

The Application of a Star (A*) Algorithm on the Android-Based Pacman Adaptation Educational Game as a Learning Media for SMK

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Abstract: Playing game constitutes an activity which stimulates children to achieve integrated development, in physical, intellectual, social, moral, and emotional terms. Referring to the definition, it can be concluded that game is a medium which can be used as a stimuli to child development. Numerous types and genres of games were created, one of which is labyrinth game or so-called Pac-man. This game is played by requiring the played to eat all points without running into the enemy. It is aimed that the implementation of the game assists the learning activity of vocational high school (SMK) students by the addition of learning materials within that the game becomes a learning medium. The modified version of the game requires AI (Artificial Intelligence) as well as A* (A-star) algorithm in the development process. The algorithm functions to determine the shortest track with minimum cost by summing the actual distant with the estimated distance, so the minimum cost is obtained. The Artificial Intelligence (AI) is applied to the enemy, so the player faces obstacles in order to achieve the objective of the game.

Keywords: A* algorithm, artificial intelligence, game, Pac-man, learning media.

player faces an enemy, then the game ends. The implementation of this game in the SMK student learning media is by adding an educational element. In this case is in the basic programming subject which matching the elements to create a program properly and correctly.

A*(A star) Algorithm is the algorithm inserted in this game. The application of this algorithm is used so that the enemy can reach out the player, hence the player will not able to finish the game. The use of A* Algorithm enables enemies to reach player with the shortest distance and minimum cost so that players find it very hard to complete this game.

This game will be created in the form of 3D with *Unity 3D* application so that it will produce an interesting visualization. The output of this game will be played on mobile game which is played by mobile devices. This option of output determination is based on its easy access, considering the targets of making this game are SMK students. The advantages of the output in the form of this mobile game are the easy access and flexible time as long as the users have mobile devices which are capable of running mobile games.

I. INTRODUCTION

Game is an entertainment media used by humans which constitutes a structured activity or used as a means of education. Nowadays, game is created with various purposes. Apart of as an entertainment media, these days game is used as an effective learning media for students. The entertaining characteristic of game, its interesting visual and fun activities when playing them make game as a beneficial media to support learning which later is called an educational game.

Pac-man game is one of the most popular arcade video games. In playing it, the player will be asked to eat the dots which are scattered and dubbed by the maze-shaped wall. In order to finish this game, a player is asked to eat the whole food by the rule of without facing the enemies. If the

II. THEORETICAL FRAMEWORK

a. A* (A star) Algorithm

A* algorithm is an improvement of the best first search method by modifying its heuristic function, A* algorithm will minimize total cost of the track. In the right condition, A* Algorithm will provide the best solution in the optimal time. (Kusumadewi, dalam Yamin dkk, 2015:4). In its implementation, this algorithm has the principle of traversing one at a time to get the shortest path. This algorithm works by counting each possible path from the starting point to the destination point then restoring the result, after that it calculates the distance back with a different route from the starting point to the destination point, and so on until there is no possible distance anymore.

Subsequently, from those many distances that have been calculated, the A* algorithm will opt the shortest path using the following formula.

$$f(n) = g(n) + h(n)$$

with :

$f(n)$ = evaluation function

$g(n)$ = cost incurred from the initial state to the state n

$h(n)$ = estimated cost for arriving at the destination starting from n

b. Educational Game

Game is a loanword which means *permainan* in Indonesian. Many games are identified as an activity to release fatigue which is intended as an entertainment or a means of having fun. According to Nilwan, (in Zaka, 2014:11) game is a computer game made with animation methods and techniques. In order to fathom the use of animation, it is important to understand the making of games both techniques and animation methods since they are interrelated. Meanwhile, in general educational game can be interpreted as a game that contains element of education. This is based on the statement of Echol which describes its meaningful educational game (in Kusumaningrum, 2016:17), that *education* means education which is related to education. Meanwhile according to Echols dan Shadily (in Kusumaningrum, 2018:17) game has the meaning of game. It is an act that creates pleasure at a time.

Furthermore, Ismail (in Kusumaningrum, 2016:17) said that educational game is a very enjoyable activity and can be assumed as an education means or tool. On the other hand, Wolf (in Kusumaningrum, 2016:17) stated that educational game is a game that aims to deliver learning material with scoring element, time, and feedback in it.

c. Game Pac-man

Pac-man is an arcade game that was once popular in the society. This game is a game with a simple visual and control consisting of one player and several enemies (controlled by computer).

