

Data Mining in Sports

Implementation and analysis of machine learning prediction models to find potential influential factors in results of matches in the Australian Football League

Bachelor Thesis

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Declaration of honour

I declare on my word of honour that I have written this Bachelor Thesis on my own and that I have not used any sources or resources other than stated and that I have marked those passages and/or ideas that were either verbally or textually extracted from sources. This also applies to drawings, sketches, graphic representations as well as to sources from the internet. The Bachelor Thesis has not been submitted in this or similar form for assessment at any other domestic or foreign post-secondary educational institution and has not been published elsewhere. The present Bachelor Thesis complies with the version submitted electronically.

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Abstract

Despite the large amounts of data produced by the sporting industry every year, there has been relatively little crossover between academic data science and professional sports. On the other hand, Data Mining techniques such as Machine Learning, Neural Networks and Association Methods, have seen rapid increases in their complexity and use over a wide variety of fields and disciplines. This paper aims to address this issue of a lack of data science applications in sports, with regards to the Australian Football League (AFL), by applying Data Mining techniques to improve upon already utilised data analysis techniques present in modern professional sports. In this paper statistics and results from the previous 10 AFL seasons will be assessed to identify key features and possible trends and use them to create more explainable white box prediction models. This will help not only sports professionals and data scientists but also casual viewers to understand the finer statistical details behind sports.

Keywords: Data Analytics, Machine Learning, Sports Prediction, Neural Network

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Introduction

This paper will apply Data Mining techniques on Australian Rules Football data in an attempt to identify any trends that may occur in individual seasons and then further apply this information into a Neural Network to create a prediction model for subsequent games.

The field of Data Mining has seen a rapid increase as we enter the digital age dominated digital information also commonly known as data. While many believe data mining to simply be the extraction of data it is actually a much broader topic. Data extraction is only the first step in data mining, the goal of data mining is to extract 'previously unknown' and unseen patterns from this data [1], much of which would be impossible to uncover without the help of computer systems. Data Mining is most commonly applied in commercial business. There it can be used to 'help identify and predict individual and aggregate behaviour' [2], or more commonly to predict how customers will consume/buy products and their buying habits so that they can more efficiently market their products in specific situations. Data Mining in sports however is much less advanced, despite massive amounts of data being produced by the sporting industry, it is mainly kept behind closed doors, with much of it focusing on player and team performance.

Although it is a quite unrepresented research area, there have been some recent attempts at data mining in sports, which have been used in a variety of areas including, classification [3], action recognition [4] and image recognition [5]. While data mining has also been used to aid in the creation of sports prediction models [6][7][8], none of these models aim to identify trends within the sports apply these as part of their prediction model.

An issue with many prediction models is the lack of transparency in their decision making, a key concept of this issue is the idea of black box and white box models. Black Box models are in most cases more accurate than white box model but much more difficult to interpret, the internal decisions and processes of the algorithms are much more difficult to extract, resulting in more difficulty when wanting to view how they came to certain decisions. In this paper a combination of exploratory data analysis, data mining and feature extractions will be used in an attempt to overcome this lack of interpretability. Although the final prediction model will still be a black box model, the aforementioned methods will be utilised to extract meaningful interpretable information from the data set regarding which features are likely to have the greatest impact on the prediction model.

The final stage of the practical work will be to input the analysed data into a Neural Network to create a prediction model. Neural Networks are computing systems which aim to 'mimic the way that biological neurons signal to one another'[9]. Neural Networks have a multitude of uses in a variety of fields including medical diagnosis by image classification, targeted marketing and financial predictions through behaviour data analysis and financial data processing, natural language processing and time series analysis. The use of neural networks in sports, like data mining, is very limited in the public domain. Unlike data mining the vast majority of neural networks used in sports deal with prediction models and cover a variety of sports codes. The most common applications are in Football (Soccer)[10], American Football [11] [6] and Basketball [7] [12].

In Australian Football, one of the most data rich sports [13], data is used in many ways. In a professional capacity this includes real time analysis of players and the modelling of games based on Geographical Positioning System (GPS). There also exist some prediction models created in both professional and non-professional settings, however in most cases the full data sets are only available in the professional environments. Most of the data and analysis models are kept internal and utilised only by clubs and a small group of media companies with rights to the data. As a result many prediction models rely on only a small subset of the collected data that is made available to the general public.

As this paper is discussing Australian Football a basic background should be given to understand some of the terms and structure of the game, as well as to understand the structure of the data set.

1. On match day a team is made up of **22 players**, 18 on the field and 4 reserve players
2. The aim is to score more points than the opponent by kicking the ball through either the **goals**, worth 6 points, or **behinds**, worth 1 point.
3. Each team plays **22 games** per season, each season occurs between March and October in the Australian winter.
4. The finals are contested between the top 8 teams from the regular season, the finals series lasts for **4 weeks**
5. There are currently **18 teams** in the competition.
6. 10 teams are based in Victoria. New South Wales, Queensland, South Australia and Western Australia each have 2 teams in the competition.

This paper aims to explore the impacts of external factors on the outcomes of Australian Football matches and generate interpretable results which can be utilised in further analysis and prediction of matches.

Background

2.0.1 Research Questions

The area of focus of the paper is the implementation and analysis of machine learning models to find potential influential factors in results of matches in the Australian Football League (AFL). From here I have defined the following research questions which will be explored:

Can data mining be used to find key features and patterns and explain results in professional sports?

Can these extracted trends and features be used to create an reliable prediction model?

How can the results be utilised in the sporting industry?

If the model can reliably predict outcomes, how many rounds will the model need before it becomes reliable?

2.0.2 Technical Background

The practical section of the paper will follow a basic flow of a Machine Learning process (ML Process) for a classification problem. Which follows the format of Problem Exploration, Data Engineering, Model Engineering, Deployment and Monitoring. Data and Model engineering will be the main areas of the data flow applied in the practical section.

Classification is a technique in which the model tries to predict the discrete class of a given input data. This is also a supervised problem meaning that the

classes are already known to the model and as such no additional methods will be needed to extract the classes from the data set.

