

The 2D Android Game 'Bung Tomo Adventure' uses the Finite State Machine Method

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Abstract

Educational games are an effective media to improve the youth's understanding on national history, especially when the game is presented in an interactive and engaging manner. The adoption of Finite State Machines (FSM) in 2D games makes the game to be more realistic and more dynamic. This research aims to develop an Android-based 'Bung Tomo Adventure' game by adopting the FSM method to control character's behavior and to enhance the user's playing experience. The research methodologies include literature review, system's design, coding using Godot Engine, Black Box Testing, device testing, and user evaluation. Besides that, the Black Box testing outcome shows that the game features work as expected. The user experience testing shows that 87% respondents gave positive response (categories Good and Average), which means this game is quite well received especially in terms of storyline and ease of play, although some aspects such as visual appearance and game distribution need more improvement.

1. Introduction

The history of Indonesia's war of independence is a fundamental legacy that reflects the resilience and fighting spirit of the nation. The Battle on the 10th of November 1945 in Surabaya was not just a historical war, but there was a crucial moment of the Indonesians to defend independence. In this battle, history shows that the people of Surabaya, Surabayan, with minimal weaponry were able to fight against the well-trained Dutch troops with modern armed. Bung Tomo as one of the Surabayan was a heroic figure who gave very encouraging speech, then successfully moved the masses to carry out total resistance. This battle was then known as the "Battle of November 10" which became a symbol of the struggle and courage of the Indonesian nation [1]. About 68% of today's youth has very little understanding national history, including the history of Bung Tomo. This is due to traditional teaching methods with lack of interactive visualization, which often renders historical class boring [2].

Currently, 2D game development faces its own challenges because user interest tends to be higher towards three-dimensional (3D) games that offer more realistic visuals and a more immersive experience [3]. Nevertheless, 2D games are still able to compete in the game development industry because they have advantages in terms of design simplicity, lighter resource requirements, and flexibility in development. In addition, advances in mobile device technology have significantly driven the growth of the gaming industry. Games can now be played on Android and iOS-based smartphones, so users can access games anytime and anywhere without having to use a Personal Computer (PC) device [4].

One of the Artificial Intelligence (AI) methods that can be adopted in the 'Bung Tomo Adventure' game is Finite state Machine (FSM). The FSM method allows computer (non-player) characters to behave dynamically and adaptively [5], and it is like the troops combat strategy in the Battle of November 10th, 1945. This FSM controls the behaviour of character conditions between states such as patrol, chase, attack, and cover, thus creating more complex and less predictable game playing. The FSM was adopted in the game because of its ability to accommodate the decision-making process through the design of a control system [6]. This AI technology allows players not only to face enemies that move linearly, but to face opponents who have state transition logic that makes it look more realistic and challenging [7].

Several previous studies have shown that the application of FSM in game development is effective in improving the quality of interaction and behavior of non-player characters. Nugraha et al. [5] stated that the implementation of FSMs can increase game development productivity because the character's logic flow becomes more structured and easier to control. Meanwhile, the research results of Firdaus et al. [8] show that the implementation of FSM can simplify game mechanisms and improve the overall quality of game mechanics, especially in terms of state transitions and character action responses. In addition, Pukeng et al. [6] also proved that the use of FSM in intelligent agents in educational games can create adaptive character responses and support the delivery of learning materials more interactively. These

findings indicate that FSM are not only relevant for improving the technical aspects of artificial intelligence in games but also have the potential to strengthen the educational value and learning experience of players.

Therefore, this research develops a 2D game entitled 'Bung Tomo Adventure' by implementing the FSM method and a pathfinding algorithm adapted to the historical flow of Bung Tomo's struggle. This research not only focuses on the development of game applications but also aims to explore the use of Artificial Intelligence technology in creating interactive learning media that are more immersive and educational. It is hoped that the game 'Bung Tomo Adventure' can become an innovative model in the development of educational games and can foster knowledge, understanding, and appreciation of the younger generation towards the role of national heroes through interactive and meaningful learning experiences.

