

The Application of Binary Tree to Determine the Value of 5-Star Characters in Genshin Impact for Early Game Players

Juan Christopher Santoso - 13521116
Program Studi Teknik Informatika
Sekolah Teknik Elektro dan Informatika
Institut Teknologi Bandung, Jl. Ganesha 10 Bandung 40132, Indonesia
13521116@std.stei.itb.ac.id

Abstract— A tree is a connected, acyclic, and undirected graph in which two vertices are connected by exactly one path [1]. A binary tree, on the other hand, is defined as a tree where each node has at most 2 children, typically those are named left and right child [2]. The binary tree itself can be used to determine accumulated value from the root down to the leaf of the tree. Therefore, this method can be used to evaluate the value of a 5-star character in *Genshin Impact* game. It is expected that this implementation can be a helping hand for a new player to decide which 5-star character someone should get.

Keywords— tree, binary tree, value, Genshin Impact

I. INTRODUCTION

Genshin Impact is an online, action RPG, and open-world video game made by a game developer company, named HoYoVerse. The game itself was released on 28th September 2020 for Windows, PlayStation4, iOS, and Android, while for PS5, it was released a year later.

Inside the game, a player will be playing as one of the Traveler twins, called Aether and Lumine, in exploring a region called Teyvat. As the story goes by, the player can travel across the map offered by HoYoVerse to do whatever things the player like. In addition, players can also join other players' worlds or invite other players to their worlds to explore the map together.



Image 1.1 Screenshot of Genshin Impact's In-game

(Source: Author's Archive)

While exploring the map, players are able to bring a team, consist up to 4 characters. Players can use every playable character that they have in order to build the desired team. However, in order to make various combinations of dream teams, players need to have various characters. While on the other hand, players need to face the reality that having every character in the game is almost impossible, especially for those who just started the game. Thus, players tend to think twice about whether a character is considered 'worth it' to be wished for.

II. THEORETICAL BASIS

A. Graph

A graph can be defined as a diagram to explain the connections of discrete objects [3]. A graph is formally denoted as:

$$G = (V, E), \text{ where}$$

V is a non-empty set of vertices $\{V_1, V_2, \dots, V_n\}$, and

E is a set of edges that connect a pair of vertices $\{e_1, e_2, \dots, e_n\}$.

Based on whether a graph has a loop or multi edges, graph can be divided into three types, which are:

- Simple Graph, that does not contain any loops or multi-edges,
- Multi-graph, which contains multi-edges, and
- Pseudo-graph, which contains loops.

Since multi-graph and pseudo-graph contain either multi-edges or loops, those types are considered non-simple graphs [4].

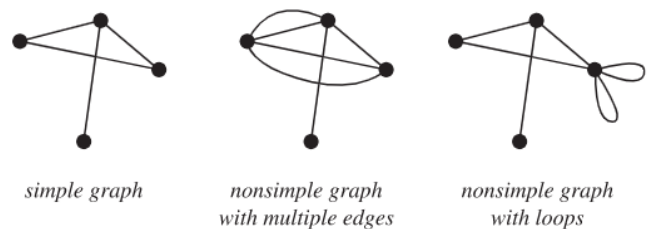


Image 2.1 Several Types of Simple and Non-simple Graph

(Source: <https://mathworld.wolfram.com/SimpleGraph.html>)

Based on the edge's orientation of direction, graph can also be categorized into two types, which are:

- Undirected graph, in which edges do not show any direction, and
- Directed graph, in which edges show the direction from one vertex to another one.

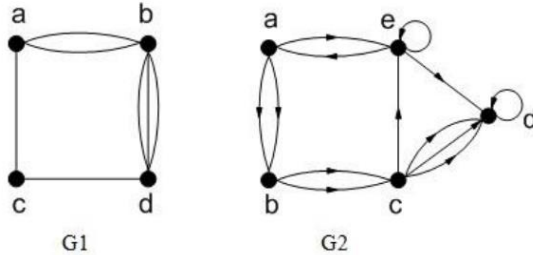


Image 2.2 From Left to Right, Undirected and Directed Graph

(Source:

<https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2020-2021/Graf-2020-Bagian1.pdf>)

In order to discuss any further about graph, these are the terms used to explain graph and its parts:

- Adjacent

Two vertices can be defined as adjacent one to another if both vertices are directly connected by an edge.

