Application of Depth-First Search for All Endings Exploration in Study § Steady

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***Abstract*—Study § Steady is a romantic visual novel set in a lighthearted and charming world, where the protagonist becomes romantically involved with four heroines, each with their own unique personalities and stories. The game focuses on themes of love, personal growth, and meaningful relationships, with player choices shaping the direction of the narrative. There are 8 possible endings: 2 distinct endings for each of the 4 heroines. These outcomes are determined by the player's decisions, with each choice leading to a different progression in the story. The game emphasizes character-driven storytelling and branching paths, offering a relaxing and heartfelt experience for fans of romance and slice-of-life narratives. This paper will discuss how to reach all endings using the Depth-First Search (DFS) method.**

***Keywords*—Choices, DFS, Study § Steady, Visual Novel**

I. Introduction

Visual novel is an interactive storytelling medium, often presented as a game, that blends text, visual art, and audio to create an immersive narrative experience. Originating in Japan, it focuses on story-driven gameplay where players make decisions that influence the plot, character relationships, and outcomes, often leading to multiple endings. Visual novels feature detailed character sprites, static or animated backgrounds, and atmospheric audio, including voice acting and music, to enhance the narrative. With branching storylines and themes ranging from romance and comedy to psychological thrillers and mature content, visual novels offer a unique blend of literature and interactive gaming, appealing to those who enjoy immersive, choice-driven storytelling.

Figure 1.1. Main Menu From Study § Steady Taken From The Game

Study § Steady (Japanese: スタディ§ステディ) is a romance adventure adult game developed by MARMALADE, released on September 27, 2019. A Chinese and English version was released on June 30, 2021[1]. On May 28, 2021, a fan disc titled Icha Icha Steady (イチャ×2スタディ) was released, with a Chinese and English version following on June 17, 2022.

Each ending route can be reached based on the player's decisions. To achieve all route endings, the Depth-First Search (DFS) method can be utilized to systematically explore all possible choices and their resulting paths, ensuring that no ending is missed.

II. Theoretical Basis

A. Graph

A graph is a structure used in mathematics and computer science to represent objects and their relationships. It consists of vertices (V) and edges (E) and defined as G = (V,E). The study itself is inspired by the Königsberg Bridge Problem (1736).

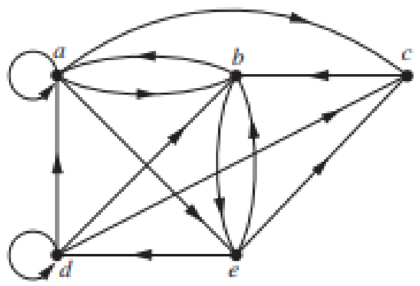

Figure 2.1. Directed Graph (Rosen, 2012)

Nowadays graphs are widely used to model networks, dependencies, and relationships in fields like computer science, biology, and artificial intelligence, making them essential for solving problems involving connectivity and paths.

B. Tree

A tree is a connected, acyclic graph with no cycles, where there is exactly one path between any two vertices. For example, in a computer network, trees ensure a unique path between any two nodes, optimizing routing. Trees are used in applications like network routing algorithms, hierarchical structures (e.g., organizational charts, file systems), and decision trees in machine learning. They are also fundamental in search algorithms like depth-first search (DFS) and breadth-first search (BFS) for exploring nodes efficiently.

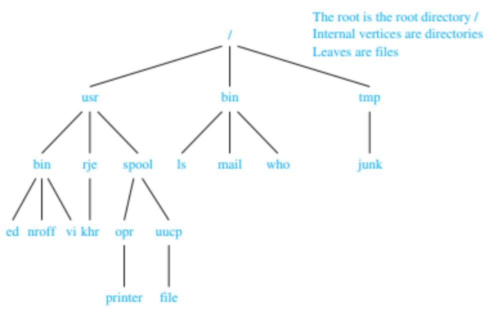

Figure 2.2. A Computer File System (Rosen, 2012)

Theorem. let (G = (V, E)) be a simple, undirected graph with n vertices. Then, all of the following statements are equivalent:

1. (G) is a tree.
2. Every pair of vertices in (G) is connected by exactly one path.
3. (G) is connected and has (m = n - 1) edges.
4. (G) contains no cycles and has (m = n - 1) edges.
5. (G) contains no cycles, and adding one edge to the graph will create exactly one cycle.
6. (G) is connected, and all its edges are bridges.

