

A* Algorithm for Path Finding on General Sudirman Battle Game Based on Mobile

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Abstract— Game application of General Sudirman is a game genre with 1st person shooter has two levels and each level has a different mission that narrated the heroism story of General Sudirman to defend the Indonesian independence. At Level one, the battle setting is the attack of two villages in Ambarawa, the mission of the second levels take place when General Sudirman is on guerrilla attack with his troops. The application is supplied with certain artificial intelligence algorithms in order to the player character in this game is more intelligent and realistic. The animation design and behavior of the characters using Finite State Machine (FSM), there are four characters: 1. Infantry (Indonesian army and allied soldiers), 2. Army Standby, 3. Tank, 4. Stretcher Sudirman. Each character implements A* algorithm for avoiding obstacle. Each AI based character have its own area an standby point. The area can detect the who approaches the area, When enemy enter an area, the AI character will react by attacking the enemy. When the enemy leave the area, the AI character will return to its standby point. The AI character comprises of infantry character and the general Sudirman sketcher character. The 3D game is mobile based and have good graphics quality for entertainment and education.

Keywords— General Sudirman Battle; A* Algorithm; Path Finding; authority area; FSM; 3D Game Based on Mobile

I. INTRODUCTION

Nowadays, increasingly, people have become less aware with history. Moreover, several people thought that history is a collection of an overlooked past event. Through studying history, we can learn our failure from the past to prevent it from its occurrence. As quoted from the famous proverbs from Spain philosopher, George Santayana: "Those who cannot remember the past are condemned to repeat it" [1].

Heroism is one of the remarkable parts of history. General Sudirman is a well known hero to many Indonesians, in spite of few people know who he is and his services for the nation. The best way to learn the history of General Sudirman is from reading books. On contrary, from some people, reading books is tedious way to study history. More stimulating way to learn

history is from games. Nowadays, many games had been on market. One of the renowned game is Blitzkrieg that covered the history of World War II [2] [3]. Some of the games that based on Indonesia history, e.g.: Pallawa, P10NER, and Travel Kartini. Palawa is a game that based on the history of General Sudirman, inspire our research. On Palawa, General Sudirman is assigned into a set of chronological mission, notably called as Palagam Ambarawa battle, consists of Magelang combat, Jambu village incident, the attack Ambarawa castle, and Ambarawa battle [4]. P10NER is a game that narrates the history of the battle 10 November [5], and Travel Kartini is an RPG game that narrates the lifetime of RA Kartini [6].

Game of General Sudirman covered the wars that were led by General Sudirman: Palagan Ambarawa, Dutch Military Aggression II, and General Offensive March 1, 1949 will each be divided into level 1 to level 2. The game, that applied artificial intelligence (AI), is a genre of action and sub genre of first person shooter (FPS) with a view of the user on the non-player arena game character (NPC). AI in FPS games generally is applied for planning path, picking up items, use items, and war. For fighting, NPC is also expected to choose specific strategies such as humans [7]. The strategies consist of pursuing the opponent, attacking the opponent or avoiding the opponent. The attacking strategy can be varied, for example, the strategy for attacking by baiting the enemy to attack and then in certain circumstances turn into evasion.

Developing games on smartphones is different from the developing games on system console and personal computer in terms of lower processor speed and memory size. Therefore, the choice of algorithms for searching scene in the smartphone game is definitely important to develop a game with optimized result. The application of AI in the game development results in realistic view of different character e.g. an intelligent enemy character, attractive dialogue between character, and so on. On contrary, AI application on smart phone takes a longer time to calculate the distance of the path and attacking strategy, rather than AI application on computer [8].

Attacking strategy in the game Sudirman for NPC scenario applied Finite State Machine (FSM). FSM is the most commonly used in AI game because of its simplicity, its efficiency, its ability to expand and cope with wide variations of situation [9] . FSM is applied to achieve a consistent and realistic behavior of the characters of the game in order to react appropriately to the actions of other characters . A* algorithm is a Djijkstra heuristic algorithm approach for finding a path in developing a strategy game [10] [11] . Djijkstra algorithm requires a table to calculate the cost , whereas $f(n) = g(n) + h(n)$ [12] [13] .

