Application of Graph and Logic in Video Game Artificial Intelligence

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***Abstract*— Video Game Artificial Intelligence has been around since the beginning of the development of single-player video games. Artificial Intelligence, in the context of video games, are to simulate human-like behavior in game as to increase gameplay experience. This paper will provide an overview to the flow of thought in Video Game Artificial Intelligence, mainly explained by the flow of logic and graph as finite automata in the program. Finally, a number of examples will be included to give further understanding of logic and graph usage in the construction of Artificial Intelligence.**

***Keywords*— video games, artificial intelligence, game artificial intelligence, graph, logic, finite automata**

I. INTRODUCTION

Video games are games played on electronic devices known as platforms. The development of video games is tightly linked to the development of Artificial Intelligence to give players a sense of variety in game playing. Example of Artificial Intelligence in game is NPC (Non-Player Character), which may consist of townsfolk/villagers, allies, enemies/monsters, and much more.

Game Artificial Intelligence differs for each genre of game. For example, an FPS (First-Person Shooter) game has the Artificial Intelligence know how to hide, evade, and shoot, while an RPG (Role-Playing Game) may have the Artificial Intelligence exploit the weakness of the player's character.

Video Game Artificial Intelligence development started together with the development of the first single player video game, one of which is Pong. Pong is a two dimensional table tennis game designed for one or two players manufactured by Atari. The Artificial Intelligence of Pong predicts where the ball will arrive at with calculations and moves the paddle to the designated area. This, however, is complemented with the computer skipping its adjustment at an interval of eight frames to simulate human error. [3]

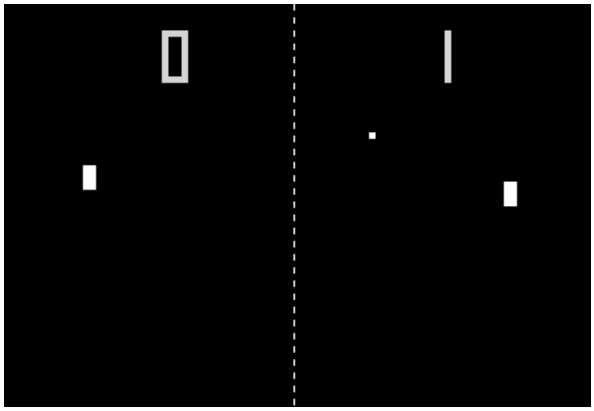

Fig. 1.1 Pong – Interface

We can see from the example above that Video Game Artificial Intelligence is a form of program which simulates human behavior in NPC to an extend that the program is almost invincible yet are still able to perform an error to allow players to achieve victory. This form of Artificial Intelligence is to give players different kinds of excitements to experience and obstacles to conquer.

II. RELATED THEORY

A. Graph

Graphs are one of the primary objects of study in discrete mathematics. A graph is a mathematical structure that models a relation between two parallel objects that are adjacent to each other. Graph are often used to represent various fields of study.

Definition 2.1

A graph G = (V, E) consists of V, a nonempty set of vertices (or nodes) and E, a set of edges. Each edge has either one or two vertices associated with it, called its endpoints. An edge is said to connect its endpoints. [4]

An example of the usage graph to model a road network in Central Java Province.

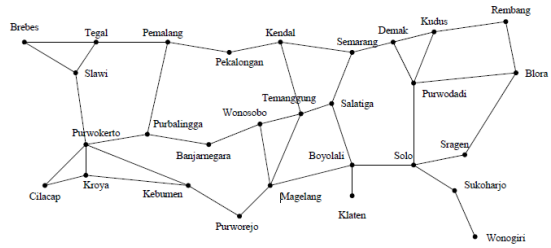

Fig. 2.1 Central Java Province Road Network

A graph can be divided into a few categories based on its point of view.

1. Based upon the existence of loops or dual edge in a graph, then a graph can be categorized into Simple Graph, which contains none of the above and Multigraph, which contains either one or both of the mentioned.