- Incidency

Incidency is a term to describe the relation between an edge and the two connected vertices. If vertex V_1 and V_2 are connected by an edge E_1 , then E_1 is incident to V_1 , the same way as E_1 is incident to V_2 .

- Degree

Degrees can be explained as the number of edges incident to a vertex. If the vertex has a loop edge, then it will be counted as two degrees.

- Path

A path can be described as a set of edges that connect vertex V_1 to vertex V_2 . The length of a path, usually denoted as n , is the number of edges included in the set.

- Circuit

A circuit is a path where the starting vertex is the same vertex as the final vertex.

- Connected

Two vertices, vertex V_1 and V_2 is connected if there exist a path that connect V_1 to V_2 . A graph is categorized as a connected graph if every pair of vertices V_1 and V_2 in a set of V has a path from V_1 to V_2 . Else, it is defined as a disconnected graph.

- Weighted Graph

A weighted graph is a graph in which every edge of the graph is given a weight (or a value).

B. Tree

A tree is a connected and undirected graph that contains no circuit. If an object in graph is called vertex, then in tree, the very same object is called node. As a type of tree, there is called a rooted tree where one node of the tree will be chosen as a root of the tree [5]. In a rooted tree, there are terms used to explain further, which are:

- Parent and child

If there is a vertex that is connected to one or several vertices below, then that specific vertex is called a parent. On the other hand, the connected vertices below are called children. However, if there is only a vertex, it is called a child.

- Leaf and internal nodes

A leaf is a node that has no child node. On the other hand, every node that has a child is called an internal node, including the root itself.

- Level

Level in a tree is the number of parent nodes to a specific node of the tree. The level of the root node is 0 since the node does not have any parents. The level of children of the root is 1 since they have a parent that is the root.

- N-arry tree

N-arry tree is a term used to describe a tree that every node of the tree has N maximum number of children. If N equals 2, then it is called a binary tree.

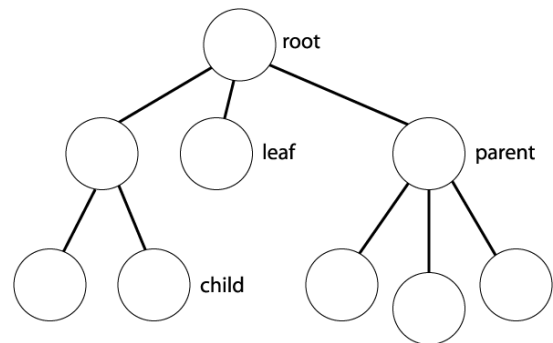


Image 2.3 The Details of 3-ary Tree Parts

(Source: <https://stackoverflow.com/questions/19330731/tree-implementation-in-java-root-parents-and-children>)

C. Binary Tree

A binary tree is a tree in that every node of the tree has a maximum number of children of 2. Those children are named the left child and the right child. There is a term called full binary tree, also called proper binary tree, which is a special type of binary tree in which every internal node has either two or no children [6]. In addition, there is also a special type of binary tree, called complete binary tree, which is defined as a binary tree in which every level, except possibly the last, is completely filled while all nodes are as far left as possible.