In this study, the A* algorithm is used as the method for AI characters to find the shortest path to pass through the obstruction. Each obstruction has different costs, depending on the parameters. The parameters can be distance, type of obstruction e.g. buildings, trees and hills. The application of A* is performed on the state of characters who pursue the enemy. Results of this study is to propose a new approach in the form of a game application as an option to learn the story of General Sudirman. The game is based on mobile and runs on the Android OS platform .

II. METHOD

A. Block Diagram of the System

Figure 1 shows the application design phase, consists of a 3D object modeling (using Blender and Google sketchup), the design of the events and its scenarios (level), the design of AI (FSM and A*) , the programming implementation for each level and the AI is completed with unity [14] and visual C#.

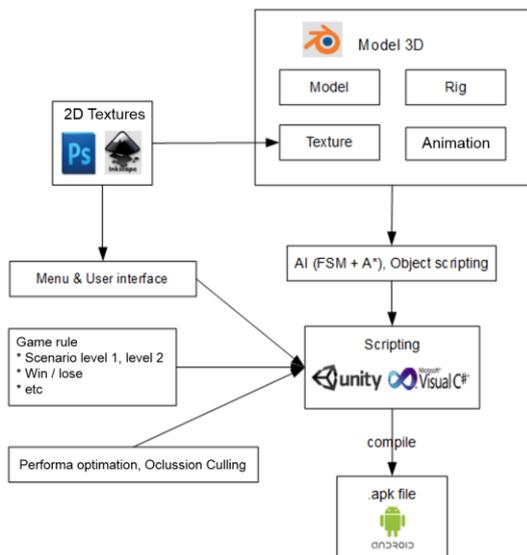


Fig. 1. Application design phase

B. Level Design and Scenario

The game consists of three levels . Each level has a specific mission. Each level mission is excerpt from an actual story of General Sudirman . The levels in the game can be explained as below:

1) Level 1 (Ambarawa)

At level one, the battle setting is the attack of two villages in Ambarawa, that is formerly seized by the Dutch. The battle led to the destruction of enemy defenses in the church compound Margo Agoeng , and a large-scale battles in the streets of Semarang - Ambarawa [15] [16] [17] . The mission of RI forces in this level are :

- Encircle Jambu village in Ambarawa area under the command of Lt. Col. Isdiman. (In the end, Lt. Col. Isdiman die due to being besieged by enemy troops)
- Destroy allied defense in front of the church complex Jl . Margo Agoeng.
- Attack all out all-out , retreat to the village to Bedono before pursuing enemy.
- Sudirman lead war on highway Semarang - Ambarawa . Its mission is to destroy the enemy's defense.
- Release the city from enemy soldiers.

2) Level 2 (Dutch Military Aggression II)

The mission of the second levels take place when General Sudirman is on guerrilla attack with his troops . On december 19,1948, Sudirman left Yogyakarta for guerillas. The guerillas lasts for 7 months with a distance of over 1000 km. Sudirman become the figure of the most wanted enemy by the Allies [15] [16] [17] . The RI forces mission are :

- Protects Sudirman is in a stretcher
- Destroy small groups of enemies
- Destroy several tents of the enemy
- Sabotage of various facilities such as food warehouses .
- Discharge the area from enemy soldiers

C. Player Character Description

In the game , there are three categories of characters . The character is

1) The Infantry

Infantry is the armed soldiers without vehicle . The character of infantry in this game consists of :

- The character of the Indonesian army
- The character of the Allies army
- The character of Lieutenant Colonel of Indonesia

The Indonesian military character is shown in below Figure 2(a) , the Dutch soldiers character is shown in Figure 2(b), and the Lieutenant Colonel of Indonesia character is shown in Figure 2(c).