2. Research Method

This research uses a systems development approach consisting of several structured stages in designing and building the 2D game 'Bung Tomo Adventure'. The research stages are depicted in Figure 1. The research methodology used in the development of the 2D game 'Bung Tomo Adventure' employs a systematic, step-by-step system development approach. The initial stage began with a literature review, examining various references such as books, e-books, and national and international journals discussing 2D game development, the FSM method, pathfinding algorithms, and the application of artificial intelligence in educational games. This literature review aimed to establish a strong theoretical foundation as a basis for determining the methods and design of the system to be developed [9],[10].

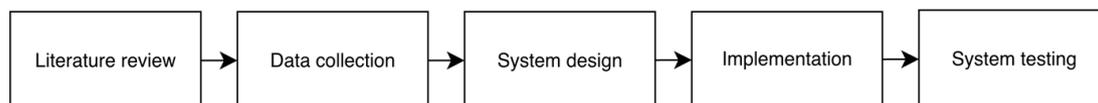


Figure 1. Research stages

Next, the data collection and analysis phase involved gathering historical information about Bung Tomo's struggle as the basis for the game's narrative, character and environment design references, and the system's technical requirements. The data obtained was then analyzed to identify functional and non-functional requirements, develop the game's flow, and determine the behavior of the NPC characters to be implemented using FSM and pathfinding.

The next stage was system design, which included designing the artificial intelligence architecture in the form of block diagrams, developing flowcharts and FSM state transition diagrams, and designing pathfinding algorithms for NPC navigation. Furthermore, game assets such as characters, settings, and visual elements representing the historical context were designed, as well as a user interface designed to be interactive and easy to understand.

After the design phase was completed, the system was implemented using Godot Engine as an Android-based development platform. GDScript offers an intuitive, Python-like syntax that significantly simplifies game logic design for developers [11]. FSM implementation and various other complex logic systems have proven to be very effective in creating interactive and modular games [12].

At this stage, the entire design was translated into program code, including the implementation of FSM logic for NPCs, the integration of pathfinding algorithms, and the integration of visual and audio assets into the game system. The final stage is system testing, which includes blackbox, controller, device, and user testing. The test results were then analyzed as a basis for system evaluation and refinement before the game was declared ready for use.

2.1. Main Menu

Figure 2 displays the main menu structure in the 'Bung Tomo Adventure' game. On the initial screen, players are presented with four main menu options: Play, About, Settings, and Exit. The Play menu serves to start the game and direct players to the available levels, starting with Level 1, then gradually continuing to Level 2 and Level 3. The About menu contains information about the developer's profile and a brief story about Bung Tomo as the background story in the game. The Settings menu provides game settings, such as volume settings and gameplay instructions, that help players understand the game's mechanics. Meanwhile, the Exit menu is used to exit the game application. This menu structure is designed hierarchically and simply to facilitate navigation and provide an insightful user experience.