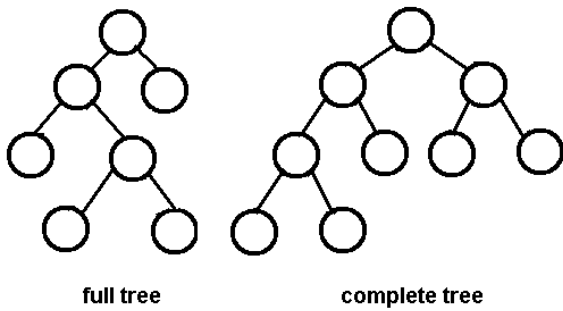


Image 3.4 Differences Between Full and Complete Binary Tree

(Source: <https://stackoverflow.com/questions/19330731/tree-implementation-in-java-root-parents-and-children>)

D. Genshin Impact

As it has been mentioned before, Genshin Impact is a game where the players can explore the open-world map using the desired team that the players have built. However, to decide which character is the best to be included in their team, players need to understand several terms used in Genshin Impact, such as Adventure Rank, Characters, Roles, Team Compositions, and Ascension Materials. Below is displayed the definition and explanation of those terms.

1. Adventure Ranks








Adventure Ranks (AR) can be defined as the level of an account. When a player just made a new account, the game will start with AR 1. As players making progress in the story, players would get Adventure Rank Exp to get into higher AR, up to AR 60. Players can be categorized as three categories based on their AR, low, mid, and high. Although there is no specific range to divide those three categories, Genshin Impact community tends to specify AR 1 – 30 as low AR, AR 31 – 50 as mid AR, and above AR 50 as high AR [7]. Early-game players can be categorized as those who are still in low AR.












2. Characters







Characters in Genshin Impact are basically divided into two categories, 5-star and 4-star characters. In order to get a new character, a player needs to do a wish mechanism by affording it using Primogems (one of the currencies in Genshin Impact).




The focus of this paper will be set on the 5-star characters. Therefore, details regarding 4-star characters will not be discussed any further. So far, excluding the Traveler, there are 30 playable 5-star characters in Genshin Impact [8]. Below is displayed the details of 5-star character, including the details that might be important for early game players to know.

Table 2.1. List of 5-Star Characters and the Details

Characters (Element/ Weapon)	Details
 Albedo (Geo/ Sword)	Roles: Sub-DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay Mechanism: Simple Team: Several teams with 2 Geo
 Aloy (Cryo/ Bow)	Roles: Sub-DPS <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay Mechanism: Simple Team: Melt team Can only be gotten once in a previous event
 Ayaka (Cryo/ Sword)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Simple Team: Freeze and Melt team Could infuse normal attack with Cryo element by herself.
 Ayato (Hydro/ Sword)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Simple Team: Freeze and Vaporize team Change normal attack into Hydro damage using Elemental Skill.
 Cyno (Electro/ Polearm)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Aggravate team
 Diluc (Pyro/ Claymore)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Vaporize and Melt team
 Eula (Cryo/ Claymore)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Complex Team: Physical team Does not dependent on elemental reaction damage.

 Ganyu (Cryo/ Bow)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Freeze and Melt team Deals huge damage using charged-attack shot. 	 Kokomi (Hydro/ Catalyst)	Roles: Support <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Simple Team: Every team Has the ability to constantly heal teammates.
 Hu Tao (Pyro/ Polearm)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Complex Team: Vaporize team Could boost her own damage with the cost of her HP 	 Mona (Hydro/ Catalyst)	Roles: Support <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Complex Team: Every team Gives buff teammate's damage.
 Itto (Geo/ Claymore)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Simple Team: Mono element team 	 Nahida (Dendro/ Catalyst)	Roles: Sub-DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Complex Team: Every dendro element team Could constantly apply dendro element to enemy and needs a deeper understanding of dendro-based reaction.
 Jean (Anemo/ Sword)	Roles: Support <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Every team Could heal teammates using Elemental Burst. 	 Nilou (Hydro/ Sword)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Complex Team: Bloom team Has a unique ability to change work mechanism of Bloom reaction.
 Kazuha (Anemo/ Sword)	Roles: Support <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Complex Team: Every element-based team Gives buff to teammate elemental damage but needs a deeper understanding of swirl reaction. 	 Qiqi (Cryo/ Sword)	Roles: Support <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Every team
 Keqing (Electro/ Sword)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Aggravate team 	 Raiden Shogun (Electro/ Polearm)	Roles: Sub-DPS <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Complex Team: Every electro element team Could constantly apply electro element to enemy and give boost to teammate's Elemental Burst Damage.
 Klee (Pyro/ Catalyst)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Complex Team: Vaporize team 		