In this game, the players are in charge of eating all the food arranged with wall barriers called the labyrinth. This labyrinth serves as a breaker for the path that the player will pass. The enemies serve as an obstacle object for the player which caused troubles for the players in eating all the food. These enemies will be controlled by computer (using AI), by utilizing A* (A Star) Algorithm which works in finding the shortest distance to reach the player, so that the player fails to complete the game.

d. Android

Android is a linux-based operating system that is open source and designed for touch screen cellular devices such as smartphone (Lee, in Kusumaningrum, 2016:18). Android was officially released to the market in 2007, along with the establishment of the Open Handset Alliance. According to Salbino (in Megawati, 2016: 23) states that Android display is based on direct manipulation, using touch input similar to actions in the real world, such as

swiping, tapping, pinching and reversing pinch to manipulate objects on the screen.

e. Unity 3D

One of the most used game engines today is Unity 3D. Unity 3D is a cross-platform based engines is that is used for game creation, building architecture and simulation.

The scripting features provided by Unity 3D are three programming languages: Java Script, C#, and Boo.

III. METHODS

a. Game Description

This game will be created and named Go Straight Game, this game was adapted from the Pac-man arcade game that was once popular. The implementation of this game is intended as a medium of learning for SMK students on basic programming subjects.

b. Object In Game

There are several essential objects that need to be known and interrelated. These objects are the core of the game, includes the control by the player. The following describes the essential objects contained in the game.

- Pac-man (Player)

A player here is the main character in the game who is in charge completing the game to the final level. The main character in this game is designed as an emoticon resembling a yellow ball. In order to play the game, the player needs to aim the direction buttons on the keyboard. The player in this game needs to answer questions that have been raised at the beginning before the game starts. The player is required to eat food which is the correct answer to be able to proceed to the next level before being caught by "ghosts".

- Ghost (Enemy)

The ghost in this game is an obstacle in the form of a moving object that is in charge to prevent players from eating food, the correct answer of the question, so that the player cannot continue to the next level. The ghosts will move from the starting point, to approach the player then catch it, using the shortest distance from the player's point at the moment.

- Food/Element

Food or elements in this game is an objective that must be obtained by the player so that they are able to answer the questions displayed at the beginning of the game. Food here is an answer choice indicator which means it will spread and contain different answers. When a player is able to pick food that contain the correct answer, the player can continue the game to the next level, and vice versa if the player chooses the wrong answer, the game will return to the starting mode, up to 3 opportunities are given.

c. Gameplay dan Rules

1. Game Flow

The game flow here is the procedure for playing the game so that the game can be completed. The following is the flow of the game presented in Table 3.1 below.

1	Game initial display, contains menus of the game
2	Start, the game starts
3	The game raises questions that must be solved by the player
4	Player controls to run the character
5	The player eats food that contains the correct answer of the question
6	Player proceed to the next level

2. Rules

In making the game design, a binding rule is needed so that there are certain limits to measure the game can be assumed to be successful or not. The following are the rules in the game presented in Table 3.2 below.

Eating food that contains the right answer	
Player Control	In order to get food that contains the correct answer, the user must move the player using the keyboard to the right, left, up and down.
Answer the question	At each level of the game, questions will arise related to basic programming subjects that must be answered by the user in a way of eating food containing the correct answer in order to proceed to the next level.
Game Limit	At each play, the user has 3 opportunities to play again when the user does not succeed in getting food containing the correct answer, or when in the process of reaching food, and the player is first caught by a ghost. When 3 opportunities have been washed-up at each level, the user must repeat the game starting from the beginning.
Scoring	In this game the scoring is not indicated by numbers, but with the ability of the user to control the player to be able to reach the next level.

d. User Target

In accordance with the purpose of the design of this game, namely as a tool or learning media for basic programming subjects, the intended targets are all SMK1 students who get basic programming subjects.

e. A* Algorithm Implementation

In the A* Algorithm, 2 queues are needed, specifically

- :
 - OPEN, which contains nodes that have been raised, already has a heuristic function but has not been tested.
 - CLOSED contains nodes that have been tested.