C. Forest

A forest is a collection of disjoint trees, or a disconnected graph that does not contain any cycles. In this context, each component within the graph is a tree, which is a connected, acyclic graph with exactly one path between any two vertices. Since a forest consists of multiple trees, it may have several disconnected components, with each component being a separate tree. This structure ensures there are no cycles, and it is often used in scenarios where multiple independent subgraphs need to be represented or analyzed.

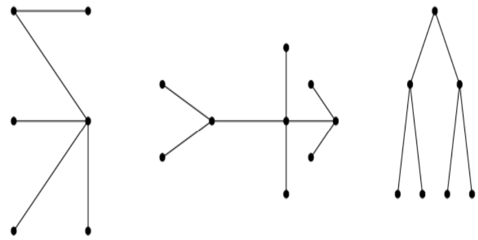

Figure 2.3. Forest Consisting Of Three Trees (Source:https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2024-2025/23-Pohon-Bag1-2024.pdf, page 4)

D. Rooted Tree

A tree where one of its vertices is designated as the root and all edges are assigned a direction to create a directed graph is known as a rooted tree. In this structure, the root serves as the starting point, and all other vertices are organized hierarchically, with directed edges indicating parent-child relationships.

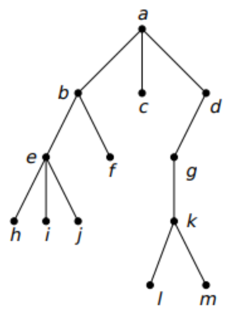

Figure 2.4. Rooted Tree (Source:https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2024-2025/23-Pohon-Bag1-2024.pdf, page 5)

Based on figure 2.4. there are few terminologies of a rooted tree:

i) Child and Parent
b, *c*, and *d* are the children of vertex *a*, and *a* is the parent of those children.

ii) Path
Path from *a* to *j* is *a*, *b*, *e*, *j*, and path length from *a* to *j* is 3.

iii) Sibling
f is *e*'s sibling, but *g* isn't *e*'s sibling, because they have different parents.

iv) Subtree
A subtree is a smaller tree that is located within a tree.

v) Degree

The degree of a node is the total number of subtree (or child) that a node has, meanwhile the degree of a tree is the biggest degree of its node.

vi) Leaf
A node that has zero degree (doesn't have a child nor subtree) is called leaf.

vii) Internal Nodes
A node that has a child is called an internal node.

viii) Level
A number of predecessors a tree has from its root is called level.

ix) Height or Depth
The biggest level a tree has is called height/depth.

E. N-ary Tree

A rooted tree which every node has at most n child is called an n-ary tree.

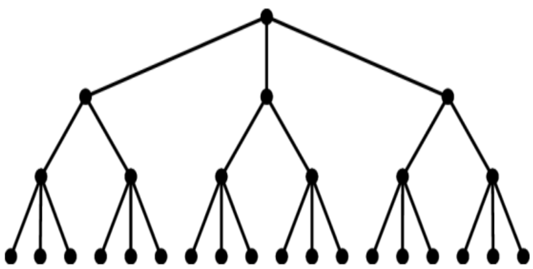

Figure 2.5. 3-ary Tree
(Source:https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2024-2025/23-Pohon-Bag1-2024.pdf, page 13)

F. Depth-First Search (DFS)

Depth-First Search (DFS) is a key algorithm for traversing or searching through trees and graphs. Starting at the root or a chosen node, it explores each branch as deeply as possible before backtracking, making it ideal for problems like pathfinding or cycle detection. DFS can be implemented recursively or iteratively using a stack. In trees, it follows specific orders: pre-order (root, then subtrees), in-order (left subtree, root, right subtree), or post-order (subtrees, then root). With a time complexity of O(V + E) and space complexity of O(V), DFS is a simple yet powerful tool widely used in algorithmic problem-solving.

