Pugilistic Prognosticating: Machine Learning Approaches in Predicting the Outcome of a Mixed Martial Arts Bout

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Introduction

The aim of this project is to develop a machine-learning based approach to predict the outcome of a mixed martial arts (MMA) bout using retrospective data. The sports gambling industry is an international juggernaut, with an estimated total value of approximately $100bn ("Global Sports Betting Market Size 12. 4% Annual Growth," n.d.). Effectively forecasting the outcomes of sporting events is of considerable interest to gaming stakeholders, as doing so allows them to set an enticing odds line and manage their risk effectively. Of course, such a model would also be of interest to gamblers, especially to the extent that its predictions differ from lines set by sportsbooks (Holmes et al., 2022). Regardless, a predictive model for MMA bouts allows interest parties to effectively engage in the MMA gambling markets.

Mixed martial arts is a combat sport, comparable to boxing or kickboxing, albeit with a relatively limited ruleset that notably allows for more involved grappling exchanges, as well as chokeholds and jointlocks. For details regarding the rules, regulations, and terminology of MMA, refer to the Associated Boxing Commission's Unified Rules statement (*Unified Rules – Association of Boxing Commissions*, n.d.). Its viewership reach is estimated around 260 million, and MMA gambling is estimated to be 1% of total sport gambling revenue (Post, 2020). Given the market size of MMA gambling, there is a strong profit motive in developing a predictive algorithm that provides a betting edge.

Methods

Description of Data

These data are drawn from a publicly available dataset on Kaggle. They were compiled by (CITE). The complete data set spans from 1995-2020, and includes bouts contested within the

Ultimate Fighting Championship™ (UFC), the premier international MMA promotion, both in terms of valuation (est. 4bn market capitalization), and talent roster ("Current MMA Rankings," n.d.).

These data include 13322 observations of 530 variables. Only bouts contested since 2010 will be considered. This limits the data to a subset of 10834 observations. Variables are too numerous to exhaustively describe within the main text of this manuscript, but include sufficient data to identify the contest (names of both fighters, date), fighter descriptives (age, height, reach), the result of the contest, and numerous summary statistics of actions taken during the fight (strikes attempted and landed, takedowns attempted and landed, submissions attempted and landed), and similar statistics of each fighter from prior bouts.

As the goal of this endeavor is to accurately predict the outcome of the match using only a priori data, only variables using data accumulated prior to the match will be considered. This will likely limit the predictive accuracy of the model, as statistics of the match itself will be highly deterministic—though not completely so--of the result of the match (by analogy, including the score differential of a game such as basketball or soccer would be perfectly predictive of the outcome, but engender a useless predictive model).

Missingness was assessed to be minimal. Recent pre-competition data was the most missing at approximately 30%. In a sport with a poorly recorded regional competition scene and high turnover, such missingness is expected.

Included Variables

The variables being considered will include all data retrospective at the time of the event. Within the dataset, these are variables with the prefix "precomp", and include averages of

attempted and completed strikes (of various type), takedowns, submissions, and ground control. Similar statistics of the fighters most recent bout (with the prefix "recent") will also be considered. Age, reach, and the differentials of each between fighters will also be included.

Generated Variables

As well, several new variables have been generated from these data. Notably, these include a value based on a cluster analysis from the above variables, as well as a skill rating based on the elo rating method. It applies, in effect, a number that allows for ordering of players by skill.

The elo method is a well-understood methodology for rating relative skill in zero-sum games. Its use is perhaps most associated with chess, although it sees use in numerous other sports. By examining past wins and losses within a social network, a single numeric skill rating can be generated for a competitor that will allow for projecting the probability of victory or defeat. While elo ratings in other sports have been demonstrated to be highly predictive of outcome (Angelini et al., 2022; Hvattum & Arntzen, 2010), their application in MMA is more contentious, due to the nature of the sport, which is considered both more stochastic and based on the interaction of the stylistic approach of the respective competitors. The distribution is show below. The distribution approaches normality with some skewness likely due to turnover at the lower levels of the promotion. Only wins and losses prior to the competition were considered in generating this rating.