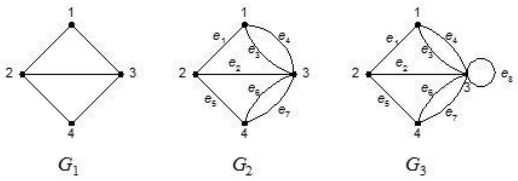

Fig. 2.2 G_1 Simple Graph, G_2 & G_3 Multigraph

2. Based on the finiteness of the graph, a graph can be categorized as a Limited Graph or Unlimited Graph.
3. Based on the direction of the edges, a graph can be categorized into Undirected Graph, which edge's direction is ignored, and Directed Graph, which edges are directed from one vertices to another.

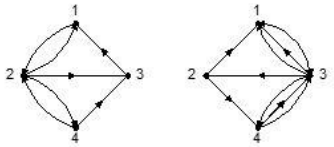

Fig. 2.3 Directed Graph

A graph is called a Weighted Graph if a number or a certain variable exists on each edge of the graph. The given variable or number represents a value from a vertex to another vertex.

B. Logic

Logic is a field of study in mathematics that explores the connections of one sentence, known as proposition, with another or more sentences using logical connectives, such as ∧ (conjunction), ∨ (disjunction), → (implication), ↔ (biimplication), and ¬ (negation), which will then be called premises. A set of premises can be used to deduct a conclusion using rules of inference, resolution, provable identities and much more.

Table 2.1 Types of Graph

Type	Edges	Multiple Edges	Loops
Simple Graph	Undirected	No	No
Multigraph	Undirected	Yes	No
Pseudograph	Undirected	Yes	Yes
Simple Directed Graph	Directed	No	Yes
Directed Multigraph	Directed	Yes	Yes

First-order logic is a subfield of logic, which studies the sentential formula with quantifiers to each non-logical objects. First-order logic differs from propositional logic in that it uses quantifiers whereas the latter does not.

C. Between Logic and Graph

The combination between logical reasoning and graph, if used correctly, can produce a variety of "logically weighted graph". This graph is more widely known as finite automata. Finite automata are models used for many kinds of hardware and software. Finite automata are directed graphs that are weighted with a certain kind of logic to "move" from one vertex to another. These vertices are called states, with the weights called inputs, and the edges point from one state to another.

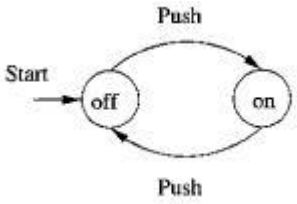

Fig. 2.4 On/Off Button Finite Automata

Finite Automata are divided into two based on its deterministic property. Deterministic finite automata (DFA) are automata that will only transition to one other state from its current state for each input, while non-deterministic finite automata (NFA) are automata that may be in several state at once.

III. Artificial Intelligence in Video Game

A. Artificial Intelligence

Artificial Intelligence, abbreviated as AI, is a field of study in science and engineering of non-human intelligence, usually in machines or programs. AI research started first after WWII, where a number of scientist tried to build intelligent machine. However, scientists soon found out that researching AI is best done over programming computers. Recent studies of AI exploit the accuracy and speed of processing of computers to simulate almost any kind of machine.

B. *Birth of Game AI*

Before the appearance of game AI, video games are made to be played by two people, which gameplay was more about competitive spirit and skills. The first appearance of video game AI started during the first single-player video game, e.g. Pursuit by Atari, Qwak by Atari which uses basic AI. At this time, most games are played on old-fashioned mainframe computers, which are unable to implement random elements in it. Game like Star Trek, which uses a scripted text based gameplay and enemy movements are fixed on certain patterns. This changed together with the introduction of microprocessors, allowing the computation of random elements.

C. *Early Games AI*

In terms of video game, AI is a system, which controls NPCs to simulate human-like behavior, used to give players a sense of interacting with intelligent entity. Game AIs vary differently for most video games and each game has a different complexity of AI appointed in them.