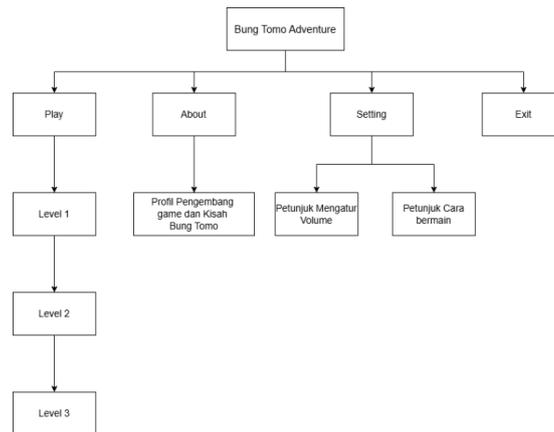


Figure 2. Main menu

2.2. Flowchart

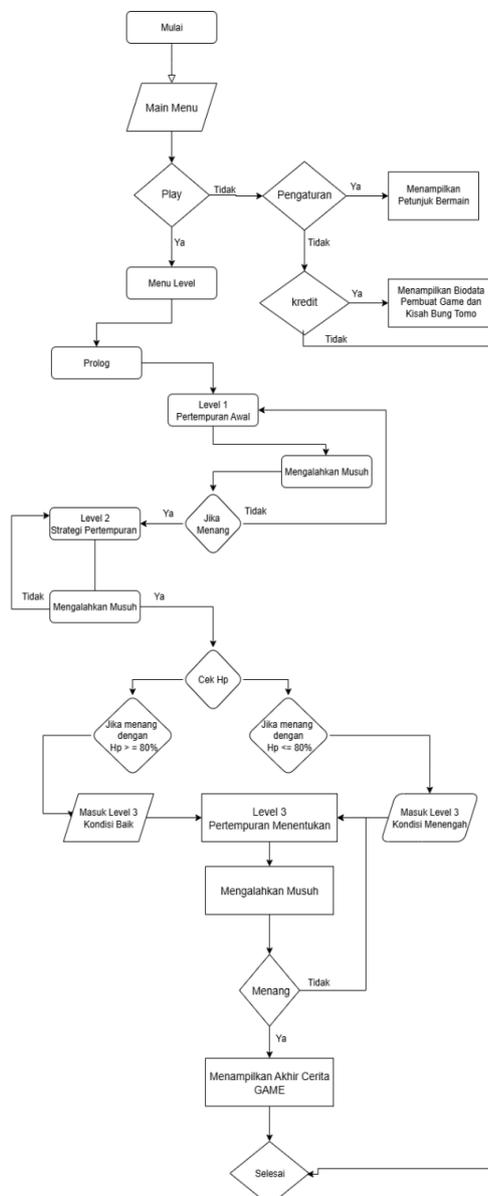


Figure 3. Flowchart

Figure 3 shows a flowchart of the 'Bung Tomo Adventure' gameplay from start to finish. The process begins with the Start button, which directs players to the Main Menu. At this stage, players can select several options: Play, Settings, or Credits. Selecting Settings displays gameplay instructions, while selecting Credits displays information about the game's creator and a brief history of Bung Tomo. Selecting Play will take the player to the Level Menu.

The game begins with the Prologue, then progresses to Level 1 (Initial Battle), where players must defeat enemies to advance to the next stage. If successful, players advance to Level 2 (Battle Strategy). At this level, the system checks the victory conditions. If the player wins, their HP (Health Points) are checked to determine their condition upon entering Level 3. If HP is 80% or higher, the player enters Level 3 in good condition, while if HP is <80%, the player still enters Level 3 but in moderate condition. In Level 3 (Decisive Battle), players must defeat the enemy again as the game's final stage. If the player wins, the system displays the game's ending, and the process ends at the Finish stage. However, if the player fails, the game will restart at a specific point according to the predetermined flow. This flowchart illustrates the game's systematic structure, with branching decisions based on the player's circumstances, creating a dynamic and structured gameplay experience.

3. Results and Discussion

3.1. Game Design

The game "Bung Tomo Adventure" is designed with three difficulty levels, each gradually increasing in challenge and complexity. Each level presents a variety of enemies, attack patterns, and combat strategies, requiring players to adapt their tactics. The difficulty increases as the game progresses, both in terms of the number of enemies, response speed, and the variety of attack patterns. Each level has characterized whose behavior is controlled by FSM method.

The design of characters and items refers to the design of the objects in the game. It includes player-controllable characters and non-player-controllable characters. The character designs in 'Bung Tomo Adventure' game are shown in Table 1. Table 1 shows the characters in 'Bung Tomo' Adventure game. This table includes information about the main character controlled by the player, as well as the types of computer character in the game. Each character is designed not only to support the storyline but also to create challenging and educational gameplay dynamics.

Table 1. Character design

No	Character	Description
1.		The people of Surabaya. This is the main character in this game.
2.		The Dutch soldier. This can attack when the main character approaches.
3.		Sergeant Van. It attacks when the main character approaches.
4.		Boss at level 3. It has a very high Health Point, HP (100%) and causes very high damage.

Table 2 shows various types of environments in the development of 'Bung Tomo Adventure' game. Each environmental element has a specific function and visual role in creating a game atmosphere that supports the engagement theme. The use of these elements follows the design level, character movement paths, and different elevations (flat ground, hills, and underground areas).

Table 2. Desain environment

No	Character	Description
1.		Enviroment Grass. It is used from level 1-3 on the ground.
2.		Enviroment Dirt. It is used from level 1-3 on the ground as a road.

No	Character	Description
3.		Environment Hills. It is used from level 1-2 as highground.
4.		Environment Underground. It is used from level 1

3.2. The Adoption of Finite State Machine

At the beginning, the character is typically in an 'idle' or 'standby' state. At the 'idle' state, the game is waiting for any valid input or any conditions that trigger an attack. When an attack command is issued, the game will move from 'idle' state to the 'preparing attack' state. In this state, the game will display initial animations, such as getting ready for attack.

