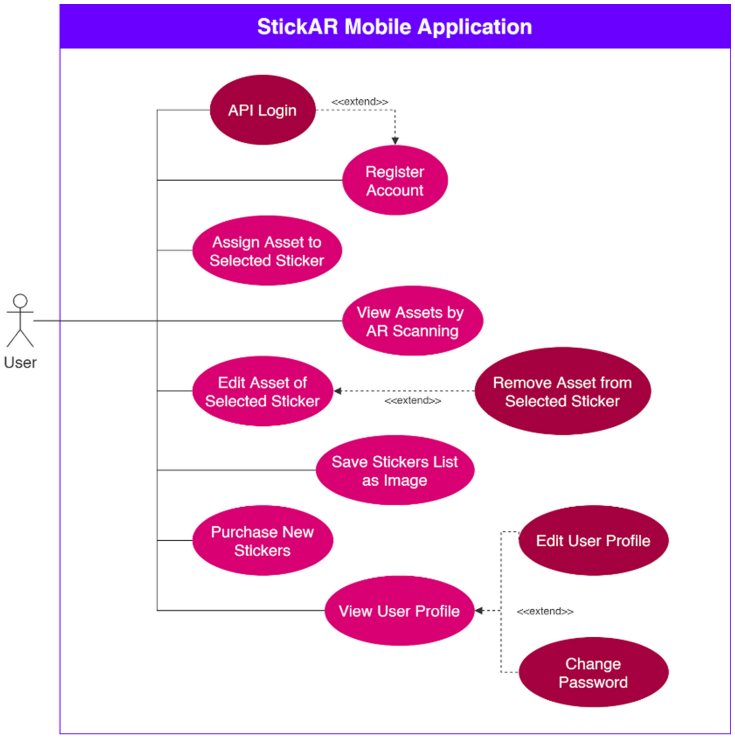


Fig. 4. The use case diagram of StickAR mobile application.

Use Case Actors. Currently, there is only one type of user role, which is User, as shown in Table 3. The User is the consumer and user of the system.

Table 3. The user roles and its descriptions.

ID	User role	Description
UR1	User	The User uses the mobile application to scan the AR marker and manage the assets

Use Case Descriptions. Table 4 shows the requirements and its detailed descriptions.

Table 4. The requirements and its description.

ID	Requirement	Description
RQ1	Register account	User registers a new account
RQ2	API login	User login using Facebook account
RQ3	Assign asset to selected sticker	User assigns assets, such as image and video, to the selected sticker
RQ4	View assets by AR scanning	User views the assets by AR scanning
RQ5	Edit asset of selected sticker	User edits and views the assets of the selected sticker
RQ6	Remove asset from selected sticker	User removes the asset from the selected sticker
RQ7	View user profile	User views the information of the user account
RQ8	Edit user profile	User updates the profile image, username, and email
RQ9	Change password	User updates the password
RQ10	Save stickers list as image	User saves a list of stickers as an image, such as pdf, jpeg, png, for printing
RQ11	Purchase new stickers	User purchases a new sticker pack

3.2 System Design

The system architecture of StickAR mobile application is illustrated as in Fig. 5. The client layer consists of a graphical user interface (GUI) for the users to interact with the application.

The middleware layer contains all the application programming interface (API) and software development kit (SDK) implemented in the StickAR mobile application. The Unity Scripting API forms a major part of the application, which handles the frontend and interaction, browse manager for assets management and server manager to allow the communication between the client and the StickAR HTTP server. The Vuforia SDK provides the VuMark API, which provides the tracking and metadata extraction of the registered StickAR marker. Besides, Facebook Login API is utilized to offer the user with an alternative method to login to the StickAR application.

All the HTTP requests, such as get, update and delete, are sent to the HTTP server to create a new record or update the available record in the database. The HTTP server stack includes the PHP scripts to handle the standard request operation and also the PHP-FFMpeg software to generate the thumbnail of the uploaded video assets. In addition, the information of the users and assets are uploaded and stored in the MySQL database in the resource layer. Both the server and database are hosted in an Ubuntu Linux server. In addition, Table 5 shows the identified software requirements for the system development phase.