 Shenhe (Cryo/ Polearm)	Roles: Support <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Simple Team: Freeze team Give boost to the team's Cryo damage.
 Tartaglia (Hydro/ Bow)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Complex Team: Vaporize team The Elemental Skill cooldown is linear to the usage duration.
 Tighnari (Dendro/ Bow)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Spread Team
 Venti (Anemo/ Bow)	Roles: Support <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Every element-based team Could apply crowd control to multiply enemies
 Wanderer (Anemo/ Catalyst)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Complex Team: Every element-based team Receive different buffs according to the swirled elements.
 Xiao (Anemo/ Polearm)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Several teams with 2 Anemo Deals huge damage while the Elemental Burst is active but slowly drains his HP while in that duration.

 Yae Miko (Electro/ Catalyst)	Roles: Sub-DPS <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Simple Team: Aggravate and Mono element team Could summon turrets that automatically attack enemy.
 Yelan (Hydro/ Bow)	Roles: Sub-DPS <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Simple Team: Vaporize, Freeze, and Electrocharged team
 Yoimiya (Pyro/ Bow)	Roles: Main DPS <ul style="list-style-type: none"> The ascension materials are not accessible for low AR Gameplay mechanism: Simple Team: Vaporize team Could infuse her Normal Attack with Pyro Element using Elemental Skill.
 Zhongli (Geo/ Polearm)	Roles: Support <ul style="list-style-type: none"> The ascension materials are accessible for low AR Gameplay mechanism: Simple Team: Every team Could protect teammates using a thick shield.

3. Roles

Characters in Genshin Impact can be categorized into three major roles, Main DPS, Sub-DPS, and Support.

a. Main DPS

Main DPS is a role in which a character deals the most damage. A character with the role of Main DPS usually takes most of the time as the on-field (active) character.

b. Sub-DPS

A character with a Sub-DPS role has a job to deal additional damage to the enemy besides the damage dealt by the Main DPS. This type of role is usually used as a 'quick-swap' character when the Main DPS character's skills are still in cooldown.

c. Support

Lastly, the Support role is given to those characters who don't deal much damage to the enemy but are needed in order to support the other teammates. Support roles can be divided into several categories, such as Healer, Shielder, and Buffer.

4. Team Compositions (Team comps)

As mentioned before, a team in Genshin Impact consists of a maximum 4 characters. The composition of the team itself usually contains a Main DPS, 2 Sub-DPS, and a Support character. However, the composition might differ depending on the situation and how it is

used.

There are several popular team compositions among the Genshin Impact community [9], such as:

- a. Vaporize team
 - b. Freeze team
 - c. Melt team
 - d. Mono element team
 - e. Aggravate/ Quicken/ Spread team
 - f. Bloom team
 - g. Physical/ Superconduct team
 - h. Electrocharged team
 - i. National team
5. *Ascension Materials*

The character's level in Genshin Impact is capped in several stages. In order to ascend a character into the next stage, a player needs to have some specific ascension materials. These ascension materials are different and unique for every character in Genshin Impact.



Image 4.5 Ascension Materials

(Source: https://www.ign.com/wikis/genshin-impact/Materials_-_Different_Types_of_Materials_in_Genshin_Impact)

The ascension materials can be divided into 4 categories [10], which are:

- a. Element Gemstones
- b. Specific Mob Drops
- c. Specific Boss Drops
- d. Local Specialties

III. APPLICATION

A. Considerations

Several considerations need to be noted to determine whether a character is better than another, especially in the context of early game gameplay. Some of the considerations that will be included in this chapter might be irrelevant for high AR players since they have access to a lot of aspects to make a character release its full potential. On the other hand, low AR player does not have the access to that level yet. Limitations and boundaries in the low AR are the foundations of these considerations.