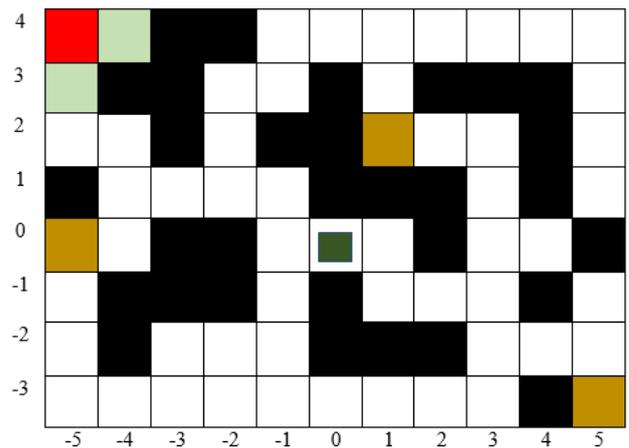
In this case the implementation of the A* algorithm will generate the node closest to the solution. Then, it will be saved to the list by the order of which closest to the best solution.

In order to determine the best node, this algorithm calculates the values of each node in the search tree using an evaluation formula mentioned above. In this game each ghost has a different pattern of movements, but each ghost has each plot or location of each destination that needs to be reached. In this case there will be a discussion of ghosts at the level one where ghosts appear only 1. This ghost1 has a chasing movement pattern, where the ghost will automatically move to chase the player.

In order to implement the chase mode, heurst values or estimated costs must be used from the starting point (n) to the Euclidean distance destination point that can be written mathematically as follows.

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

By using this formula, there will be a fastest route for the ghosts to chase the players. The Euclidean distance formula is used because it is assumed that ghost1 moves through the appropriate path which follows existing curves and it cannot penetrate the existing wall. To be able to do the calculations, then the shortest distance determination can be simulated as follows.



Goal coordinate (0, 0)

Start of coordinate (-5, 4)

$$\begin{aligned}
 H_n &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-5 - 0)^2 + (4 - 0)^2} \\
 &= \sqrt{25 + 16} \\
 &= \sqrt{41} \\
 &= 6,4
 \end{aligned}$$

G start = 0

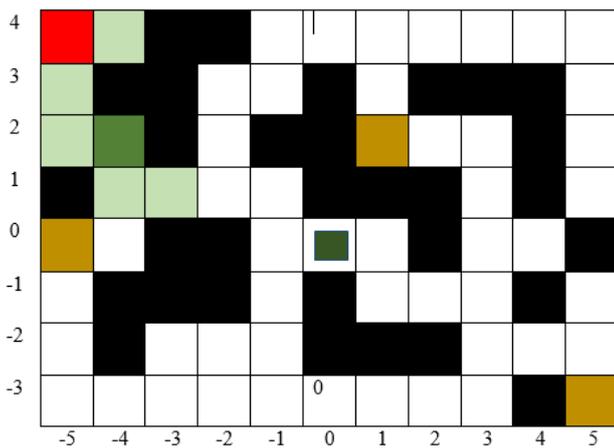
$$\begin{aligned}
 G_{(-4,4)} &= g_0 + \sqrt{(x_{awal} - x_{n-1})^2 + (y_{awal} - y_{n-1})^2} \\
 &= 0 + \sqrt{(-5 - (-4))^2 + (4 - 4)^2}
 \end{aligned}$$

$$\begin{aligned}
 &= 0 + \sqrt{1} \\
 &= 0 + 1 \\
 &= 1 \\
 F &= g(n) + h(n) \\
 &= 6,4 + 1 \\
 &= 7,4
 \end{aligned}$$

$$\begin{aligned}
 H_{(-5,3)} &= \sqrt{(-5 - 0)^2 + (3 - 0)^2} \\
 &= \sqrt{25 + 9} \\
 &= \sqrt{34} = 5,8
 \end{aligned}$$

$$\begin{aligned}
 G_{(-5,3)} &= g_0 + \sqrt{(0 - (-5))^2 + (0 - 3)^2} \\
 &= 0 + \sqrt{25 + 9} \\
 &= 0 + \sqrt{34} = 5,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 5,8 + 5,8 \\
 &= 11,6
 \end{aligned}$$



