Leveraging Decision Trees and Combinatorics for Strategic Optimization in Balatro

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***Abstract*—The gaming industry has gotten stagnant with the widespread release of cash-grab products. Amid this industry, *Balatro* by LocalThunk has managed to create significant reverberation due to its inventive integration of Poker, Deckbuilder, and Roguelike elements. Within its unique and innovative gameplay, however, lies a deep mathematical root that can be exploited to increase player satisfaction and in-game performance. This paper explores said mathematical roots to create a framework that optimizes the score gained by each round of this award-winning game. Using concepts such as combinatorics, decision tree, and probabilities, it is possible to create a pipeline in which players can increase their enjoyment of the game and maximize their score according to game state parameters. As a result, players can make their own decision tree where they can analyze and choose the best decision to increase their score in the game.**

***Keywords*—Poker, Decision Tree, Boolean Algebra, Roguelike Video Games, Deckbuilding Video Games.**

I. Introduction

The game of Poker has existed for an extended period. This game has been a household name for many centuries. With its capabilities to withstand the test of time, the game Poker has been in everyone's heart for as long as time itself. The game's popularity has inspired people to create new avenues for playing the game. One of the newest inventions in poker is the award-winning game *Balatro*.

Balatro rose to prominence due to its fun gameplay and inventive integration of the roguelike format and classic Poker elements. This new game has many people hooked on its gameplay and had made a huge wave in the deckbuilding and roguelike scene. The gameplay of *Balatro* is simple. The player obtained a set number of cards of which they need to make a poker hand out of 5 or less of them. With different hand types possessing different scores and multipliers, the player aims to reach a certain score to proceed to the next level. The unique twist *Balatro* brought is the introduction of joker cards. Joker cards are bonus cards which hold the power to decide the chance of winning a round.

Within its gameplay, there are applications of mathematical theorems and models in the game which can optimize the player's resulting score. While optimizing a score in a game is trivial, the mathematical concept within it is still intriguing to explore. Using a mathematical approach to playing *Balatro* may increase one's understanding of the concepts of combinatorics, probabilities, and decision trees, while maintaining a fun and inquisitive façade.

In this paper, the use of mathematical concept of combinatoric, decision tree, and probability is used to create an analysis and a framework for a player to maximize their score in a round of *Balatro*.

II. Theoretical Foundation

A. Poker

Poker is a sophisticated game of cards that combines logical reasoning and luck. David Sklansky states in his book, and I paraphrase, while the word poker itself does not refer to a game, all variation of Poker contains an inner logic, general precepts, concepts, and theories that apply to all of them. This means that with its many variations, there are logic and concepts that are still the same through all of them.

Amongst all the variations, the hand type, round robin system, and used deck are usually the same. This is the foundation of what makes a game a 'Poker' game [1].

The card used in a Poker game contains 52 cards and 4 suits with the value of the suit dependent on the variation of Poker played. The existence of a Joker card is also dependent on the variation of Poker but at its base, Joker cards are not used. The rank of the card is sorted with the Ace as the highest value, and the 2 as the lowest value. While many variations use a different rule set where 2 is the highest value, the formal recognition is that 2 is the lowest value [2].

A poker hand is a combination of 5 cards that form a pattern. According to [2], the main recognized poker hands, in descending order of rank, are:

- **Royal flush:** A set of Ace, King, Queen, Jack, and 10 cards in the same suit.
- **Straight flush:** A collection of five cards of sequential rank in the same suit e.g. 2,3,4,5,6 of Hearts.
- **Four of a kind:** A collection of four cards of the same rank with one random card.
- **Full house:** A set of three cards and two cards of the same rank.
- **Flush:** A set of five cards with the same suit.
- **Straight:** A set of five card of sequential rank.
- **Three of a kind:** A set of three cards of the same rank

and two random cards.

- **Two Pair:** A set of two cards of the same rank, another set of two cards of the same rank, and a random card.
- **One Pair:** A set of two cards of the same rank, and three random cards.
- **High cards:** A random set of five cards with the highest rank being its score.

B. Balatro

Balatro is a roguelike deckbuilder video game developed by one person known as LocalThunk [3]. In the game, players combine valid poker hands with unique Joker cards to create varied synergies and builds [3]. The core of the gameplay of *Balatro* is its poker-based system with elements from deckbuilding and roguelike format integrated within it.