The data engineering phase deals with the acquisition, cleaning and exploration of the data set. Data engineering is a very important part of the ML process, as it is critical to have clean and consistent data for a model to function correctly. Without clean data a model cannot be trained efficiently, the model will be unable to extract any meaningful information from the data.

The data acquisition process can vary between projects. In the simplest cases, a data set can be readily and publicly available, needing only to be downloaded before the cleaning and exploration phases can take place. With more complex or industry specific data sets, the data may already exist but be owned by an institution which measured, converted and stored the data set. In these cases the data is normally available via payments or contracts. In the most complex cases the digital data set does not exist at all and must be gathered from physical real-world data and converted into a digital data set by the members working on the project.

Once the data has been acquired Exploratory Data Analysis (EDA) can be performed. EDA is the initial analysis of the data set, it allows for a basic overview of the characteristics of the data to be investigated and identified. Additionally EDA can allow for the easier detection of anomalies and errors within the data set which can be handled in the data cleaning phase. The main method of EDA is data visualisation, which allows for the entire data set or individual features to be viewed in plots. Scatter Plots and Histograms are the most common to implement and will be utilised in the paper, in the initial analysis. Scatter plots are useful in trend identification as they show the relationship between two variables, which would be impossible to see by just viewing the raw data. Histograms are used to separate quantitative values into an interval scale, these interval groups can be used to identify where distributions lie within the data set. In addition a basic description of the data set will be analysed, pandas dataframes offer functions to describe the contained data in each column, which will be used to view the averages, standard deviation and percentile distributions of each column in the data set.

Data cleaning ensures that the incoming data is able to be read and interpreted properly by the computer model. The important steps are ensuring that missing

values are handled gracefully, either by removing affected rows and columns, or using imputation to replace null values. The data must also be formatted correctly so that it can be read by the model. As the data is being read by a machine this is in most cases a numerical input. In this paper two methods will be used to convert text and categorical inputs to numerical values, integer encoding and one hot encoding. Integer encoding involves converting every unique categorical value to a numerical value and replacing the original value in the data set. The issue with integer encoding is that models can also infer false information from the values, one way this occurs is that the model can assume the categorical values have a specific order that applies to them inferred from the order of the numerically encoded values. The solution to these issues is to use One Hot Encoding, this is when a binary value is included for each categorical value. This separates each value into its own feature that the model will interpret individually.

The final phase of the Data Engineering is the feature engineering process. This is the process of extracting features from the raw data set which can be used by the machine learning model to enable it to understand the data. In the case of tabular data, as is being analysed in the paper, a feature is one column of the data. Feature Engineering generally consists of four processes "Feature creation, transformations, Feature extraction and Feature selection" [14]. Feature creation is the creation of features based on domain knowledge and human input or intuition. Transformations deal more with the adjusting of the data to ensure that all of the data is in a similar scale, this can be done via normalisation which converts every value in the data set to a value usually between 0 and 1, or -1 and 1. Min-max normalisation $x' = (x - min)/(max - min)$, is applied to each feature in the data set and normalises the feature values between 0.0 and 1.0 based on the minimum and maximum value present in each feature. Feature extraction "generates new variables by extracting them from the raw data" [14] via detection algorithms, these are also used to combine and reduce the number of variables used in the final model. This will not be utilised in the paper due to the available data set already containing a limited number of features. The final stage is the feature selection, after all of the features have been established, the features that are most useful for the end model in its predictions are identified, and the remaining irrelevant features which have no impact or a negative impact on the results of the model are filtered out from the data set.

Data set splitting also occurs during the data engineering phase. The data set needs to be split into a training set which will be used to train and tune the model and a testing set which will be completely held out from the training phase and used to analyse the final model on unseen data. Additionally a validation set can be created to aid in the training phase, similar to the testing data set, the validation data is also held out when training the model, but is used to analyse the model during the training and tuning phase. Commonly between 70 percent and 80 percent of the data is used for the training set, with the rest being evenly split between the validation and test sets.

Decision Trees and Random Forests are extremely useful prediction tools, as they can also be used as feature extraction tools. Decision Trees are a "supervised learning method used for classification and regression" [15]. Supervised learning is a machine learning method in which the model is presented with both input and output data so that it can learn the relation between the two and predict the outputs of new input data. The aim of a Decision Tree in classification is to split the data set into subsets called nodes until each node contains only data points of the same class, sometimes called pure leaf nodes. At each node a decision is made by the model which attempts to create a node that is as pure as possible, there are many ways to test for the purity two of the most common are the gini index and entropy. The Gini Index "measures how often a randomly chosen attribute it misclassified", whereas Entropy "measures the impurity of the sample values" [16].

$$GiniIndex = 1 - \sum_j p_j^2 \quad (2.1)$$

$$Entropy = - \sum_j p_j \cdot \log_2 p_j \quad (2.2)$$

Both methods are quite similar and have the same aim to minimise the function, have a value as close to 0 as possible. Where Decision Trees become useful in feature engineering is they store the decisions they made and from this can later compute which features had the greatest overall impact in the model. While Decision Trees are useful, they do tend to overfit to the training input data, they become very good at predicting the training data but do not perform as well when introduced to new unseen input data. There are multiple ways to penalise a decision tree, to stop it from over fitting to the training data. Setting a depth level will ensure that the tree will only make a predefined number of splits before stopping. If this is not set the tree will continue to grow until every leaf node is pure, meaning the

splits will be too specific to the input data. With a limited number of splits only the more general decisions will be found, which should then be able to explain new unknown data.

A minimum node size can also be set, this stopping criteria will stop the model from splitting a node further once the subset of data in the node reaches a minimum size. A larger minimum node size will result in a smaller tree being made and as such will prevent the model from overfitting to the training data.

