



WEBGL TOWER DEFENSE GAME WITH IMPLEMENTATION OF  
A\* INTELLIGENCE TECHNIQUE

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## ABSTRACT

This research focused on intelligent strategy game named Tower Defense which allow good interaction between players and the game. In this 10 levels of game, players are allowed to build and arrange towers in order to attract the enemy (fruits). This game was develop using JavaScript Object in WebGL platform which PNG was used as the source of images. A-Star intelligence technique been implemented to assist the enemy in finding the shortest path from the starting point to the end point of game. This intelligent strategy game may increase the attraction of players toward this game.

## ABSTRAK

Kajian ini memberi focus kepada pembangunan permainan computer berstrategy berasaskan kepintaran buatan. Permainan berkomputer yang diberi name 'Tower Defense' ini membolehkan pengguna berinteraksi dengan permainan berkomputer dengan lebih baik. Di dalam permainan berkomputer yang mengandungi 10 peringkat ini pengguna boleh membina dan menyusun menara penyerang untuk menyerang musuh yang terdiri daripada buah-buahan. Permainan berkomputer ini dibangunkan menggunakan 'JavaScript Object' yang terdapat di dalam WebGL platform, dan PNG format digunakan sebagai sumber bagi imej. Teknik jarak dekat digunakan di dalam permainan berkomputer ini digunakan di dalam permainan berkomputer ini membolehkan musuh mendapatkan laluan terpendek dari kawasan permulaan sehingga ke kawasan tamat. Pembangunan permainan berkomputer berasaskan kepintaran buatan ini dilihat mampu untuk menarik minat pengguna untuk terus bermain tanpa jemu.

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## CHAPTER 1

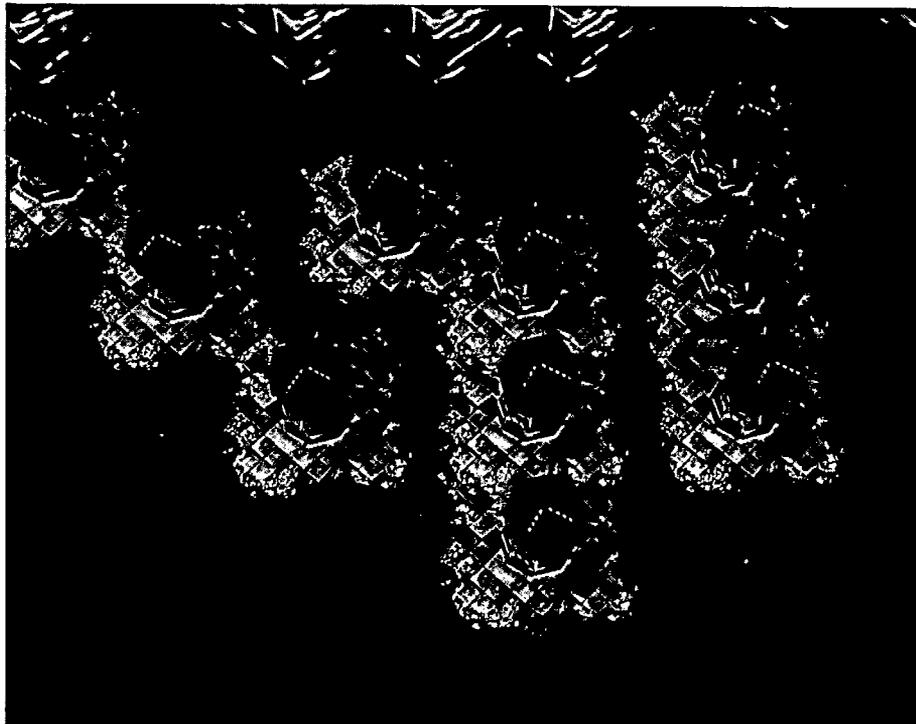
### INTRODUCTION

#### 1.1 Introduction/Overview

Tower Defense [1] or we called TD games are one of the strategy games that focusing on unit (tower) placement that used to get rid of the enemies or resource allocation. In simplest form to describe, TD consist of interaction between user and the game with the human player (users) can buy and organize defensive towers that fire upon the waves of the enemies. The human player can earn the money that need to build the defensive tower by killing each of the enemies. With the higher level of the wave of enemies, the money that earned for each enemy will be higher.