Roguelike is a genre of games that originated in 1980 with *Rogue*. The term Roguelike itself is implying that the game is like that of the game *Rogue*. According to [4] and 'the berlin interpretation', the genre Roguelike has 9 "high-value" factors that indicates its identity. These factors are:

- **Random environment generation:** The game 'world' is randomly generated in a way that increases replayability. This means that each level for each run is always different with a very slight chance that a run might occur the same way twice.
- **Permadeath:** Each time player loses, the player is required to complete subsequent level to reach the level they lose at.
- **Turn-based:** Each command corresponds to a single action.
- **Grid-based:** The world is represented as grid tiles where each actor takes one tile.
- **Non-modal:** Each action an actor (Player or enemy) took is always available at any point in the game without the need for changing states.
- **Complexity:** Several solutions can be done for a common goal.
- **Resource management:** Player need to manage their resources and use it appropriately.
- **Hack'n'Slash:** The game is player-vs-world where the player (alone or with companions) need to face against the enemy and there are only two sides in the game.
- **Exploration and discovery:** Player is required to explore and discover activities in the game.

Out of all these factors, *Balatro* fulfils six of them which makes *Balatro* a roguelike game despite its unconventional gameplay.

Deckbuilder is another video game genre in which players modify cards in their deck during the game lifetime. This is stark in contrast to traditional card games where players compete with decks that are prepared beforehand. Deckbuilder generally starts the player off with simple and weak cards in which the goal of the player is to discover new cards or upgrade a weaker card and use it on their own deck to create more powerful decks [5]. This genre of games was first popularized by the game Dominion back in 2008 [5]. *Balatro* takes notes from this genre by its feature in which players can upgrade and add new cards to their pool of cards. The deckbuilder element in *Balatro* may stark in contrast to the roguelike element but it is still a big influence in how players complete their run.

In *Balatro*, players start with a simple 52 card Poker deck with no special cards and no Jokers. Players will then be required to choose to whether play a round of small blind or skip to the big blind. After a player complete a blind (small, big, or boss blinds), they are rewarded with money where the amount depends on the blind where small blinds give smaller rewards, the remaining hands not used, and the current money the player has. Afterward they are taken to the shop where they can buy new cards, consumable cards, or joker cards.

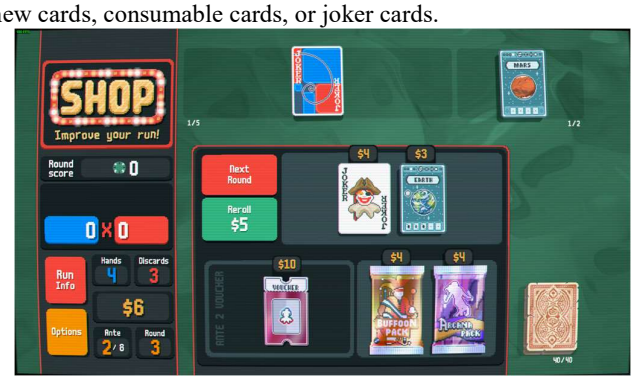


FIGURE 1
DISPLAY OF THE SHOP

If the player chooses to play a blind, the round will then start where the player is given eight cards. Each round consists of four hands and three discards. Each time a player makes a poker hand and plays it, the game will count the score of the poker hand and then add the rank of each played hands to the base chip of the poker hand type and lastly add bonuses that may take effect. Each turn, the Player may discard up to five different cards out of the eight they currently hold for random remaining card in the deck. As seen in Fig. 2, each poker hand has its own multiplier and base chips. The goal of the player is to maximize the chips by using bonuses and consumables to reach the blind, the score cap needed to continue to the next stage.