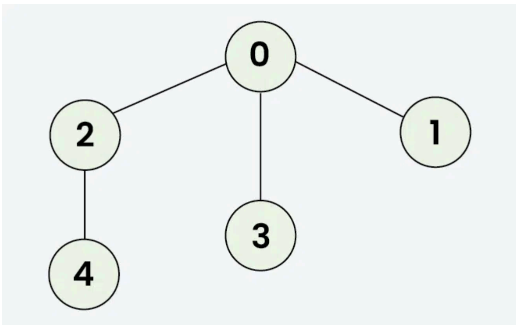

Figure 2.6. DFS Example

(Source: https://www.geeksforgeeks.org/depth-first-search-or-dfs-for-a-graph/)

Output: 0 2 4 3 1
Explanation: DFS Steps:

- Start at 0: Visit and mark as visited. Output: 0
- Move to 2: Visit and mark as visited. Output: 2
- Move to 4: Visit and mark as visited. Output: 4 (then backtrack to 2 and further backtrack to 0).
- Move to 3: Visit and mark as visited. Output: 3 (then backtrack to 0).
- Move to 1: Visit and mark as visited. Output: 1

Note: The DFS traversal can vary depending on the order in which adjacent vertices are selected. In this case, vertices are chosen based on their insertion order.

III. Study § Steady and Its Mechanics

In this section, the writer uses the Study § Steady English version, which can be downloaded from RyuuGames along with the v1.03 patch update available on the same site. The program is run on a Windows 10 system, and any differences or issues encountered should be attributed to either variations in the game version or the platform being used.

A. What is Study § Steady?

Study § Steady is a Visual Novel where the player takes on the role of a main character whose name can be chosen freely. The protagonist is a young man who moves to his grandparents' house in a peaceful, snow-covered town to start a new chapter in his life. As he adjusts to his new surroundings, he meets four unique heroines, each with their own quirks, dreams, and challenges. Through shared moments like studying together, helping out with tasks, and enjoying daily life, the protagonist gradually builds deep connections with each heroine. The story focuses on warmth, romance, and the bonds that grow from everyday interactions, offering a heartwarming journey of love and friendship in a picturesque winter setting.

B. Mechanics in Study § Steady

The mechanics of Study § Steady are similar to those of other typical visual novels. The player interacts with the game through a dialogue box at the bottom center of the screen, which displays the character interactions and story progression. Next to the dialogue box is an expandable control section that offers various options like save/load, settings, replaying dialogue, viewing the backlog, skipping text, and activating auto-play. Players can navigate through the dialogue by left-clicking or pressing the return key, while right-clicking or the spacebar hides the dialogue box. The Ctrl key is used to fast-forward through text. Additionally, the game features a settings menu where players can adjust options like volume, text speed, and other preferences to customize their experience.

Figure 3.1. Playing Prompt From Study § Steady Taken From The Game

C. Endings

The game features multiple endings that are determined by the player's choices throughout the story. In total, there are 17 possible endings, with 16 of them corresponding to each of the four heroines, and 1 bad ending. The endings are:

- Nanoka’s Ending A
- Nanoka’s Ending A 2nd Var
- Nanoka’s Ending B
- Nanoka’s Ending B 2nd Var
- Yuu’s Ending A
- Yuu’s Ending A 2nd Var
- Yuu’s Ending B
- Yuu’s Ending B 2nd Var
- Mai’s Ending A
- Mai’s Ending A 2nd Var
- Mai’s Ending B
- Mai’s Ending B 2nd Var
- Hazuki’s Ending A
- Hazuki’s Ending A 2nd Var
- Hazuki’s Ending B
- Hazuki’s Ending B 2nd Var

The player would only get a bad ending if they didn’t choose any of the four heroines.

Figure 3.2. Choice Prompt From Study § Steady Taken From The Game

To reach any of the possible endings, players must carefully make decisions whenever a choice prompt appears. Each heroine’s route contains three such prompts, and while the questions differ slightly, they generally follow a similar pattern across all the routes, requiring the player to choose how to respond in key moments that will ultimately shape the outcome.

The three prompts that will be presented to the player throughout the playthrough, in sequential order, are as follows:

1. Have You Read XXX’s Letter?
   This is the first prompt the player will encounter after selecting their main heroine. In this choice, the player is given two options: "yes" or "no." However, to move the story forward, the player must select "yes." If the player chooses "no," the game will repeatedly present the same prompt until "yes" is selected, ensuring the progression of the narrative.

2. Which One Do You Want To See?
   The second prompt the player encounters during the playthrough presents two choices, with the options varying depending on which heroine has been selected. This choice plays a key role in shaping the direction of the story and the relationship with the chosen character and will determine the variation of the ending the player will get.
   However, for Mai's and Hazuki's routes, this prompt will appear as the third and final choice instead of the second. This small variation in the sequence adds a unique touch to the progression of their individual storylines.

