Integrating Augmented Reality in Learning Plants

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Abstract. Malaysia's biodiversity forests are producing numerous species of plants. Books, picture walls, posters, and brochures often use to display these plants' static images to promote these wilderness treasures. Though the use of these static images fits its purpose, they are less attractive in providing information. ARPlant prototype provides an interactive application that enhances rainforest plants' information displayed using the mobile platform. We use the Mobile Application Development Lifecycle (MADLC) to design and develop ARPlant. We gauge potential users' requirements and needs by conducting a survey. We then conduct the user testing using the System Usability Scale (SUS) score. The augmented reality in ARPlant allows users to learn by interactively exploring rainforest plants. Users can view the plants in a 3-dimensional environment.

Keywords: Augmented reality, Mobile application, Plant learning, Interactive learning

1. Introduction

Medium like books, picture walls, posters, and brochures often use to display these plants’ static images to promote these wilderness treasures. Though the use of these static images fits its purpose, they are less attractive in providing information. Often, there is limited space to provide information on the medium. Consequently, the audiences could not learn more about the plants [1].

This paper presents ARPlant prototype to enhance the information on rainforest plants using the mobile platform. ARPlant is an application that leverages augmented reality technology to learn and explore plants. Augmented reality (AR) is an active technology that allows users to construct new understanding based on virtual objects that bring underlying data to life. AR is used in education to attract audiences to engage with materials in learning actively. Hence, we leverage augmented reality technology to increase audiences' interest in exploring and learning more about rainforests plants. Furthermore, the application provides interactive videos to aid the user's understanding related to the topic.

AR provides image transfer information via digital devices that allow users to experience the interaction with virtual images in real-world contexts [2]. AR applications generate virtual objects and
overlay them into real-world footage based on the marker [3]. It can easily simulate complex information and visualize it as a highly interactive form of learning [1].

Currently, less technology is being used to learn about the plants in a more exciting way and at the same time able to attract more people to learn about rainforest plants’ species. This paper presents the design and development of the ARPlant application. The paper is written as follows: Section two explains the plant applications and augmented reality literature review. Section three describes the methodology of the ARPlant. Section four presents the results of the development. Finally, section five concludes the paper.

2. Literature Review

Malaysian forests are considered among the oldest rainforests in the world and are the second richest flora and fauna species per unit area in South East Asia [4]. Tropical rainforests provide habitat for flora and fauna, which are many still undiscovered. Food, wood, medicine, freshwater, and fresh air are among a vast array of resources provided by the forests to all living organisms on earth. Therefore, education and awareness to the public on the importance of preserving our tropical rainforests are crucial. Nevertheless, the rich information and knowledge about tropical rainforest flora species exposure to the public are still limited. The rich and rare floral species often have different ecosystems, such as unique and bloom for a specific time. Hence, it is challenging for the public to explore and learn about the species by only browsing the internet or printed materials. During the pandemic, the availability of rich and interactive content on tropical rainforest flora species has never been so crucial as before.

Computational botany uses taxonomy, systematics, and keys, and software to identify around 400,000 species of plants on earth [5]. Plant identification was also recognized as a novel solution in agronomy, conservation, environmental impact, natural product, drug discovery, and other applied areas [6]. Plant identification software applications such as Leafsnap, PlantSnap, iNaturalist, and Rainforest Plants of Australia allow users to learn about plants. For example, Leafsnap [7] is an application that allows users to identify the trees by taking a photo of their leaves. The result is that it will provide the tree's name, high-quality photos, and information about the tree, such as the tree's bark, flower, fruits, and seeds. Users of the application can learn about the plants that they want just by capturing the leaf of the plants. The system will recognize the name of the plants, and the user can know about its information. Plantsnap is another application that enables users to explore flora by snapping the actual photo of plants. The application displays information based on the image recognition of the actual photo. Plantsnap database stores up to 625,000 plants and trees [8]. iNaturalist is an application that allows users to scan plants using the mobile devices' camera [9]. Similar to Plantsnap, it displays the plant's information in real-time. It presents the name, facts about the plants, and places where they can be found. Rainforest Plants of Australia is a mobile application that provides information about rainforest plants, including images and details. The information is about the rainforest plants in eastern Australia, south of Rockhampton, through New South Wales to Victoria. The application contains more than 1140 species. Users can learn about the plants by clicking on any image or searching the name of the plants, and they can read the information.