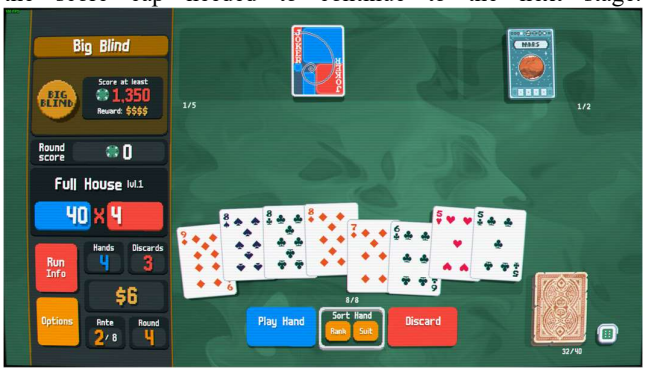


FIGURE 2
A ROUND OF BALATRO WITH A FULL HOUSE

As mentioned before, *Balatro* uses the rule of Poker for scoring with additional hand types that are available due to the deckbuilding element. The score of each hand type follows the classic poker rank where Royal Flush has the highest base chips and multipliers while the High Card has the least. In order to increase the score of each hand, the player must use consumable as seen at the top-right of the screen of Fig. 2 or use Joker cards

as seen at the top of the screen of Fig. 2. Each Joker card and consumable is bought at the shop and while consumables can only be used once, the joker cards will take effect each time an action is done (Playing a hand or discarding). The order of bonus application is from left to right which will have a big impact later. There are three types of consumable cards which the player can use, which are Tarot cards, Planet cards, and Spectral cards. Tarot cards focus on modifying the current deck or hand in smaller scales while the spectral card does it in the larger scale. Planet cards differ from both card types in which they are specifically used to increase the base chips and multiplier of each poker hand. Other than consumable cards, there are also available voucher which the player can use which will give a buff for the whole run but costs more than the normal consumable cards.

Balatro, like its predecessor Poker, is a game of logic and luck. However, we can use mathematical concepts and theories to maximize our results in this game.

C. Combinatorics

Combinatorics is a mathematical field that is said to be the mathematics of the finite. One of the most basic qualities of finite sets is its number of elements. The type of problem associated with the number of elements or how many ways a thing can be done is called enumeration [6]. Combinatorics delves into ways we can count the number of ways we can organize something without enumerating every possible outcome [7].

A basic concept of combinatorics is the concept of *counting*. The two basic rules of *counting* are the rule of product and the rule of sum [7]. We use the rule of sum when the enumeration is mutually exclusive to each other. For example, when one person is going to be chosen from two different categories, we use the rule of sum where we add the amount of candidate from one category with the other category to get all the choice rather than multiplying it. We use the rule of product when the different categories will change the result of the selection. For example, when a person is taking two balls from the same basket which contain ten balls, the amount of combination of ball that can be chosen is $10 \cdot 9$ rather than $10 + 9$ [7].

Another concept in the field of combinatorics is the concept of permutation and combination. Permutation is the number of different methods an object can be organized e.g., how many words can be made by using the letters from the word "four" [7]. The basic formula for permutation is as follows:

$$P(n,r) = \frac{n!}{(n-r)!} \tag{1}$$

which means the amount of r elements that can be chosen from n elements [7]. If all elements are mutually exclusive, then the actual elements will not matter to the result. Combination, on the other hand, is the number of ways a set amount of element can be chosen without caring for the sequence of the element.

$$C(n,r) = \frac{n!}{(n-r)!n!} \tag{2}$$

(2) loosely translates to, the amount of ways r elements can be taken from n elements without caring of the sequence in which the elements were taken in [7]. Both concepts will be helpful in finding the combination of cards one might get in a round of *Balatro*.

D. Probability

According to [8], probability is the means of evaluating the likelihood of the occurrence of an event resulting from statistical experiments. In easier terms, probability is the chance of something to happen based on empirical data.

In probability, a sample space (S) is the set of all possible outcomes of a statistical experiment. For example, if Andy rolls a six-sided die once, the amount of outcome, or sample space, of the event is six since there can only be six outcomes. The probability of an event to occur is a ratio of the outcome where said event occur and the sample space. If an experiment will result in N outcomes and n of these outcomes will result in event A, the probability of event A occurring is

$$P(A) = \frac{n}{N} \tag{3}$$

As the outcomes of a statistical experiment is also enumeration, probability follows the same rule as combinatorics. The rule of sum and rule of product also applies to counting probabilities. In fact, the use of combinatorics inside probabilities is a well-established use of the mathematical concept.