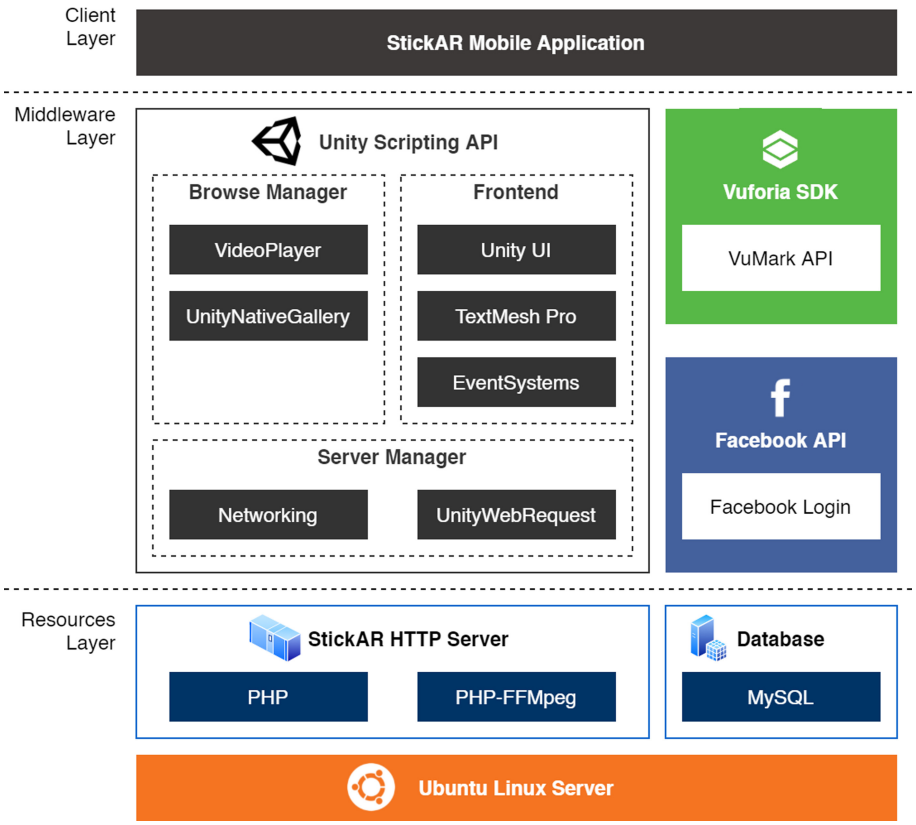


Fig. 5. The high-level architecture design of StickAR mobile application.

3.3 Prototyping

In the system development phase, the prototype was created by using Unity3D for the Android-based mobile application.

The AR function was implemented in the prototype which allows the users to scan the VuMark AR marker for user interaction. The VuMark is one of the AR tracking methods provided by the Vuforia AR SDK that can allow the developer to create a stylish sticker, each with its distinctive code. It is similar to a QR code but for AR application. Figure 6 shows the example of the StickAR markers' design based on the VuMark guidelines in Adobe Illustrator provided by Vuforia [26]. The unique code in the markers is generated by submitting the VuMark design into Vuforia Developer Portal. Each marker represents a unique string of twelve characters specified by the developer.

Besides, the web server function was also created to facilitate the users to upload their information and assets. In addition, the images and videos gallery were created to allow the users to view the assets uploaded to the server in their StickAR mobile application.

Table 5. The software requirements and its description.