These applications are beneficial in presenting plants information. However, active exploration using these applications is not possible due to the pandemic lockdown, travel limitation, and the closing of national parks to the public. To bridge these limitations, we propose the use of AR technology in plant exploration. In this context, users can view these plants in their original rainforest habitat without visiting the tropical rainforests.

Augmented reality can be defined as technology that overlays an object from the real world into a virtual world. It creates a virtual illusion that engages users effectively using visual devices. Augmented reality is a technology that keeps growing from day to day in many industries as it is being
used as one of their business marketing. Users of the augmented reality application will get more exposure to the object they are learning as they are involved with new technology [10]. Augmented reality technology can be used by all ranges of people regardless of their age as it is a simple technology and easy to use. According to [3], people can get knowledge about plants by using augmented reality technology as a new way of learning and teaching methods. According to [11], the system of augmented reality application generates the three-dimensional object, a virtual object and blends it in the real environment based on the marker that users scan in the first place. The system will allow the user to manipulate the object through virtual buttons and access the object's properties. Information at the poster displayed in 2-dimensional images tends to provide limited information such as text and static image only. Augmented reality offers additional content such as diagrams, photographs, audio, video clips, and 3-dimensional models to be shown to viewers in real-time by using an application installed on users' smartphones.

There are several types of augmented reality, such as marker-based, marker-less and location-based. In this project, we use the marker-based technique. Marker-based AR uses a mobile device's camera to perform image recognition on a predefined marker, which will trigger computer-generated content. The camera can track the markers from any distance and angle [12]. Then, the screen displays the information of the object with its virtual image. The content can be in the form of animation, video, and audio.

3. Methodology
This project follows the Mobile Application Development Lifecycle (MADLC) in the design and development process. This project also employs a survey approach to collect user requirements and needs and use the System Usability Scale (SUS) Score in user testing.

3.1. Mobile Application Development Lifecycle (MADLC)
Mobile Application Development Lifecycle (MADLC) is one of the existing methodologies, and it can be categorized as the latest methodology. Mobile Application Development Lifecycle (MADLC) has seven phases: identification, design, development, prototyping, testing, deployment, and maintenance [13]. However, only five phases are involved in this project which are the identification phase, design phase, development phase, prototyping phase, and testing phase.

3.2. User Requirements
We gather users’ requirement for this project using survey method. Hence, a survey was conducted using the Google Form platform. The survey was about how people learn about plants and their opinion on a mobile application using augmented reality technology to understand plants. The survey has received 80 responses. Based on the survey conducted, 60% of the respondents are female, and 40% are male. 70.1% of the respondents are 21-25 years old, while 23.8% are below 20 years old and 6.3% are more than 30 years old. In addition, 58.8% of the respondents are students, while another 41.3% are working.

3.3. User Testing
Table 1 shows the list of tasks performed during the testing phase. Participants were also asked to note whether the functions to perform a task is well functioning or not. Comments from the tasks performed were also recorded if any. Immediately after using ARPlant prototype, the participants were asked to evaluate the application using the System Usability Scale (SUS).

The SUS (System Usability Scale) was introduced by Brooke [14] in 1996. It is a reliable tool used to measure perceived ease-of-use with a ten-item questionnaire using five-point Likert items from 1
(strongly disagree) to 5 (strongly agree) (see Table 2). Then, in 2008, it was modified by [15]. In this study, the later version was used.