In finding the most optimized round of a *Balatro* game, the dense roguelike and poker elements of the game means that combinatorics and probability will be a powerful tool to be used.

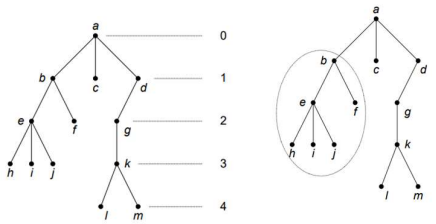
E. Decision Tree

A tree is an undirected graph that is connected and does not contain any kind of circuits. According to [9], a tree follows these following qualities:

- Every pair of vertices is linked through a single path.
- A tree is connected and contains V-1 edges where V is the number of vertices.
- A tree does not contain any circuit and addition of one edge will result in one circuit being made.

A tree where one of the vertices is considered as a root and the edges is given direction so it becomes a directed graph is called rooted tree. A rooted tree may contain

- **Child and Parent:** Child is the receiving end of an edge while the parent is the giving end. As seen in (a), a is a parent while b, c, and d is its child.
- **Path:** A collection of vertices that will form a path from one vertex to the other. In (a), the path from a to k is a, d, g, k.
- **Subtree:** A subtree is a part of the tree that contains it own roots. As seen in (b), the circled part is a subtree.
- **Degree:** The degree of a vertex in a tree is the number of children it has. For example, the degree of a is 3.
- **Leaf:** A vertex with degree 0.
- **Level:** The depth of a vertex.
- **Depth:** The maximum level of a tree.



(a) (b)

FIGURE 3
EXAMPLE OF A TREE

A decision tree is a rooted tree where each nodes is representing a state and each branch representing a decision or operation [10]. A decision tree is used to find the shortest path to a final decision of a problem that is based in statistical data. After creating a decision tree, one can use search algorithm such as depth-first search (DFS) or breadth-first search (BFS) to find the path to a certain decision leaf. The use of decision tree will be the basis of this paper optimization of a *Balatro* round.

III. ANALYSIS

A. Problem Statement

While being a fun and relaxing game, *Balatro* is capable of being played as a competitive game by carefully thinking over decision to maximize the output chips that a hand can give. In this paper, we will try to maximize this output by using decision tree models while taking notice of current player hand, remaining card in the deck, Joker cards, consumable cards and other means of increasing scores.

B. Nodes

We first need to take notice of several things that may affect the final chips that the player gains per round. Each node in the decision tree will represent:

- **Current chips:** The current accumulated chips from the previous hand played if any.
- **Current cards held in hand:** A set of current held cards.
- **Playable Hand:** playable hand that can be made from the current cards held in hand.
- **Remaining hands:** The number of remaining hands to be played, not to be mistaken with poker hands. This in combination with remaining discards will connotate the depth of the tree
- **Remaining discards:** The number of discards not used yet. This in combination with remaining hands will connotate the depth of the tree.
- **Remaining playable cards:** A set of remaining cards in the playable deck.
- **Active Jokers:** Owned joker cards that may increase the final chips of a hand played.
- **Current held consumables:** Held tarot, spectral, or planet card.
- **Poker hand statistic:** The number of times the player has played a certain hand type throughout the whole game.
- **Optimal Score Threshold:** The optimal chips needed to get the blind chips at the final hand.

However, in practice, it is not required for the node to contain all the above parameters since some of them will require foresight to fill.

C. Branches

In this decision tree, the branches represent actions done that may change the state of the child node. By incorporating weighted branch with probability, players may find which combination is the most likely to appear. There are three types of action a player can take.

FIGURE 4
EXAMPLE ROUND OF A BALATRO RUN

The first type is Discards. The child of a discard branch is all the possible card combination given the remaining card in the deck and the amount of card discarded. However, in a big sample like a deck of cards, it will be no short of a herculean task to list out all possible combinations. Therefore, rather than listing out all combinations, the player should just use probability to find the best amount of card to discard and type its probability in the branch. For example, in Fig. 4, we can see that I have one 9, two 8, one 6, one 5, two 3, and one 2. If I chose to discard one card, there will be 32 outcomes that can happen which are I got one of the remaining 32 cards still in the deck. As seen in Fig. 4, my strongest hand in this current node is a two pair with the total score of

$$(20 + 8 + 8 + 3 + 3) \times 2 = 84 \text{ chips} \quad (4)$$

As seen in the top left, 84 chips are not nearly enough to reach the cap of 450 chips for the blind. Therefore, if I use one of my discards, I will have a chance to create a better hand. For example, I can aim to create a full house if I just get one 3 card or 8 card. If we analyze the result of the discards, we can gain this data using combination like in (2), rule of sum, intersection, and complements.