To determine whether a character is suitable for an early game player, these are the preconditions that are better fulfilled:

1. A character that suits a lot of team comps is a better choice than the one who fits only in a specific team comp.

As mentioned before, low AR players do not have access to various characters, either 4-star or 5-star.

Therefore, a character that can 'solo' the game is

preferable to the one who works best only in a certain specific team.

2. The character's ascension materials should be accessible for low AR players.

There are several materials in ascension materials that are not accessible until the player reaches a certain AR. Characters whose ascension materials can be accessed in low AR, can be built as the players doing progress in the story. On the other hand, if the materials are inaccessible, the player will have to wait until a certain stage of the game to finally upgrade the wanted character.

3. The character is better to be useful and relevant not only in low AR but also in high AR.

Next, the characters that are considered suitable for the early game are not always considered the same for late game. In determining whether a character is good for early game players to wish, the character is expected to also be useful when they reach high AR. In this case, characters that are considered still useful in the high AR will be taken from the top 15 5-star characters used in the last patch's Spiral Abyss [11], those are:

Table 3.1

Top 15 5-Star Characters Used in Last Patch's Spiral Abyss

	Characters		Characters
1	Yelan	9	Raiden Shogun
2	Kazuha	10	Ayaka
3	Zhongli	11	Tartaglia
4	Kokomi	12	Ganyu
5	Nahida	13	Ayato
6	Yoimiya	14	Venti
7	Nilou	15	Cyno
8	Hu Tao		

4. Main DPS role characters are preferable to the other roles.

Gameplay in low AR (early game) does not demand various and complex mechanisms from the player. A character who can beat enemies and bosses is surely enough for those players. Thus, instead of having a character that supports other characters, a character who mainly deals damage to enemies is prioritized.

5. A character with a complex mechanism is less desirable.

Genshin Impact offers a lot of characters to be played. Obviously, different characters have different gameplay mechanisms which are either simple or complex. Characters that have simple gameplay mechanisms are suitable for early-game players since they do not need to have a deep understanding of the characters.