As stated above, Pong, a two dimensional table tennis game, has the AI calculate the position of the ball and moves the paddle, and skips its adjustments every eight frames. The simplest way to understand this will be by using Finite Automata.

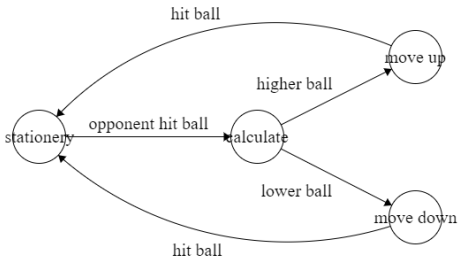

Fig. 3.1 Pong AI Logic

Another example of simple game AI is Pac-Man. Pac-Man is a simple maze game where player controls Pac-Man through a maze to eat pellets. Four enemies, colored red, blue, pinky, yellow, roam around the maze to catch Pac-Man. Once Pac-Man touches an enemy, players lose a life. The enemies, known as ghosts, are AI that moves according to a fixed algorithm.

Fig. 3.2 Pac-Man Ghosts AI

Scripted AI became a staple technique in video game AI design. Scripted AI is an AI program which had the units move following a scripted pattern, e.g. move back and forth or chase player if nearby. One of the first game to implement scripted AI is Super Mario Bros.

D. *Mid Game AI*

Game AI has developed further into becoming more complex. For example, the game The Sims, a life simulation game where players control semi-autonomous people. The AI moves the characters, while not being controlled by players, so that they will execute their most urgent needs, if not their hobbies. The characters in The Sims are able to interact with objects in environment with unique logic.

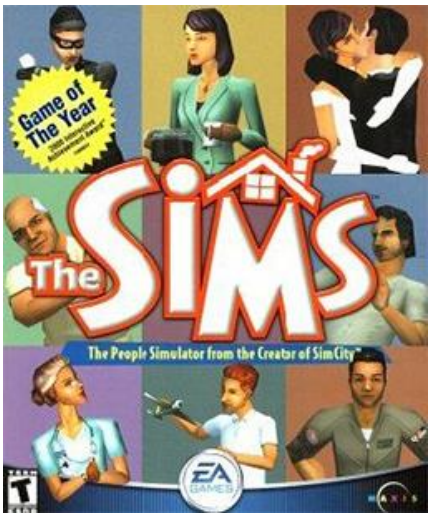

Fig. 3.3 The Sims Cover

After the development of simulation games, combat oriented games are becoming more popular. The evolution of AI to adapt to certain situations where they can use special attacks or combo moves to defeat player are also a kind of obstacles or players to experience. Most combat games come in modes, where player may choose easy, normal, or hard mode. These modes give different AI for each mode chosen, being more difficult respectively.

E. *Today's Game AI*

Today, game AI has the ability to adapt dynamically. Halo, an FPS game, has its enemies react dynamically towards players, environment, and even allies. They can work together against players and would react differently in different situations. Open World RPG are also becoming more advanced. The NPCs in open world RPG can react dynamically with players and each other.

Fig. 3.4 Skyrim – Open World RPG

IV. Analysis and Discussion

A. *Analysis*

Finite state machine is commonly used for video games AI. Each state in the machine corresponds with a character behavior according to various events. In a simple automata, the characters may move exactly the same due to the fact that each state has the same input and output. For example, Pac-Man's ghost will have a common thought process:

1. Wander the Maze
2. Chase Pac-Man
3. Flee Pac-Man
4. Return to Base

These behaviors can be made into a four-state DFA, with the transition declared as situations happening in game, for instance, Pac-Man eats power pellets, Pac-Man eats the ghosts, etc.