TABLE I
TABLE OF PROBABILITIES FOR GETTING ONE OR MORE "8" CARDS OR ONE OR MORE "3" CARDS

Discards used	Probability of 8	Probability of 3	Combined probability
1	1/16	1/16	1/8
2	$1 - \frac{435}{496} = \frac{61}{496}$	$\frac{61}{496}$	$\frac{122}{496} - \frac{4}{496} = \frac{118}{496}$
3	$\frac{900}{4960}$	$\frac{900}{4960}$	$\frac{1792}{4960}$
4	$\frac{8555}{35,960}$	$\frac{8555}{35,960}$	$\frac{17110}{35,960}$
5	$\frac{58870}{201376}$	$\frac{58870}{201376}$	$\frac{117740}{201376}$

As we can see in Table. I, the higher the number of discards

used, the higher the chance of gaining either an 8 or a 3. We can then include the biggest probability into the decision tree in the discard branch. For example, using the Table. I as data, we can conclude that using five cards to discard is the most promising to land a full house, therefore the player should include in their tree a branch for discard which will contain the probability. We can also count the probability of creating another type of hand in to the tree so that we can better conclude whether to discard or play hands.

The next type of action is the Play hand. The play hand branch, similar to its counterpart Discard branch, is used to remove card while simultaneously increasing the current chip. In this branch, the joker effect will come into play. Using the current node's data, we can create a specific threshold for chips to indicate whether a player should discard or play their hands. The threshold should be

$$\frac{Blind - \text{Current Chips}}{Remaining\ Hands} \quad (5)$$

With this threshold, it will be guaranteed that the player will at least get the amount of the blind so they can continue to the next blind. Using this threshold is also very useful to pick which branch you want to go since if a play hand branch does not contain enough chips to surpass the threshold, it is not recommended to continue through the branch.

Using threshold is not the only method to choose whether to discard or play hands. We can also combine the probability of getting a poker hand type with its value and the next node threshold to decide whether to switch card using discards or play hands. For example, we can count the resulting full house chips if we discard as

$$(40 + 8 + 8 + 8 + 3 + 3) \times 4 = 280 \text{ chips} \quad (6)$$

If we count the next node threshold if we play a hand, we can conclude that playing a hand may be more beneficial than just using discards. If we play the remaining card in the hand that is not the 8s and 3s, we can get 5+9 = 14 chips. This means that the next node Optimal score threshold will be

$$\frac{450-}{3} = 146 \text{ chips} \quad (7)$$

Since the full house will result in 280 chips, the chips will be more than enough to fulfil the optimal score threshold and might be more beneficial than using a discard.

The last type of branch type is the consumable use. This branch type is the most risk-free branch type out of all the other branch types. Consumables in *Balatro* is divided into three separate categories. The Tarot cards, the Planet cards, and the Spectral cards. An example of usage of consumables branch is when you are just short of a card of a certain rank to create a four of a kind. Using the tarot card "death", you can convert one card in your hand in to the card you need to complete the four of a kind. While its usage is limited, the consumable impact on the game is permanent which is something that can be taken note of.

FIGURE 5

EXAMPLE ROUND OF BALATRO WITH "WILY JOKER"

A joker card has the capability to change which decision to choose by increasing the result chips of a specific poker hand. For example, as seen in Fig. 5, in this round I obtained the "Wily Joker" card which increases the base chip of a hand if they contain a three of a kind. In this scenario, there are a couple decisions I could make. One is to play a straight to gain

$$(30 + 6 + 7 + 8 + 9 + 10) \times 4 = 280 \text{ chips} \quad (8)$$

However, I can also discard or play irrelevant hand to create a three of a kind of 9s or 10s. I can input the outcome I want (gain 280 chips with straight or create a full house with at least one 10 card or 9 card) Into the decision tree and do an analysis of the tree to find the most rewarding path. The current tree will look like Fig. 6 in Appendix A where the most optimal path to take is to discard and hope for one 9 or 10. The reason being, if I manage to do it, I will get the highest score.