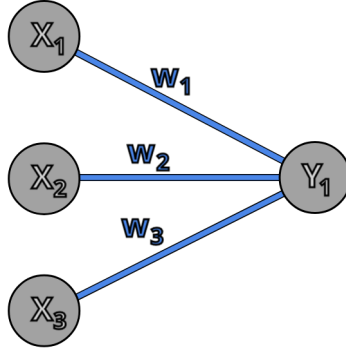
It is also important not to set the stopping criteria too far in the opposite direction and reducing the complexity too much. This would result in the model underfitting and not being able ascertain any valuable information from the data.

Random Forest is an extension of Decision Tree methods that utilises multiple Decision Trees to reach a prediction. Random Forests consist of a collection of Decision Trees that are each trained on a different random subset of the original data set. A random forest has multiple hyper parameters that must be set before training, these include node size, number of trees and number of features to train on. The Random Forest model will create the specified number of trees and then for each tree it will select the random selection of the data set, and then it will randomly select the features based on the number of features defined in the hyper parameters. All of the trees will then be trained on their individual data sets and the results of all the trees will be used to decide on the final result and the most important features present in the data.

For many ML projects using Decision Trees or Random Forests will cover both the feature engineering and the Model Engineering phases. Other models can still be built in the model engineering phase, with the Decision Trees acting as not only a feature engineering tool but also a comparison tool for the final model. In this paper a more complex neural network will be built to further analyse the data in the model engineering phase.

Neural Networks are computer systems designed to replicate the neuron systems in biological brains. They consist of a collection of nodes, also called perceptrons, organised in layers that mimic the way that biological neurons communicate. There are three distinct types of layers in Neural Networks, each contains one input layer, multiple hidden layers and one output layer. All of the nodes are interconnected between layers. Each node takes the input data, either from previous layers or from the input data, and analyses it in a fashion similar to multiple lin-

Figure 2.1: Basic Neural Network Formula



$$Y_1 = \text{Activation}(W_1 * X_1 + W_2 * X_2 + W_3 * X_3) \quad [17]$$

ear regression. The formula for a Neural Network perceptron is shown in figure 2.1. Once the inputs have been computed by the formula the results are passed through an activation function which decides whether the neuron is important and if it should be activated or not. The activation functions also remove the linearity from a neural network. As the basic formula of the neural network follows the linear regression formula, the outputs would also be linear. By using the activation functions to add non linearity to the outputs it allows the Neural networks to find more complex representations of the input data.

$$\text{Linear Regression} : y = b_0 + b_1 * x_1 \quad (2.3)$$

$$\text{Multiple Linear Regression} : y = b_0 + b_1 * x_1 + b_2 * x_2 + \dots + b_n * x_n \quad (2.4)$$

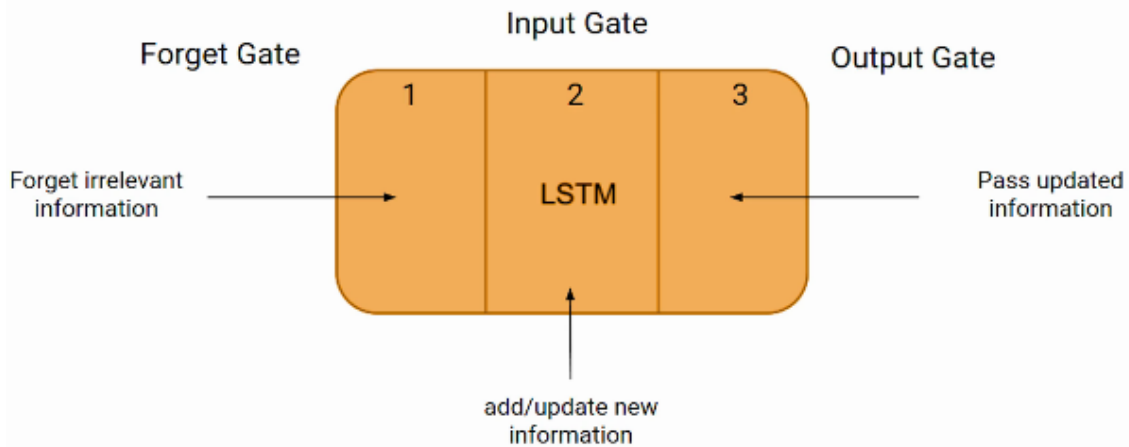
There are two commonly used activation functions in neural networks, sigmoid and tanh. Both functions are quite similar in that they limit the input to within a certain range, the sigmoid function returns a value in range of 0 and 1 whereas tanh returns a value in range of -1 and 1. [18].

$$\text{Sigmoid} : s(x) = \frac{1}{1 + e^{-x}} \quad (2.5)$$

$$\text{Tanh} : \tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}} = 2s(2x) - 1 \quad (2.6)$$

Traditional Neural Networks also face an issue of handling sequential data, which is partly solved with Recurrent Neural Networks (RNN). RNN add a memory

Figure 2.2: Long Short Term Memory network gates



[19]

element to traditional Neural Networks, meaning that the output of the previous layers are remembered sequentially. The most common applications of RNN are within time series forecasting and natural language processing. The issue with RNN is that "they cannot learn long term dependencies due to vanishing gradients" [19], this occurs because the weights of the previous layers that are passed through each stage are multiplied which will always result in a smaller number, meaning the loss will decrease towards 0. Long Short Term Memory networks (LSTM) overcome this issue by introducing memory gates (Figure 2.2). The forget gate analyses the information from the previous time step, called the hidden state and decides whether it is important and should be kept or if it should be forgotten. The input gate is used to identify the importance of the current input values. The output gate determines the value of the hidden state which will be stored and analysed in the next time step.

After the model has been built and tuned to produce the best result, the Deployment and Monitoring phase can begin.

The first section of this paper will be the exploration of the data set with the aim of identifying trends and important features within the data. Important features are features that have a greater impact on the final result of a prediction model. Trends will be defined as features or feature patterns that occur in multiple seasons. Both known and unknown features and trends will be extracted and from the data set. Known features will be defined as factors that are currently used in

analysis of sports games, which stem from less scientific analysis of data. These known features are generally used in predictions of games by both domain experts and casual observers and are widely accepted to be true, but there has been little research to provide evidence to the claims. The unknown features and trends will be discovered during the data exploration and will be represented by the important features, the factors which have the greatest effect on the outcome of the model, extracted during the feature engineering process.

