**Portfolio Project**

Alec Meyer

Colorado State University Global Campus

CSC510

Dr. Luis Gonzalez

4/6/2025

**Problem Statement**

Magic: The Gathering is a complex card game requiring in-depth knowledge and experience to make optimal decisions. At the start of each Magic: The Gathering game, each player draws seven cards and then makes the decision to keep or mulligan. If a player decides to mulligan, they shuffle their seven cards back into their deck and draw seven new ones, then put one card from their hand on the bottom for each time they have mulliganed. The decision to keep or mulligan the opening hand of cards is critical and will determine the game's trajectory. In some opening hands, it can be obvious whether to keep or mulligan; for example, if your hand has too many of one resource, such as lands, it can be easy to make the decision, but in other cases, it can be a very complex decision, especially for novice players. This project aims to help a user determine whether they should keep or mulligan their opening hand of seven cards. This project will take the input of seven cards and then predict keep or mulligan.

**Methodology**

There are over 27,000 unique Magic: The Gathering cards with their mechanics. Building a model that could recognize patterns between every card in the game would require an immense amount of data. A standard Magic: The Gathering deck has 60 cards, and you can only have four duplicates of a card. The deck used as a reference for this project is called "Izzet Delver" and has around 23 unique cards—the nCr of 23 unique cards and choosing seven results in over 1.5 million combinations (*Izzet Delver Deck*, n.d.). Unfortunately, there is not a large-scale set of opening hand data for Magic: The Gathering, so a different approach is required to help assist a model with limited data.

Each card in Magic: The Gathering can be grouped into functional subclasses. Without going too in-depth into the fundamentals and rules of the game, the sample" Izzet Delver" deck has five functional subclasses: Lands, Card Advantage, Interaction, Creatures, and Ramp. Each card in the deck can be mapped to its basic functionality, which results in an nCr of 5 choose 7, which results in only 330 possible combinations. "Izzet Delver" is a fundamental deck, which is why only five sub-functions are present; a more complex deck could have more functional areas. In the case of using five sub-functions, a sample hand would look like: *["Land", "Land", "Card Advantage", "Interaction", "Creature", "Creature", "Ramp"]*

The data for this project was gathered from friends and fellow Magic: The Gathering players who provided me with data on whether a prompted hand was a "Keep" or a "Mulligan." One hundred sixty unique samples were collected and used for training.

**Tools, Libraries, and APIs**

* **Python 3:** Language used for simple artificial intelligence and machine learning scripting.
* **Python Interactive Notebooks allows the** execution of specific blocks of code while preserving variables defined in other code blocks in memory.
* **Numpy:** used for advanced array support and simple matrix arithmetic.
* **Pandas:** Pandas is used to import the train and test data using the DataFrame format.
* **Matplotlib:** Displaying feature importance and confusion matrices is done through Matplotlib.
* **Sklearn:** Scikit-Learn leverages other machine learning models, such as Random Forest Classification and Logistic Regression. It also splits the input data into a training and testing set.

**Classification**

The use case for this project is determining whether an opening hand of Magic: The Gathering cards is keepable or requires a mulligan. This means that the problem space has two possible outputs; "Keep" or "Mulligan." Therefore, this use case is treated as a binary classification problem. Three methods are used for binary classification: Artificial Neural Network, Random Forest, and Logistic Regression. Each of these classification methods has its strengths and weaknesses. Logistic regression is a simple and lightweight model that provides insights into feature selection (through L1 Regularization or LASSO) (Kanade, 2022). Random forests can identify feature importance and require very few assumptions about the input data (Singh, 2024). Artificial Neural Networks are extremely powerful and can identify complex patterns and relationships between features that other classification methods cannot. The neural network for this project has a single hidden layer of three neurons as it is recommended to have a number of neurons between the size of the input and output layers to prevent overfitting (Krishnan, 2021). These three methods are trained and tested on the same data set, and the same training and test are split, and their results will be compared. Logistic regression and the Artificial Neural Network output a value between 0 and 1, where 0 is a mulligan, and 1 is a keep; if a prediction is below 0.5, it will be considered a mulligan. Otherwise, it will be considered a keep. On the other hand, Random Forest, a collection of decision trees, will provide an output of 0 or 1, where 0 is a mulligan and 1 is a keep.