Next the game's state change from 'Idle' state to the 'attacking' state. In this state, a character executes the attack and the game displays attacking animation. During this attack, the game may check several conditions, such as whether the attack hit the target, whether the player canceled the attack with another input. If the attack successfully hits the target, the game will record to reduce the target's HP. Figure 3 is an example of the application of a FSM.



Figure 3. The Adoption of Finite State Machine

3.3. Blackbox Test Results

'Bung Tomo Adventure' game utilizes several testings, including blackbox, controller, device, and user testing. Blackbox testing is conducted to ensure the input and output functions work properly on Android. Table 3 shows that the five main features tested in the Bung Tomo Adventure game worked as expected. User inputs such as selecting the main menu, selecting the start button, accessing game instructions, selecting game's level worked properly without any error. All five test scenarios demonstrated a 100% success rate.

Table 3. Blackbox test result

No	Tested input	Expected output	Output	Comment
1.	Game Start Menu Button	The game enter the PLAY menu		OK
2.	The Start button The Help button	The game enter the LEVEL menu		OK
3.		The game displays How To Play page.		OK

No	Tested input	Expected output	Output	Comment
4.	The Level 1 Button	The game enter the LEVEL 1 page		OK
5.	The Play Button	Ready to Play Level 1		OK

3.4. FSM Method Test Results

This test contains scenarios to ensure the computer character behaves as expected. The computer characters attack when the player is within their target range, and the characters are expected to die when their health point down to zero. The FSM testing results are shown in Table 4. Based on Table 4, testing was carried out to ensure that the FSM in the game’s characters was working as intended. This testing focused on two main conditions: attack behavior and death. In the first test, when the player entered the character's target range, the game was expected to automatically switch the character's status to attack mode. The test results showed that the character successfully recognized the player's presence and responded by attacking. It worked well as expected.

Table 4. FSM method test results

No	Action	Expected result	Comment
1.	Attack when the player is within range	Computer character attack the main character	OK
2.	Die when a character HP down to 0	Computer character dies when their HP down to 0	OK

The second test was carried out to verify that the character would die when its HP was down to zero. In this scenario, the character was expected to death state when it got damaged until its HP was depleted. Based on the results, the haracter completely ceased activity or disappeared when its HP down to zero, also indicating a 100% success. Overall, the FSM testing of this game showed that the transition between states worked well and aligned with the designed character behavior in the game.

3.5. Control Test Results

Control test involves examining every button used to move the player character in the game. The test results are shown in Table 5. Based on Table 5, the Control Test result shows that all control buttons worked properly without any error. With all test results show 100% compliance. It can be concluded that the game controls are responsive and provide a comfortable and optimal playing experience.

Table 5. Player control test results

No	Button	Function	Comment
1.		To move upwards	OK
2.		To move to the left	OK
3.		To move to the right	OK
4.		To attack	OK

3.6. Device Test Results

The importance of testing on various devices is in line with research by Fang et al. (2023), which states that operating system fragmentation and variations in hardware specifications in the Android ecosystem can lead to inconsistent application behavior (non-deterministic behavior) [13]. Testing across a range of hardware specifications

is crucial given the significant variation in game engine performance in mobile environments [14]. This test was carried out to determine the device specifications to run 'Bung Tomo Adventure' game. Based on Table 6, testing on some Android versions 10 - 13 devices with various specifications proves that Bung Tomo Adventure game runs smoothly. Five tested devices yielded 100% compatibility, indicating good compatibility and performance across a wide range of smartphones.

Table 6. Device test results

No	Device	Spesification	Result
1.	REALME 10 2022	RAM 4GB RAM, Android 11, Screen 2400 x 1080, 405 ppi	OK
2.	Poco x3 nfc	RAM 6GB, Android 12, Screen 1080 x 2400 px	OK
3.	Realme c17	RAM 6GB, Android 10, Screen 1600x720	OK
4.	Redmi Note 9	RAM 4 GB, Android 10, Screen 2340x1080 px	OK
5.	Samsung Galaxy A52	RAM 8 GB, Android 13, Screen 2400x1080	OK

3.7. User Test Results

This testing aimed at determining whether the game was running properly. This testing was carried out by 42 respondents and yielded the test results as on table 7. Involving a representative number of respondents (over 30 people) is crucial to achieve a sufficient level of confidence in identifying usability issues that may have been missed during the development stage [15]. According to Pressman (2014), user validation testing aims to ensure that the software built meets functional requirements and performance expectations in the actual usage environment [16]. Referring to Table 7, the test involved 42 respondents who evaluated five main aspects of the 'Bung Tomo Adventure' game. Each question was divided in three categories: Good, Average, and Poor. The maximum total score for all questions was 210.