In the analysis of AFL games there are many factors that are said to have an impact on results by domain experts and casual viewers alike, these factors will be analysed as known features in the data set. There are two main ideas behind exploring these features. Firstly, it is useful to take domain knowledge from experts, even if it second hand as in this case. Having access to expert domain knowledge can provide a solid foundation in data analysis workflows, it allows for the analysis to be applied in a specific area of the data set without the need for pre-analysis and feature extraction. The second reason is to statistically analyse whether there is any truth to these claims and if this analysis can be useful when used as a feature in a computer aided prediction model.

The main points that will be explored from this expert analysis are the effects of weather conditions both during and in subsequent games, the length between games and the impacts of travel on future results. The impact of weather will be analysed in two features, the first being the impact of a previous games rainfall conditions as it is believed that it can negatively affect a team's performance in future weeks, as the game becomes more contested thus requiring a greater physical output. The second will be the impact of rainfall on a current game, rainfall during games generally reduces disposal efficiency making results closer, and also different game plans are impacted more by rainfall thus it can be assumed that rainfall will have some correlation to specific teams (rainfall for the model will be taken as predicted rainfall, connected to teams). While with travel it is suggested that spending long times in planes both before and after games can affect a teams' recovery and preparations. There has been research done on the impact of weather on team performance in the AFL[20], which focuses on the analysis of results as such the findings are not used to aid in any prediction models, which this paper aims to do.

While trends can be extremely useful for prediction they can also be difficult to interpret and extract from data. This is another reason why the expert analysis is being explored. It gives a starting point from which the data can be analysed. Basic visualisation of the data set will be used to assess the expert analysis. Further extraction of trends will be entirely theoretical and based solely on algorithmic interpretation of the data set. This will be very important for the project as it will hopefully enable hidden features to be found, rather than just proving or disproving already voiced opinions. These trends would be much more valuable in the industry as they would give professionals a completely new insight into their analytics.

The final key section will be the implementation of a prediction model. Prediction models are used regularly in sports. However as there are so many unknown factors in these prediction models it is very difficult to explain their predictions and how they came to these decisions. The aim is to create a prediction model based on the extracted trends and important features, that is more explainable than other models. Assuming that the prediction model does reliably work, one more key piece of information will be extracted, the final research question, what number of rounds/games does the model need before it can reliably predict the outcomes of games? This can be useful not only for this model but for other prediction models for the AFL, as it can give a greater understanding of when results and match data will stabilise and become reliable in defining the characteristics of a season. The general consensus is that after 4 - 6 weeks of matches is when a reliable data set begins to form. There are many algorithms and techniques that can be used in Data Mining and sports, this paper will mainly utilise the following:

Decision Trees: A tree like predictive models that shows where certain decisions were made via nodes.

Random Forest: A collection of decision trees, that uses a random subset of the data in each iteration.

Long Term Short Term Neural Networks (LSTM): A type Neural Network that introduces the concept of memory and feedback connections allowing it to process data sequences.

3.1 Description of the Scientific Method

3.1.1 Technical Environment

0.5 pages The project was completed using python as the main programming language, a combination of Jupyter Notebooks and Python files were created to handle different tasks. Jupyter Notebooks were used to sequentially implement workflows of the project and define minor functions. Major functions and more complex code was written in Python files which were accessed in the necessary code blocks within the Jupyter notebooks. There was no traditional database structures used, the data was stored in csv files. There were many libraries used over the different stages of the implementation, in depth explanations of their uses will be given in the individual phases. The pandas library was used throughout the entire project as the main data handling tool. All data was accessed using pandas read csv functions to store the data in Data Frames within the project and the to csv function was used to store the manipulated data sets. Numpy was used for additional data manipulation in combination with pandas. The Selenium library was used in the data acquisition phase to scrape additional data which was not available in the original data set. Scikitlearn, a machine learning library for python, was used in the implementation of the feature engineering and prediction models Treeinterpreter library was used in feature engineering to analyse the Decision Tree and Random Forest models. Tensorflow and Keras were used in the prediction phase to build the prediction models.

3.1.2 Phase 1: Data Acquisition

The main dataset was taken from Kaggle [21]. It is a comprehensive dataset, containing statistics from every AFL game between 2012 and 2021 and is comprised of 3 tables. Games, containing data about the games and environment of the games, it contains 12 columns. Players which contains player basic information in 7 columns. Stats containing individual player statistics for every game has 31 columns. Overall there are over 90000 data points across the three tables.

However there were some values that were not present in the original data set, which were required to enhance the data. The data set did not contain any values that rated player performance, which is a useful data point in sports prediction models. There are two prominent player scoring systems in the AFL, "Supercoach" and "Fantasy", which comprehensively rank every player after each game. To acquire this data I utilised scraping software selenium to scrape and store both sets of player scores from footywire.com.

Additionally some values needed to be manually calculated from the raw data set, these were all handled in the feature engineering phase to construct the final data set.

3.1.3 Phase 2: Data Engineering

Data Engineering is a key process in any data science project. Without good clean data it is nearly impossible to generate clean useful results from a model. At the end of the data acquisition phase I was left with a data set that required considerable cleaning. The acquired data was stored in 4 sets, 'Games', 'Stats', 'Fantasy' and 'Supercoach'. The Players data set identified in the acquisition, only contained basic meta information about the players to it was left out from project. I also decided that the data should be split into individual seasons, firstly to reduce the computation needed to analyse the data final data sets, and also to allow for the analysis of each individual season. The main data engineering was thus divided into three stages, split each data set by year, for each year merge required features into central data set, from here the data could be analysed with basic exploratory data analysis (EDA). The merging of the data set overlaps slightly with the feature engineering as I was only choosing a selected set of data to merge into the final data set. But this was necessary to be able to perform any sort of initial analysis on the data, having the data spread out in different data sets would not yield as

insightful results during EDA. Every feature was calculated for the home and away team separately, to avoid repetition when I will discuss the features as a group and not distinguish between the home and away feature.

