

Implementation of FAST Corner Detection and Natural Feature Tracking Algorithms on an Augmented Reality Application for Introducing Global Warming

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ABSTRACT

Global warming is an increasingly alarming environmental issue, making early education essential. To enhance students' understanding of its causes, an educational application based on augmented reality (AR) technology was developed. This application employs FAST Corner Detection and Natural Feature Tracking algorithms to detect natural markers on real-world objects. Recognized markers trigger interactive 3D objects and audio narration explaining key global warming factors, such as the greenhouse effect, pollution, and deforestation. The testing process was conducted in two stages: alpha testing using the black-box method to validate functionality, and beta testing, which involved distributing questionnaires to teachers to measure the perceived effectiveness and satisfaction level with the application. The results indicate that the application functions correctly and, based on user feedback, shows significant potential as an engaging and interactive learning medium for introducing environmental issues to students.

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1. INTRODUCTION

Global warming is a pressing environmental issue due to the increasing concentration of greenhouse gases, especially carbon dioxide (CO₂), which causes the Earth's surface temperature to rise. The impact of global warming is not only limited to climate change, but also disrupts the balance of ecosystems, triggers natural disasters, and threatens human life [1]. This makes global warming one of the main focuses of Sustainable Development Goals (SDGs) point 13 by the United Nations.

In the context of elementary education, environmental topics have been introduced through Natural and Social Sciences (IPAS) lessons. The goal is to foster environmental awareness from an early age. However, learning, which is still dominated by conventional lecture methods, has proven ineffective, as observed at SDN 4 Bunter, which showed low student attention and participation in understanding the IPAS material [2]. The lack of engaging learning media also exacerbates the situation, making students passive and unmotivated to learn.

Factors causing learning difficulties can originate from within the student, such as low motivation, or from outside sources, such as a lack of varied learning media [2]. In facing these challenges, the concept of Education 4.0 presents a solution, encouraging the integration of digital technology to create adaptive and engaging learning. Information technology has developed rapidly, especially with the widespread use of smartphones that offer various multimedia features, including interactive games.

Unfortunately, students often use technology excessively to play online games, which can negatively impact the learning process and academic achievement [3]. Therefore, there is a need to shift the use of technology towards a more educational direction, one of which is through the use of Augmented Reality (AR) technology.

AR is a visual technology that allows users to view 3D digital objects integrated with the real environment in real time through the device's camera [4]. This technology can increase the interactivity

and appeal of learning, including in the context of introducing environmental issues such as global warming. With the help of AR, children can learn in a fun way through visualizations of the greenhouse effect, deforestation, and human activities that impact the earth [5].

To support AR performance, an image processing algorithm capable of accurately detecting and tracking visual features is required. The FAST (Features from Accelerated Segment Test) Corner Detection algorithm is used to quickly and efficiently detect important corners on markers. Meanwhile, the Natural Feature Tracking (NFT) algorithm is used to track the natural features of images so that 3D objects can appear stable in the real world [6].

This research aims to develop an Augmented Reality-based learning application using the FAST Corner Detection and Natural Feature Tracking algorithms, designed to introduce the concept of global warming to elementary school students. This application combines 3D visual elements, audio narration, GIF illustrations, and interactive quizzes as a learning tool. It is hoped that this application can improve students' understanding of environmental issues while creating an engaging, enjoyable, and educational learning experience.

2. METHOD

This research uses a Multimedia Development Life Cycle (MDLC)-based system development approach as the primary method in designing and building Augmented Reality (AR)-based learning applications. MDLC is a multimedia development model that integrates various elements such as images, text, audio, video, and animation, to create interactive and engaging learning media [7]. This process aims to increase students' interest and understanding of the material, particularly on the topic of global warming.

The MDLC model consists of six main stages: Concept, Design, Material Collecting, Assembly, Testing, and Distribution, which are visually depicted in Figure 1

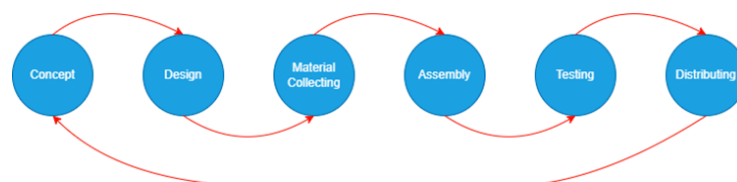


Figure 1. MDLC Method

2.1 Concept

This stage is the initial step to determine the application's primary objectives and identify target users. This application is designed for elementary school students in grades IV–VI with the aim of serving as an educational medium to introduce the issue of global warming visually and interactively. This stage also involved a needs analysis and initial data collection through direct observation at SDN 4 Bunter, as well as a literature review of relevant issues and technologies.

2.2 Design

This stage includes designing the application structure, navigation flow, user interface (UI) design, and a storyboard to guide the application's appearance and interactions. The design takes into account aspects of readability, user engagement, and visual consistency. Furthermore, the AR technology's operation is determined, including the implementation of markers, corner detection using the FAST Corner Detection algorithm, and feature tracking using Natural Feature Tracking.