Figure 1. Elo rating distribution
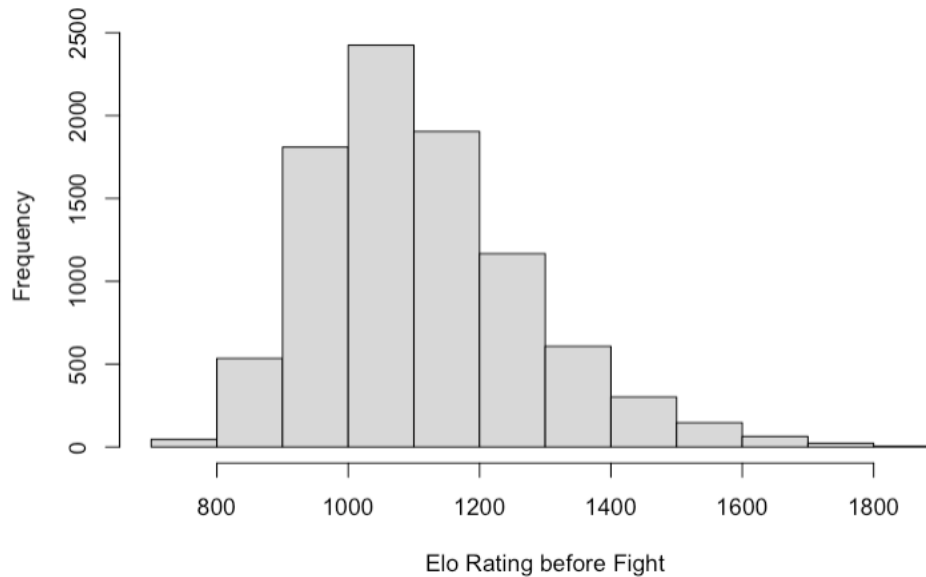
Best summarizing this concern is the common aphorism "styles make fights." By generating a variable that includes style of both competitors, the concern should be addressed. To do so, a cluster analysis of each fighter was conducted, then the particular style by style matchup was encoded.

The cluster analysis revealed class membership by actions taken in prior fights. Visual inspection of plots for average silhouette and elbow methods of determining optimal clusters suggest 2-3 clusters. This analysis uses 3 clusters. However, a more theoretically derived approach would likely be a more optimal approach. Limiting the number of variables to those salient to determining "style" may improve validity. The distribution of clusters is shown below (Figure 1). A dummy variable indicating the style matchup (cluster membership for each combatant) was generated. Thus, there are a potential 9 variables to indicate matchup.

Figure 2. Count by Cluster Membership
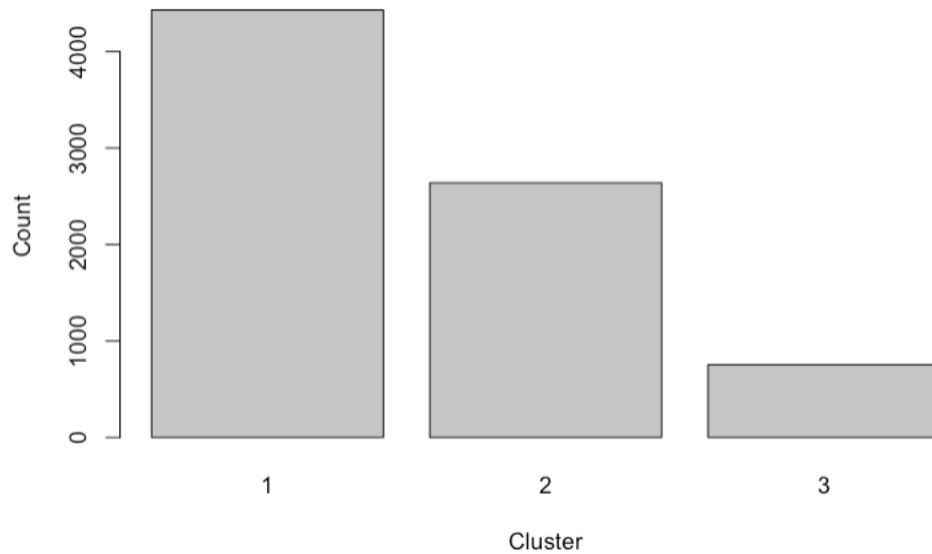
It is hypothesized that these two bespoke variables, as well as age differential, will be most salient.