Splitting the data set by year was the simplest of the phases. Each csv was read into python as a pandas data frame. From there a script was created to separate each data set by year and create individual data frames for each year, these were then saved into individual csv files.

The largest section of the data engineering was the merging of the data sets into one central group of data. The idea was to build the data around the 'Games' data set, because this already contained the results information from which the final model would be building the prediction. No columns were removed from the data set until the data was being fed into the final model. This was to keep the data set as complete as possible, in case extra features needed to be computed from the existing data then there would be no missing data which would need to be re-acquired.

To identify the team changes and previous results I created a python script entitled team changes. This which counted the number of changes between the selected team and the team the previous week.

The distance travelled by each team was also calculated. Travel can be hard to define so it was calculated based on the teams home location. Each group had up to 6 travel categories based off the distance between their home location and the location of the game.

Ladder positions were taken based off two factors. The first was the historic ladder, so that the model could view where the team had finished in the previous season. For the historic ladder I decided to hard code the final positions and then create a data frame to match each team to the ladder position. This was then used to create the LadderPosition columns. The CurrentLadderPositions required a ladder model to be created. I generated this by creating a set of data frames for each round in the season, they tracked the teams, the points score by the team, the points scored against the team, the teams percentage (points for / points against * 100), and the total points (win = 4, draw = 2, loss = 0). To fill in the data each round was iterated over and each corresponding field was updated, the ladders were then ordered by points and percentage. Once the set was created the fields were added to the main data structure, along with each teams total points for, points against and percentage.

The Fantasy and Supercoach data is used to give an overview of the strength of each team based on the players in the selected sides. I had the option to either include each individual player in the final data set, or to combine the scores from every player and only include this value. I decided on the latter option, as it allowed for the result to stay consistent in its position in the final data set. If I were to include individual player scores as features, it would have required either a column for each individual player, or 22 columns for all selected players but the order of the players would not be consistent. I believed it would be better to have one consistent overall value to describe the teams as opposed to the more inconsistent and changing values.

As the main data set and the supercoach and fantasy data sets were acquired from different sources they required the greatest level of preparation to be able to merge the data sets. The naming conventions between the data sets were slightly different, both player names and team names varied between the data sets. This became an issue when attempting to extract values from the supercoach and fantasy data sets, as I was using these names to search for the corresponding data. The first step taken was to find the inconsistencies in the player names as this was a more difficult process. First I created a script to identify which names were present in either of the data sets that were not present in the other. From here I could view which names were different and which naming conventions were different. After multiple iterations I had discovered and removed the major inconsistencies and was left with only a handful of differing names, in this case I hard coded the name in which I wanted to keep as there were so few names left that it was the quickest option. The same process needed to be repeated for the team names. This was a much quicker process as there were only 18 names to analyse in each data set, meaning I could easily hard code the changes I needed and update the supercoach and fantasy data sets.

The fantasy and supercoach points combined for each player to give an average value between the two as they performed the same function of rating the players, the entire teams average was then used in the final data in 4 features. TeamImportanceDifference, marked the average scores of players who played in the previous match but were not selected in the forthcoming game. TeamImportanceLastGame, calculated the average score of the team in the previous game. TeamImportanceLastFiveGames, calculated the teams average scores over the previous five games to assess a teams recent form line, if 5 games had not been played then the average

was taken from the games that had been played. TeamImportanceSeasonAverage, calculated the average over the whole season for the team.

The final data points added were the break between games for each team. This was done with a simple python script to find the number of days between the previous game that the team played and the upcoming game. To simplify the script it initially only looked at games from the previous round, this needed to be updated to consider games from the previous two rounds because bye rounds resulted in no games being identified in many cases. The break was initialised to 7 days as this was the median value identified.

The final stage of the data preparation was one hot encoding of team and venue data. One Hot Encoding (OHE) is a way to add categorical data into computer models that require a numerical input. Each venue and team are assigned a numerical value which is then added to the data set in place of the text value. In some cases the model will incorrectly assume that the size of the numerical numbers is an important factor, to combat this each category is assigned as its own feature in the data set that is either active (1) or inactive (0). This was only implemented in the final stages of the model and not added to the main data set, because some functions in the EDA and feature engineering sections perform better without OHE as it also creates a large number of empty variables in the data set.

Once the main data set was built EDA was then used to explore relationships within the data. This was mainly implemented on features that had been proposed by domain experts. For the EDA scatter plots and histograms were created to identify any trends and relationships between the data.

3.1.4 Phase 3: Feature Engineering

3 pages Once the final data set had been defined in the data engineering phase, the data was then analysed in the feature engineering phase. The models used for feature engineering were decision trees and random forests. Although the models are traditionally used for prediction and classification, they can also be used in feature engineering as they are able to track which features were most important when creating a decision node, which can then be analysed for the final model. Also as they do provide a prediction model it allowed me to have extra prediction models to compare with the final results of the project.

Before the data could be inputted into the model it needed to go through a final phase of pre processing. The y value, which was taken as the home team winning,

was first separated from the data set. Two sets of y values were analysed. The first set analysed wins, losses and draws, the second set simplified this to only win and loss. Draws only made up 1 percent of total game outcomes, resulting in a significantly underpopulated feature, which could dramatically affect the result of the model. I didn't want to use any upsampling, creation of extra data rows, as I wanted the data to be as close to real life as possible. So to overcome this problem I decided to perform the feature engineering with both sets of y values.