SUS has been used by many. Various applications and software have also been measured using the SUS assessment, including Excel, Gmail, and Wii [16]. Since the introduction to 2013, it was reported that SUS had been cited in more than 1,200 publications [17].

### Table 1. Task activity for users to perform during user testing.

| Tasks                                                                 |
|----------------------------------------------------------------------|
| 1. Launch the ARPlant application.                                   |
| 2. View the list of plants.                                          |
| 3. Open the AR camera and scan the marker.                          |
| 4. View the video of the plants.                                     |
| 5. View 3D plants.                                                   |
| 6. Read plant’s information that appears with 3D plants.             |

### Table 2. SUS evaluation questions.

| SUS Questions                                                                 |
|--------------------------------------------------------------------------------|
| 1. I think that I would like to use this application frequently.              |
| 2. I found the application unnecessarily complex.                           |
| 3. I thought the application was easy to use.                               |
| 4. I think that I would need the support of a technical person to be able to use this application. |
| 5. I found the various functions in this application were well integrated.  |
| 6. I thought there was too much inconsistency in this application.           |
| 7. I would imagine that most people would learn to use this application very quickly. |
| 8. I found the application very awkward to use.                             |
| 9. I felt very confident using the application.                            |
| 10. I needed to learn a lot of things before I could get going with this application. |

4. **Results**

#### 4.1. User and System Requirements

The survey used to identify the user requirements was answered by 80 respondents and was conducted from 15th May 2021 until 25th June 2021. The results show that 46.3% of the respondents like to go to plant exhibitions. In addition, 73.8% reported being interested to learn about rainforest trees. 93.7% of the respondents believe that augmented reality could enhance learning experience when learning about plant and 97.5% thinks it will be interesting. In addition, 95% of respondents want the information displayed to be minimal to avoid loaded information. The majority of the respondents (98.3%) also expect a user guide to help them understand the application and how to use it.
The functions to be included in the application were also identified, including displaying the information about the plants, allowing users to scan the marker and view the plant as a 3D model and in video form.

4.2. The Design of ARPlant
Designing the user interface of ARPlant includes three stages – low-fidelity, mid-fidelity and high-fidelity. In the low-fidelity, a storyboard was used using pencil and paper. The storyboard aims to help in visualizing the functions or features that are needed in the application. Figure 1 shows the storyboard of the ARPlant mobile application.

A Mid-fidelity prototype is a design prototype that shows the interactions and navigation possibilities between each interface. The prototype is not functioning as a high-fidelity prototype, but it is clickable to show how the mobile application will work. The mid-fidelity was designed using Marvel software which is a tool to create and design the prototype. Figure 2 shows the mid-fidelity prototype of the ARPlant mobile application.

In high-fidelity, a prototype was developed. It is the design of the system before publishing them as a product. A detailed explanation of the ARPlant prototype development will be discussed in section 4.3.

![Figure 1. Low-fidelity of ARPlant application](image-url)
Figure 2. Examples of mid-fidelity design of ARPlant application

This project uses marker-based augmented reality. For that, markers were identified. Images were chosen to be the marker; for example, in this project, images pictured in Figure 3 were used as markers. The images act as the marker and will be recognized using the mobile phone camera and will further trigger the computer-generated content (i.e., plant’s video or 3D image). The markers were designed to track them from any distance and angles, as suggested by [11]. The object that was designed to be viewed in 3-dimensional images, can be rotated by rotating the marker, and users can view the object in more detail and from a different angle. This creates a virtual illusion that may improve user engagement.

Most images and videos used in this ARPlant mobile application were captured during the Taman Negara Scientific Expedition II at Kuala Keniam, Taman Negara Pahang in September 2020. The expedition was organised by the Institute of Biodiversity and Sustainable Development, UiTM. Other images were from individual collection or publicly available.

Figure 3. Examples of images used as the image target or markers

4.3. The Development of ARPlant Prototype

The ARPlant was developed using Firebase for its database; Android Studio for its user interface and module integration; and Unity 3D, Vuforia and Blender to enable the augmented reality. The image target used for the marker was developed using Vuforia, while the 3D models of plants were created using Unity.