Description of the Models

Three predictive models were fit to these data: a non-regularized logistic regression model, a ridge regression model, and a gradient boosting tree model. All analyses were conducted in R (R Core Team, 2022). Packages used in these analyses include here, eloRating, cluster, factoextra, tidyverse, finalfit, caret, and recipes (Greenwell et al., 2022; Harrison et al., 2022; Kassambara & Mundt, 2020; Kuhn, 2022; Kuhn & Wickham, 2022; Maechler et al., 2022; Neumann & Kulik, 2020; Thiele & Hirschfeld, 2021; Wickham et al., 2019).

Non-regularized Logistic Model

Logistic regression models were used since the outcome of a fight is, for all intents and purposes, a dichotomous variable (win vs loss). This model uses Maximum Likelihood estimation to estimate parameters for predictor variables corresponding to probability of

classification. Logistic regression does not make many key assumptions associated with ordinary least squares algorithms: residuals do not need to be normally distributed, nor is homoscedasticity required. This model does not have any hyperparameters to optimize. Model performance will be assessed using area-under-curve (AUC), accuracy (ACC), true positive rate (TPR), true negative rate (TNR), and precision (PRE).

Ridge Regression Model

This model will function in a similar manner to the previous model but is regularized to avoid overfitting our data. While n>>p, and we therefore expect minimal incremental improvement over the non-regularized logistic regression model, we will empirically test this hypothesis. While a lasso model would allow for feature selection, as noted above, we envision this as an exploratory work, with feature selection primarily an a priori process. Ridge regression, being more effective in handling correlated features, seems a preferable model, as many of these variables are expected to correlate (Boehmke & Greenwell, 2019). This model optimizes a single hyperparameter, lambda (λ), the penalty term for this model. Model performance will be assessed using area-under-curve (AUC), accuracy (ACC), true positive rate (TPR), true negative rate (TNR), and precision (PRE).

Gradient Boosting Tree Model

A gradient boosting machine (GBM) is also tested, primarily due to their success in predictive competitions (Boehmke & Greenwell, 2019), and the role of this paper is to develop and compare successful predictive models. Gradient boosted machines iterate through decision tree models and improve on the previous model using that models residuals as feedback.

Numerous hyper-parameters will be tested: number of trees (total trees in the sequence), learning

rate (the contribution of each tree on the final outcome), tree depth (longest path from root to

terminal node), and minimum number of observations in terminal nodes.

Model performance will be assessed using area-under-curve (AUC), accuracy (ACC), true

positive rate (TPR), true negative rate (TNR), and precision (PRE).


Results

Model Fits

    See table 1 for a comparison of model fit. As hypothesized, regularization does not

significantly improve on the non-regularized model. This is likely due to the high number of

observations relative to predictors. However, the GBM approach does appear to have added

incremental value despite the added computational complexity. The ROC curve for the GBM

model is shown below (Figure 3).

Table 1. Model Comparison

Model	AUC	ACC	TPR	TNR	PRE
Logistic Regression	0.8229	0.7425	0.7483	0.7370	0.7322
Logistic Regression with Ridge Penalty	0.8226	0.7425	0.7500	0.7354	0.7315
Gradient Boosted Tree	0.8294	0.7616	0.7618	0.7614	0.7542

*Figure 3. ROC Curve for the Boosted Gradient Tree Model*

ROC curve
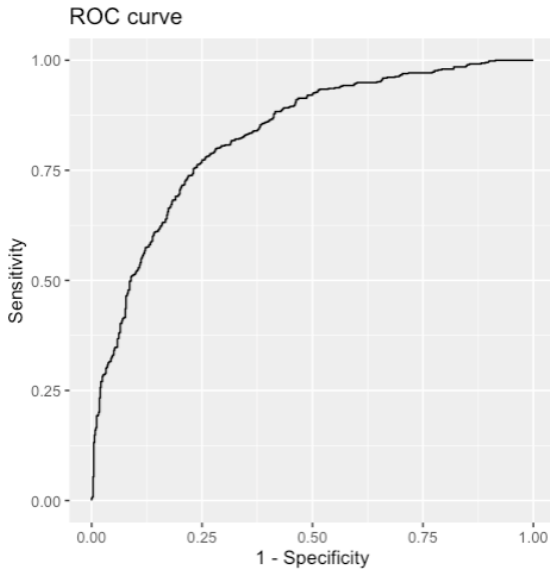
Given that the GMB model dominates across all metrics employed, this model would ultimately be selected moving forward. The cutoff this model uses is .491, approximately .5. Additional cutoff points were not considered, as the goal for this is to predict wins or losses for gambling purposes, and there is no real-world trade-off between the two, so long as the prediction ultimately matches the result.