Label encoding was used to remove the text values from the data set and replace them with numeric variables. One Hot Encoding was not utilised during feature engineering, due to the smaller number of variables and the number of features that required OHE being quite large this would have created too many empty data points relative to the size of the data set. After the encoding all unused variables were dropped from the data set, these points comprised of metadata about the games (date, gameId, year, round, startTime), values that had been encoded (teams, venue) and features that described the outcome of the games (homeWin, homeTeamScore, awayTeamScore). Normalisation was then applied to the data set. This was done using a MinMaxScaler which reduces the size of the data points but keeps the original scale of each point. A min max scaler computes the points distance from the minimum value in the feature and divides it by the total range of the data in the feature, this reduced the range of the data points between 0 and 1.

$$\text{MinMaxScaling} : X_{std} = (X - X_{min}) / (X_{max} - X_{min}) \quad (3.1)$$

Once the data had been normalised it was returned as a numpy array however I needed to transform it back into a pandas DataFrame to be able to view the columns in the final stages of the feature engineering. The normalisation steps were repeated however an extra step was added to extract the columns from the initial DataFrame, then once the normalisation was applied the data was transformed back into a DataFrame keeping the stored columns of the original data set. The data set was both split by year so that each season could be analysed individually, and joined into one single data set so that the model could analyse the entire volume of data. This resulted in 11 separate data sets which would be analysed. The train test split was set to .8 : .2, for the year by year data the model was trained on the first 19 rounds and tested on the final 4 round. The only exception being the 2020 season which was shortened due to COVID, the final 4 rounds were still held out for testing leaving only 14 rounds to train the model on. The merged data set

was trained on the first nine seasons with the final 2021 season held out for testing. A baseline score was also identified for each data set to determine the percentage of homeWins per season so that any future predictions could be analysed in relation to the baseline.

Before the features could be extracted the models needed to be trained and have the hyper parameters tuned to ensure the features were extracted from the best performing models. The first model created was a simple decision tree classifier (DT). The DT was also to be used as a baseline prediction parameter. Instead of being used to describe the ground truth the DT would be used to describe the prediction capabilities of a basic model on the data set. As such no hyper parameter tuning was performed on the DT. The model was first trained by fitting the training X and y values on the DT. Then a score was generated to display the average accuracy of the model on the validation data. Finally a prediction was made using the 'predict' function, a function print score was also defined to display the confusion matrix of this predicted outcome against the true outcome of each game.

Once the DT models had been established a Random Forest Model (RF) was created for each data set. The RF models are the main models used in the feature engineering so there were 3 phases of tuning on each model to extract the most important features. The first RF models were also quite basic, they consisted of 200 trees, and all of the default parameters of the scikitlearn RandomForestClassifier model. The second RF models a grid search was used to establish the best hyper parameters for the model. The grid search was implemented on each data set and was populated with the following criterion:

'criterion':	['entropy','gini']
'min samples split':	[3, 5, 7, 9, 10]
'min samples leaf':	[8, 9, 10, 11, 12]
'max features':	[0.5, "sqrt", "log2", 0.8]
'n estimators':	[50, 100, 200]

The best estimators were then extracted from the second RF model to create the third RF model. The third models were trained and fitted on the data sets as in the previous steps. To extract the feature importance the treeinterpreter python module was used. A script from fast ai was used to extract the important features from a RF model given an inputted data set in this case the x values of the problem set, returning a pandas DataFrame of each feature and its importance score. The data frames were then plotted to visually analyse the distribution and scale of the

important features over each year. The top 20 features were then extracted from each model, a weight of 20 was given to the most important feature extracted and 1 was given to the least important feature, these were then tallied to identify which features were the most important over all years. As the majority of features were paired between home and away teams, if only one of the features were present the corresponding feature was also included in the final feature set, replacing the lowest ranked features. After this process the top 20 features selected for the final feature set were:

The final stage of the feature engineering was to run a final RF model on the data set containing the selected features to identify one last base prediction to have in comparison to the final prediction model. The final RF model used the same hyper parameters utilised in the third model and the data set was reduced from the original data set to only include the important feature set. The final confusion matrices were then plotted to view the performance of each model.

3.1.5 Phase 4: Predictive Model

The final phase was the constructing of the prediction model. The prediction model used was a Long Short Term Memory Neural Network (LSTM). Again only the final pre processing steps needed to be taken. The original data set was again imported from the csv files separated by year. The string values of the data set then were both label encoded and one hot encoded. This differed slightly to the feature engineering steps, in which the data was only label encoded. This was due to decision tree based models such as random forests performing worse on the sparse data distributions created by one hot coding, while Neural Network models are generally not negatively impacted by OHE. I also did not want the model to infer any immediate relationship between the team and venue data sets, which is a common issue when only applying label encoding.

After encoding the labels the unused features were dropped from the data set. Two different data sets were created in this step. For the main data set only the features identified in the feature engineering were kept in the final data set, along with the OHE team and venue features. Although the two feature sets were analysed in the feature engineering phase as label encoded values and as such were subject to the same ranking principles applied in the the feature engineering phase, I decided that as they were two key features in general sport predictions they should

not be removed, also OHE these features meant that different weights and importance could be determined for the features compared to the label encoded features which were in the feature engineering data set. The second data set comprised of the entire data set used in the feature engineering. This was done to assess the impact of the feature engineering and selected features on the final model, it would provide an insight on whether the RF model and final model extracted similar implications from the data set or whether the LSTM was able to understand the full data set better than the reduced data. As LSTM models are generally used for time series data, the order of the data sequence is an important factor, so the data set was not shuffled for when inputted in the final model.