TD games nowadays have proved that it is a challenging, addictive and it will be a lot of fun to pass the time. The TD game can be used for completely research purpose. For the example of the TD game is the Element TD which using the Warcraft III engine [2]. This Element TD is one of the first implementation of TD games since 2004. With the screen shot (Figure 1) of this Element TD [2] game, we can prove that the TD game is a very challenging game with the build of defense tower intended to get rid of the enemies. There are enough description with the enemies, towers, gold earn for every enemies killed and the total of 20 lives. If the lives are finished before get rid of all the waves, means the game over and human player need to restart the game.

With this project, the TD game that is mainly used to develop is the webGL [3]. There are many games are developed in everywhere with the creativity of developer especially with the development of openGL [4]. In year 2006, the new technology of game programming named webGL has been developing until now. “Fruit TD” is a tower defense with 2D graphics rendering game with the theme of fruits. With the combination of the webGL, JavaScript, HTML5 and the Path Finding Artificial Intelligence (AI), it is guaranteed that this TD game will be an interesting and challenging game.



**Figure 1.1:** Example screen shot of the ElementTD game

## 1.2 Problem Statement

. Nowadays, lots of game included the tower defense game. Most of them are developed using OpenGL and it needed more processing time comparing with the WebGL. OpenGL, or we called Open Graphics Library [4] is a popular 3D graphics language that developed by Silicon Graphics and has been wider exploring by developers. Since the WebGL is still new technology, which starts develop by Mozilla Foundation in year 2006, there is more functionality that worth to explore. WebGL , or called Web Graphics Library [3] is a JavaScript API which used for rendering the interactive 3D graphics and also for 2D graphics with any web running cross-platforms [5] without any of the plug-ins needed.

Every game needs Artificial Intelligence. Without Artificial Intelligence it would be no fun at all because it has no interaction between user and game. For the example Angry Bird [6], it has no Artificial Intelligence but only physics [7] that used to achieve realistic behavior and special effects. To increase the interaction and fun of the game, what we actually need is Artificial Intelligence. Moreover, with this proposed project titled tower defense game, if this game is without Artificial Intelligence it will make the fun of game drop to zero.

There are lots file type can be used to store the game resource. For the example .PNG file [8] and .GIF [9] file and so on. But for this project, the tower defense game, those file type will be used to comparing and see the file size and the quality of images to determine the image resources using the most optimized file type. Besides that this project will also determine which image resources are nicer to implement in the tower defense game without affecting the game environment.

### 1.3 Goal & Objective

The goal of this project is to create an intelligence tower defense game by using the WebGL language which is a JavaScript API for rendering the interactive 3D graphics and also for 2D graphics with any compatible web browser without any plugins needed. To achieve this goal there are 3 objectives.

- To develop an interactive intelligence tower defense game with WebGL
- To implement the game using A-star Artificial Intelligence technique.
- To create graphical representative of games using JavaScript Object

### 1.4 Project Scope

This proposed project scope contains 4 categories. They are platform, module/level of game, component of game and data.

#### 1.4.1 Platform

Language for this “Fruit TD” is using the WebGL language to develop the interactive 2D graphics rendering. Furthermore, this game will combine with the JavaScript, HTML5, and A-star Path Finding Shortest Path Finding Technique.

#### 1.4.2 Module / Level Of Game

Due to this game is using 2D graphics rendering game, which means the map for this game will be only related to X and Y coordinates or we called grid. There will be a destination from the point A until point B which letting the enemies go through from start to the end of path. If the enemies successfully go through until the end of the path, live will be deducted. There are total of 20 lives. To avoid the enemies to deduct the lives, player must build the tower maze

strategically to block the enemies end their path smoothly. Good interactions are available between the user and the game.

Users are available to build of tower (Component refer to table 1) beside the path way with fixed coordinates that will be given. For example  $x = 2$   $y = 2$  coordinates or in other ways we called matrix 3 x 3 coordinates. Towers can be upgrade until level 5 (maximum). The greater the tower upgraded, the damage taken is higher.

In the other side of the coin, there are 10 types of fruits which are the enemies. Each wave will consist of 45 enemies. Each wave of enemies is each level of the game, which totally will be has 10 waves of enemies. The higher the level of wave, their life will be longer and tougher. There will be pop out of fruits (enemy components refer to table 1) after 5 seconds of every wave killed. 10 waves of fruits will appear.