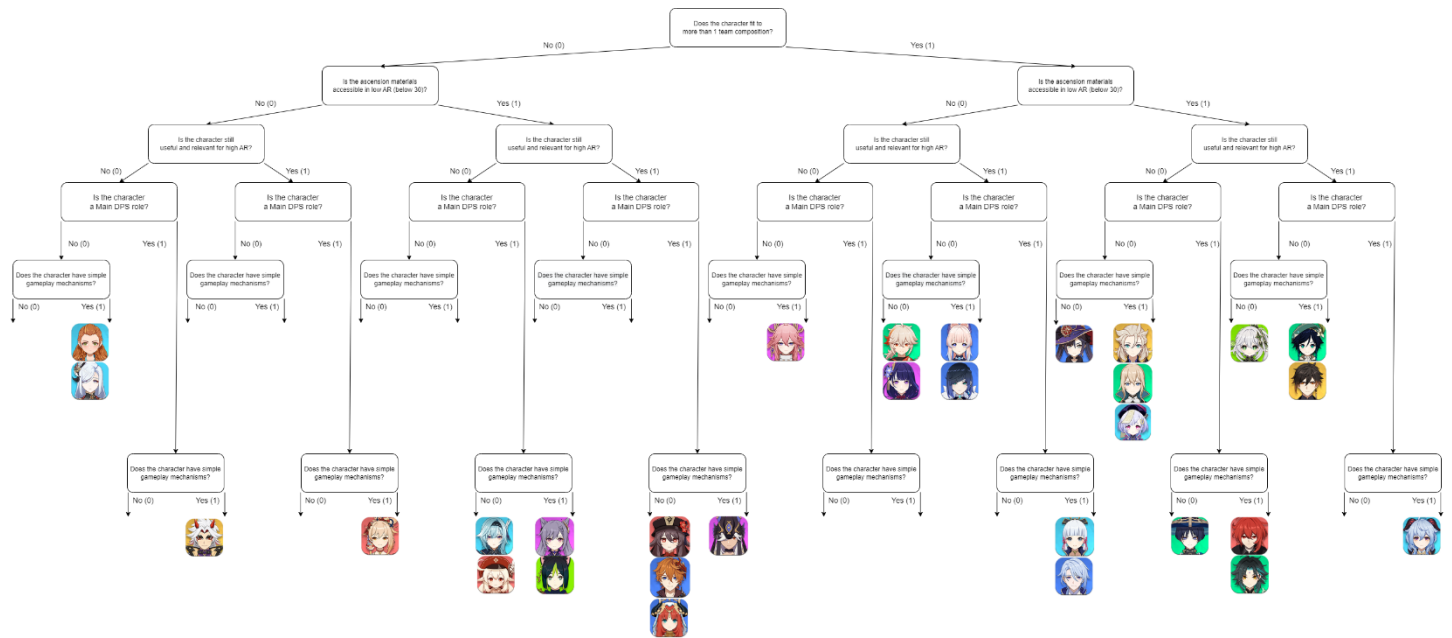


Image 3.1 The Implementation of Binary Tree to Determine the Value of 5 Star-Characters

(Source: Author’s Archive)

B. Binary Tree Implementation

In determining the value of 5-star characters in Genshin Impact, a binary tree can be used in order to evaluate the characters capabilities to fulfill all the mentioned considerations. Every node of the tree will represent a question regarding whether a character is favorable to a certain consideration. For every internal node in the tree, since it is a binary tree, has two children each connected by an edge that represent yes or no. Left child is connected by an edge that represent a “No” answer while the right child is connected by the one that represent a “Yes” answer.

Every edge, which is the answer to a question inside a node, contains a certain value. The “Yes” answer has the value of 1, while the “No” answer has the value of 0. This value will be accumulated from the first question, the root, down to one of the leaf nodes. Thus, the accumulated value will be the result value of a 5-star character in binary.

From the root node, down to the lowest internal nodes, the questions are sorted descending from the aspect of relevancy for early game players. Therefore, the question inside the root node sits on the highest level of priority hierarchy while questions inside the ones closest to the leaf nodes are the least prioritized.

Asked question for every level node sorted from the root down to the leaf are:

1. Does the character fit to more than 1 team composition?
2. Is the ascension materials accessible in low AR (below 30)?
3. Is the character still useful and relevant for high AR?
4. Is the character a Main DPS role?
5. Does the character have simple gameplay mechanisms?

Since there are 5 questions and each questions have 2 possible answers, there are 32 possible result values of a 5 star-character. However, as it has been mentioned before, there are only 30 5-star characters in Genshin Impact. Therefore, there will be

“empty” possible result values that no character has those specific values. Furthermore, having more than 1 characters with the same values is acceptable, adding more to the reasons that there will be “empty” possible result values.

Binary tree implementation used to determine value of 5-star character can be seen in Image 3.1.

IV. ANALYSIS

Based on Image 3.1, it can be concluded that characters with the most value are those who are on the right-most leaf nodes of the binary tree. The result value itself is the accumulated value that a character get after going through all the edges from the root node down to the leaf node. Therefore, here are the list of 5-star characters, sorted descending based on the accumulated value on Image 3.1:

Table 4.1 List of 5-Star Characters and the Result Values

	Characters	Binary Value	Decimal Value
1	Ganyu	11111	31
2	Venti	11101	29
3	Zhongli	11101	29
4	Nahida	11100	28
5	Diluc	11011	27
6	Xiao	11011	27
7	Wanderer	11010	26
8	Albedo	11001	25
9	Jean	11001	25
10	Qiqi	11001	25
11	Mona	11000	24
12	Ayaka	10111	23
13	Ayato	10111	23
14	Kokomi	10101	21
15	Yelan	10101	21