Software name	Type	Description
Unity3D version 2019.4.18f1	Game engine	To implement the frontend, interaction, and backend logic of the StickAR mobile application To build the APK files for installation
Vuforia for Unity version 9.8.8	SDK	To implement the AR functionality
PHP	Scripting language	To handle the HTTP requests on the server
PHP-FFMpeg	Software	To generate the video thumbnail of the uploaded video assets
MySQL	Database	To store the users and assets information in the server
Android SDK Platform 10.0 (Q)	SDK	To build the Unity project into an Android APK file for Android deployment

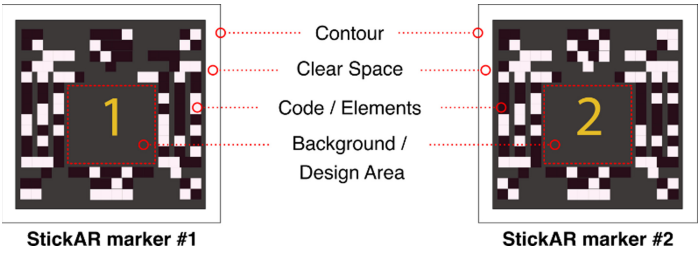


Fig. 6. The important parts of StickAR markers, which are based on the VuMark design guidelines [26].

3.4 Deployment

In the deployment phase, the Android application package (APK) file was created and integrated with the web server for users and assets management. The deployment settings and configurations for generating the APK are as follows:

1. Set the display configuration to portrait mode only.
2. Set the minimum API level to Android 4.4 "KitKat" (API level 19).
3. This project is built as a 32-bit application for faster building time and ease of testing.

4 Result and Discussion

4.1 AR Scanning Interaction

The AR scanning interaction is the major contribution of this work. Figure 7 shows the AR scan interaction flow. Users can access the desired StickAR marker folder immediately by using the AR scan functionality. This interaction provides a faster way to locate the folder for various purposes, such as uploading a new asset or viewing the uploaded assets.

Fig. 7. The AR scan interaction flow for note-taking activity.

This function, which is represented by requirement RQ4, can be performed by the users by clicking on the AR scan button in the home page. Then, the application activates the AR camera for the users to scan the physical StickAR marker. Once the StickAR marker is recognised by the Vuforia, the success panel is displayed on top of the camera view. Next, the users can click on the scan button to open the view assets page relative to the scanned StickAR marker.

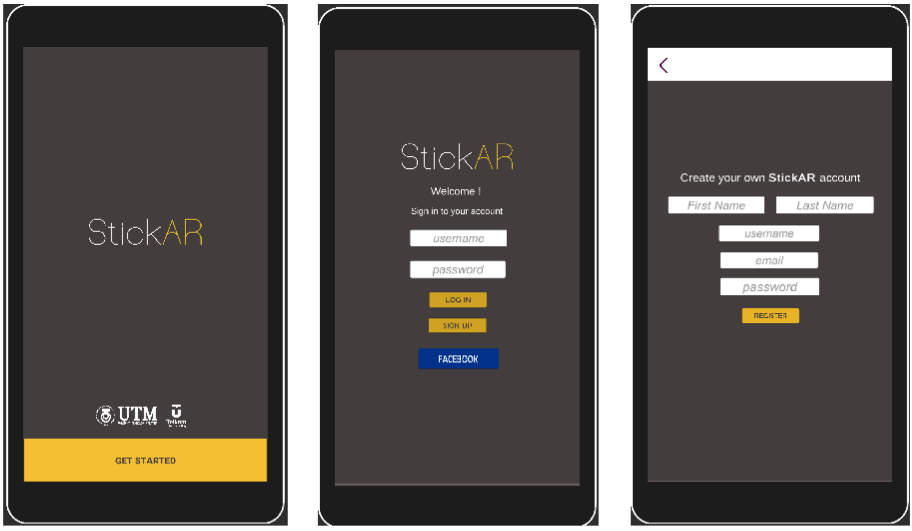
Besides, the AR scan interaction also promotes the integration of physical activity with virtual functionalities, such as note-taking. Users can paste the StickAR marker beside their notes, and then, add the multimedia contents, such as images or video recordings, inside the folder through StickAR mobile application which act as a supplementary information.

Figure 7 shows the example of the note-taking process in the real-world scenario. The student documented the growth of the plant in the notebook and used a smartphone to capture the photo of the plant. Then, the student pasted the StickAR marker beside the notes and scanned the marker by using the StickAR application. Lastly, the student uploaded the image of the plant to assign to this marker. Hence, the student can use the StickAR application to scan the AR marker to retrieve the selected image of the plant when he or she revisits the note again.