### **1.4.3 Component Of The Game**

For attackers, which are the towers, there are 2 types of towers, they are Ice Tower and Arrow Tower.

Arrow Tower's function is to only hit one fruit at one time. The higher the level of the Arrow Tower, the damage will be higher and the speed of attack will be increase.

There are also 10 types of different fruits. There will be apple, orange, strawberry, star fruit, banana, grape, mango, watermelon, mangoes teen, and durian. The higher the level, the life for the fruit will be longer and tougher.

#### **1.4.4 Data**

Portable network graphics (PNG) file will be used to replace those fruits. Comparing with the 3D modeling object file, although it will be nicer, but PNG file is better because it may reduce the processing speed. 3D modeling object file will consume a lot of processing speed and might slower the computer processing time. Furthermore, PNG file format is better quality than GIF images. It is because PNG format can be full transparency comparing with GIF images which can only 1 bit transparency.

### **1.5 THESIS ORGANIZATION**

#### **Chapter 1**

Chapter 1 will discuss on introduction towards this project. In Chapter 1 contains Introduction, Problem Statement, Objective and Goal, Project Scope and Thesis Organization

#### **Chapter 2**

Chapter 2 is a Literature Review. In this chapter will review and analyzing the work, the comparison between several games that related to this project.

#### **Chapter 3**

Chapter 3 is Methodology. This method will explain about the procedure and step of this project with details.

## **Chapter 4**

Chapter 4 is Implementation. This chapter will explain about the designed project development on how the project is going to be developed and what technique will be used to implement this project.

## **Chapter 5**

Chapter 5 will discuss on the results and data analysis. In Chapter 5 contains Result analysis, Project limitation and suggestion and project enhancemen

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

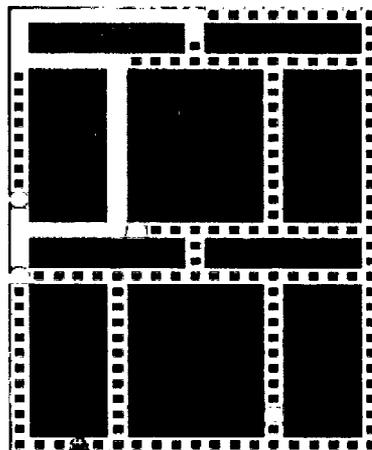
This chapter briefly discusses on literature review related with the proposed project. The first section will introduce about the comparison between two games. Second section will introduce about the PNG and GIF image format, the difference between them and the the last section will introduce about artificial Intelligence (AI) [12] and problems of Dijkstra path finding [13] that can be solved by A\* path finding algorithm [14] and finally technically describe the Artificial Intelligence that will use in the tower defense game.

#### 2.2 Intelligence Game

Intelligence game [15], also called Artificial Intelligence (AI) game means the game is developed by adding Artificial Intelligence Techniques inside to make the game more fun and more interesting, the most important is AI can be used to interact with the player. The role of Artificial Intelligence in game is very important because this AI can affect the success of failure of a game. AI was always left for the last development life cycle for the game. For AI development in game, one must very understand the flow of game, more time and energy spent on developing AI system. There are three intelligence games that will be described and compare whether which AI is the most suitable for this proposed project. The three games are Pac-Man, Robot Defense and Flash TD.

### 2.2.1 Pac-Man

Pac-Man [12] was developed by Midway Games West Incorporation in 1979. Pac-Man was the first game that developed and this game was remembered by many people and it still now playing and it will never get bored although it is just a simple game with fledgling AI. The flow of this Pac-Man game is the Pac-Man, the game avatar that controlled by player need to eat all the pellets that appeared in mazed-shaped stage by avoiding the opponents which are the ghosts. If the Pac-Man touched by the ghost, the game is over and need to restart. Pac-Man is a two dimensional (2D), multi-agent and grid motion with x and y axis. The game graphic is just simple yet remembered by many people until now. The figure 2 will show the snapshot of the Pac-Man game. The white round color object is the Pac-Man and others are the ghosts. Pac-Man needs to eat the pellets which are the black square object. The AI used for this Pac-Man game is neural network or they named it Neural Controlled Ghosts [16].The sigmoid function is employed at each neuron to manage the ghosts' motion. With these sensors, ghost will inspect the environment of their own point of view and decide what next action will be taken.