3. What is Your Decision?
   In Nanoka's and Yuu's routes, the third and final prompt plays a crucial role in determining which ending the player will reach. However, for Mai's and Hazuki's routes, this prompt influences the variation of the ending, with the second prompt being the key choice that decides the outcome of their storylines.
   Like the previous prompts, this final choice also presents the player with two options. The selection made here will directly impact the direction of the ending, shaping the conclusion of the protagonist’s relationship with the chosen heroine.

Based on the explanation of the question prompts above, all the checkpoints can be summarized in the following table:

No.	Question Prompt	Ending
		Nanoka’s Ending A
1	Have You Read Nanoka’s Letter?	Yes
2	Which One Do You Want To See?	I wanna see that!
3	What is Your Decision?	Strive to be a veterinarian with her

Table 3.1 Nanoka’s Ending A Answer Table

No.	Question Prompt	Ending
		Nanoka's Ending B
1	Have You Read Nanoka's Letter?	Yes
2	Which One Do You Want To See?	I wanna see that!
3	What is Your Decision?	Support her in your own way

Table 3.2 Nanoka's Ending B Answer Table

No.	Question Prompt	Ending
		Nanoka's Ending A.2
1	Have You Read Nanoka's Letter?	Yes
2	Which One Do You Want To See?	But I like your raving swimsuit
3	What is Your Decision?	Strive to be a veterinarian with her

Table 3.3 Nanoka's Ending A 2nd Var Answer Table

No.	Question Prompt	Ending
		Nanoka's Ending B.2
1	Have You Read Nanoka's Letter?	Yes
2	Which One Do You Want To See?	But I like your raving swimsuit
3	What is Your Decision?	Support her in your own way

Table 3.4 Nanoka's Ending B 2nd Var Answer Table

No.	Question Prompt	Ending
		Yuu's Ending A
1	Have You Read Yuu's Letter?	Yes
2	Which One Do You Want To See?	The bikini, please
3	What is Your Decision?	Marry you

Table 3.5 Yuu's Ending A Answer Table

No.	Question Prompt	Ending
		Yuu's Ending B
1	Have You Read Yuu's Letter?	Yes
2	Which One Do You Want To See?	The bikini, please
3	What is Your Decision?	Aim for the same college as you

Table 3.6 Yuu's Ending B Answer Table

No.	Question Prompt	Ending
		Yuu's Ending A.2
1	Have You Read Yuu's Letter?	Yes
2	Which One Do You Want To See?	The swimsuit, please
3	What is Your Decision?	Marry you

Table 3.7 Yuu's Ending A 2nd Var Answer Table

No.	Question Prompt	Ending
		Yuu's Ending B.2
1	Have You Read Yuu's Letter?	Yes
2	Which One Do You Want To See?	The swimsuit, please
3	What is Your Decision?	Aim for the same college as you

Table 3.8 Yuu's Ending B 2nd Var Answer Table

No.	Question Prompt	Ending
		Mai's Ending A
1	Have You Read Mai's Letter?	Yes
2	What is Your Decision?	Live with me
3	Which One Do You Want To See?	Your current hairstyle

Table 3.9 Mai's Ending A Answer Table

No.	Question Prompt	Ending
		Mai's Ending A.2
1	Have You Read Mai's Letter?	Yes
2	What is Your Decision?	Live with me
3	Which One Do You Want To See?	Ponytails

Table 3.10 Mai's Ending A 2nd Var Answer Table

No.	Question Prompt	Ending
		Mai's Ending B
1	Have You Read Mai's Letter?	Yes
2	What is Your Decision?	Our love will survive any time or distance
3	Which One Do You Want To See?	Your current hairstyle

Table 3.11 Mai's Ending B Answer Table

No.	Question Prompt	Ending
		Mai's Ending B.2
1	Have You Read Mai's Letter?	Yes
2	What is Your Decision?	Our love will survive any time or distance
3	Which One Do You Want To See?	Ponytails

Table 3.12 Mai's Ending B 2nd Var Answer Table

No.	Question Prompt	Ending
		Hazuki's Ending A
1	Have You Read Hazuki's Letter?	Yes
2	What is Your Decision?	I'd be happy with it!
3	Which One Do You Want To See?	As is