The LSTM models were implemented using the keras python library. Each model required an input shape for each data set. The input shape of the data set after feature engineering was (88,1), it contained 88 features, whereas the full data set had a shape of (111,1) or 111 features. LSTM networks also have the option to identify time steps where data points are grouped by points in time and analysed together. In the case of this data set I had the option to create a window with information from the previous round or rounds which could be fed into the model together with the information for the game in question. I considered 3 options for this data input method, adding games from the previous 1, 2 and 3 rounds. Adding the 9 games of the previous round would alter the input shape to (10,88)/(19,88)/(28,88) and (10,111)/(19,111)/(28,111) respectively for each data set. To implement this I first needed to create a larger data model which would then be broken down into the 3d windows. The first step was to initialise a data array of the required expanded size. In the case of adding games for the previous round and using the reduced data set was the shape was (1980,88)

$$((Totalgames) - (Gamesperround)) * (gamesperround) + ((Totalgames) - (gamesperround))$$

$$(207 - 9) * 9 + (207 - 9) = 198 * 10 = 1980$$

(3.2)

. This however led to multiple complications, the greatest being a reduction in the data set size. Although the number of data points remained the same, the model only had 22 groups of data to be trained and tested on which was too small of a data set to extract any meaningful information. The second reason was due to the structure of the season some rounds did not feature every team, although the final total of games could still be divided into groups of 9 the structure of the groups be-

came too compromised, as matches from different rounds ended up in the same time group. Because I wanted the data structure to be as close as possible to the actual season structure I decided that not using the time groups was the best option, instead inputting games as individual data points. Therefore the input layer for each model remained as (88,1) and (111,1) for each of the 2 data sets.

The first model that was implemented contained the most basic structure, it consisted of only 3 layers 2 LSTM layers and one Dense layer. The input layer was a LSTM layer containing 128 neurons. The activation function and dropout levels of the first layer were both tuned in the testing phase, it was found that tanh was the optimal activation function. Dropout is a function in Neural Networks where a random selection of nodes are temporarily disabled in the network, creating a new temporary architecture. Dropout rates of .4, .3, .25 and .2 were analysed with .3 found to be the optimal rate in both the standard and recurrent dropout. The middle layer was also a LSTM layer, this time with only 64 neurons. The only tuning done to the layer was the activation function, the default tanh function was found to be the optimal function. The final output layer was a Dense layer with 2 neurons, again only the activation function was tuned, tanh was also found to be the optimal activation function.

The second model added to the complexity of the network by adding in a third LSTM layer and a second Dense layer to the first model. The parameters from the first model remained the same in the second model. In the added LSTM the number of neurons in the added were tuned along with the dropout rate of the layer. Two values were tested for the number of neurons, the first being 128 to match the number of neurons in the input layer, and the second being 64 to match the neurons in the second LSTM layer from the first model, both number of neurons performed similarly well, with 64 chosen as it performed marginally better. Once the ideal number of neurons were identified the dropout level was then tuned, only 0.2 and 0.3 were tested as they were the two best performing levels from the first model, again 0.3 was found to be the ideal dropout level. In the added dense layer the number of neurons were also tuned. First 64 neurons were tested to match the number of neurons in the final LSTM layer, and then 32 neurons were tested to reduce the dimensions between the final LSTM layer and the Dense output layer.

The third and final model that was created added one more layer of complexity to the model. A U-shaped model was created to reduce and then expand the dimensions in the LSTM layers. 2 additional LSTM layers were added the first with 32 neurons and the second with 16 neurons, the number of neurons in the final LSTM layer was then reduced to 32. The dropout level of the first 32 neuron Layer was tuned, with rates of .3, .2, and .1 being analysed. No tuning was performed on the 16 neuron layer or on the 32 neuron layer. An extra dense layer containing 16 neurons was also added to the model between the existing 32 neuron layer and output layer.

After the training of the models I analysed the final research question. How many rounds would it take per season for the models to start producing consistent predictions. For this phase the final prediction model was taken, along with the reduced data set from the feature engineering. The data was then split by rounds, beginning from round 3 as it was identified by many experts as the round where the data pool begins to be significant enough to describe a season. The final round used was round 12, this is 1 round past the midway point of the regular season. Although the models were trained with 19 rounds of data, this step aimed to identify if there was a point in the season when the accuracy of the model would plateau and not learn any more from the data. Because a prediction model would theoretically be used over the course on an entire season, I only looked if the model would be reliable in the early stages of the season. From here the was fed the data for each year at the specified round split, the average accuracy for each split over each model was then identified to analyse at which round a plateau occurred.

4

Results and Discussion

4.0.1 EDA Results

4.0.2 Feature Engineering Results

4.0.3 Final Model Results

Related Works

5.0.1 Data Mining

Although data mining is not a big subject in sports it is a major influence in many other industries. Data Mining has a very broad use case in both Supervised and Unsupervised learning. Supervised learning is a subcategory of machine learning that deals with data where the input and output is known, as is the case with the data in this paper, it aims to map input data to resulting output data. Supervised learning can be further divided into two categories Classification, where the output is a class or category and Regression where the output is continuous.

There are many state of the art data mining techniques in both Classification and Regression. There have been some Classification Methods already mentioned in the paper, Decision Trees and Neural. Other widely used algorithms include K Nearest Neighbour (KNN), Support Vector Machines (SVM) and Bayesian Methods [22]. The K Nearest Neighbours attempts to classify a data point based on the class of its Nearest Neighbour points, a SVM is a method that aims to define boundaries to separate a space into classes. Bayesian Methods are more complex it is based upon a method that “combines prior information about a population parameter with new evidence from information contained in a sample to guide the statistical inference process” [23], the basis of the inference is gained through an application of Bayes Theorem [23]. The main application of these algorithms is to forecast how a certain input will act based on their characteristics, in the finance industry this can be deciding how likely a customer is to default on their payments based on their previous behaviours, in the medical industry these can be used to predict how likely a patient is to have a certain medical condition.

5.0.2 Long Short Term Memory Networks

The state of the art of Long Short Term Memory networks is very centralised around stock market predictions and natural language processing, with some forays into image and video analysis. Time series forecasting, techniques, similar different Time Series [24]

Stock market predictions, techniques, similarities Indonesia[25] Bitcoin [26] Dividend [27]

Natural language processing, techniques, similarities, Sentence Embedding [28] Spam [29]

5.0.3 Data Mining in Sports

Although there are many state of the art use cases of data mining, they have limited use in the field of sports. As discussed in “Sports Data Mining” by Robert P. Schumaker et al. [30]. This text looks at which data should be collected to properly performing data mining in sports and “how to best make use of it”. It also discusses the issues faced by those entering data mining in sports not only in the initial phases but also the final phases of data mining. One of these difficulties is the relationships between sports organisations and their data, many were unwilling to embrace data mining techniques at the time of the publication of the book. They defined 5 levels of relationships between organisations and the data they produced. Shown below in table 2, taken from Chapter 1, page 2 from the book.