**Figure 2.1:** Snapshot of the Pac-Man game

### 2.2.2 Robot Defense

Robot Defense [17], is the game that quite similar to tower defense game that first implemented by Scott Wallace. Robot Defense platform consists of the real-time strategy game. The flow of this game is also similar like tower defense, insects act as the enemies will move around the tiled-based map from a fixed location to the one or more destination. There will be towers that built to defense and block the path of those insects to reach the destination. Robots role in this game is to collect the crystal in order to upgrade the towers such as vacuums and fans. Thus, this game is viewed by two teams. The first side is the insects that trying to reach the destination and the second side is the towers trying to prevent this from happening. Robot Defense is implemented in Java. In this game, there is a lot of Artificial Intelligence developed such as Dijkstra and A-star search techniques. We will focus on A-star techniques. The autonomous robot will appear at random locations on the map and search for the resource, which is the crystal that can used to upgrade the towers. Figure 3 will show the Robot Defense game using A-star algorithm.

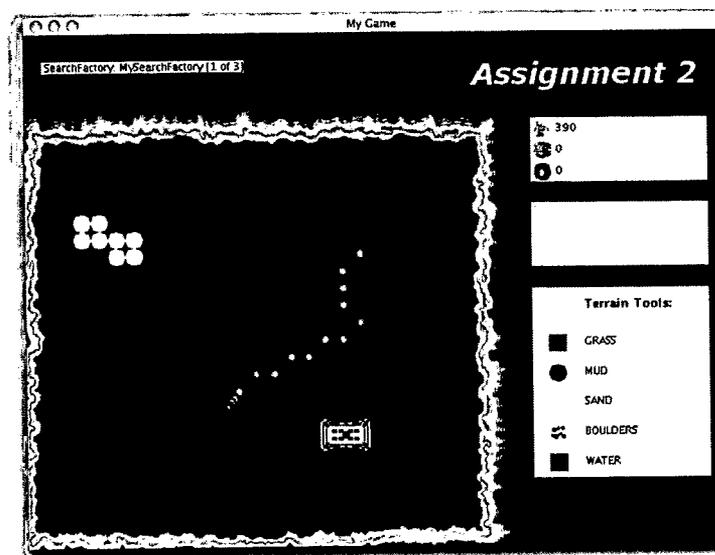


Figure 2.2: The snapshot of Robot Defense game

### 2.2.3 Flash Element TD

Flash Element TD [18] was implemented by David Scott in January 2007 and this game was inspired by the Element TD for Warcraft III which was the first implementations of Tower Defense games. Figure 4 will show the snapshot of Element TD games. This game consists of three different types of tower. The first one has low damage tower but it can be used to attack land and air enemies, the second tower is to attack the land enemies and the third tower is to attack the air enemies. As we earn more gold by killing the enemies, we can upgrade the towers into stronger towers. In Figure 4, the tower can only build beside the path which is the light brown color area, and the light brown color is the path that let the enemies pass by from start until destination. There are total of 31 waves of enemy. Every single enemy successfully cross from start until destination means the live of 20 will deduct by 1. Once the live has finished, the game is over and need to restart again. Flash Element TD is implemented by Flash web implementation. The Artificial Intelligence for this game is Computational Intelligence which is search-based paradigm. Evolutionary algorithm is used to search a content space for game content that maximizes certain criteria.