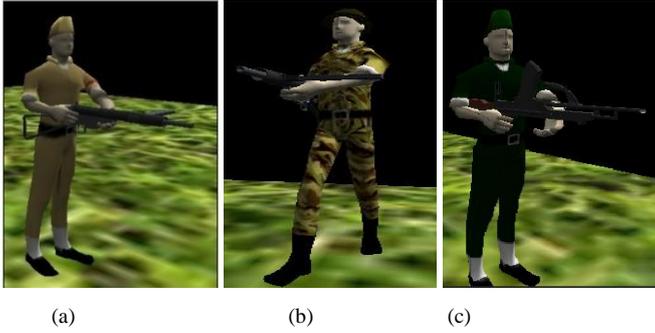


Fig. 2. Figure 2. Various infantry character in the game consists of (a) Indonesian army character, (b)Dutch army character, and (c) Lieutenant Colonel of Indonesia character

Infantry character exists on every level of the game, even players also control the infantry character. The infantry character is distinguished by the ability to switch weapons. Each weapon has its own advantages and disadvantages. The weapon can be obtained as a bonus that appear when the player successfully kill an enemy character. As a rule for the killing, not every the effort for killing the enemies can receive a bonus, but only killing 30% of the enemies. As a rule for the kinds and types of weapons, in Figure 3 , we depicted the the weapons used in the game. The weapons are made as closely as possible with the weapons used in the past by some references. All weapons have bullets that can be discharged. When the bullets are discharged, the weapon cannot be used and will automatically have to be removed. Some characters have different weapon, called as standard weapons, which have infinite bullets. Standard weapons have specifications that are relatively poor compared to most other weapons.

2) Tank

Tank character appeared on level 1. The tank is only owned by the Allies. Figure 4 shows the tank character. The appearance of this tank character is based on historical story that when Sudirman with his entourage besieged in battles in front of the church compound in Jln . Margo Agoeng. Next, Sudirman entourage fled to the village of Bedono. This tank is very strong, therefore, when the tank appears, Sudirman entourage will avoid this tank.

3) The Sudirman Stretcher

The Sudirman stretcher character is a stretcher carried by four Indonesian infantry. The stretcher illustration is shown in Figure 5 .

The above illustration shows the character of the stretcher used by Sudirman when he was sick .

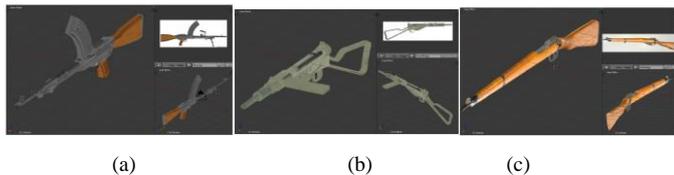


Fig. 3. Figure 3. Various weapons in the game (a) Bren, (b) Sten MK II, dan (c) Enfield



Fig. 4. The tank character

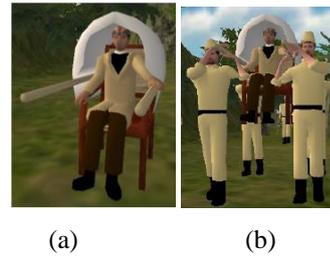


Fig. 5. Figure 5. The Sudirman Stretcher (a) Sudirman sit in a stretcher, (b) Sudirman stretcher is carried by four Indonesian infantry

The stretcher character describes as a bamboo chair covered with a white cloth . The stretcher character is the only main character that cannot perform any attack . The stretcher, driven by AI, is supposed to follow the characters that are driven by players. Besides protecting their selves , the player 's mission is to protect the stretcher . Mission will fail if the General Sudirman on the stretcher is dead . The stretcher character appears from level 2 and some parts at the end of level 1 .