Level	Relationship
One	No relationship
Two	Human domain experts make predictions using instinct and gut feeling
Three	Human domain experts make predictions using historical data
Four	Use of statistics in the decision-making process
Five	Use of data mining in the decision-making process

Table 5.1: Hierarchy of Sport and Sport Data Relationships.

Schumaker claims in the text that at the time of publishing many organisations resided in level 3 or 4 of the hierarchy. The issue is that there is currently no straightforward way to identify if organisations are using data mining and how they are using it. Another issue highlighted in the text is the inconsistencies and misinterpretations of statistical sports data. As is pointed out in the text many long standing statistics are misleading in modern contexts where we now have a better

grasp on these methods and much greater available computing abilities. However, these methods still remain prominent and in use today, as such the book seeks to define new methods to ensure proper algorithms and applications of data analysis and data mining are used. In the book the Data-Information-Knowledge-Wisdom Hierarchy (DIKW) is used to separate techniques and use cases into each of the categories, to identify the best methods and algorithms to be used on each use case.

Moving into the field of academic papers there are only a handful of resources that explore similar issues to this paper. The most common areas of focus are American Football, Basketball and Baseball.

Carson Leung and Kyle Joseph, explore a prediction model for American Football in their paper, “Sports Data Mining: Predicting results for the college football” [6]. They employ an interesting dropout technique for their prediction model, in which they do not explore the results of the two teams that will be predicted, instead focusing on “a set of teams that are the most similar to each of the competing teams” [6], [page 716]. Similarly, they identify statistics on which the final model will be based, but only 4 instead of the larger set as in the model in this paper.

On the more analytical side is the paper “Sports analytics— Evaluation of basketball players and team” by Vangelis Sarlis and corresponding author Christos Tjortjis. This paper looks at and “evaluates the existing performance analytics used in Europe and NBA (in USA) basketball” [7]. They identify two metric types, Player and Team, and four criteria groups; Key Performance Indicators (KPIs), Defensive criteria, Offensive Criteria and Overall Performance Criteria, as well as outlining a Comparison Matrix and Data Mining Techniques used in sports analysis. They also explore if they can optimise existing performance analysis metrics that are used in basketball.

An overall review of the current techniques used in sports prediction (as of 2013) is given in the paper “A review of Data Mining Techniques for Result Prediction in Sports”, M. Haghighat et al., [31]. 6 Methods are analysed in the resource of which two, Artificial Neural Networks and Decision Trees are used in this paper. Bayesian Method, Logistic Regression, Support Vector Machines and Fuzzy Methods are the other methods that are analysed. Since nearly 10 years have passed since this resource was published, there has been many improvements to the models that are used in this paper, specifically in the field of Neural Networks.

A more limited set of comprehensive work has been completed regarding Data Science and Australian Football. In 2008 McCabe and Travathan briefly explored

the usability of neural networks in predicting the outcomes of sports in their conference paper “Artificial Intelligence in Sports Prediction” [32]. Here they reached an average accuracy of around 65 percent using 11 performance metrics. This model did not only focus on AFL, it also aimed at predicting Rugby League, Rugby Union and Soccer, as such the features used were not specific to any of the predicted sports. The model in this paper aims to be more specific to features occurring in AFL.

H. Jelenik et al in their article “Using meta-regression data mining to improve predictions of performance based on heart rate dynamics for Australian football” [33], follows a similar scientific method to that which is used in this paper, utilising Random Forest algorithms to extract key features from the dataset. However the type of data differs greatly, this article features gps data and medical data with the predictions being more focused on individual player performance as opposed to team performance prediction. M. Aarons et al also utilised GPS data in their article on “The effect of team formation on defensive performance in Australian [34], which analysed a team’s defensive positioning and the effect it had on defensive performance, similarly to this paper decision tree analysis was also utilised in the article, however the majority of the methods and data differed. These both used minimal similar decision tree and random forest techniques in their analysis but the data set and overall prediction scopes differed from what was used in this paper.

Sports ML [35]

Human Activity Modelling [36]

Summary

6.1 Summary

Overall this paper aimed to explore and understanding the use of Data Mining in Professional Sports, specifically the Australian Football League. It aimed to build upon methods already being used in sports data mining and to combine them with existing methods being utilised in other fields of data mining and to explore the following research questions:

Can data mining be used to find key features and patterns and explain results in professional sports?

Can these extracted trends and features be used to create a reliable prediction model?

How can the results be utilised in the sporting industry?

If the model can reliably predict outcomes, how many rounds will the model need before it becomes reliable?

The results of the paper were varied, many improvements could have been made to the processes used in the project. With more time and resources the quality of the data could have been greatly improved as well as utilising different techniques and methods when defining the data set. Continuous vs discrete data. A greater use of discrete data could have been used to increase the expressiveness of the data. The majority of the final data set was continuous. Data complexity [37] warn that adding complexity to data does not always lead to better results in sports predictions. There are many factors that can influence the outcome of a

game which are not always indicative of a teams strength these can be affected by random chance or human factors and therefore are had to quantify and analyse in a model. Although I believe adding additional complexity to the data in this case could have been useful, specifically in the case of team travel and home ground advantages. In the model I only looked at basic factors in this regard of, where the game was being played and categorised how far each team needed to travel to reach the destination venue. TheAFLLab [38] investigates this topic in much greater depth analysing an additional 5 features.

A major change I would make in subsequent work on this topic would be to change the neural network used to create the prediction model. Long Short Term Memory Networks are designed to handle time series and sequential data. As sport seasons are in general also sequential by nature I believed that the data set could be adapted in a manner that would be able to be fit to the LSTM model. However there were some problems with the data mapping which I did not initially take into consideration when I began the project. Although the data was sequential, LSTM models are also built to handle data in time steps which lead into each other. The issue with sports data is that every game is independent and thus the weights from the game

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