FIGURE 7

EXAMPLE LEAF OF THE DECISION TREE IN A BALATRO ROUND

As seen in Fig. 7, The result is I got a full house by discarding and I can surpass the current blind of 600 chips with resulting chips from the full house of

$$(40 + 100 + 10 + 10 + 10 + 9 + 9) \times 4 = 752 \text{ chips} \quad (9)$$

D. Pipeline

To efficiently use decision tree to optimize a round of a *Balatro* run. It is recommended for players to do the following:

1. See current card in hand and make an initial root node.
2. Analyze current hand to find possible hand to make.
3. Create children for said root nodes with a discard branch and a play hand branch which are relevant to the possible hands.
4. Continue creating children for each subsequent children until the child node is too abstract (too random to analyze, no more relevant child).
5. Analyze the tree to find the most optimal route. Find tell such as higher outcome but lower hand and discard use.

6. Commit to a path and redo the process all-over again until the blind is reached.
7. Make sure to include Jokers and probabilities to improve analyzation parameters.

IV. Conclusion

Balatro, the award-winning indie game that was made by one person, has been a hot topic in the gaming community for quite some times now do to its inventive integration of poker, deckbuilders, and roguelike format. Due to its deckbuilding and roguelike elements, mathematical concepts such as probability, combinatorics, and decision tree can be implemented into navigating the game so a player can have the most optimal choice in a round.

While it is unconventional, the usage of decision tree can be helpful in deciding whether to do an action in a round of *Balatro*. By creating nodes of the tree as game state and the branches as action such as play hand, discard, and use consumables, a player can analyze a tree and choose the best path to traverse so that they can get the most optimized round possible at that certain blind.

V. Appendix A

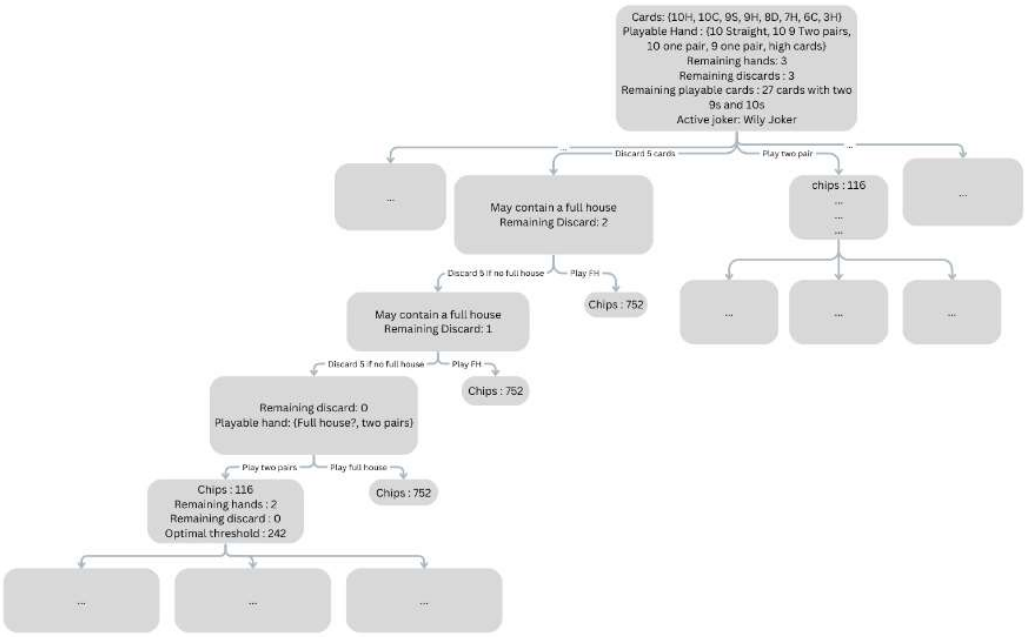


FIGURE 6
EXAMPLE DECISION TREE FOR A ROUND OF BALATRO

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Bandung, 6 January 2025

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