D. AI Design with FSM Application

Any AI character has an area to be maintained. AI character will attack any enemy who enter its area. Whenever the enemy ran from the arena or the enemy AI is dead, the character will return to its original position. The FSM design for infantry character is shown in Figure 6 . Infantry is the character of armed soldiers without a vehicle . The infantry character in this game consists of :

- The character of the Indonesian army
- The character of the Allied forces

Some description about the state that is shown figure 6 :

1. *Silent / Standby State* : This state is a condition when an AI character silent or standby at a certain point. The objective of this state are waiting and scrutiny the area whenever the enemies enter the inspection area. Whenever an AI enemy enter the area, the AI character will enter into a new state : "Chasing the Enemy"

2. *Chasing the Enemy State* : This state occurs when from silent/standby state position, suddenly, an enemy enter the inspection area. The purpose of this state is to approach the enemy very close, overtake them and put the enemy within firing range. The chasing leads to two possibilities :
 - a. Chasing enemy is within the firing range : Enemies can be overtaken so that the state is changed to a new state : " Aiming the enemy state "
 - b. Chasing enemy out of the area of the firing range: The enemy ran too far to leave the area so that the chasing state is changed to " Searching for Enemy In Area "
3. *Aiming the enemy state* : This state occurs when the chase was successful and the enemy entered within a firing range. The purpose of this state is to ensure weapons state points directly to the enemy and to ensure there are no obstructions between the shooter and the enemy target. The aiming state leads to three possibilities
 - a. The obstruction is not within the enemy team. This condition occurs when the obstruction between shooter and enemy target is a tree, a building, or other things that is not included inside enemy team. For this condition, the AI character will continue its state and will keep aiming the enemy until there is no obstruction between shooter and the target enemy.
 - b. The obstruction is within the enemy team. This condition occurs when suddenly there are other characters that pass between shooter and the target enemy. Because the obstruction is within the enemy group, the shooter will shoot the obstruction, even though the obstruction is actually not the main target. The aiming state will move to the new state: "Shooting"
4. *Shooting state* : This state occurs when an AI character that has been aiming for a target enemy and nothing is blocking the AI character with the target . The purpose of this state is to attack the enemy by firing the weapon to kill the enemy . The shooting state leads to two possibilities:
 - a. The enemy dead : This condition occurs when the attack from the AI character successfully kill the enemy . The AI characters will seek out another enemy that enters its territory. The state will change into a new state : "Seeking out the area"
 - b. The enemy is alive : This condition occurs when the enemy managed to escape. In this condition, the AI character will seek out the fleeing enemy and enter a new the state "Tracking down the area"
5. *Seeking Out the Area State*: This state occurs when an AI character successfully kills an AI enemy. The purpose of this state is seeking out new enemy in the area . The seeking leads to two possibilities :
 - a Enemy is found: This condition occurs when the AI character successfully found new enemy. The AI

character will change into new state "Tracking down the area"

- b. Enemy is not found: This condition occurs when the AI character failed to find enemy. The AI character will return to its idle position and change into a new state " Return to area"

6. *Return to area state* : This state occurs when the area is clear from enemy and the AI character return to its base and back to standby position. The purpose from this state is to walk down and perform standby position. After the AI character back in its standby position, the AI character will enter new state: Silent/Standby state

The Sudirman stretcher character is described as the character stretcher carried by four Indonesian infantry. The FSM implementation for the stretcher the is shown in Figure 7.

E. FSM Implementation

Each AI character owned a specified area and a standby point. The area can detect each time the enemy approaches to enter it. When the enemy enters the area, AI character will react by attacking the enemy. When the enemy leaves the area , the AI character will return to the standby point . Description of the AI character and its standby points are described in the figure 8.

When the enemy enter the area then automatically the AI character will attack. When the enemy exit the area, the AI character will back to its original point or standby point . In addition to AI scripting , scripts are also needed for menu and user interface. The buttons are all created using the touch screen. The script for game scenario is needed for the rules of the game.

a. Algoritma A*

In this study, the A * algorithm is used by AI characters to find the shortest path to pass through the obstruction. Figure 9 shows an example of an algorithm A * . The green pixel indicates the starting point, the red pixel indicates the destination point, a blue pixel indicates the obstacles that must be avoided and the yellow pixel indicates the point with the smallest cost score and utilize as a chosen path.