2.3 Material Collection

At this stage, all required multimedia elements are collected, such as 3D objects, voiceovers, illustrations, and animated GIFs. The content is tailored to the theme of global warming, including visualizations of the greenhouse effect, fossil fuel combustion, and deforestation. This process is carried out concurrently with the technical design and application development to ensure time efficiency [7].

2.4 Assembly

All collected multimedia elements are combined into a system using the Unity development platform and the Vuforia Engine library. The AR markers are tested to detect digital objects quickly and stably using the FAST Corner Detection algorithm, while NFT ensures accurate image tracking in a real-

world environment. This process produces a prototype AR-based educational application that is ready for testing [7].

2.5 Testing

Application testing is conducted in two stages:

Alpha Testing, which is initial testing conducted by the developer to ensure each feature functions as intended. The main focus is testing application functionality, including marker scanning, 3D object appearance, menu navigation, and element interactivity [28].

Beta Testing, which is testing by end users (teachers and students) to evaluate usability, ease of navigation, and effectiveness of material delivery. Testing is conducted using the Mean Opinion Score (MOS) method [29].

The MOS method uses a scale of 1–5 to assess application quality based on user perceptions, with the following categories:

1 = Bad, 2 = Poor, 3 = Fair, 4 = Good, and 5 = Excellent [30].

The average score of all user responses will be used to measure satisfaction levels and serve as the basis for evaluating and improving the application.

2.6 Distribution

The final stage of the MDLC process is the distribution of the application to users. Applications that have passed the testing phase will be packaged in APK format for Android and shared through platforms such as Google Drive or uploaded to the Google Play Store. The results of the distribution phase will serve as valuable input for the revision and development process of the next version [9].

3. RESULT AND DISCUSSION

This section presents the outcomes of the research along with a comprehensive discussion to support the analysis. The results are displayed through structured tables and descriptive explanations to enhance the readers' understanding of the application's performance and its effectiveness as a learning tool for introducing global warming concepts to elementary school students, following recommendations from previous studies

3.1. Augmented Reality Application Functionality Test Results

Functionality testing was conducted by users to ensure that each feature in the global warming-themed Augmented Reality learning application functioned properly according to its intended purpose. This testing evaluated the extent to which the application met users' technical needs in conveying information about global warming issues. The assessment was divided into two categories: Success if the feature worked as expected, and Failure if the feature encountered problems.

3.1.1 Alpha Testing

Alpha testing aims to identify and prevent functional errors during the system development process. The technique used is black box testing, which tests system functionality based on input and output without viewing the internal code.

3.1.1.1 Alpha Testing Results

Alpha testing was conducted internally by Rusky Intan Pratama, S.T.P., M.Si., a technical evaluator, to ensure that all features in the global warming recognition Augmented Reality (AR) application functioned as designed. This testing employed black-box testing, focusing on the system's response to various user inputs without examining the internal structure of the code. The test results showed that all key features in the application functioned well, although there were some limitations in marker detection under certain conditions. The following is a summary of the alpha testing results:

Table 1. MDLC Method

No.	Test Class	Test Result
1	Start Menu	Successfully displays the camera and navigation buttons (next, back, home).

No.	Test Class	Test Result
2	Quiz Menu	Able to display questions, receive answer input, and provide correct/incorrect feedback.
3	Questionnaire Menu	Successfully displays the questionnaire form.
4	Information Menu	Displays information panels and allows navigation between pages.
5	Image Tracking	Capable of displaying 3D objects from various distances and angles (15 cm–45 cm; 45°–90°) with varying response times. At a distance of 45 cm and an angle of 45°, most markers failed to be detected.
6	GIF Illustration	Illustrations and page navigation run smoothly.
7	PlayAudio Button	Functions properly to play audio explanations.
8	Download Marker	Functions properly to download image markers.

Overall, the alpha testing results indicate that the application is functionally stable and technically sound. All primary features including AR tracking, multimedia integration, and user interface navigation met the expected performance criteria. Minor issues were found in marker detection at more challenging viewing distances and angles, which is a common limitation in vision-based AR systems. These findings support the application's readiness for further testing and deployment to end-users in the beta phase.

3.2. User Experience and Perception Testing of Application Quality

This test aims to evaluate the level of user satisfaction and perception of the educational AR application regarding global warming, with a focus on aspects of appearance, ease of use, information delivery, and attractiveness in the learning process.

3.2.1. Beta Testing

Beta testing was conducted to gather end-user feedback on the quality and effectiveness of the developed Augmented Reality (AR) application. This phase involved a qualitative evaluation approach by distributing structured questionnaires to three elementary school teachers, each representing different grade levels: Grade 4, Grade 5, and Grade 6. These participants were selected to ensure diverse perspectives across the targeted user group.