4.2 Start Pages

Figure 8 shows the graphical user interface (GUI) of the start pages. When the users open the StickAR application, they are first greeted by the start page, as shown in Fig. 8(a). Once the users click on the "Get Started" button, the StickAR application will navigate the users to the sign-in page, as shown in Fig. 8(b).

Users can choose to sign-in by using the StickAR account or Facebook Login. For first-time users, they can create a StickAR account by clicking the "Sign Up" button in the sign-in page to open the create account page, as shown in Fig. 8(c). Both functionalities represent the requirements RQ1 and RQ2.



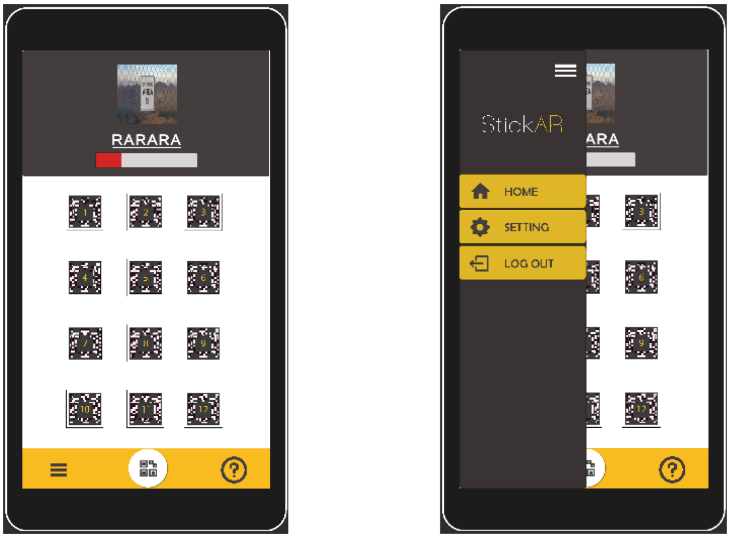
(a) (b) (c)

Fig. 8. The GUI of StickAR mobile application: (a) start page; (b) sign-in page; (c) create a new user account page.

4.3 Home Page

Once login to the StickAR application, users are directed to the home page, as shown in Fig. 9(a). In the home page, there are three buttons located in the bottom toolbar. Starting from the left, the first button is the hamburger button which opens the side menu panel, as shown in Fig. 9(b). The centre button is the AR scan button to open the AR scanning interaction that is explained in Sect. 4.1, while the right button is the tutorial button which provides fast access to the tutorial page.

In the side menu panel, there are another three buttons, which are the home button, setting button and log out button. Both the home button and logout button are self-explanatory. The setting button can direct the users to user management pages, as presented in Sect. 4.5.



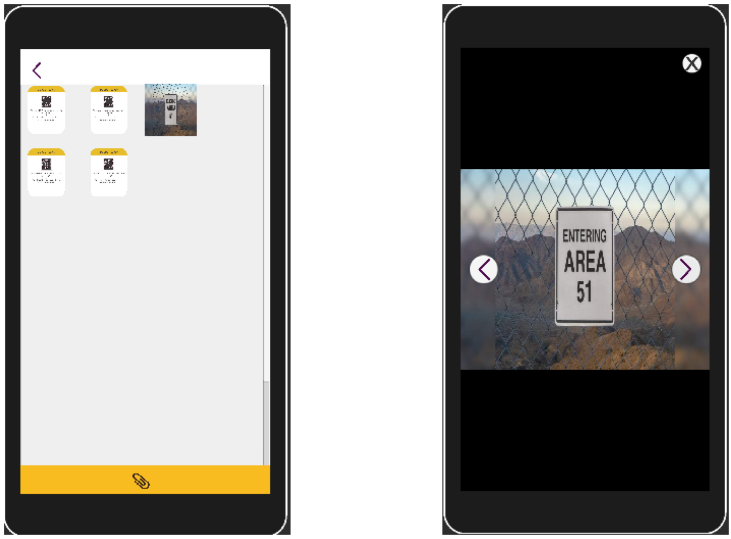
(a) (b)

Fig. 9. The GUI of StickAR mobile application: (a) home page; (b) activate the hamburger menu panel.