Process starting from the definition of the arena, the cost assumptions when the horizontal movement or vertical movement are worth 10, and when diagonal movement is worth 14. These values are stored in the variable G, shown in the Figure 9(a). The calculation is continued to estimate the cost of the movement of every point to the destination point. It is assumed that each time the point with the distance 10 is passed by, the obstruction is ignored and the value of this process is stored in the variable H. This is shown in Figure 9.b.

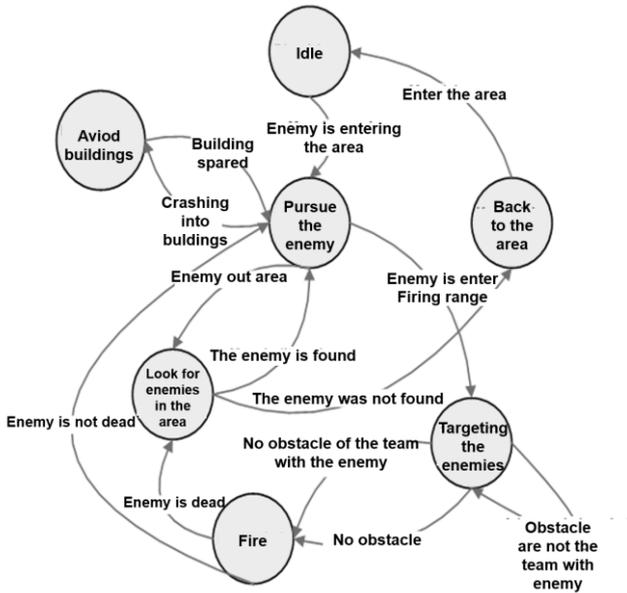


Fig. 6. FSM of the Infantry character

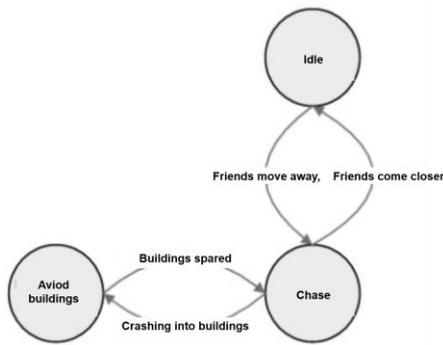


Fig. 7. FSM of the Sudirman Stretcher

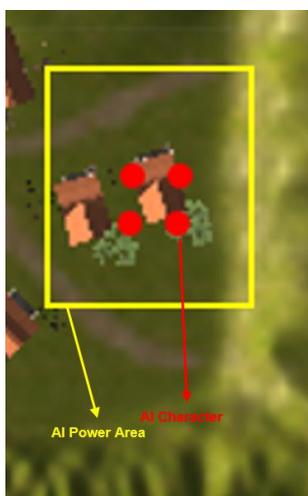


Fig. 8. AI Characters and Its Standby Points

Once the value of G and H are obtained, then the scores is calculated from each point to be traversed. Scores are symbolized, e.g. with F where $F = G + H$. The F value is then introduced in each point of each step to be traversed. The results of scoring process is continued by selecting the smallest scores as a step movement. The illustration of the process is shown in Figure 9c. From step 1 to 3, looping is performed to obtain the optimal path to the destination point, as shown in Figure 9d.

b. Occlusion Culling

As a 3D game, in this application, Occlusion culling techniques is added. This techniques can improve the performance of the game, namely, by reducing the number of draw calls. Draw call itself is the number of mesh or dots on rendering 3D models [15]. In other words, occlusion culling is a technique to minimize the rendered object, by rendering only the objects those are visible to the user [15]. The objects, those are not visible to the user, will not be render.

Culling occlusion is the simplest technique is to divide the game area into smaller groups. The details is shown in Figure 10.

II. RESULT AND DISCUSSION

A. Experiments

1) Main Menu Scene

The preview of main menu scene as shown in Figure 11.