Table 3.13 Hazuki's Ending A Answer Table

No.	Question Prompt	Ending
		Hazuki's Ending A..2
1	Have You Read Hazuki's Letter?	Yes
2	What is Your Decision?	I'd be happy with it!
3	Which One Do You Want To See?	As is

Table 3.14 Hazuki's Ending A 2nd Var Answer Table

No.	Question Prompt	Ending
		Hazuki's Ending B
1	Have You Read Hazuki's Letter?	Yes
2	What is Your Decision?	We need to plan better
3	Which One Do You Want To See?	I like it down

Table 3.15 Hazuki's Ending B Answer Table

No.	Question Prompt	Ending
		Hazuki's Ending B.2
1	Have You Read Hazuki's Letter?	Yes
2	What is Your Decision?	We need to plan better
3	Which One Do You Want To See?	I like it down

Table 3.16 Hazuki's Ending B 2nd Var Answer Table

IV. DFS Application To Find All Endings

To apply the DFS method for finding all possible endings, the first step is to model a rooted tree that represents the structure of choices and outcomes in the game. This tree will act as a framework for navigating through different paths and determining how each decision influences the final outcome. The structure of the tree will be based on the detailed explanation of the game's mechanics provided in Section III.

The rooted tree in Figure 4.1 represents the progression of decisions and consequences in the game. At the root, the player enters a common route where no specific choices have been made yet. The tree branches out based on character-specific choices: Nanoka, Yuu, Mai, or Hazuki. Each character route further divides based on key decisions, such as whether or not the player reads a letter, and subsequent responses that steer the story toward different endings.

The tree employs conditional paths where each decision node either terminates in a final outcome (leaf node) or leads to further decision nodes. Leaf nodes represent distinct endings of the story, categorized under each character route into variations such as "Ending A," "Ending B," or other specific outcomes. Notably, failing to choose a character results in a "Bad Ending," signifying a suboptimal conclusion to the narrative.

To apply Depth First Search (DFS) for identifying all endings, the traversal explores each branch to its deepest extent before backtracking. This ensures that all paths are fully examined, allowing us to catalog every unique ending associated with the game. Below is the DFS traversal applied to the tree:

1. Start at the Root ("Common Route"): Visit the root node (Common Route). Output: Common Route.
2. Move to "Chose Nanoka": Visit the "Chose Nanoka" node. Output: Common Route → Chose Nanoka.
   - Move to "Have You Read Nanoka's Letter?": Visit this node. Output: Common Route → Chose Nanoka → Have You Read Nanoka's Letter?.
     - Path 1: "I wanna see that!" → "Strive to be a veterinarian with her": Visit and mark as a leaf node. Output: Nanoka Ending A.
     - Path 2: "I wanna see that!" → "Support her in your own way": Visit and mark as a leaf node. Output: Nanoka Ending A 2nd Var.
     - Path 3: "But I like your raving swimsuit" → "Strive to be a veterinarian with her": Visit and mark as a leaf node. Output: Nanoka Ending B.
     - Path 4: "But I like your raving swimsuit" → "Support her in your own way": Visit and mark as a leaf node. Output: Nanoka Ending B 2nd Var.
   - Backtrack to "Common Route".