Discussion

Despite the common perception that MMA is a chaotic and unpredictable sport, this preliminary foray into developing a predictive algorithm is promising. Exploration of important variables in predicting outcome is surprising. Elo difference did not appear to be particularly influential. It is notable that defensive statistics were important, despite defense not being scored in a fight. Average submission attempts and defense are also important, which is also surprising, as submissions are by far the least common manner of finishing a fight.

Figure 4. Variables in order of importance
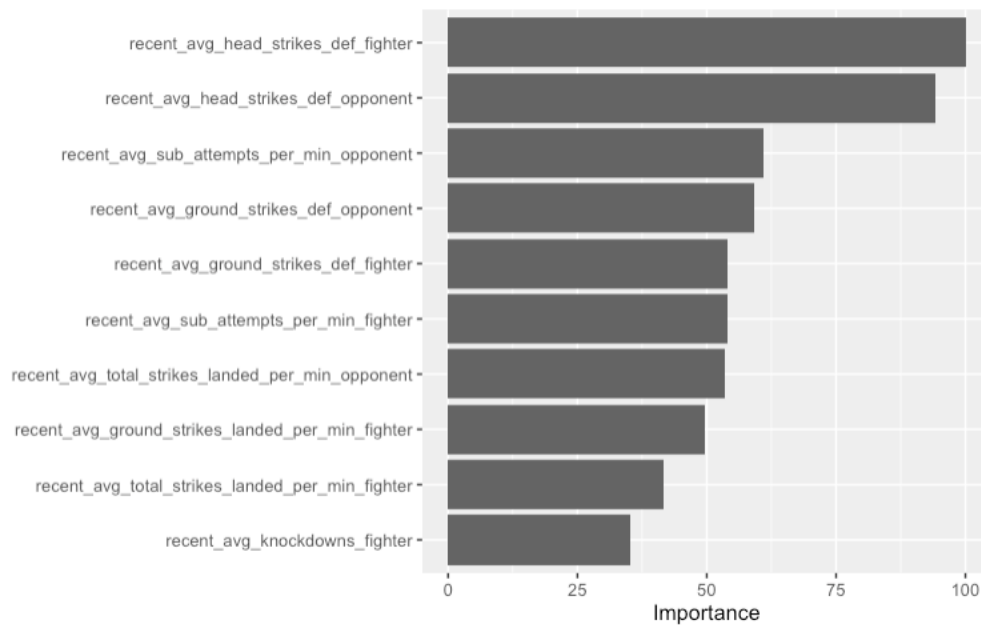
The GBM model dominated the other models tested. This model is computationally far

more expensive than the other models (taking around twelve hours to run), with little incremental

predictive advantage over the other two models. However, this added computational time is of

little concern for this application, as fights are announced well in advance of the competition,

giving the model sufficient time to generate predictions. However, the regularized model was, on

a few metrics, worse than the non-regularized model, although they are remarkably close and

these findings may shift somewhat depending on how additional simulations fare. It is unclear as

to the applicability of these findings. For the individual gambler, further analysis needs to be

done to compare these predictions against historic odds. To the extent that the model is correct

when in disagreement with official odds lines, the model may prove to be profitable. Of course,

from the perspective of the sportsbook, the model would need to outperform current models. As

this is an active area of scholarship (Hitkul et al., 2019; Holmes et al., 2022; Sharma & Uttam,

2021), the comparison of this model to extant (non-proprietary) models is an empirical question the deserves exploration. Further, enticing bettors is not inherently a process of accurately predicting a fight, although it remains helpful. It would also be of interest to compare the findings of this model across similar combat sports. Given the more restricted ruleset of kickboxing or boxing, it would be of interest whether these sports are more accurately predicted with a similar approach. It would also be of interest to those engaged in those sports whether the most predictive variables across sports share a similar rank order. If so, it would suggest both an optimal training approach both within and between sports. Thus, findings contained herein may be of interest to individual gamblers, gambling market makers, athletes, trainers, and others involved in mixed martial arts and combat sports more broadly.

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