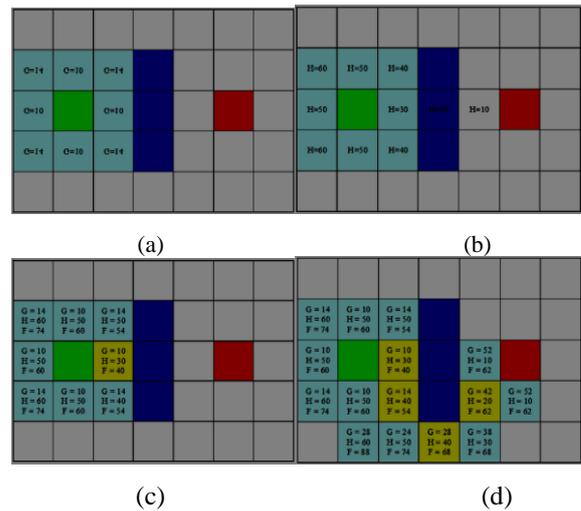


Fig. 9. Algoritma A* (a) Points with G (b) Points with H (c) Points with FG (d) The optimal path from start to destination

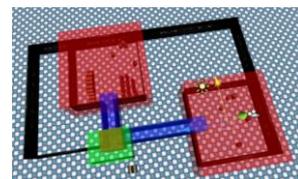


Fig. 10. Area division into smaller groups

2) Intro Scene

The intro scene is the prelude before the main scene. Intro scene gives a guideline for the player on how to take part in the game. The screenshot of the scene is shown in Figure 12.

On the level 2, intro scene will give a prelude to player before playing level 2. Intro scene in level 2 will illustrate the beginning of Dutch military aggression II. The intro starts with the attack on Maguwo airport by the Allied forces, as shown in the Figure 13(a). The attacks are the reasons for the General Sudirman to leave Yogyakarta for guerrilla mission. The screenshot of the intro scene for level 2 is shown in Figure 13(b).

3) Level Scene

On level scene, the testing is performed to ensure that every scene has been running as in the scenarios. The testing is shown in the Figure 14.

4) FSM Testing

The first testing is performed by giving opportunity for the enemies to enter the area. The AI character will be in state "chasing the enemy" and when AI character can overtake the enemy, the AI character will enter a new state "aiming the enemy" as shown in the Figure 15. When the enemy is out from the area, the AI character will return to standby state, as shown in the Figure 16.



a) b)

Fig. 13. Intro Scene of Level 2 (a) Maguwo airport attack, (b) General Sudirman enter the forest for guerrilla mission.



a) b)

Fig. 14. Level Scene (a) Level 1, (b) Level 2



Fig. 11. Main Menu Scene

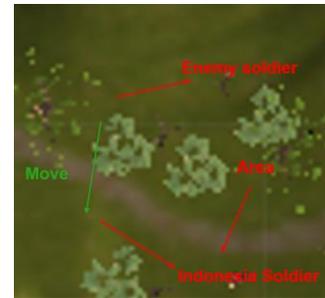


Fig. 15. AI character is in state "chasing the enemy"



(a) (b)



c)

Fig. 12. Intro Scene of Level 1 (a) The Allies army arrived, (b) The liberation of war prisoner, (c) The battle between Indonesia army vs the Allied army.

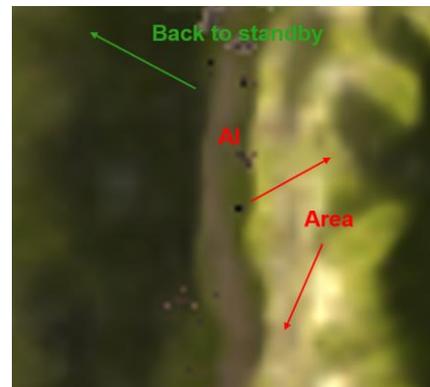


Fig. 16. AI character is in state "standby"



Fig. 17. The AI character encircling the path using A* algorithm

5) A* Testing

A* testing is performed by creating AI character walk to certain destination. Between the starting point (where the charter AI starts to walk) and the destination (where the character AI stops) is given obstruction. A* algorithm application is successful if AI character walks through the obstruction without stepping in. The result is shown in Figure 17. On the Figure 17, the AI character walks to destination by encircling a tree.