Goal coordinate (0,0)
Player coordinate (-5, 3)

$$\begin{aligned}
 H_{(-5,2)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-5 - 0)^2 + (2 - 0)^2} \\
 &= \sqrt{25 + 4} \\
 &= \sqrt{29} = 5,3
 \end{aligned}$$

$$\begin{aligned}
 G_{(-5,2)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 5,8 + \sqrt{(-5 - (-5))^2 + (3 - 2)^2} \\
 &= 5,8 + \sqrt{0 + 1} \\
 &= 5,8 + 1 \\
 &= 6,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 6,8 + 5,3 \\
 &= 12,1
 \end{aligned}$$

$$\begin{aligned}
 H_{(-4,2)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-4 - 0)^2 + (2 - 0)^2} \\
 &= \sqrt{16 + 4} \\
 &= \sqrt{20} \\
 &= 4,4
 \end{aligned}$$

$$\begin{aligned}
 G_{(-4,2)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 6,8 + \sqrt{(-5 - (-4))^2 + (2 - 2)^2} \\
 &= 6,8 + \sqrt{1 + 0} \\
 &= 6,8 + 1 \\
 &= 7,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 7,8 + 4,4 \\
 &= 12,2
 \end{aligned}$$

$$\begin{aligned}
 H_{(-4,1)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-4 - 0)^2 + (1 - 0)^2} \\
 &= \sqrt{16 + 1} \\
 &= \sqrt{17} \\
 &= 4,1
 \end{aligned}$$

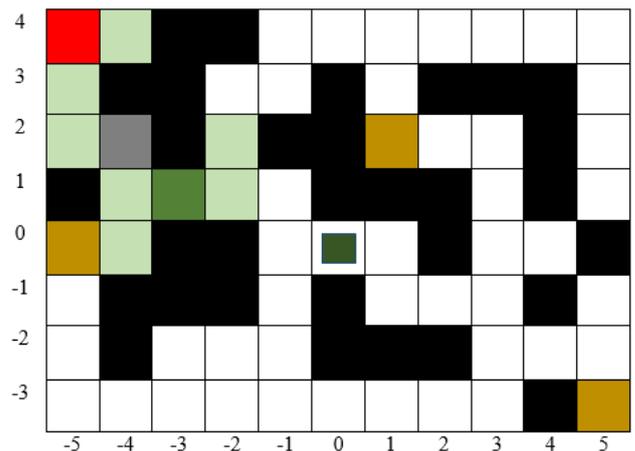
$$\begin{aligned}
 G_{(-4,1)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 7,8 + \sqrt{(-4 - (-4))^2 + (2 - 1)^2} \\
 &= 7,8 + \sqrt{0 + 1} \\
 &= 7,8 + 1 \\
 &= 8,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 8,8 + 4,1 \\
 &= 12,9
 \end{aligned}$$

$$\begin{aligned}
 H_{(-3,1)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-3 - 0)^2 + (1 - 0)^2} \\
 &= \sqrt{9 + 1} \\
 &= \sqrt{10} \\
 &= 3,1
 \end{aligned}$$

$$\begin{aligned}
 G_{(-3,1)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 8,8 + \sqrt{(-4 - (-3))^2 + (1 - 1)^2} \\
 &= 8,8 + \sqrt{-1 + 0} \\
 &= 8,8 + 1 \\
 &= 9,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 9,8 + 3,1 \\
 &= 12,9
 \end{aligned}$$



Goal coordinate (0,0)
Player Coordinate (-3,1)

$$\begin{aligned}
 H_{(-2,1)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-2 - 0)^2 + (1 - 0)^2} \\
 &= \sqrt{4 + 1} \\
 &= \sqrt{5} \\
 &= 2,2
 \end{aligned}$$