The ARPlant mobile application has several main menus, including About, Plants and AR Camera (see Figure 4). About menu provide information about the application and a user guide on how to use
the application. This is in response to the requirement identify from the survey conducted during the identification phase.

Plants menu provide search, categories, and a list of rainforest plants (see Figure 5). The search function and types of plants’ families enable users to find the plant quickly and provide alternative ways of searching for a plant.

Figure 4. Homepage of ARPlant application

Figure 5. Search, categories, and list of plants

Figure 6 shows the video of a plant being displayed on the screen after the user scans the picture of the plant that is the marker to trigger the augmented reality to display the digital content. For this example, the user can view a video of Korthalsia Scortechinii plant in its habitat and the structure of the actual plant.

Figure 6. Plant’s video generated from scanning a marker
Figure 7 shows the 3D model of the plant displayed upon scanning the marker. There is also information about that plant that appeared on the left side of the screen. Users can view the plant as a 3-dimensional image, which improves the visual of the plant and could be attractive to users compared to the 2-dimensional image.

Figure 7. 3D model of plant and its information generated from scanning a marker

To develop the augmented reality, Unity 3D, Vuforia and Blender were used. The images chosen to be the image target or markers were stored in Vuforia (see Figure 8). These markers were then exported to Unity. While 3D models were designed using Blender and, when finished, were exported to Unity 3D. In Unity (see Figure 9), the plants’ 3D models and videos were mapped to the object markers, and the project was integrated.

Figure 8. Vuforia database
4.4. User Testing and System Usability Scale (SUS) Score

There were eight participants involved in the user testing. The participants were first asked to perform the task list in Table 1 and immediately answer the SUS evaluation form.

Comments from the participants while using the application were also recorded. Participants were identified to acknowledge that the application was accessible, friendly, engaging, attractive, and informative. The use of videos and 3D images to view the AR plants, as an example in Figure 10, was able to gain participants interest as the participant mentioned it is interesting (P1, P3, P5, P8) and attractive (P1, P4, P5, P7). The information about the plants provided, along the 3D images, also able to let the participants to learn new knowledge (P1, P2, P4, P6, P8).

Table 3 presents the total scores for each participant. The participants had scored between 82.5 and 95. The average SUS score for the ARPlant application was calculated and return 87.81. This indicates that the ARPlant is acceptability by the users and is also excellent compared to the grade rankings of SUS scores as featured in [16]. As we further analysed each question, it is clearly identified that all participants agreed that the application is easy to use. All positive questions (i.e. Q1, Q2, Q3, Q5, Q7, and Q9) scored 4.00 and above. All the negative questions (i.e. Q4, Q6, Q8 and Q10) return scores of below 2 which reflect that the application is easy to use which they do not or require less assistance to use the application.

Table 3. SUS scores for each participant.

| Participants | SUS Score |
|--------------|-----------|
| P1           | 82.5      |
Table 4. Mean SUS scores for each question.

| SUS Questions                                                                 | Mean |
|-------------------------------------------------------------------------------|------|
| 1. I think that I would like to use this application frequently.              | 4.38 |
| 2. I found the application unnecessarily complex.                            | 4.13 |
| 3. I thought the application was easy to use.                                | 5.00 |
| 4. I think that I would need the support of a technical person to be able to use this application. | 1.13 |
| 5. I found the various functions in this application were well integrated.   | 4.50 |
| 6. I thought there was too much inconsistency in this application.           | 1.00 |
| 7. I would imagine that most people would learn to use this application very quickly. | 4.63 |
| 8. I found the application very awkward to use.                              | 1.00 |
| 9. I felt very confident using the application.                              | 4.50 |
| 10. I needed to learn a lot of things before I could get going with this application. | 1.25 |

5. **Conclusion**

This project proposes a mobile application that uses augmented reality techniques to enhance people to learn about plants and their information. ARPlant is a mobile application that uses augmented reality (AR) to learn about plants differently rather than read the information in the textbook, poster or 2-dimensional information and images. This mobile application allows users to view the plants as virtual plants in their smartphone and other visual aids such as text that display information about the plants, with the implementation of AR and the use of videos and 3D images to gain users’ interest to use and learn plant.