B. Performace Testing

The performance is optimized by using M2HCulling libraries. This script divides the area into smaller one and performs rendering only on area around the player. In the Figure 18, the Occlusion Culling testing shows that the rendering area only appear near the player.

Unity statistic result shows a significant increase on the performance before and after occlusion culling is applied. The results of statistics can be seen in Figure 19. From this figure, a considerable decrease of resource from the main thread (thread number), draw calls (the number of vertices in the rendering), used texture (the amount of texture used), VRAM usage (virtual RAM size), and the number of frames that can be processed per second (frame rate) increased from 15.5 fps to 25.6 fps .

C. Device Testing

Device testing is performed on two devices with different screen size. The CPU and RAM size is described in Table 1.



Fig. 18. Occlusion Culling testing



Fig. 19. a) Before occlusion culling, b) After occlusion culling

TABLE I. THE TESTING DEVICE SPECS

Spesifikasi	Sony Ericssons Live With Walkman (WT 19i)	Smartfren Andromax C
OS	Android 1CS 4.0	Android 1CS 4.0
CPU	1 Ghz	1,2 GHz Dual Core
RAM	512 MB	1 GB
GPU	Qualcomm Adreno 203	Qualcomm Adreno 202
Screen	320 x 480 pixel	800 x 480 pixel
Testing	-The user interface button close to each other - The button become bigger because of the small screen resolution (320 x 480).	- The user interface is good -The resolution of the device is the same as the resolution of the game (800 x 480).
Game Preview		

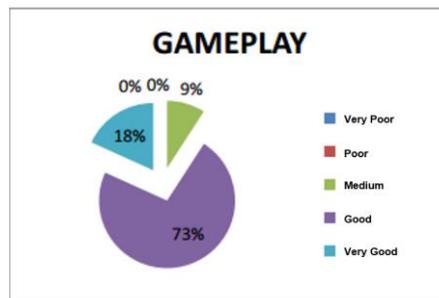


Fig. 20. Testing the game application questionnaires

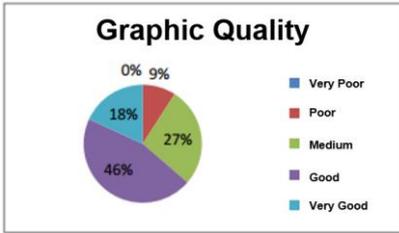


Fig. 21. Testing the graphic quality questionnaires

D. Testing Applications on the Respondents

The testing is conducted by filling out the questionnaires from every user who had tested this game application . Tests carried out on three things : the game application ,the graphics quality, and the control of the game.The result is shown in the user assessment graphs in Figure 20 , Figure 21 and Figure 22.

The questionnaires shows that 73% users who perform the game application testing are satisfied and around 18 % user are very satisfied.

The questionnaires shows that 48% user confirmed that the graphic quality is good, around 27 % user confirmed that the result is average, and around 18% confirmed that the result is very good.

The questionnaires shows that 73% users confirmed that the control is easy, around 27 % users confirmed that the control is average.



Fig. 22. Testing the game control questionnaires

TABLE II. TESTING THE EDUCATION CONTENT

Question no	Before Testing the Game		After Testing the Game	
	Correct	Wrong	Correct	Wrong
1	0	11	8	3
2	5	6	9	2
3	5	6	6	5
4	4	7	6	5
5	0	11	5	6

D. Education value testing

Before and after running the game, 11 users are given 5 questions relating to the battle of General Sudirman as shown in Table 2 . The number of questions which are answer as correct increasing after playing the game. Before playing the game, 14 questions are answered correct. On the other hand, after playing the game, the number of question answering correct is increased to 34 questions, for all eleven players .