**Expert Systems**

Magic: The Gathering is a game that requires immense domain knowledge to fully understand, which is where an expert system, such as a decision support system (DSS) can be a potent tool for generating heuristics about in-game decisions. However, building an expert system to determine the quality of an opening hand is a highly complex task and requires many paths to account for every hand combination. So, the purpose of the expert system in this use case is to help reinforce or persuade the decisions made by the above-mentioned machine learning models. By adding basic rules such as, "A hand must have at least one land" or "A hand cannot have seven lands," the DSS assists the machine learning models when they may have an incorrect prediction or a prediction that lays around 50% (0.5) uncertainty. Decision support systems are powerful tools, especially in Magic: The Gathering, where mechanics and functions are well-defined and allow for more informed decision making (Gillis, 2024).

**Search Methods**

Search methods and intelligent search methods are very powerful aspects of machine learning and artificial intelligence. Common use cases for search methods are determining the shortest path between two points in a graph or determining the optimal set of moves to achieve a predetermined goal state. Unfortunately, for the use case of determining the quality of an opening hand in Magic: The Gathering, there is no use for search or intelligent search methods. Search methods for machine learning applications require a state space with nodes for each state and actions connecting them as edges (Subramaniam, 2025). For this use case, there is not a defined initial and goal state that the algorithm is trying to satisfy; it is a classification problem through and through. A potential use for a search method could be trying to find the minimal number of card draws required to achieve a desired opening.

**Results**

**Classification Results**

The results shown in **Figure 1** were reported using a confusion matrix with a test size of 48 samples. The top left and bottom right cells of the matrix represent true negative and true positive predictions, while the other two cells are incorrect predictions. Figure 1 also shows the accuracy below each matrix, which is calculated by summing the correct predictions and dividing them by the total number of test samples. The model with the highest accuracy was an artificial neural network with the assistance of a decision support system, which resulted in an accuracy of 83.33%

**Figure 1**

| **Logistic Regression**    Accuracy: *72.92%* | **Random Forest**    Accuracy: *81.25%* |
| --- | --- |
| **Artificial Neural Network (No DSS):**    Accuracy: *79.17%* | **Artificial Neural Network (With DSS):**    Accuracy: *83.33%* |

**Representing Knowledge**

This project represents knowledge by being able to identify patterns and reason through the complex decision of whether to keep or mulligan a hand of Magic: The Gathering cards. The Random Forest Classifier was able to report the importance of each feature, which shows that the model was able to build a knowledge base that concluded that “Lands” were the most important feature right after “Creatures.” The Artificial Neural Network could represent its knowledge more abstractly as the weights of its hidden layer neurons. While it is tough to interpret the weights set for each node, they represent the ability of the model to learn the patterns and relationships required for prediction.

**Conclusion**

Overall, determining the quality of an opening hand of Magic: The Gathering cards was not trivial. Leveraging multiple classification models such as random forest, logistic regression, and an artificial neural network, I could predict whether a hand is a keep or a mulligan with around 83% accuracy. While this prediction accuracy may not be impressive to a Magic: The Gathering professional, a novice player can use this system to assist with their opening-hand decisions.

**References**

Gillis, A. S. (2024, September 25). *What is a decision support system (DSS)?* Search CIO. https://www.techtarget.com/searchcio/definition/decision-support-system

*Izzet Delver Deck*. (n.d.). MTGGoldfish. https://www.mtggoldfish.com/deck/7019388#paper

Kanade, V. (2025, March 10). *Everything you need to know about logistic regression*. Spiceworks Inc. https://www.spiceworks.com/tech/artificial-intelligence/articles/what-is-logistic-regression/

Krishnan, S. (2022, August 6). How to determine the number of layers and neurons in the hidden layer? | by Sandhya Krishnan | Geek Culture | Medium | Geek Culture. *Medium*. https://medium.com/geekculture/introduction-to-neural-network-2f8b8221fbd3

Singh, A. (2024, November 11). *Random Forest algorithm in machine learning*. Applied AI Blog. https://www.appliedaicourse.com/blog/random-forest-algorithm-in-machine-learning/

Subramaniam, A. (2025, March 25). AI Search Algorithms: Uninformed Vs Informed Search Explained with Real World Examples. *Medium*. https://medium.com/ai-simplified-in-plain-english/ai-search-algorithms-uninformed-vs-informed-search-explained-with-real-world-examples-1e73ea9d5905