In addition, the home page also shows all the folders of available StickAR markers. Users can view the uploaded assets or add new assets in the folder by clicking on the StickAR marker they want. Then, the application will navigate to the view assets page as presented in Sect. 4.4. Besides, the StickAR application also displays the available storage space of the users as a horizontal scrollbar, which is located at the top of the home page and below the username and user's profile image. Currently, the prototype limits a user to store a total of 1 GB note size to the StickAR server. This is the feature for future application production, where the users can sign up for a free account with a total of 1 GB note size. The StickAR application should also provide an upgradable option to increase the storage capacity if the users require more memory space.

4.4 View Assets Page

There are two ways to access the view assets page. Firstly, it can be accessed through the AR scanning interaction flow, as presented in Sect. 4.1. Secondly, the users can also click on one of the StickAR marker buttons in the home page, as shown in Fig. 9(a). Figure 10(a) shows the GUI of view assets page.



(a) (b)

Fig. 10. The GUI of StickAR mobile application: (a) assets gallery page; (b) view the image gallery.

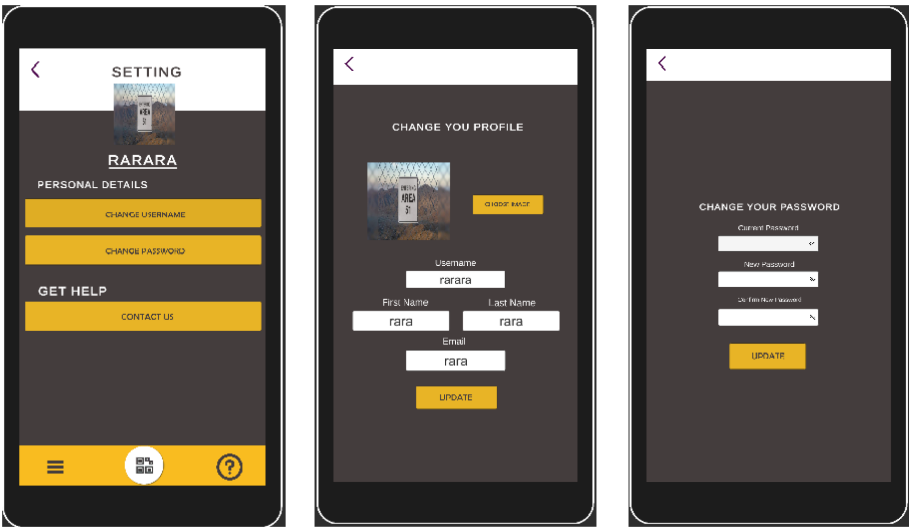
Inside the view asset page, users can perform several functionalities for assets management purposes, which are assigning new assets, view and edit the assigned assets, and remove the assets from the StickAR marker. They represented the requirements RQ3, RQ5 and RQ6, respectively.

Users can click on the clip button below to assign a file to this StickAR marker's storage. It will redirect the users to the file browser for them to search for the images or video recordings that they wanted to upload. Once assigned, all the multimedia contents are displayed in the middle of the view assets page in the form of a thumbnail. Then, users can click on one of the thumbnails to open the multimedia gallery, as shown in Fig. 10(b). Therefore, the users can browse through the images or video recordings that are assigned to this StickAR marker.

4.5 User Management Pages

Lastly, the StickAR application provides users with the functionalities to edit their profile information, which are represented as requirements RQ7 to RQ9. Figure 10 shows the GUI of the user setting pages.

Figure 11(a) shows the main user setting page which users can access from the hamburger menu by clicking the "Setting" option as shown in Fig. 9(b). In this page, users can choose to change their username or password. Figure 11(b) and (c) show the interface design of edit profile page and change password page, respectively. In the edit profile page, users can change their full name and profile image.