IV. CONCLUSION AND SUGGESTION

A. Conclusion

Results of this research is a game with a 1st person shooter genre using A * and FSM algorithm. The application of the algorithm successfully applied AI characters into a more realistic one, who can move to chase and evade the enemy without stepping in the obstruction. The infantry owns seven state with more than one conditions to move into another state.

A questionnaire based on the game is distributed to 11 users. Around 73% of users proclaim that this game is good, around 43% of users proclaim that the quality of the graphics are satisfied with the game, and around 73% users proclaim that the game control is easy.

General Sudirman game can provide gamers with high educational value by increasing the number of correct answer from 14 to 34.

The application of Occlusion culling with the M2Hculling library can reduce the resource consumption from the main thread (thread count), draw calls (the number of vertices in the rendering), used texture (the number of texture amount used), VRAM usage (virtual RAM size). The four factors, finally increase the number of frames that can be processed per second (frame rate) from 15.5 fps to 25.6 fps.

B. Suggestions

Improving the FSM AI methods to make the game more. Adding a variety of characters and weapons to make the game more interesting .3. Adding more surprises at each level

REFERENCES

- [1] <http://internasional.kompas.com/read/2010/11/02/03211061/Afganistan.Perang.Terloma.dalam.Sejarah.AS> (Diakses 10 Juli 2012) (Diakses 28 Juni 2012)
- [2] <http://www.derelictstudios.net/blitz2/> (Diakses 28 Juni 2012)
- [3] <http://asia.gamespot.com/blitzkrieg-2/reviews/blitzkrieg-2-review-6141184/> (Diakses 28 Juni 2012)
- [4] <http://www.gameedukasi.com/2010/12/palawa-game-sejarah-palagan-ambarawa/> (Diakses 28 Juni 2012)
- [5] <http://www.gameedukasi.com/2010/10/p10ner-pertempuran-10-nopember/> (Diakses 28 Juni 2012)
- [6] <http://www.gameedukasi.com/2010/12/palawa-game-sejarah-palagan-ambarawa/> (Diakses 28 Juni 2012)
- [7] Yunita Miftachul Arif, Mochamad Haridi, Supeno Mardi, *Integrasi Hierarchy Finite State Machine dan Logika Fuzzy untuk Desain Strategi*

International Conference on Electrical Engineering, Informatics, and Its Education 2015

NPC Game, MATICS Volume 4 Nomor 3, Universitas Islam Negeri Maulana Malik Ibrahim.

- [8] Thepparit Sinthamrongruk, Krisada Mahakitpaisarn, and Wapee Manopiniwes, "A Performance Comparison between A* Pathfinding and Waypoint Navigator Algorithm on Android and iOS Operating System", IACSIT International Journal of Engineering and Technology, Vol.5, No.4, August 2013
- [9] Buckland Mat, *Programming Game AI by Example*, Texas: Worldware Publishing, Inc: 2005
- [10] J. Hu, W. G. Wan, and X. Q. Yu, "A path finding algorithm in real-time strategy game based on unity3D," in Proc. 2012 International Conference on Audio, Language and Image Processing (ICALIP), pp. 1159 – 1162, 2012.
- [11] P. E. Hart, N. J. Nilsson and B. Raphael, "A formal basis for the heuristic determination of minimum cost paths," SIGART Newsletter, vol. 37, pp. 28–29.
- [12] S. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach*, Prentice Hall, 1994.
- [13] M. DeLoura, *Game Programming Gems 1*, Charles River Media, 2000.
- [14] Kyaw, Aung Sithu, Clifford Peters, Thet Naing Swe. 2013. *Unity 4.x Game AI Programming*. Brimingham : Packt Publishing Limited
- [15] Chidmad, Tataq, dkk, *Serangan Oemoem 1 Maret 1949*, Yogyakarta: Media Presindo, 2005
- [16] Susilo, Taufiq adi, "Soedirman Biografi Singkat 1916-1950", Yogyakarta: AR-Ruzz Media, 2010
- [17] A.H Nasution, *Sekitar Perang Kemerdekaan Indonesia, Bandung*: PTAngkasa Bandung, 1973