Improvements can be made to this application where the application should be able to run on other platforms as the development only covers Android. Including another element, a voice to describe the plant could also be implemented to make the learning plant more interesting.

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References

[1] Yew AY, Morsidi HM, Chan JH. Augmented Reality Project Poster: Using Mobile Augmented Reality Application to Enhance Project Poster. In Proceedings of the 11th International Conference on Advances in Information Technology 2020 Jul 1 (pp. 1-10).

[2] Klopfers E, Sheldon J. Augmenting your own reality: Student authoring of science-based augmented reality games. New directions for youth development. 2010 Dec; 2010 (128):85-94.

[3] Patil S, Prabhu C, Neogi O, Joshi AR, Katre N. E-learning system using Augmented Reality. In 2016 International Conference on Computing Communication Control and automation (ICCUBEA) 2016 Aug 12 (pp. 1-5). IEEE.

[4] Khalid RM, Kamaruddin H, Yaakob A, Wook I, Sulaiman SS, Mustafa M. Outstanding universal values of the Malaysian forests. International Journal of Asian Social Science. 2018; 8(7):427-33.

[5] Govaerts R. How many species of seed plants are there?. Taxon. 2001 Nov 1; 50(4):1085-90.

[6] Nagendra H, Rocchini D. High resolution satellite imagery for tropical biodiversity studies: the devil is in the detail. Biodiversity and conservation. 2008 Dec; 17(14):3431-42.

[7] Kumar N, Belhumeur PN, Biswas A, Jacobs DW, Kress WJ, Lopez IC, Soares JV. Leafsnap: A computer vision system for automatic plant species identification. In European conference on computer vision 2012 Oct 7 (pp. 502-516). Springer, Berlin, Heidelberg.

[8] Irimia, C.I., Matei, M., Iftene, A., Romanescu, S.C., Lipan, M.R., Costandache, M. Discover the Wonderful World of Plants with the Help of Smart Devices. In Proceedings of the 17th International Conference on Human Computer Interaction RoCHI 2020, 22-23 October, (2020).

[9] Nugent J. iNaturalist. Science Scope. 2018 Mar 1; 41(7):12-3

[10] Colley A, Wolf D, Kammerer K, Rukzio E, Häkkilä J. Exploring the Performance of Graphically Designed AR Markers. In 19th International Conference on Mobile and Ubiquitous Multimedia 2020 Nov 22 (pp. 317-319).

[11] Vithani T, Kumar A. Modeling the mobile application development lifecycle. In Proceedings of the International MultiConference of Engineers and Computer Scientists 2014 Mar 12 (Vol. 1, pp. 596-600).

[12] Zhao G, Zhang Q, Chu J, Li Y, Liu S, Lin L. Augmented reality application for plant learning. In 2018 IEEE 9th International Conference on Software Engineering and Service Science (ICSESS) 2018 Nov 23 (pp. 1108-1111). IEEE.

[13] Brooke J. SUS-A quick and dirty usability scale. Usability evaluation in industry. 1996 Jun 11; 189(194):4-7.

[14] Bangor A, Kortum PT, Miller JT. An empirical evaluation of the system usability scale. Intl. Journal of Human–Computer Interaction. 2008 Jul 29; 24(6):574-94.

[15] Kortum, P.T. and Bangor, A., Usability ratings for everyday products measured with the System Usability Scale, Intl. Journal of Human–Computer Interaction, vol. 29, no. 2, pp. 67–76, 2013.

[16] Brooke J. SUS: A retrospective. Journal of usability studies. 2013 Feb 1; 8(2):29-40.