(a) (b) (c)

Fig. 11. The GUI of StickAR mobile application: (a) user setting page; (b) edit profile page; (c) change password page.

4.6 Discussion

Figure 12 shows the overview of the SWOT (strengths, weakness, opportunities, and threats) analysis which is used to discuss and assess the capabilities and future potential of the StickAR mobile application. The detailed descriptions are presented as follows:

1. **Strengths:** The StickAR mobile application provides the users with many stylish AR stickers, which allows the users to stick them in their notebook to bookmark their experiences in terms of video recordings and images at that physical point by using the AR technology. Compared to other traditional cloud storage applications, StickAR allows the users to obtain the desired data immediately by scanning the AR marker. The other storage application requires the users to search for them manually folder by folder. This feature can become the hypothesis for the user evaluation stage.
2. **Weaknesses:** The current product is still in the work-in-progress and prototyping stages. The function is also limited to the user. Besides, there are some requirements that are not implemented, which is from RQ10 and RQ11. The system also lacks the administrative functions to manage the StickAR markers and users.

3. **Opportunities:** The application provides a new opportunity for the artists and content creators to design the sticker that can be featured in this StickAR application. The AR functionality can also be used in exhibitions, for example museum and art gallery, or book publication which allows the owner and publisher alike to add the relevant information to the StickAR application. Then, the users can view this additional information by using the StickAR mobile application. In addition, the growing market demands of digital note-taking applications also provides a new opportunity to innovate and improve the user experience of these applications.
4. **Threats:** The competition from the existing note-taking applications and cloud storage applications, which offer competitive features and affordable options to the users. This study requires further user evaluation to determine and compare the efficiency of these applications with the proposed method.

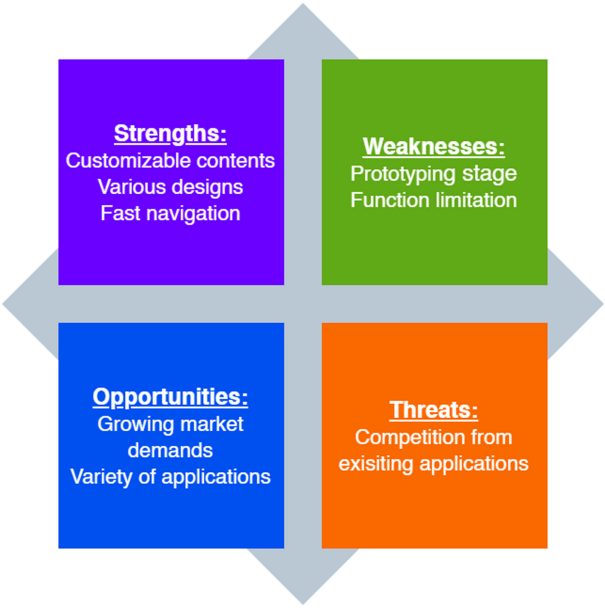


Fig. 12. The overview of SWOT analysis.

5 Conclusion

This paper presents the work-in-progress StickAR mobile application that can help the users to capture important physical events in the form of images or video recordings, along with the hand-written notes. These digital multimedia contents are stored in the StickAR web server by assigning them to a StickAR marker, and the marker can be sticked beside the notes. Then, the users can use the AR scanning interaction method of StickAR mobile application to navigate to the correct supplementary information

immediately by using the smartphone's camera to scan the StickAR marker. For the next steps of the StickAR mobile application:

1. Complete all the use case requirements.
2. Create a web application for administration functions.
3. Conduct a formal user evaluation and case studies.

Lastly, there are more suggested future works to improve the features and user experience of the StickAR mobile application:

1. Support text-based entries like Evernote and OneNote.
2. Utilize the 3D capability of AR technology to display 3D contents.
3. Create a new platform for the content creators to provide their custom AR marker design.
4. Collaborate with potential partners, such as museums, art galleries, schools, and publishers.

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