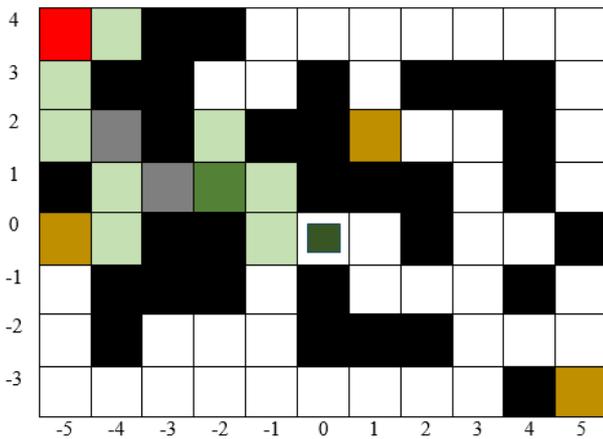
$$\begin{aligned}
 G_{(-2,1)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 9,8 + \sqrt{(-3 - (-2))^2 + (1 - 1)^2} \\
 &= 9,8 + \sqrt{-1 + 0} \\
 &= 9,8 + 1 \\
 &= 10,8
 \end{aligned}$$

$$\begin{aligned}
 &= 9,8 + 1 \\
 &= 10,8 \\
 F &= g(n) + h(n) \\
 &= 10,8 + 2,2 \\
 &= 13
 \end{aligned}$$

$$\begin{aligned}
 H_{(-2,2)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-2 - 0)^2 + (2 - 0)^2} \\
 &= \sqrt{4 + 4} \\
 &= \sqrt{8} \\
 &= 2,8
 \end{aligned}$$

$$\begin{aligned}
 G_{(-2,2)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 10,8 + \sqrt{(-2 - (-2))^2 + (1 - 2)^2} \\
 &= 10,8 + \sqrt{0 + (-1)} \\
 &= 10,8 + 1 \\
 &= 11,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 11,8 + 2,8 \\
 &= 14,6
 \end{aligned}$$



Goal coordinate (0,0)
Player coordinate (-2,1)

$$\begin{aligned}
 H_{(-1,1)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-1 - 0)^2 + (1 - 0)^2} \\
 &= \sqrt{1 + 1} \\
 &= \sqrt{2} \\
 &= 1,4
 \end{aligned}$$

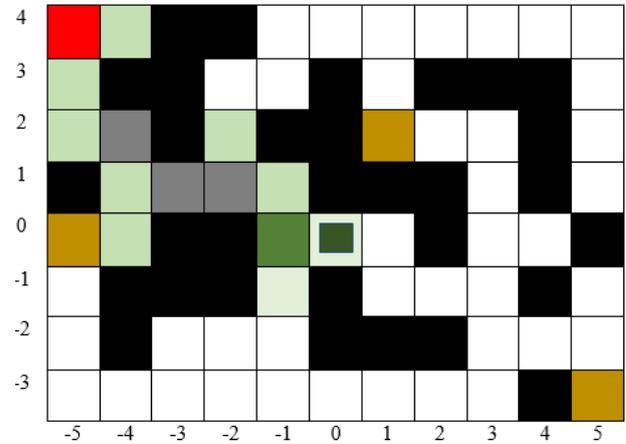
$$\begin{aligned}
 G_{(-1,1)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 11,8 + \sqrt{(-2 - (-1))^2 + (1 - 1)^2} \\
 &= 11,8 + \sqrt{-1 + 0} \\
 &= 11,8 + 1 \\
 &= 12,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 12,8 + 1,4 \\
 &= 14,2
 \end{aligned}$$

$$\begin{aligned}
 H_{(-1,0)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-1 - 0)^2 + (0 - 0)^2} \\
 &= \sqrt{1 + 0} \\
 &= \sqrt{1} \\
 &= 1
 \end{aligned}$$

$$\begin{aligned}
 G_{(-1,0)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 12,8 + \sqrt{(-1 - (-1))^2 + (1 - 0)^2} \\
 &= 12,8 + \sqrt{0 + 1} \\
 &= 12,8 + 1 \\
 &= 13,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 13,8 + 1 \\
 &= 14,8
 \end{aligned}$$



Goal coordinate (0,0)
Player coordinate (-1,0)

$$\begin{aligned}
 H_{(-1,-1)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-1 - 0)^2 + (-1 - 0)^2} \\
 &= \sqrt{-1 + (-1)} \\
 &= \sqrt{-2} \\
 &= 1,4
 \end{aligned}$$

$$\begin{aligned}
 G_{(-1,-1)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 13,8 + \sqrt{(-1 - (-1))^2 + (0 - (-1))^2} \\
 &= 13,8 + \sqrt{0 + 1} \\
 &= 13,8 + 1 \\
 &= 14,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 14,8 + 1,4 \\
 &= 16,2
 \end{aligned}$$