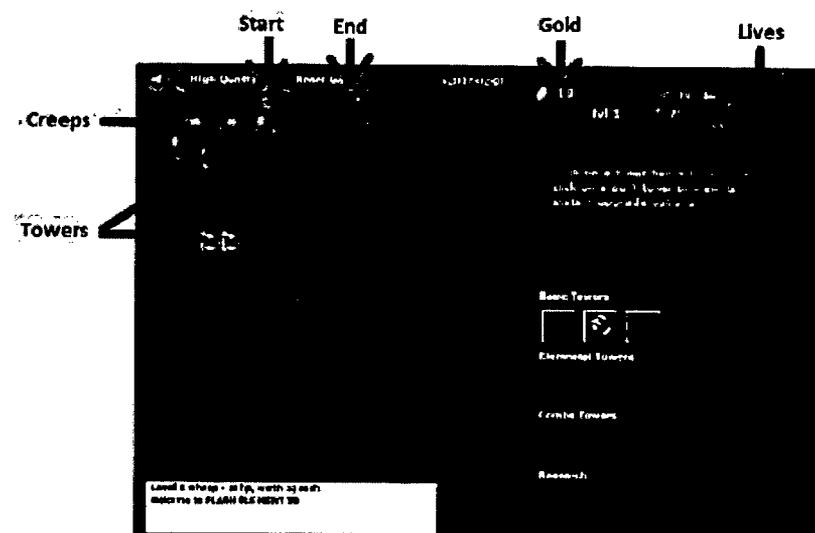


Figure 2.3: Snapshot for Flash Element TD game

#### **2.2.4 Comparison Between Pac-Man, Robot Defense And Flash Element TD**

The first difference between Pac-Man, Robot Defense and Flash Element TD is the implementation. For Pac-Man, there are more than one implementation due to the game is old and there are still many ways to improve it, the developer use different programming language such as JavaScript and C/C++ to develop it. For the Robot Defense, the implementation is Java and the Flash Element TD implementation using Flash web game. Lately flash web game is getting popular but there is a new technology is used to overcome this flash web game which is WebGL, the JavaScript and HTML5.

Artificial Intelligence techniques that used to implement in game is to increase the fun and interest of the players. For the Pac-Man, the AI used is neural networks, the Robot Defense is using A-star search techniques and for the last Flash Element TD is using Computational Intelligence which is Evolutionary algorithm to implement. In this comparison, the technique that is used lately in the technology and is the fastest is A-star shortest path algorithm, which will technically describe in the later section.

Graphics is important in the games. But we can see obviously the Pac-Man game graphics is too simple, for Robot Defense also very simple. While these two games are simple, the later game Flash Element TD is using graphics that is nicer than the 2. games. Nowadays a lot of game is developed in 3D (Three Dimensional) but some of the people think 3D is too complicated yet 2D (Two Dimensional) is less complicated than 3D and very easier to understand the game. This proposed project will implement using 2D with grid. For summarize of this comparison may refer to Table 2.1

**Table 2.1: Comparison between Pac-Man, Robot Defense and Flash Element TD**

<b>Game</b>	<b>Developer</b>	<b>Implementation</b>	<b>Artificial Intelligence</b>	<b>Graphics</b>
Pac-Man	Midway Games West Incorporation	JavaScript	Neural Network	2D( simple)
Robot Defense	Scott Wallace	Java	A-star Shortest Path techniques	2D( simple)
Flash Element TD	David Scott	Flash Web Game	Evolutionary algorithm	2D( better)

### 2.3 Tool Of Game Development

There are a lot of tools can be used to develop games. They are OpenGL, WebGL, Unity, and MOAI. Sections below will describe about the descriptions of these game development engine and their comparison.

#### 2.3.1 OpenGL

OpenGL often referred to Application Program Interface [19] which in simple form we called application programming interface or simple API. Their function is to collect the programming instructions that will enable computers to communicate directly with one another. OpenGL used to create or develop 2D or 3D computer graphics. OpenGL is a short form of the open Graphic Library. The function of OpenGL is to issue or execute command to the operating system. OpenGL often use the C/C++ language to develop.

### **2.3.1.1 C/C++ Languages**

C/C++ language is a generic library that usually relied on templates. Most of the codes are parameterized by values and types. C/C++ language can be used to implement the reusable data structure and algorithms. Lots of different algorithm can be used to develop the C/C++ coding. The code can be applied to families of types. Normally C/C++ language uses a compiler to compile. One of the compiler is codeblock.

### **2.3.2 webGL**

Web-based Graphical Library (WebGL) is an abstract programming interface (API) [20] which is designed to allow the use of 2D or 3D graphics directly in web browser without any requirement of software of plug-ins that need to separate from core browser. WebGL is not same like OpenGL because it is an API implementation using JavaScript and HTML5 language that nearly all web browsers understand the language such as nowadays Google Chrome and Mozilla Firefox.