16	Kazuha	10100	20
17	Raiden Shogun	10100	20
18	Yae Miko	10001	17
19	Cyno	01111	15
20	Hu Tao	01110	14
21	Tartaglia	01110	14
22	Nilou	01110	14
23	Keqing	01011	11
24	Tighnari	01011	11
25	Eula	01010	10
26	Klee	01010	10
27	Yoimiya	00111	7
28	Itto	00011	3
29	Aloy	00001	1
30	Shenhe	00001	1

Based on Table 4.1, Ganyu has the title of 5-star character with the most value for early game players. Then, she is followed by Venti and Zhongli who have equal value of 29. In conclusion, those three characters, Ganyu, Venti, and Zhongli, are the three most suitable characters for early game players to have. On the other hand, Aloy and Shenhe both have the same value as the least suitable characters for early game players with the value of 1.

V. CONCLUSION

A tree can be used for several usages, one of those usages is determine a value of an object. Calculating value using tree can be done by accumulating a path's value from the top node, the root, to the bottom node, the leaf. The method itself can be implemented in many aspects, including calculating the value of an object in a video game.

VI. ACKNOWLEDGEMENT

First, I would sincerely express my gratefulness to the Lord that this paper can be completed well and within the given deadline. Then, I would like to express my deepest gratitude to:

1. All Discrete Mathematics Lecturers, especially Ms. Fariska Zakhralativa Ruskanda, for all the lectures that has been given to me,
2. My closest friends, that has been supporting me for the time being, and
3. The rightful owner of all the references that I used in writing this paper, for every knowledge that has been passed upon me.

REFERENCES

- [1] "Tree (graph theory)." https://p2k.unkris.ac.id/IT/en/3065-2962/tree_22179_p2k-unkris.html (accessed Sep. 12, 2022).
- [2] GeeksforGeeks, "Binary Tree Data Structure," Dec. 08, 2022. <https://www.geeksforgeeks.org/binary-tree-data-structure/> (accessed Sep. 12, 2022).
- [3] "Graph Theory." <https://byjus.com/maths/graph-theory/> (accessed Nov. 12, 2022).

- [4] R. Munir, "Graf (Bag.1)." Accessed: Nov. 12, 2022. [Online]. Available: <https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2020-2021/Graf-2020-Bagian1.pdf>
- [5] R. Munir, "Pohon (Bag.2)." Accessed: Dec. 12, 2022. [Online]. Available: <https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2021-2022/Pohon-2021-Bag2.pdf>
- [6] programiz, "Full Binary Tree." <https://www.programiz.com/dsa/full-binary-tree#:~:text=A%20full%20Binary%20tree%20is,Full%20Binary%20Tree> (accessed Dec. 12, 2022).
- [7] "What is considered low/mid/high level?," Sep. 19, 2021. <https://genshin-impact.fandom.com/f/p/440000000000271774> (accessed Nov. 12, 2022).
- [8] "List of All 5-Star Characters | Genshin Impact," Dec. 07, 2022. <https://game8.co/games/Genshin-Impact/archives/297582> (accessed Oct. 12, 2022).
- [9] "Genshin Impact Best Team Build." <https://www.genshinlab.com/team/> (accessed Oct. 12, 2022).
- [10] "Character Level Up Materials Guide," Dec. 09, 2022. <https://gamewith.net/genshin-impact/article/show/22632> (accessed Oct. 12, 2022).
- [11] H. Krdzic, "Genshin Impact Reveals Most Used Characters in 3.2 Spiral Abyss," Nov. 20, 2022. <https://gamerant.com/genshin-impact-most-used-characters-3-2-spiral-abyss/> (accessed Oct. 12, 2022).

STATEMENT

Hereby, I state that this paper is written on my own, not an adaptation, or translation from other people's paper, and not plagiarism.

Bandung, 12 December 2022



Juan Christopher Santoso - 13521116