3. Move to "Chose Yuu": Visit the "Chose Yuu" node. Output: Common Route → Chose Yuu.
    - Move to "Have You Read Yuu's Letter?": Visit this node. Output: Common Route → Chose Yuu → Have You Read Yuu's Letter?.
        - Path 5: "The bikini, please" → "Marry you": Visit and mark as a leaf node. Output: Yuu Ending A.
        - Path 6: "The bikini, please" → "Aim for the same college as you": Visit and mark as a leaf node. Output: Yuu Ending A 2nd Var.
        - Path 7: "The swimsuit, please" → "Marry you": Visit and mark as a leaf node. Output: Yuu Ending B..
        - Path 8: "The swimsuit, please" → "Aim for the same college as you": Visit and mark as a leaf node. Output: Yuu Ending B 2nd Var.
    - Backtrack to "Common Route".
4. Move to "Chose Mai": Visit the "Chose Mai" node. Output: Common Route → Chose Mai.
    - Move to "Have You Read Mai's Letter?": Visit this node. Output: Common Route → Chose Mai → Have You Read Mai's Letter?.
        - Path 9: "Live with me" → "Your current hairstyle": Visit and mark as a leaf node. Output: Mai Ending A.
        - Path 10: "Live with me" → "Ponytails": Visit and mark as a leaf node. Output: Mai Ending A 2nd Var.
        - Path 11: "Our love will survive any time or distance" → "Your current hairstyle": Visit and mark as a leaf node. Output: Mai Ending B.
        - Path 12: "Our love will survive any time or distance" → "Ponytails": Visit and mark as a leaf node. Output: Mai Ending B 2nd Var.
    - Backtrack to "Common Route".
5. Move to "Chose Hazuki": Visit the "Chose Hazuki" node. Output: Common Route → Chose Hazuki.
    - Move to "Have You Read Hazuki's Letter?": Visit this node. Output: Common Route → Chose Hazuki → Have You Read Hazuki's Letter?.
        - Path 13: "I'd be happy with it!" → "As is": Visit and mark as a leaf node. Output: Hazuki Ending A.
        - Path 14: "I'd be happy with it!" → "I like it down": Visit and mark as a leaf node. Output: Hazuki Ending A 2nd Var.
        - Path 15: "We need to plan better" → "As is": Visit and mark as a leaf node. Output: Hazuki Ending B.
        - Path 16: "We need to plan better" → "I like it down": Visit and mark as a leaf node. Output: Hazuki Ending B 2nd Var.
    - Backtrack to "Common Route".
6. Move to "Didn't Chose": Visit this node. Mark as a leaf node since it leads directly to the Bad Ending. Output: Bad Ending.

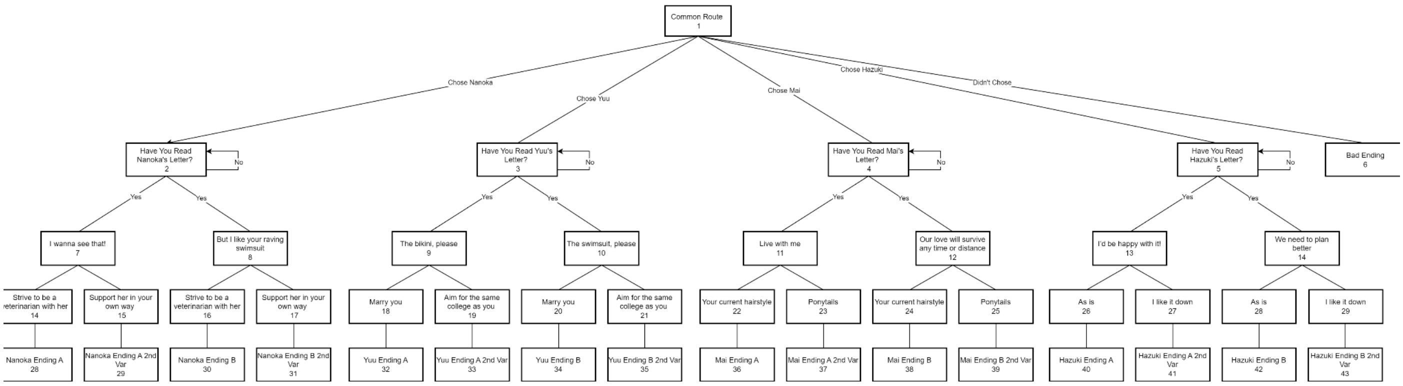

Figure 4.1. Rooted Tree of Choice Prompts and Its Endings

This exhaustive traversal ensures that all 17 possible endings (16 character-based + 1 bad ending) are identified, categorized, and associated with their respective decision paths. The DFS approach efficiently navigates the decision space, demonstrating the logical framework underlying the game mechanic.

V. Conclusion

To discover all possible endings in the game Study § Steady, the process can be modeled using a rooted tree and the application of depth-first search (DFS). This model is chosen because it enables a thorough traversal, ensuring that no important points are overlooked. Additionally, it provides a visual guide, which helps users navigate the process more easily. With the numerous possible outcomes in the game, the DFS model aims to assist users in uncovering all available endings.

However, it is worth noting that finding all endings in Study § Steady can also be represented through other theorems or models beyond DFS. Therefore, further research is necessary to identify the most effective method for achieving this objective.

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PeRNYATAAN

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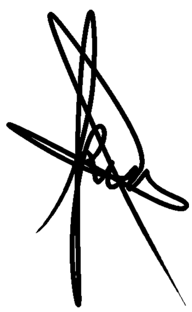
Bandung, 29 Desember 2024



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