#### **2.3.2.1 JavaScript**

JavaScript is an interpreted language with a C like syntax. The JavaScript was released by Netscape and Sun Microsystems in 1995. JavaScript is a programming language. Besides that it also can implemented in object-based programming. Nowadays, it is widely used and supported especially in web browsers and mobile phone. It is accessible and easily understanding by the beginners. In JavaScript programming language, we can show, hide, change, resize images, and create image rollovers. Furthermore, we also can interact with the user by do some processing of forms and can validate user input when the user submits the form.

### **2.3.2.2 HTML5**

Previously, there was a platform called Hypertext Transfer Protocol (HTTP) [21] with lots of function that we can implement on the web browsers. It is a programming language that can be used to create table, adjust the font and so on. But recently, there is a new technology called HTML 5. With this new and latest programming language, it can be used to import audio, video, even canvas that used to draw the area. The drawing area controlled by Javascript. Generally, HTML5 is the best combination with the JavaScript.

### **2.3.3 Flash**

Flash [22], included ActionScript is a game software application that normally used for creating animation, and eye catching cross platform application. Due to it's ability, it can be used to create multimedia creation by adding audio, video, and graphics with interactive content in the development of online game. Besides that, Flash also can be used to create e-learning tools, and database driven web sites. Flash are nowadays intend to build the Flash Professional CS6.

### **2.3.4 Comparison Between WebGL, OpenGL, and Flash**

One of the advantage of the WebGL over OpenGL is WebGL implementation programming language doesn't need any plug in or any installed software to run, it just need a simple notepad that already have in Windows to implement. Besides that, to run the WebGL or to test it, it only needs to easily run through web browsers like Google Chrome and Mozilla Firefox. However, to implement the computer graphic programming language OpenGL, it need an Utility Toolkit named GLUT [23]. GLUT is a windows independent development toolkit for writing OpenGL programming language. Without GLUT, OpenGL programming language cannot even be run through the software

implementation called CodeBlock. For Flash, it needed plug-in before implement. The plug-in is Adobe ActionScript Code Coverage Plugin [24]

Image loading [25] also one of the advantage of WebGL over OpenGL. As we know there are few image loading facilities have been developed by OpenGL, but there are no current standard exists. But for WebGL application, it can simply use the default web browser or any web browser to run the image loading facilities directly. Image loading for Flash can be load by library [26] itself.

Besides that, WebGL is possible to create and manipulate the canvas element in Hypertext Markup Language specification version 5(HTML5) [27]. HTML5 is the major revision of HTML, the new technology in World Wide Web which used to overcome the Adobe Flash. The canvas elements that used to draw the graphics is come from HTML5. The canvas created through the scripting JavaScript Language. Furthermore, HTML5 can also be used to import video, audio, or any function that Adobe Flash can do, HTML5 can also do without any problem. Flash can implement canvas by only using its preset that is AS3 Flex [28]. For summarize of this comparison may refer to table 2.2.

**Table 2.2: Comparison of OpenGL and WebGL**

	Plug-ins	Image Loading	Canvas
OpenGL	GLUT is needed	Not stable	Need extension
WebGL	No Plug-ins needed	Can run by web browsers	Can create easily

Flash	Adobe ActionScript Code Coverage Plugin is needed	By using its own library	AS3 Flex is needed
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There are several advantages of webGL over openGL, so this proposed project tower defense game will use webGL platform to implement it.

## 2.4 Shortest Path Artificial Intelligence Techniques In Game

A game without Artificial Intelligence (AI) is like a game without fun. Nowadays lots of game are now combining with AI which will make the game more interesting and more fun. Mostly Tower Defense games are using path finding AI or another name is shortest paths.

There are many type of shortest path techniques for the example Breadth-First Search, Bidirectional Breadth-First Search, Depth-First Search, Iterative Deepening Depth-First Search, Natural Paths, Bezier Curve, Finite State Machines and Decision Trees, A\* and Dijkstra [15].

In this section we are going to focus on A-star shortest path finding, Dijkstra shortest path finding, and Breadth First Search techniques. The type of AI that are going to develop in this tower defense game is A\* Path Finding Artificial Intelligence [29].

### 2.4.1 A-Star Shortest Path Finding

A\*, pronounce as A star is an algorithm that used for general problem solving. Basically A\* Path Finding is some kind of searching area method. It is used for path finding,