$$\begin{aligned}
 H_{(-1,1)} &= \sqrt{(n_x - goal_x)^2 + (n_y - goal_y)^2} \\
 &= \sqrt{(-1 - 0)^2 + (1 - 0)^2} \\
 &= \sqrt{1 + 1} \\
 &= \sqrt{2} \\
 &= 1,4
 \end{aligned}$$

$$\begin{aligned}
 G_{(-1,1)} &= g_0 + \sqrt{(x_{awal} - x_n)^2 + (y_{awal} - y_n)^2} \\
 &= 11,8 + \sqrt{(-2 - (-1))^2 + (1 - 1)^2} \\
 &= 11,8 + \sqrt{-1 + 0} \\
 &= 11,8 + 1 \\
 &= 12,8
 \end{aligned}$$

$$\begin{aligned}
 F &= g(n) + h(n) \\
 &= 12,8 + 1,4 \\
 &= 14,2
 \end{aligned}$$

IV. RESULT AND DISCUSSION

a. Hardware Implementation

To be able to run this game, certain specifications are described as follows.

- 1) OS hardware windows 7 SPI T, 8, 10 (32 bit/64 bit)
- 2) CPU support SSE 2 instruction set
- 3) Graphic GPU with DX 10 capabilities (model 4.0)

b. Software Implementation

The software used to run the game has a minimum spesification of Android OS version 4.4 or above.

c. User Interface

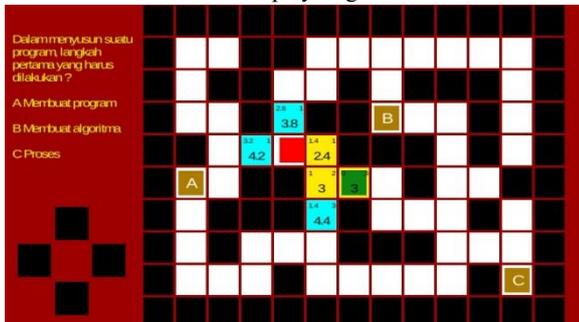
In this section, the game interface design has been built, starting from the initial appearance of the game, to displays when the game process is played.



MENU

- LEVEL 1
- LEVEL 2
- LEVEL 3

Picture 1 display of game's menu



Picture 2 display of first level

The image shows the path that the player and enemy should pass to be able to find the correct answer so that player can continue at the next level. Enemy is in charge of moving to reach the player. In reaching the player, enemy moves using the A* algorithm with the audience distance fomtula that has been described as a method chapter III.



Image 3 display of player that has been successed to finish first level



Image 4 display of player that has been loose to finish first level

In the picture shows the display when the player does not succeed in finding the correct answer or the player reached first by enemy, so the player should repeat the game from start by clicking the game's reset menu

d. Testing of A* Algorithm

In this aspect, testing the implementation of the A* Algorithm in the game is carried out and produces the result described in the following table

Lintasan	Uji coba ke-	Status	Waktu	Memory pencarian rute	CPU pencarian rute
			Rute (s)		
Enemy level 1	1	C	0,0437	459,7	46%
	2	C	0,04428	459,7	33,6%
	3	C	0,03162	447,5	60,70%
Enemy level 2	1	C	0,02733	467,4	61,6%
	2	C	0,02898	351,8	73,4%
	3	C	0,02024	287,8	54,0%
Enemy level 3	1	C	0,01931	271,8	52,1%
	2	C	0,02503	351,8	58%
	3	C	0,0091	112,5	39,5%

V. CONCLUSION AND SUGGESTION

1. Conclusion

At the conclusion based on the results in the game, it can be concluded:

- a. Pacman games can be applied using the A-Star algorithm. Because pacman is the closest search game to solving a problem
- b. Pacman game is a breakthrough game that is updated with the existence of learning questions, so that it sharpens intelligence.
- c. Pacman games are able to provide excitement and hone the speed and intelligence skills, so that pacman games can be used by anyone.

2. Suggestion

Pacman games can hone the ability to solve problems according to the thought of how the game should be played. In the Pacman game the prefix and end are needed. Among them are some of the shortcomings, namely the lack of design with limited workforce.

- a. Make changes to any problems found
- b. Perform routine checks on the game Pacman.

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