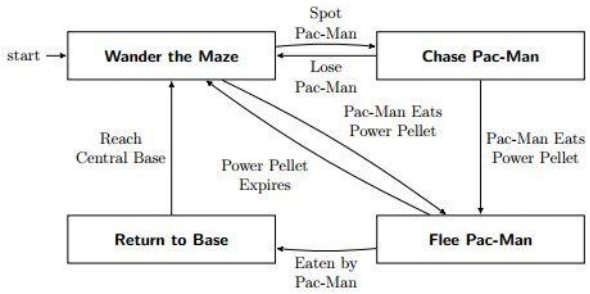

Fig. 4.1 Pac-Man ghost 4 state behavior

From the picture above, ne can clearly see that graphs are used in the making of finite automata and logic is used for the transition from one state to another. For example, while wandering around the maze, if spot Pac-Man then chase Pac-Man, else, if Pac-Man eats power pellet then flee from Pac-Man. Most logic in game AI uses this if-then-else structure to express their flow of logic. Using finite automata allows developers to easily picture the states that are needed for the characters to move and the conditions for them to move.

One for using finite automata are finite automata may be deterministic or non-deterministic, thus allowing developers to choose how they wanted their AI to react based on different inputs. Choosing deterministic means that the AI will move according to the input in each state, e.g. if they see you, they attack, if not, they patrol. While Non-deterministic allows AIs to choose between a few choices of reactions, e.g. they may attack or run away, attack with a gun or a grenade, etc. Using non-deterministic will give developers more freedom in terms of input choices.

Another example for the usage of finite automata for building a fighting game AI. In fighting game, enemies will attack, evade, and counterattack according to the player's action. The movements of the enemies are not randomly generated as to give more second player feel.

B. *Discussion*

Although finite automata may seem to be easy to understand, arrange, and implement, finite automata are not largely used today. A few problems that occur when using finite automata:

1. Finite automata are unorthodox.
   Although finite automata seem designer friendly, in truth, they are difficult to implement because of each state in finite automata need to be wired to explicitly with transition to another state, thus making it difficult to change or update.
2. Finite automata are low-level.
   Editing finite automata is very low-level and quite mechanical. Reasons are editing finite automata can only be done by editing its transition. Finite automata cannot capture the higher-level patterns like sequence or conditional.
3. Logic in finite automata is limited.
   Finite automata may be used for choosing a logical path; however, they are computationally limited. Finite automata cannot be used for counting or recognizing non-explicitly-stated transition and state.
4. Finite automata requires custom extensions.
   Because finite automata are limited, developers use external functions to implement certain features. However, these implementations are not always easy to understand and documented, thus not recommended.
5. Finite automata are hard to standardize.
   Due to its diversity, finite automata differs from each developers. Unlike algorithms, which are implemented commonly, finite automata needs to be adjusted for every different cases, thus making it narrowly applicable.
6. Finite automata are not deliberative.
   Creating goal-directed behavior in finite automata requires a lot of time. Finite automata operate reactively and not deliberately, thus making it difficult to reach a desired goal.
7. Finite automata have concurrency nightmares.
   Finite automata have difficulty dealing with external resource. When running multiple finite automata in parallel, the chances of them being compatible are slim as finite automata have much trouble storing information from other automaton.
8. Finite automata scale poorly and are labor intensive.
   They take a lot of time to work with and cannot be edited modularly. From the mentioned above,

developers will have difficulties adjusting each and every finite automata to work, and will ultimately be a source of bugs and errors.

9. Better alternatives.
   As time progresses, finite automata are slowly losing its shine. Better alternatives than finite automata, like behavior trees, are being implemented instead of them.

Beside finite automata not being a good choice for developing artificial intelligence, some argues that video game AI are overstating, as game AI is not intelligence, but rather, implementation of simple thoughts human made to look like intelligence. Another theory is that over-advanced AI in video games will cause the game to be less entertaining. Therefore, video games are not the best area for advancing AI.

V. Conclusion

Graph and Logic is a fundamental knowledge in developing game AI. Graph can illustrate the complex flow of human thoughts and its relation to each other, while logic is used to depict the reasoning behind the minds of AI. The combination of graph and logic resulted in finite automata. Although finite automata have helped in advancing game AI development, its usage are declining due to its complexity and impracticality.

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Pernyataan

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