Table 7. User testing results

No.	Question	Answer		
		Good	Average	Poor
1.	How is the visual?	27	13	2
2.	How easy is it to use?	27	13	2
3.	How easy is it to understand the storyline?	30	9	3
4.	How is the overall experience playing this game?	27	10	5
5.	How is this game accessibility?	27	11	4
Total		138	56	17

The first question is about visual appearance. The feedback was varied: 27 respondents said Good, 13 Average, and 2 Poor. This result indicates that the visual aspect is not yet fully satisfactory and requires more improvement. On the other hand, the ease of operation received quite positive responses. 27 respondents said Good, 13 Average, and 2 Poor. This indicates that the game is quite easy to understand in general. The storyline aspect received the best response. 30 respondents said Good, 9 Average, and 3 Poor. This indicates that the game's story line is well-presented and quite easily understood by respondents. Regarding the overall playing experience, 27 respondents said Good, 10 Average, and 5 Poor. This indicates that the game provides an enjoyable experience, although there is requires some improvement. On the final question related to the game accessibility. 27 respondents said Good, 11 Average, and 4 Poor. This suggests that access to the game could still be improved further to make it more accessible to users. Overall, out of 210 votes, 138 received a rating of Good, 56 Average, and only 17 Poor. This reflects that majority respondents gave a positive response to 'Bung Tomo Adventure' game, particularly in terms of storyline and ease of use. However, several aspects, such as the visual appearance and accessibility strategy, need more improvement to enhance the game's quality in the future.

3.8. Percentage Test Results

Table 8. Percentage test results

No	Respondent's response	Percentage Value
1.	Good	$138/210*100\% = 65\%$
2.	Average	$56/210*100\% = 26\%$
3.	Poor	$17/210*100\% = 8\%$

Based on Table 8, percentage values were computed based on user responses previously tested as on table 7. The results show that 65% respondents gave a Good rating for Bung Tomo Adventure game. Furthermore, 26% respondents gave an average rating, indicating that most users felt the gaming experience was as expected, although not good

enough. Meanwhile, only 8% respondents gave a Poor rating, indicating that only a small percentage of users felt the game did not meet their expectations in some respects. Overall, most user responses fell into the positive category (Good and Fair). To conclude that the 'Bung Tomo Adventure' game has been quite well received by respondents, although there are still some issues that need to be improved to provide a more enjoyable playing experience.

4. Conclusion

Through the implementation and testing process, 'Bung Tomo Adventure' game has adopted the Finite State Machine method to control character behavior, resulting in a more dynamic and organized gameplay. All control functions work properly as expected, while compatibility testing results indicate that the game can run smoothly on various Android devices with medium to high specifications gadget.

All testing results indicate that 'Bung Tomo Adventure' game works very well in terms of functionality, controls, AI characters, and device compatibility. Black Box, FSM, control, and device testing each yielded a 100% success rate, indicating the system run smoothly without any issues. Respondent feedback was also positive, with 65% said Good, 26% Average and only 8% said Poor. The game is considered as easy to play, has a clear storyline, and provides a satisfying playing experience. Overall, the game is worth playing, although some improvements are still needed in terms of visuals and gameplay.

For future development, it is recommended that 'Bung Tomo Adventure' game add some more game levels. To explore the possibility of developing in 3D format would be another advantage, as it will improve the visual quality and playing experience. In addition to the FSM method, the application of other artificial intelligence techniques can also be considered to create more diverse and realistic character behavior. Additional features such as a game save system (save & load), flexible control settings (custom control), and the integration of background sounds and historical audio effects would be very useful in enhancing the game's atmosphere. Furthermore, the implementation of achievement features and side missions is also expected to increase the appeal and motivation of players in completing the game.

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