The evaluation method used was the Mean Opinion Score (MOS) with a 5-point scale (1 = Bad, 5 = Excellent). Each question measured a specific aspect of the application's usability, content clarity, and overall learning experience. The average score of each question was then used to determine the perceived quality of the application from the teachers' point of view.

3.2.1.1 Application Trial Questionnaire Questions

Table 2. Application Trial Questionnaire Questions

No	Question
1.	Is the 3D object displayed clearly?
2.	Is the audio clearly heard?
3.	Are the quiz questions and scores displayed clearly?
4.	Is the application visually appealing?
5.	Is the application easy to use?
6.	Does the application help in understanding the material?
7.	Does the application make learning more engaging and improve memory retention?

3.2.1.2 Application Trial Questionnaire Results

Table 3. Application Trial Questionnaire Results

No.	Assessment Aspect	MOS Score	Category
1.	3D Object Display Quality	4.67	Excellent
2.	Audio Quality	4.67	Excellent
3.	Quiz Display Quality	5.00	Excellent
4.	Visual Appeal	3.67	Good
5.	Ease of Use	5.00	Excellent
6.	Material Comprehension	4.67	Excellent
7.	Learning Experience & Memory Retention	4.33	Excellent

The results of beta testing indicate that the Augmented Reality application was generally rated very highly by participating teachers. All key aspects—including object visualization, audio, quiz features, and ease of use—received positive responses with a Mean Opinion Score (MOS) above 4. Notably, the quiz feature and ease of use achieved the maximum score. This suggests that the application not only delivers information effectively but also enhances learning interest and user engagement in understanding the issue of global warming.

3.2.2 Comparative Usability Validation from Previous Research

As a comparison and reinforcement of the testing results in this study, validation data from a previous study conducted by Sayyid Naufal Amin, Sri Endang Anjarwani, and Moh. Ali Albar was used. Their research focused on the development of the Augmented Reality learning media *MenawanAR* for introducing animals to early childhood students at RA MIN Mataram.

In that study, questionnaires were distributed to 30 respondents consisting of teachers and parents. The validation assessed seven aspects of usability using a 1–5 rating scale, and the results were calculated in the form of percentages and average scores (Mean Opinion Score / MOS).

Table 4. Comparative Usability Validation from Previous Research

No	Question
1.	Is the visual appearance of the <i>MenawanAR</i> application appealing?
2.	Is the <i>MenawanAR</i> application easy to use?
3.	Is the navigation system easy to understand?
4.	Does the application display 3D objects based on detected markers?
5.	Does the application display textual information from detected markers?
6.	Does the application facilitate students in learning animal recognition materials?
7.	Does <i>MenawanAR</i> serve as an engaging technology-based learning medium?

3.2.1.2 Summary of MenawanAR Questionnaire Results

Table 5. Summary of MenawanAR Questionnaire Results

No.	Assessment Aspect	MOS Score	Category
1.	Visual Appearance of the MenawanAR Application	4.23	Excellent
2.	Ease of Use	4.53	Excellent
3.	Ease of Navigation	4.60	Excellent
4.	Ability to Display 3D Objects	4.90	Excellent
5.	Ability to Display Textual Information	4.30	Excellent
6.	Effectiveness in Supporting Learning	3.36	Good
7.	Learning Engagement	3.70	Good

The MOS testing results in the study by Sayyid Naufal Amin et al. indicate that most aspects of the AR-based learning media were rated as *Excellent*, particularly in terms of visuals, navigation, and the ability to display 3D objects. Two aspects ease of supporting learning and engagement in the learning process were rated as *Good*.

This comparison reinforces the findings of the current study on the AR application for introducing global warming, which also achieved high MOS scores (average >4.5). These results suggest that the Augmented Reality approach consistently enhances learning experiences and user engagement across different contexts and subject matters.

4. CONCLUSION

Based on the results of alpha and beta testing, the developed Augmented Reality (AR) application for introducing global warming demonstrates high functional reliability and positive user reception. The alpha testing, conducted internally by an evaluator, confirmed that all core features including object rendering, quiz interaction, audio playback, and marker tracking functioned as intended, with minor limitations noted in marker detection under certain angles and distances.

User experience evaluation through beta testing further validated the application's effectiveness in delivering educational content. The results showed that most users, represented by elementary school teachers, rated the application as *excellent* across key dimensions such as ease of use, 3D visualization, content clarity, and learning engagement. Particularly, the quiz feature and user-friendliness received the highest possible Mean Opinion Score (MOS) of 5.0.

To strengthen the findings, this study also compared its results with prior research conducted by Sayyid Naufal Amin et al. on a similar AR-based learning application. Their research yielded similarly high scores in visual design, navigation, and 3D functionality, affirming the consistency of AR's benefits across different subject matters.

In conclusion, the use of AR technology in educational media particularly for complex environmental topics like global warming proves to be a promising and effective approach. The immersive and interactive elements of AR can significantly enhance comprehension, increase learner motivation, and support memory retention, making it a valuable tool in modern pedagogical practices.

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